Guidelines on Gasket Selection, Selection Troubles, and Countermeasures

1. Introduction

As Figure1 shows, we previously reported that poor installation and poor selection account for a majority of sealant troubles at plants; troubles due to mis-selection account for approximately a quarter of all troubles.[1] To ensure that sealants function properly, appropriate selection is essential.

This article introduces issues regarding gasket selection, selection methods, troubles due to selection errors, and countermeasures.

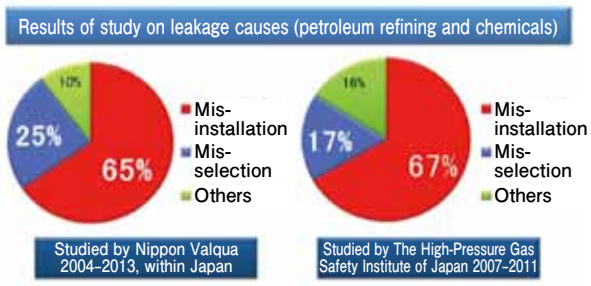


Figure 1　Statistics from study of leakage causes

2. Guidelines on gasket selection

2-1) Issues regarding gasket selection

Gaskets are used under various conditions and so a wide range of conditions must be considered and then the optimal gaskets chosen. Firstly, we will study the conditions that should be considered when selecting gaskets, as shown in Figure2.

The main conditions that must be considered without fail are fluid, temperature, and pressure. These three conditions must always be considered when selecting gaskets.

Next, the shapes and dimensions (diameter, thickness, and width) of flanges need to be confirmed. For example, for flanges with abnormal shapes or extremely narrow sealant surfaces, the spiral-wound gasket cannot be used; other gaskets such as the sheet gasket should be selected. In some cases, gaskets with non-standard dimensions should be made or flanges should be changed.

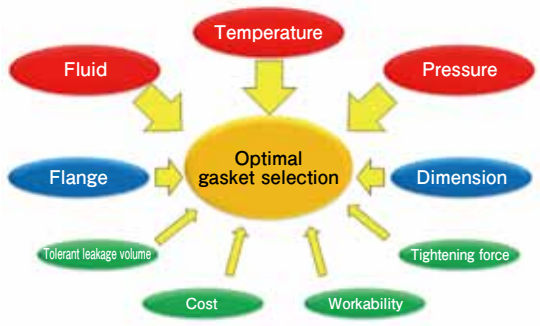


Figure2　Selection conditions for gaskets

In addition, allowable leakage volume, tightening force, cost, and workability should be considered. When priority is put on functions such as small leakage volume, the product may become expensive. Accordingly, priority conditions should be taken into account and then optimal gaskets should be selected.

In addition to the above conditions, the places where gaskets are used should be considered, as the types of gaskets that can be used may be limited depending on the application and equipment. Table1 categorizes commonly used gaskets by equipment and device.[2] For example, gaskets used for devices such as the casing of pumps have complex shapes and are usually thin, so only gaskets which meet such requirements can be selected. In addition, in important stages of manufacturing processes and in areas where leakage would significantly affect the surrounding areas, a more reliable gasket material must be selected.

Table1 Applicable equipment for gaskets

Gasket type	Equipment and device				
	Piping	Heat exchanger	Valve	Tower, tank, reactor	Pump
Non-asbestos joint sheet	◎	◎	◎	◎	◎
Foamed carbon gasket	○	△	○	△	○
PTFE-coated gasket	◎	○	○	◎	○
PTFE gasket containing filler	◎	○	◎	◎	○
Spiral-wound gasket	◎	◎	◎	◎	◎
Serrated metal gasket with foamed carbon	○	◎	△	○	△
Metal jacketed-gasket	○	◎	○	○	△
Metal flat gasket	△	○	△	○	△
Serrated gasket	△	○	△	○	△
Ring joint gasket	◎	△	◎	◎	△

Symbol ◎ : Frequently used
○ : Used
△ : Although rarely used, usable depending on conditions.

2-2) Gasket-selection procedure

Figure3 shows the gasket-selection procedure. The details of each step are as follows:

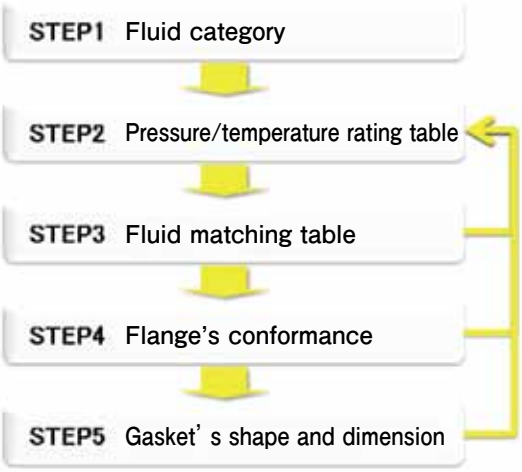


Figure3 Selection conditions for gaskets

STEP 1 Fluid category

Confirm the fluid category based on the types of fluid in use. There are 10 fluid categories as listed below. Table2 summarizes the typical fluids of each category.

STEP 2 Pressure/temperature rating table

Select an appropriate pressure/temperature selection graph for the fluid category. Then, select usable gaskets based on the pressure and temperature which will be applied to the gaskets. For example, when the fluid is water vapor with a pressure of 1 MPa and a temperature of 180C, the fluid category is ① water, hot water, and water vapor. Figure4 shows a selection graph. In the graph, the pressure and temperature

Table2 Fluid category and typical fluids

Fluid category		Typical fluids
①	Water, hot water, water vapor	Fresh water, industrial water, warm water, hot water, water vapor, superheated vapor, boiler water, drain, municipal effluent, sewage, etc.
②	Crude oil, alcohol, animal-/plant-based oils, heat-transfer oil, etc.	Crude oil, naphtha, oil gas, gasoline, light oil, kerosene, heavy oil, tar, fuel oil, lubricating oil, common mineral oil, hydraulic oil, methanol, ethanol, ethylene glycol, glycerin, animal-/plant-based oils, heat-transfer oil, etc.
③	General solvents, weak acids, weak alkalis, etc.	General solvents, aromatic hydrocarbon (including B.T.X.) ketones, amines, ethers, phenol, acrylonitrile, etc. Acetic acid, formic acid, oxalic acid, citric acid, boric acid, phosphoric acid, etc. Ammonia, sodium carbonate, etc.
④	Strong acids and strong alkalis	Sulfuric acid, nitric acid, hydrochloric acid, permanganic acid, etc. Sodium hydroxide, potassium hydroxide, calcium hydroxide, barium hydroxide, lithium hydroxide, black liquor, etc.
⑤	Air, nitrogen gas, inert gas, etc.	Air, nitrogen gas, helium, argon, neon, etc.
⑥	Exhaust gas	Exhaust gas
⑦	Combustible gas	Hydrogen, methane, ethane, propane, butane, ethylene, acetylene, propylene, etc.
⑧	Poisonous gas	Ammonia, carbon monoxide, phosgene, sulfur dioxide, vinyl chloride, vinyl acetate, methylene oxide, fluorine, chlorine, bromine, iodine, hydrogen sulfide, sulfurous acid gas, etc.
⑨	Oxygen and others	Oxygen, ozone, liquid oxygen
⑩	Cryogenic fluid	LNG, LPG, liquid nitrogen, liquid hydrogen, liquefied ethylene, liquefied argon, etc.

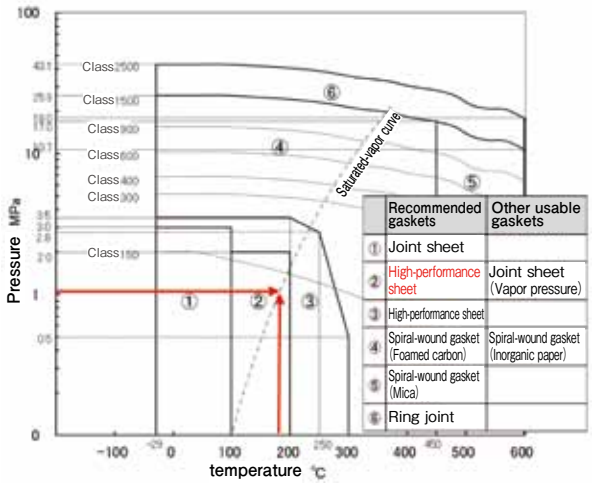


Figure 4 Temperature/pressure selection graph for water, hot water, water vapor

conditions intersect at the point ②, so a high-performance sheet gasket is selected.

STEP 3 Fluid matching table

Use the fluid matching table to confirm whether the gasket selected in Step 2 can be used for the intended fluid. If the gasket is not suitable, go back to Step 2

and select "other usable gaskets" or higher-category gaskets. Table3 shows a fluid matching table for ① water, hot water, and water vapor as an example. Under the conditions shown in Step 2, the fluid is water vapor. Therefore, the selected high-performance sheet gaskets are considered to be applicable.

Table 3 Matching table for water, hot water, water vapor

Fluid Segment	Type of Fluid	Fluid	High-performance sheet UF300	MF300	GF300	SF300	6500・6500AC	6502・6503・6503AC	7010・7010-EX 7GP66・7GP66S	7020	7026	VF-30・VF-35E	8590 Series・8590TN 8590L Series	6590 Series	7590 Series	M590 Series M590L Series	N7030 Series	1500 (reference)
water/hot water/steam	water・steam	warm water・hot water・boiler feedwater	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		clear water・industrial water	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		steam・superheat steam	○	○	○	○	△	△	○	○	○	○	○	○	○	○	○	○
		drain・municipal effluent・dirty water	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
	aqueous solution of a neutral salt	calcium chloride	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		sodium chloride	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		seawater	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		sodium nitrate	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		sodium fluoride	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
		Sodium sulfate	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

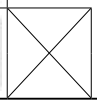
STEP 4 Flange's conformance

Confirm whether the selected gasket can be used for the shape of the flange's gasket seat. Table4 is a matching table to check whether a selected soft gasket is suitable for a flange's gasket seat. Table5 is a matching table to check whether a selected spiral-wound gasket is suitable for a flange's gasket seat and nominal pressure/diameter.

Table4 Matching table for flange sheets and soft gaskets

Gasket Type	Shape	Flange-seat type: Flat face	Raised face	Male-and-female shape	Groove shape
					
Joint sheet/high-performance sheet Fluororesin sheet (containing filler)	FF	●	●	–	–
	FR	●	●	● by 16K	● by 20K
Fluororesin sheet (Simple substance)	FF	–	–	–	–
	FR	–	–	●	●
Fluororesin jacket	FF	▲	–	–	–
	FR	●	●	–	–
Foamed carbon sheet	FF	▲	–	–	–
	FR	●	●	▲	▲

Table5 Matching table for flange seats and spiral-wound gaskets

26～60B	1/2～24B	Nominal diameter / Nominal pressure / Gasket seat	Class 150	Class 300 to 600	Class 900 to 1500
With inner and outer rings	With outer ring(1)(2)	Raised face (flat face) 	With inner and outer rings	With outer ring(1)(2)	
With inner ring		Male-and-female shape 	With inner ring		
Basic shape(3)		Groove shape 		Basic shape	

Note (1) When filler is foamed carbon or PTFE, gaskets with inner and outer rings are recommended.
(2) When fluid is monomer, gaskets with inner and outer rings are recommended.
(3) In the case of flanges with large nominal diameter, gaskets with inner rings are recommended for easy handling.

STEP 5 Gasket's shape/dimensions

Finally, determine the gasket's shape and dimensions to confirm whether the gasket can be manufactured. If the gasket cannot be manufactured, go back to Step 2 and re-select.

In addition, confirm whether the selected gasket can accommodate the gasket's tightening force. Regarding ease of tightening/removal, cost effectiveness, and market availability (delivery), determine which factors should be prioritized and select the optimal gasket.

When selecting gaskets based on fluid, temperature, and pressure conditions, please use our Gasket catalog (No. YC08) and Seal Quick Searcher™, which is a useful website for selection.[3)]

2-3) Fluids which require care when selecting

The following fluids require particular care when selecting:

① Oxygen and combustion-supporting gas: Gaskets containing combustible material should be avoided.
Spiral-wound gaskets containing PTFE filler, PTFE-blended gasket, copper jacketed-gasket, and solid-metal flat gasket are recommended.

② Polymerizable monomer: Polymerizable monomers including styrene monomer and vinyl chloride monomer can cause malfunctions in the joint sheet and PTFE-blended gasket. The spiral-wound gasket with inner and outer rings and the

metal gasket are recommended.

③ Fluid containing slurry: Soft gaskets can be damaged and leak due to erosion.
The spiral-wound gasket with inner and outer rings and the metal gasket are recommended.

④ Heat-transfer oil: The joint sheet can suffer deterioration in its rubber binder, resulting in leakage. Moreover, oil has high permeability. Therefore, the spiral-wound gasket containing non-asbestos filler can suffer leakage when used for a long time. The foamed-carbon sheet gasket and spiral-wound gasket containing foamed carbon filler are recommended.

⑤ Radioactive fluid: PTFE is vulnerable to radiation, and so PTFE gaskets are not recommended.

Foamed carbon has radiation resistance of 1.0×10^6 Gy; make a selection after checking the radiation dose.

2-4) Thickness selection

Table6 shows the relationship of gasket thickness to gasket characteristics regarding the seat gasket. The thicker a gasket is, the greater its compression amount. A thicker gasket can better absorb a flange's strain and swelling. On the other hand, the thinner a gasket is, the smaller the penetration-leakage volume is, resulting in superior sealing properties. At the same time, a thinner gasket has weaker creep relaxation, resulting in superior long-term stability. In terms of compression-failure characteristics, thinner gaskets are more tolerant to external force. From the above, thinner gaskets are recommended in principle. However, when flanges with large nominal diameters have large swelling and strain in the flange and when flanges have some roughness on the surface due to long-term use, the strain needs to be absorbed. Therefore, thicker gaskets are recommended.

Table6 Gasket thickness and characteristics (sheet gasket)

Characteristics	Gasket thickness	
	Thin	Thick
Compression amount	Little	Large
Seal property	Strong	Weak
Creep relaxation	Little	Large
Compression failure contact pressure	Strong	Weak

3. Troubles due to mis-selection and countermeasures against the troubles

Previously, examples of troubles due to fluid mismatch were introduced.[4] Following are other examples of troubles due to mis-selection.

3-1) Thermal degradation in the joint sheet gasket

One of the constituent materials of the joint sheet gasket is a rubber binder. When the temperature exceeds 100°C, the binder hardens, making the whole gasket harder. In this state, external force such as additional tightening and piping stress can cause the gasket to crack as shown in Figure5. When additional tightening is applied during maintenance, the joint sheet gasket should generally be used at a temperature of less than 100°C. If the temperature is over 100°C, high-performance sheet gaskets including No. GF300, which does not contain rubber binder, are recommended.

Figure5 Cracked joint sheet gasket due to hardening

On the other hand, when gaskets are used in equipment, to reduce the leakage volume and deterioration, thinner gaskets are used to cause stress relaxation less frequently, or the gaskets are initially tightened at a contact pressure of over 30 MPa.[4]

When the joint sheet is used at temperatures exceeding 100°C, the following countermeasures are recommended to avoid additional tightening:

① Set the gasket thickness at 1.5 mm or less.

② Apply gasket paste (including seal paste) to the gasket.

③ Set the initial tightening contact pressure at over

30 MPa.

④ Use a joint sheet gasket in areas where pipe stress is less likely to occur and where gaskets can be replaced easily.

⑤ To increase the gasket-tightening contact pressure, use a ring gasket with a gasket outer diameter equal to the bolt's bore diameter.

3-2) Deformation of fluororesin-blended sheet gaskets

Fluororesin-blended gaskets tend to occur creep relaxation even at room temperature. Especially, when gaskets made solely from fluororesin are used, deformation due to creep relaxation must be considered carefully; in principle, grooved flanges should be used.

In addition, the creep relaxation characteristics of fluororesin become more prominent at high temperature, leading to greater deformation due to softening as shown in Figure6. Therefore, when the temperature exceeds 100°C, a filler should be added, or gaskets containing less fluororesin should be selected in order to reduce creep relaxation.

Figure6 Deformation of a fluororesin sheet gasket

3-3) Deformation of spiral-wound gaskets

Regarding spiral-wound gaskets containing foamed-carbon filler or PTFE filler, when a spiral-wound gasket with outer ring is used, the filler slides. As shown in Figure7, the sliding may cause buckling deformation on the inner-diameter side, weakening the sealing properties. Therefore, when the filler is foamed carbon or PTFE, the spiral-wound gasket with inner and outer rings is recommended.

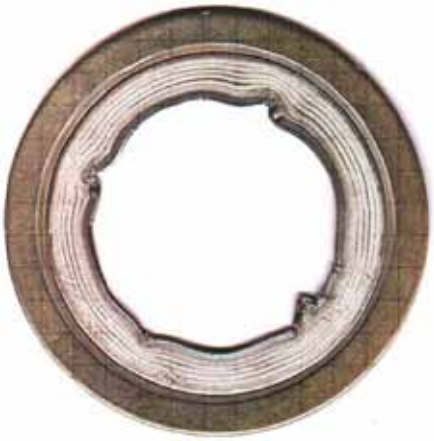


Figure7 Deformation of a spiral-wound gasket

When the fluid is a monomer, the gasket with inner and outer rings is also recommended to inhibit penetration and polymerization.

3-4) Troubles due to errors in selecting dimensions

Originally, the gasket's dimension must be set to match the flange's dimension. If they do not match, the gasket may leak. For example, when the gasket's diameter is smaller than that of a raised-face flange, the gasket will cause inaccurate centering, causing misalignment and partial narrowing on the gasket's contact surface as shown in Figure8. The narrow contact surface cannot bear the inner pressure and is pushed toward the outer diameter, sometimes resulting in deformation or rupture. The misalignment also pushes the whole gasket within the piping's inner diameter. The protrusion may damage the gasket and cause leakage.

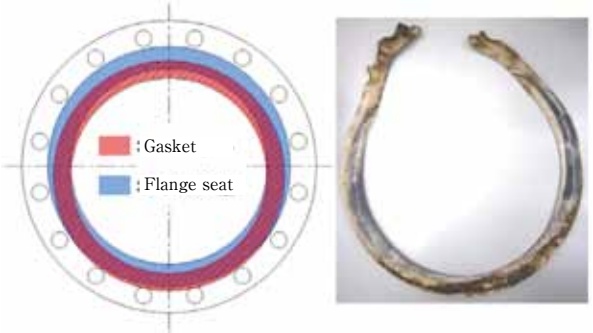


Figure8 Deformation due to gasket misalignment

3-5) Troubles due to corrosion

One example of gasket-induced corrosion is "deposit corrosion," which occurs by fluid penetrating the gap between the gasket and flange or the gasket itself, then chlorine ions in the fluid cause corrosion.

Especially when stainless-steel flanges are used in seawater, which contains many chlorine ions, corrosion is more likely to occur. Tightening contact pressure is weak in the inner-diameter area of the contact surface between a flange and gasket, resulting in minute spaces more frequently. When fluid containing chlorine ions penetrates the gap between the stainless-steel flange and gasket or penetrates within the gasket, the stainless steel forms a passivation film. This reaction creates an oxygen concentration cell, reducing pH and increasing the chlorine-ion concentration and leading to rapid deterioration of the flange metal or deposit corrosion.[5] To prevent this deposit corrosion, it is effective to use a gasket with a low chlorine content and to apply an anticorrosion paste (seal paste) to eliminate the gaps. Regarding tightening, the following measures may be used: apply a greater gasket contact pressure, modify the flange's strain, and smooth the flange seat.

Galvanic corrosion may develop at the junction between different metal flanges, and occurs as follows: 1) Metals with different ionization tendency come into contact with each other, 2) When the metals are immersed in an electrolyte solution, a potential difference occurs in the space between the metals, forming a galvanic cell, and 3) The galvanic cell corrodes the metal with lower ionization tendency. When gaskets with high conductivity including metals are used in a flange's junction between different metals, a cell is formed, sometimes resulting in corrosion of the flange. To prevent this corrosion, the flange joint assembly must be insulated. High insulation gaskets include fluororesin-blended gaskets such as fluororesin jacketed-gaskets. Not limited to gaskets, insulation, including the use of insulating bolts to insulate screw parts, is recommended.

4. Conclusion

This report explained gasket selection, selection methods, troubles due to selection errors and countermeasures. For further details on gasket selection, please refer to our Gasket catalog (No. YC08) and Seal Quick Searcher™, which is a useful website for selection. For other selection conditions than described in the catalog or website, please contact us.

We believe that by studying the issues and procedures regarding proper product selection, leakage troubles due to gaskets can be prevented. We hope this report was helpful.

5. References

1) R. Ikeda, *Valqua Technology News* No. 31, pp. 2–7; 2016.
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3) T. Enisi, *Valqua Technology News*. No. 32, pp. 22–25 (2017).
4) T. Enisi, *Valqua Technology News*. No. 33, pp. 2–3; 2017.
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Asuka Matsushita
Sales Group
Technical Solution Division