Valqua Technology News

Winter 2020

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VALQUA, LTD. HARD&SERVICE COMPANY H&S
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Greetings

Toshikazu Takisawa

Representative Director, Chairman & CEO
VALQUA, LTD.

Greetings from the early spring of the second year of Reiwa era.
We would like to sincerely thank our readers for reading our magazine on a regular basis.

The new era of "Reiwa" began on May 1st last year in the Japanese calendar.
In the first New Year of Reiwa, as concerns over a slowdown in the global economy are increasing as market conditions are reflected in the deterioration of U.S.-China relations and the effects of the new virus, and in Japan, we also saw a decline in domestic demand due to the increase in the consumption tax and the scars of natural disasters. Although there are signs of a bottoming out in semiconductor demand and automobile sales, which have continued to decline, the business environment in recent years is constantly being exposed to drastic change. For companies to survive in this rapidly changing business environment, the ability to quickly provide solutions to market issues should be important.
Our Group has positioned last year as the first year of the New Valqua Era and we have made a strong determination to leap forward as an H&S company. We are determined to transform ourselves into a company that aims to build a mindset and business model that pursues the creation of customer value, including moving from hardware only to services. Last year, to clearly communicate our resolve both inside and outside the company, we built a new management system and, with our commitment to "Value" and "Quality", which are the origins of our company name, we have been working to strengthen our system to focus on creating innovation and providing customers with new value-added products and services to provide solutions to the various challenges that may arise in the future from the steps required by the global market.
Against this background, the Company's eighth medium-term management plan "New Valqua Stage Eight (NV・S8)," which started in FY2018, ended in FY2019. From FY2020, we have decided to build new activities to achieve business growth toward our 100th anniversary under a new medium-term management plan. In this new plan, we intend to provide customers with solutions that meet the challenges of the global market by implementing more innovative activities based on the H&S concept. In addition to providing "safety and security" to customers through seal engineering services, a fundamental issue for our company, in response to the urgent global issue of environmental impact, we are working to solve issues related to sustainability in a broad sense by using the technical solutions we can provide, and we intend to contribute to sound and sustainable growth of a diverse society in line with the United Nations' SDGs (Sustainable Development Goals).

We have the Tokyo Olympics in this summer and this is the first year of change at our company which is the beginning of a new era of Reiwa. We look forward to your continued support this year and wish all our readers the best in the coming year.

Introduction to Valqua Technology News No. 38 Winter 2020

We sincerely wish everyone a happy spring of the second year of Reiwa era. Thank you for regularly reading the Valqua Technology News.

In the era of Reiwa, interest and expectations for the role of innovation for corporate growth are increasing. In the changes brought by technological innovations such as IoT and AI, there is a transition that requires a single product technology development solution to be combined with other technology solutions, and that complex and diversified new value-added products and services be offered to the market. In addition, in technology development to support this change, creating results that pursue efficiency and speed, and establishing an ecosystem of technology development that organically connects a wide variety of technology development activities that are being deployed globally is essential, and such is being implemented under the keyword of open innovation involving industry, government, and private sectors.

In this trend, we have taken various measures in our mid-term business plan NV・S8, which began in 2018, to keep up with the times. In particular, in the previous year, we opened the Valqua Advanced Materials Technology Research Laboratory of in the National Institute of Advanced Industrial Science and Technology and promoted the creation of a system that utilizes technologies from startup companies, such as those in Silicon Valley. In the new medium-term management plan beginning from this year, using these new technological solutions, we will incorporate cutting-edge new materials, sensing technology, and IoT and AI technology into core technology areas such as sealing technology that we have accumulated since our founding, and resin processing technology such as fluororesin, as well as strengthen our technology development activities to provide H&S products in areas that encompass everything from hardware products to services with solutions that customers truly seek. Furthermore, in order to provide cutting-edge technology solutions to the market as high-quality products, we are promoting activities that include the introduction of RPA for production technology innovation.

Against this background, in this issue of Technology News, we look ahead to the introduction of next-generation technologies that we are promoting, firstly focusing on the core technology of seal engineering, which is the base, and prepared an essay introducing our technology and an introduction to our core products. As for the technical essay, it is an analysis of the effect of the tightening method on the sealing characteristics of large-diameter flanged fasteners, consideration of compression behavior due to gland packing tightening, and performance evaluation of semi-metallic gaskets that readers can refer to for safety and security of their plants. Furthermore, as for the introduction to our products, we take up the quick opening and closing cylinder valve and the newly developed cleaning Spray Ball™, the usefulness of which has been once again recognized in the market, and provide useful information for customers in future product selections.

Thank you for your patronage and we hope you will continue to enjoy the Valqua Technology News this year.

Director, Managing Executive Officer CTO & CQO Mutsuo Aoki

Influence of Bolt Tightening Methods on the Sealing Performance of Large Diameter Bolted Pipe Flange Connections

1. Introduction

Gasketed pipe flange connections are used in large numbers in pressure vessels and pipe connections in various industries. It is known that the sealing performance of the pipe flange connections depends not only on the gasket characteristics but also on the tightening method. According to The High Pressure Gas Safety Institute of Japan (KHK)[1], it is reported that about 67% of leakage accidents from gasketed pipe flange connections are caused by improper bolt tightening method. One of the factors of tightening failure is the elastic interaction occurring during bolt tightening. This is a phenomenon that affects each other when a large number of bolts are tightened. Each axial bolt force falls below the target bolt axial force, and individual bolt axial forces vary. As a result, an appropriate bolt axial force cannot be achieved, the gasket compressive force required for sealing cannot be obtained and leakage may occur. It is difficult to reduce the effects of this elastic interaction to zero, and measures are being taken to reduce the effects, such as increasing the number of circular tightening cycles or performing cross-tightening. However, all of them are based on experience and it is hard to say that sufficient technical studies have been done[2)-5)].

Under these circumstances, various standards have recently proposed bolt tightening methods for achieving an appropriate bolt axial force. In the United States, ASME PCC-1[6] Guidelines for Pressure Boundary Bolted Flange Joint Assembly was proposed in 2000 and revised in 2013 and 2019. In Japan, JIS B 2251[7] "Flange joint tightening method" was issued in 2008, and in 2018, "Flange method mounting technical specification" was published in China. However, the index used in these standards is the final bolt axial force and does not deal with the actually required sealing performance of the flange connections.

In Valqua Technology News Vol.37 in the previous report, the effect of tightening methods of ASME PCC-1[6] and JIS B 2251[7] using ASME class 150 4 inches small diameter and ASME class 300 24 inches large diameter flange connections sealing performance was examined and it was clarified that both of them are appropriate methods to exhibit adequate sealing perfromance[8]. However, although ASME PCC-1[6] shows several bolt tightening methods, the effects of these tightening methods on the sealing performance of the connections have not been studied.

This reportaims to investigate the effects of the tightening methods combined with Alternative #1, #2, and #3, which are newly added to ASME PCC-1[6] by using ASME class 300 24-inch flange connections, on the variation of bolt axial force, sealing performances, bolt tightening times, and wrench moving distances. In this report, the test was conducted using our high-performance gasket No. GF300 and expanded graphite filler spiral gasket No. 6596V.

2. Test method

2-1) Test equipment

Figure1 shows the pipe flange connection with a gasket used in this paper. The dimensions are 24 inches, which is the largest nominal diameter in the ASME standard, the pressure rate is class 300, the shape is W/N, the seat is RF, and the material is SUS304. It is known that the mechanical behavior of

Winter 2020
No.38

the flanged connections changes depending on the presence or absence of the pipe. In thisreport, we used equipment with a pipe of about 800 mm to study under conditions close to the actual equipment.

The bolts are made of SNB7, and 24 hexagon bolts of size M39 are used. Two strain gauges are attached to each bolt body so that the axial force of all bolts can be measured. The strain gauge of each bolt has been calibrated in advance, and molybdenum disulfide has been applied to the thread and seat of the bolt and nut. Helium gas was used as the test gas, and the internal pressure was 2 MPa. The leakage amount of the flange connection was measured by a pressure drop method. We measured the change in pressure with a pressure gauge and calculate using the following equation (1).

$$L = 1\text{atm} \times \frac{MV}{\rho t R T_1 c}\left(P_1 - \frac{T_1}{T_2}P_2\right) \quad (1)$$

where

L : Leakage per outer circumference of gasket, [Pa·m^3/(s·m)]
M : Molar mass, [mg/mol]
V : Inner volume of pipe flange connections, [ml]
ρ : Density of test gas, [mg/ml]
t : Measurement time, [s]
R : Gas constant , (=8.314), [J/mol·k]
T_1 : Absolute temperature at the start of test, [K]
T_2 : Absolute temperature at the end of the test, [K]
P_1 : Absolute internal pressure at the start of the test, [MPa]
P_2 : Absolute internal pressure at the end of the test, [MPa]
c : Gasket contact outer circumference, [m]
atm : Standard atmospheric pressure (=0.101325), [MPa]

Figure2 shows an image of the work of tightening the pipe flange connection body. Bolt tightening is performed using a torque wrench with the target torque. Target gasket surface pressure was 40 MPa for gasket No. 6596V and 25 MPa for gasket No.GF300 and the target torque value T was determined from the following equation (2). Table 1 shows the target gasket stress and torque.

$$T = K\frac{\sigma_g}{N}A_g d \quad (2)$$

where

T : Torque, [N・m]
K : Nut factor, (=0.135)
σ_g : Target contact gasket stress, [MPa]
A_g : Contact gasket area, [mm^2]
N : Number of bolts, [pcs]
d : Bolt nominal diameter, [m]

In the experiment, the bolt axial force and the flange clearance are measured for each tightening cycle.

Figure1 Experimental setup of 24" pipe flange connection

Figure2 Image of tightening

Table1 Target torque, target axial bolt force and contact gasket stress

Size of pipe flange connection	Class300 24B	
Gasket	No.6596V	No.GF300
Suggested contact gasket stress [MPa]	50	35
Target contact gasket stress [MPa]	40	25
Target axial bolt force [kN]	98.4	85.6
Target torque [N·m]	520	451

2-2) Test gasket

The gasket dimensions used in this paper $\phi612\times\phi772\times t3.0$ for No.GF300 and $\phi603.2\times\phi628.6\times\phi685.8\times\phi717.6\times t4.5$ for No.6596V. Both are ASME class 300 24-inch diameter dimensions.

3. Tightening method

In this paper, we compared the variation of bolt axial force, sealing performance, and tightening time of the flange connection under seven types of bolt tightening methods.
Table2 shows each tightening method, and the outline of each tightening method is described below.

3-1) Tightening method JIS B 2251[7)]

In JIS B 2251 flange joint tightening method[7)], paragraph 4b) states that "if the number of flange bolts is 12 or more, 110% of the specified tightening torque shall be the target tightening torque. In this study, the measurement and examination are performed when the target torque is set to 110% in addition to 100%. 5.3b) Section 4) states that when a spiral-wound gasket is used, the gasket width is so narrow that one-sided tightening is likely to occur. To prevent this, tighten all bolts at the end of star pattern by 50% of the target tightening torque, and one round of tightening is performed by clockwise or counterclockwise tightening methods. For this reason,

Table2 Bolt tightening methods

Tightening methods	Target Torque	Gaskets		Step 1	Step 2	Step 3	Step 4	Total
JIS B 2251 110%	110%	No.6596V	Number of bolts	4	24	24	24	232 bolts
			Rounds	4	1	6	2	
			Pattern	Star	Circular	Circular	Circular	
		No.GF300	Number of bolts	4	24	24	—	208 bolts
			Rounds	4	6	2		
			Pattern	Star	Circular	Circular		
JIS B 2251 100%	100%	No.6596V	Number of bolts	4	24	24	24	232 bolts
			Rounds	4	1	6	2	
			Pattern	Star	Circular	Circular	Circular	
		No.GF300	Number of bolts	4	24	24	—	208 bolts
			Rounds	4	6	2		
			Pattern	Star	Circular	Circular		
ASME Legacy	100%	No.6596V No.GF300	Number of bolts	24	24	24	—	216 bolts
			Rounds	3	3	3		
			Pattern	Star	Circular	Circular		
ASME Alt.#1	100%	No.6596V No.GF300	Number of bolts	4	16	24	24	120 bolts
			Rounds	2	1	1	3	
			Pattern	Star	Star	Star	Circular	
ASME Alt.#2	100%	No.6596V No.GF300	Number of bolts	4	16	24	24	120 bolts
			Rounds	2	1	1	3	
			Pattern	Star	Star	Star	Circular	
ASME Alt.#3	100%	No.6596V No.GF300	Number of bolts	4	24	—	—	108 bolts
			Rounds	3	4			
			Pattern	Star	Circular			
3 Rounds	100%	No.6596V No.GF300	Number of bolts	24	—	—	—	72 bolts
			Rounds	3				
			Pattern	Star				

the tightening method of No.6596V is different from sheet gasket of No.GF300. In addition, in JIS B 2251[7], additional tightening was proposed in some cases, and the retightening was also carried out in this study.

A major feature of the tightening method[7] according to JIS B 2251 is that only four bolts (when the number of bolts is 24 or less) are temporarily tightened first, and in the final tightening, all bolts are circumferentially tightened. Since the final tightening is a simple circular tightening, it can be expected to reduce time and prevent mistakes such as forgetting to tighten.

3-2) Tightening method ASME PCC-1[6]

In ASME PCC-1[6], unlike JIS B 2251[7], the tightening method does not change depending on the gasket type. This study covers Legacy, which has been proposed previously, and Alternatives #1, #2, and #3, which have been newly added since 2013.

Legacy is a method of diagonally tightening all bolts and is the most widely used tightening method, but it has been pointed out that it takes a lot of time.

Alternative #1 and #2 are methods to reduce the number of tightening bolts in the first step by increasing the torque stepwise for four different bolts in Step 1 and Step 2.

Alternative #3 is a simple tightening method similar to JIS B 2251[7] where only four bolts are temporarily tightened and then circumferentially tightened.

The final steps of the four tightening methods described in ASME PCC-1[6] are "until the nut no longer turns," and the number of tightening times described in Table 2 is the result of the number of times the nut no longer turns in this test.

3-3) Tightening method 3 Rounds

In addition to JIS B 2251 and ASME PCC-1 tightening methods, a convenient way to make three cycles of cross tightening in stepwise is also examined.

4. Experimental results

4-1) Gap distribution between flange faces

Figure3 shows the gap distribution between the flange when tightening by seven methods. The results for the installed gasket No.GF300 are shown by solid lines, and those for No.6596V are shown by broken lines. When the gasket was No.GF300, the effect of the tightening method was minor. On the other hand, in the case of No. 6596V, almost the same results were obtained with the methods based on the standards of JIS B 2251[7] and ASME PCC-1[6], but with the 3 rounds method, the gap was slightly large and the compression amount was small.

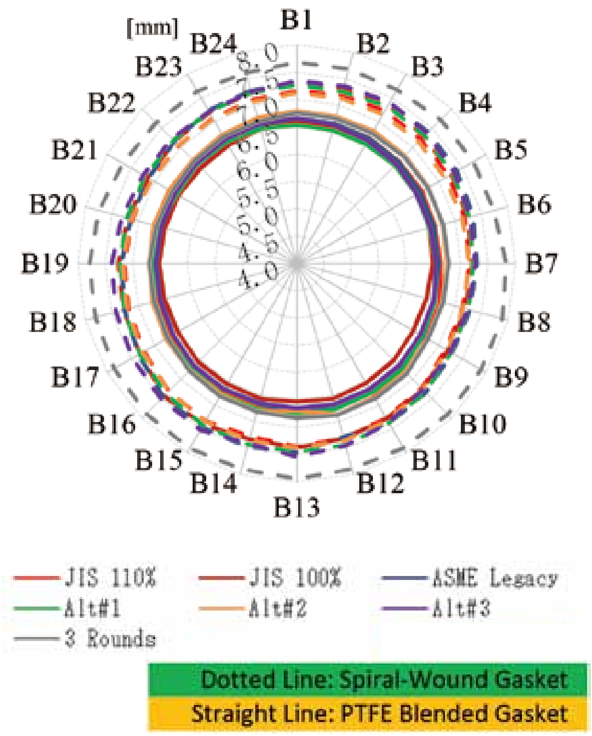

Figure3 Distribution of the flange gap

4-2) Bolt axial force distribution

Figure4 and 5 show the final bolt axial force distribution and the variation in axial force, respectively when the gasket was No.GF300. Regardless of the tightening method, variations in axial force are observed due to elastic interaction. In particular, the variation was large in the 3 Rounds method, and the tightening coefficient Q ($=F_{max}/F_{min}$) was 2.62. Regarding the minimum bolt axial force F_{min}, the target bolt axial force of 85.6 kN could not be achieved with all tightening methods due to the influence of elastic interaction. According to this, the value of Q in JIS 110% (Table2) is 1.31, and the value of Q in Alt#3 is 1.33, indicating the smallest value.

Figures6 and 7 show the final bolt axial force distribution and the results of variation in axial force, respectively when the gasket was No. 6596V. As in the case of No.GF300, the variation was remarkable by 3 Rounds method and one of the three bolts had zero axial force. In Figure 7, the value of Q becomes Q=1.47 in JIS 110%, showing the smallest value. In addition, the value of Q indicates that the tightening of No.6596V is larger than that of No.GF300.

4-3) Sealing performance

Figure8 shows the measurement results of the leak rate of the pipe flange connection tightened by each method. Regardless of the tightening method, the amount of leakage was smaller in the case where the gasket was No.GF300 than in the case where the gasket was No.6596V. The figure also shows the smallest bolt axial force F_{min} of 24 bolts. Comparing

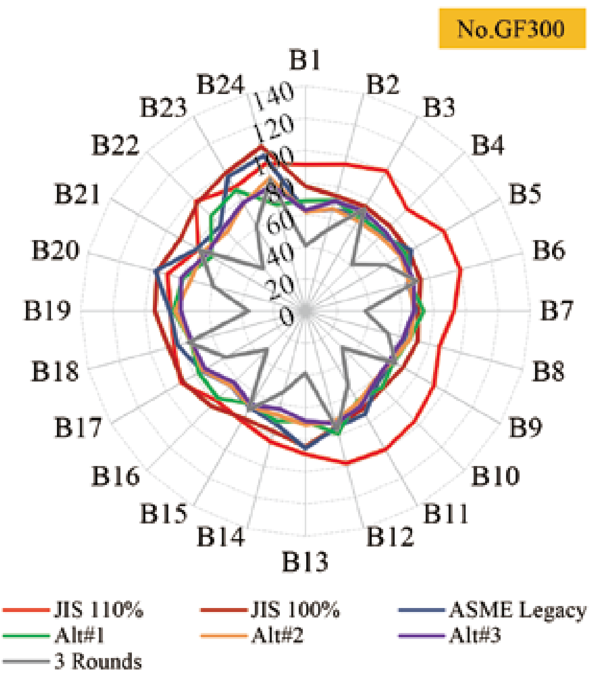

Figure4　Distribution of final axial bolt force (No.GF300)

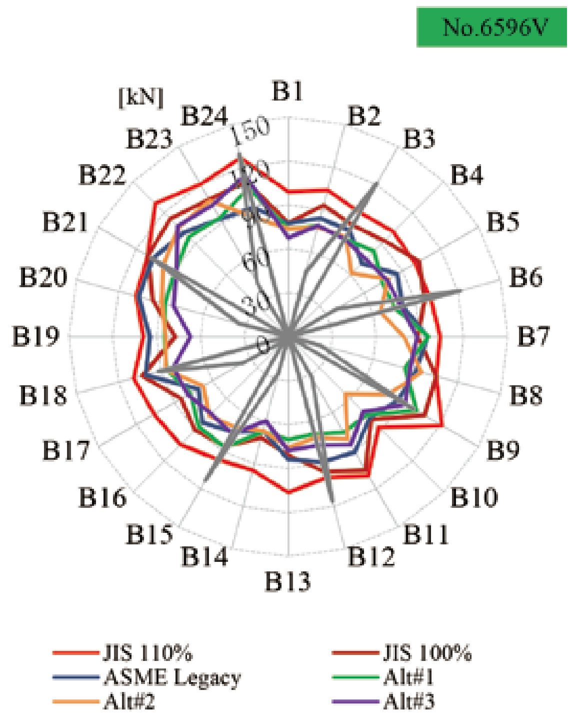

Figure6　Distribution of final axial bolt force (No.6596V)

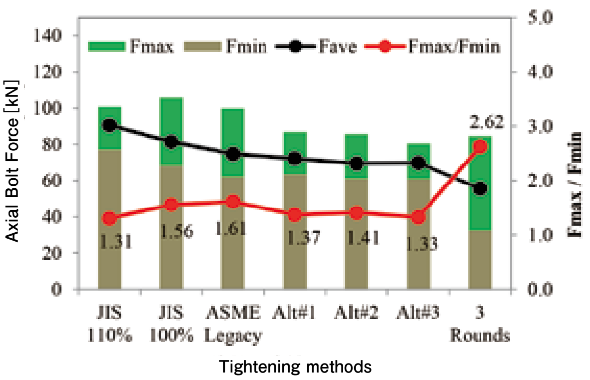

Figure5　Variation of final axial bolt forces (No.GF300)

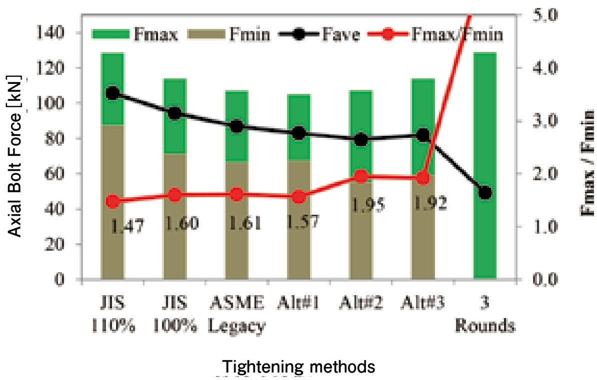

Figure7　Variation of final axial bolt forces (No.6596V)

the leak rate by each tightening method, it is understood that the leakage amount decreases as the minimum bolt axial force increases. Conversely, the smaller the minimum bolt axial force, the smaller the gasket contact stress locally and the larger the leakage amount. In other words, the minimum gasket contact stress has a large effect on the leakage. In the case of a pipe flanged joint with a gasket, if the bolt axial force is low in some parts, it is considered that leakage is likely to occur from the gasket contact surface in the vicinity. It has been shown that it is important to increase the minimum bolt axial force as much as possible to improve the sealing performance.

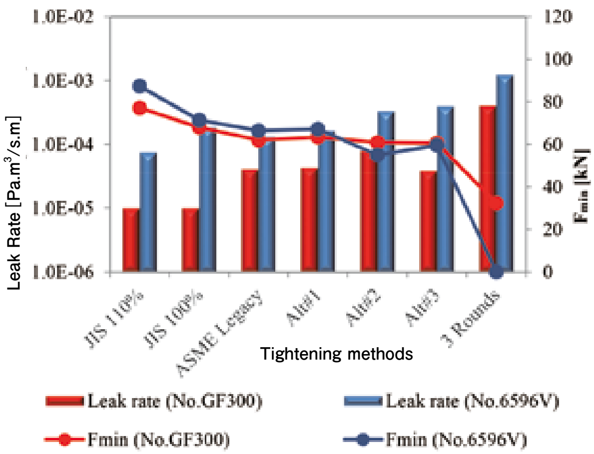

Figure8　Sealing Performance

4-4) Moving distance of wrench

Figure9 shows the moving distances of the wrenches when tightening in six different tightening methods. The moving distance is calculated not by the straight line distance between the bolt holes but by the shortest distance along the circumference. JIS B 2251 and ASME Alt#3 had relatively short moving distances. 3 Rounds method has a long moving distance in spite of the least number of tightening bolts. It can be said that the moving distance becomes shorter in the tightening method in which there are many circumferential tightening, and it can be said that the moving distance becomes longer in the tightening method in which there are many cross tightening.

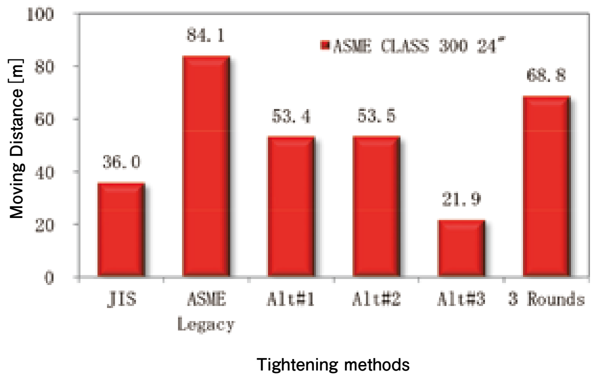

Figure9　Wrench's Moving distance

4-5) Tightening time

Figure10 shows the tightening time required for each of the six tightening methods. In this experiment, the gap between the flange faces was measured during the tightening, but the results in Figure 10 do not include the gap measurement time. JIS B 2251[7)] and ASME PCC-1[6)] Legacy, which has a large number of tightening bolts, have a longer tightening time, and the 3 Rounds tightening method with a smaller number of tightening bolts has the shortest tightening time. Although a torque wrench was used in this study, the tightening time may greatly vary depending on tools such as a hydraulic wrench and torque tensioner and the environment at the site.

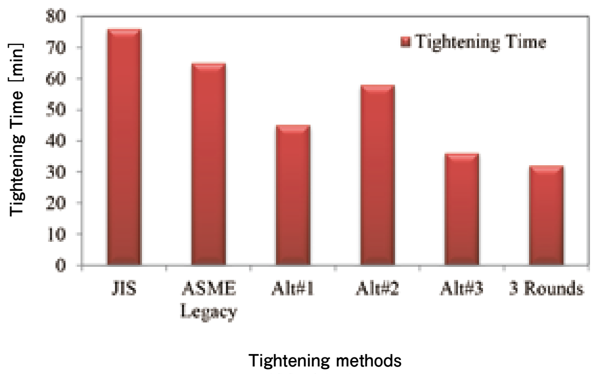

Figure10　Tightening time

5. Summary

In this paper, sealing performance, flange gap, bolt axial force, moving distance of torque wrench and tightening time of two gaskets of No.GF300 and No.6596V were used when tightened by seven different tightening methods, were measured using a large- diameter pipe flange connection, and the following results were obtained.

(1) No significant difference was found in the flange gap distribution according to these tightening methods.

(2) The sealing performance of pipe flange fasteners is affected by the tightening method and JIS B 2251[7)] 110% tightening method has the least leak rate. Then, JIS B 2251[7)] was 100%. Although it was observed that the 3 rounds tightening method was simple but the sealing performance was inferior.

(3) It was observed that the sealing performance of pipe flange joints are affected by the minimum bolt axial force and it is important to increase the minimum bolt axial force as much as possible to improve the sealing performance.

(4) As for the tightening method, the moving distance of the torque wrench tends to lengthen when the cross tightening is large, and as for the tightening method with a large number of tightening times, the tightening time tends to longer.

(5) JIS B 2251[7)] and ASME PCC-1[6)] Legacy and Alt #1 have relatively small leaks but require a longer tightening time. The 3 Rounds method has a relatively large leakage but the tightening time is less than half of JIS B 2251[7)].

6. Conclusion

The American Society of Mechanical Engineers (ASME) has introduced a factor called assembly efficiency η. η is the ratio of the final axial bolt force to the target axial bolt force, and the value is less than 1. In other words, in actual design and construction, the target value of the bolt axial force is further increased by $1/\eta$. (JIS B 2251[7)]) The basic idea of 110% is to tighten 10% larger. However, this is based on the bolt axial force and is not always appropriate, and it has been proposed to use the assembly efficiency based on tightness parameter[9)]. It seems that there is room for improvement to a more efficient tightening method to improve the sealing performance required for the gasketed flange connection. We hope that this research will help the plant tightening work.

We were advised by Mr. Koichi Morimoto of Mitsubishi Chemical Co., Ltd. about this experiment. We would like to express my gratitude by noting.

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Evaluation of the Compression methods on the Sealing Performance of Gland Packing

1. Introduction

The gland packing serves to seal the internal fluid by tightening the packing gland with bolts and compressing the gland packing. For this reason, it has been found that the sealing performance greatly depends on the compression pressure. However, the effect of the compression method is unknown. The compression method includes batch compression in which several rings are compressed at one time and divided compression in which compression is performed several times for every two or three rings. It is thought that the divided compression increases the density of the gland packing and improves the sealing performance, but the quantitative effect is not known. In addition, batch compression is generally used because it takes time for divided compression. In this study, the effect of the compression method on the sealing performance was evaluated along with the mechanical behavior such as stress relaxation using gland packing of different materials. In addition, the operation time required for each compression method was measured and evaluated from the viewpoint of sealing performance and operating efficiency.

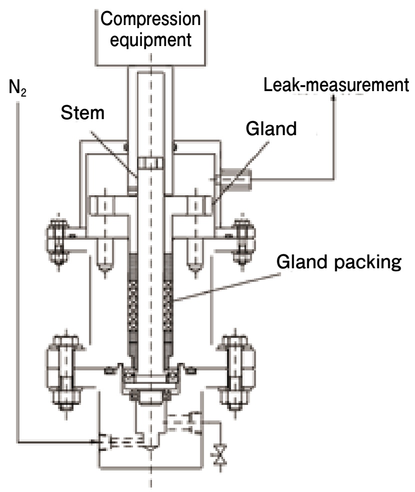

Figure1 Compression equipment and test equipment

2. Test method

2-1) Test equipment and test method

Figure1 shows a schematic diagram of the compression equipment. Using this test apparatus, the sealing performance by the compression method in the batch compression and the divided compression was compared. Furthermore, the sealing performance at the time of recompression, which has the same effect as retightening after batch compression or divided compression, was also measured. Three types of gland packing were used: carbon fiber gland packing (No. 6137), PTFE gland packing (No. 7233), and expanded graphite gland packing (No.VF-10T).

2-2) Test conditions

Compression pressure : 19.6MPa
Fluid : Nitrogen gas
Fluid pressure : 1, 5, 10 MPa
Gland packing ring number : 6 pcs

2-3) Test method

Four compression methods were used: batch compression, batch compression +recompression (hereinafter referred to as "batch +recompression"), divided compression, divided compression +recompression (hereinafter referred to as "divided +recompression"). After stress relaxation was stabilized, sealing tests were conducted.

Batch compression:

① Six gland packing rings are attached to the test equipment.
② After compressing the gland packing with compression equipment at 19.6 MPa for 30 seconds, fix the head position of the compression equipment.
③ Wait until stress relaxation stabilizes
④ Nitrogen gas (1, 5, 10 MPa) was used into the test equipment for leakage measurement
⑤ Exhaust nitrogen gas
⑥ Perform recompression (batch + recompression) under the same conditions as step ②
⑦ Carry out steps ③ to ④.

Divided compression:

① Two gland packing rings are attached to the test equipment.
② Release the compression equipment after compressing the gland packing with a compression equipment at 19.6 MPa for 30 seconds
③ ① to ② are repeated twice, a total of 6 pieces are mounted, and the head position of the compression equipment is fixed
④ Wait until stress relaxation stabilizes
⑤ Nitrogen gas (1, 5, 10 MPa) was used into the test equipment for leakage measurement
⑥ Exhaust nitrogen gas
⑦ Perform recompression (divided + recompression) under the same conditions as step ②
⑧ Carry out steps ④ to ⑤

3. Test Results and Discussion

3-1) Carbon fiber gland packing (No.6137)

Figure2 shows residual stresses after stress relaxation of carbon fiber gland packing (hereinafter, carbon fiber). The order of the lowest residual stress was as follows: batch compression < divided compression < batch +recompression < divided +recompression.

Figure3 shows the sealing test results after stress relaxation. The order of large amount of leakage was as follows: batch compression > divided compression > batch +recompression > divided +recompression. Since the leakage decreases with the compression method with high residual stress, it can be concluded that there is a correlation between residual stress and leakage.

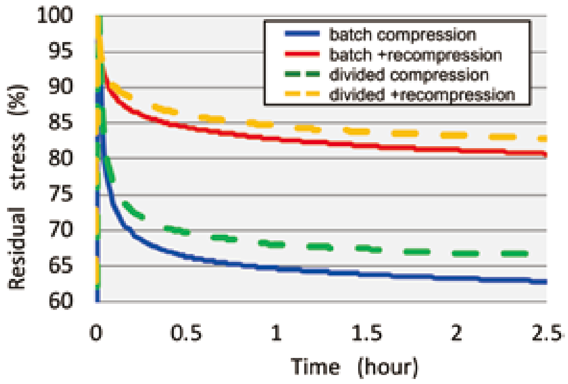

Figure2 Residual stresses of carbon fiber (No.6137)

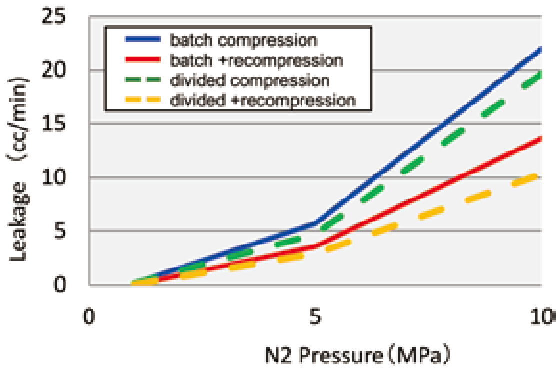

Figure3 Leakage of carbon fiber (No.6137)

3-2) PTFE gland packing (No.7233)

Figure4 shows the residual stress after stress relaxation of PTFE gland packing (hereinafter, PTFE) and Figure5 shows the sealing test results after stress relaxation. The residual stresses of batch compression and divided compression became almost the same, and batch +recompression and divided +recompression also became almost the same. However, the difference was found in each sealing performance.

This is because, as shown in Figure6, In the case of one-time compression , the number of times the compression is pressed against the sealing surface is small, and the gap between the sealing surface and the gland packing becomes large, so leakage increases but for divided compression, the gap between the gland packing and the sealing surface was filled by the three times compression, and the leakage was reduced.

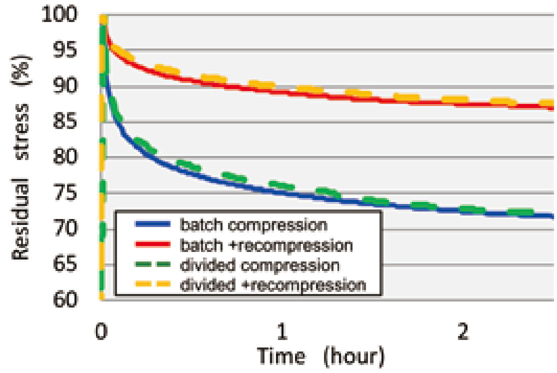

Figure4 Residual stress of PTFE (No.7233)

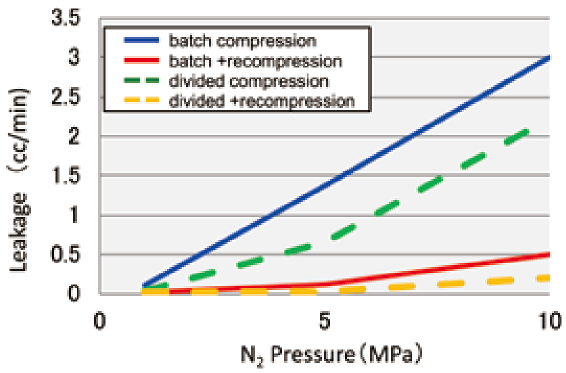

Figure5 Leakage of PTFE (No.7233)

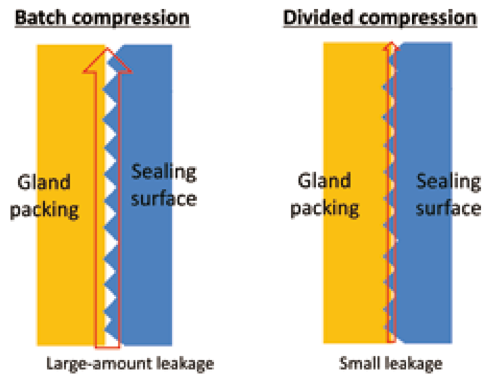

Figure6 Relationship between compression method and gap

3-3) Expanded graphite gland packing (No.VF-10T)

Figure7 shows the residual stresses after stress relaxation of the expanded graphite gland packing (hereinafter, expanded graphite). Expanded graphite originally had small voids and high density, so stress relaxation was small and the residual stress is as high as 95% or more in all compression methods, the difference between compression methods was also small. There was almost no difference in the residual stress between the compression methods, but there was a difference in the sealing performance.

Figure8 shows the sealing test results after stress relaxation. Carbon fiber and PTFE leaked less in batch + recompression than divided compression, whereas expanded graphite leaked less in divided compression than batch + recompression. In the case of the divided compression, the compression is released once to insert the next gland packing. Since the expanded graphite is obtained by pressing and solidifying the powder, it is difficult to recover even if the compression is released by divided compression, the leakage of divided compression is less likely to occur because deterioration of density and conformity of the sealing surface is smaller than batch +recompression.

Since the fibrous carbon fiber and PTFE are easily restored, it is considered that the density of the gland packing is reduced and the conformity to the sealing surface is easily deteriorated, and the effect of the split compression is considered to be smaller than that of the expanded graphite.

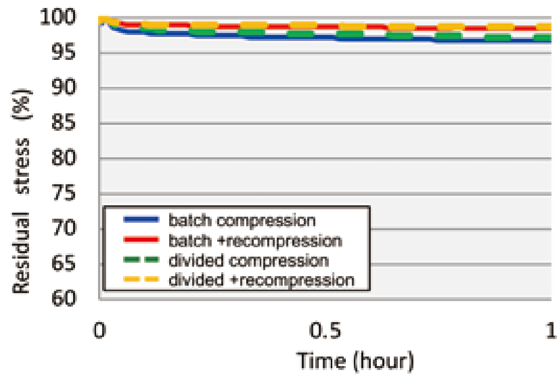

Figure7 Residual stresses of expanded graphite (No. VF-10T)

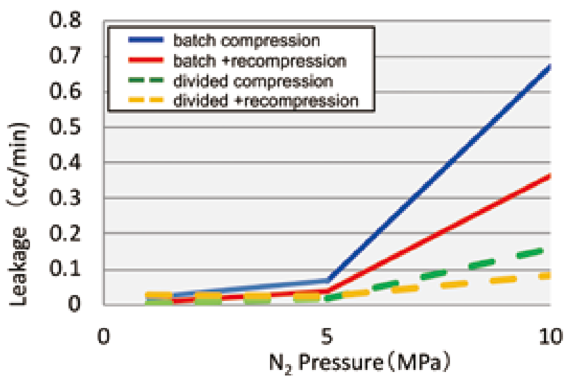

Figure8 Leakage of expanded graphite (No. VF-10T)

3-4) Effect of compression method for each packing type

Figure9 shows a graph comparing the effects of the compression method for each packing material. The vertical axis of the graph represents the rate of change of the leakage of the other compression methods when the leakage of the batch compression of the blue bar is 100%. Divided+recompression was the least leaking compression method for all types of packing.

Comparing batch +recompression and divided +recompression, the difference in carbon-fiber and PTFE leakage was 10-14% and the difference due to compression methods was small. On the other hand, the difference in leakage of expanded graphite was 43%, and the difference by the compression method became large. As described in 3-3) , carbon fiber and PTFE are fibrous and easily recovered, whereas expanded graphite is hard to recover because it is manufactured by solidifying powder. As a result, it is unlikely that the density is reduced and the conformity to the sealing surface is not easily deteriorated. Therefore, it is considered that the effect of the divided compression is remarkably obtained in the expanded graphite.

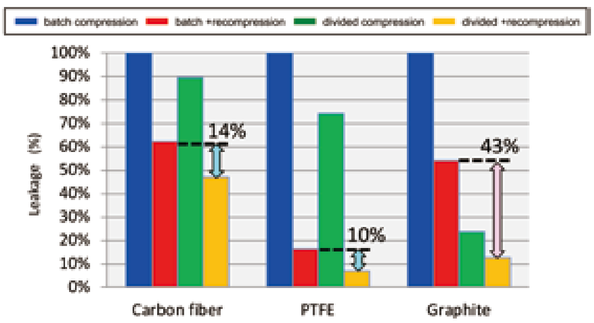

Figure9 Differences in leakage amount due to compression methods

3-5) Operation time for each compression method

Figure 10 shows the operation time for each compression method. The time required for the divided + recompression was 3.6 times that of the batch + recompression. Performing divided + recompression with carbon fiber and PTFE with a 10-14% difference in leakage is considered to be inefficient.

Divided + recompression with expanded graphite showed 43% better sealing performance than batch + recompression. Division + recompression took 3.6 times operation time than batch + recompression, so it is recommended for applications requiring high sealing performance.

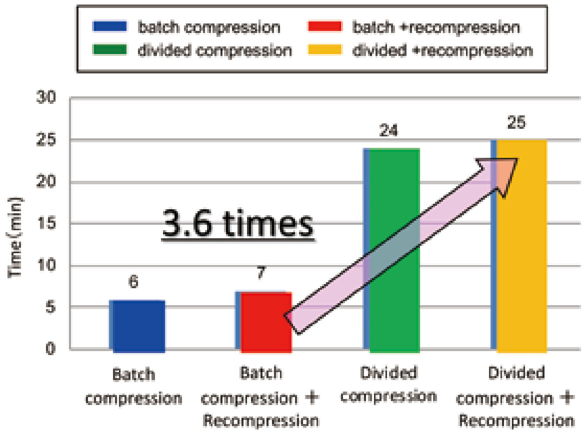

Figure10 Operational time of compression methods

4. Conclusion

This study was able to evaluate the relationship between sealing performance and operation time due to differences in compression methods. Under the present test conditions, in the case of carbon fiber and PTFE, since there was no significant difference in the leakage of batch + recompression and divided + recompression, it is recommended to perform additional tightening after batch tightening from the viewpoint of operational efficiency. In the case of expanded graphite, if the operational efficiency is prioritized, perform retightening after batch tightening, and if prioritizing sealing performance, use retightening after divided tightening. It has been observed that the desired effect can be selected by using an appropriate compression method.

It takes a lot of time to attach and detach the gland packing and to tighten it in the plant site. We hope that this study will help improve the tightening efficiency of the gland packing.

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Comparison of Semi-Metallic Gasket's Performance and Introduction of Kammprofile Gasket Series

1. Introduction

In the fields of petroleum refining, petrochemical, and energy, semi-metallic gaskets such as Spiral Wound Gaskets, Metal Jacketed Gaskets, and Kammprofile Gaskets are often used.

Spiral Wound Gaskets are widely used from piping to equipment, and Metal Jacketed Gaskets are often used in equipment such as heat exchangers because they have a narrow seal width and can make branched gaskets. The Kammprofile Gaskets have been widely used overseas, but in recent years, it is becoming popular in Japan because of its excellent performance and due to easy handling.

Though semi-metallic gaskets have been used in this way, but with the aging of equipment and the diversification of attitudes toward maintenance management, they have come to be re-selected according to usage conditions. However, there are few performance comparison data for these semi-metallic gaskets. Therefore, this report presents comparative evaluation data of semi-metallic gaskets which provide an indicator for users to select gaskets. At the same time, we will introduce the features of the Kammprofile gasket series which expanded our lineup.

This study was conducted with Spiral Wound Gasket (No.6596V) using expanded graphite, Kammprofile Gasket (No.6540H), and Metal Jacketed Gasket (No.N520).

2. Comparative evaluation

2-1) Sealing performance at room temperature

Figure1 shows the sealing performance at room temperature. The evaluation was performed based on JIS B 2490. The paste (No. 6) was applied to the metal jacketed gasket based on the general usage.

Sealing performance of the spiral wound gasket was the best at room temperature. The kammprofile gasket and metal jacketed gasket have a large amount of leakage at low gasket contact stress (12.5-50 MPa), and when loaded with 50 MPa or more, the leak amount is less than the measurement sensitivity. The sealing performance is higher than the detection level of the soap bubble test used for the leak detection at the plant.

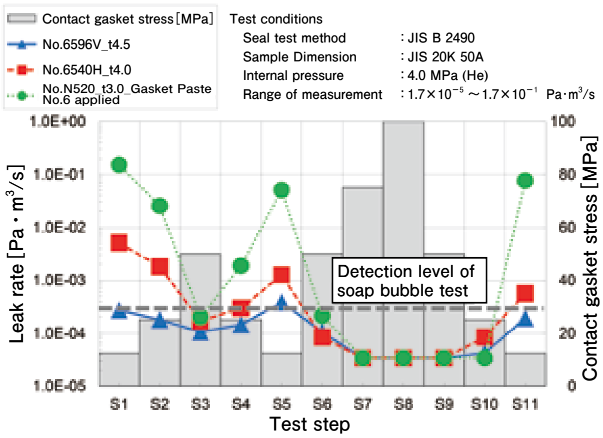

Figure1 Room Temperature Sealing Performance

2-2) Compression and recovery characteristics

Figure2 shows the compression and recovery characteristics. The difference in the amount of gasket displacement between the contact gasket stress at 5 MPa and 100 MPa was defined as the amount of compression. The difference in the amount of gasket displacement between the contact gasket stress at 100 MPa and 12.5 MPa was defined as the amount of recovery. Table 1 shows the compression and recovery amounts of gaskets.

Table1 shows that the spiral-wound gasket had the largest amount of compression and recovery. For the metal jacketed gasket, the compression amount was large but the recovery amount was small, and for the kammprofile gasket, both the compression amount and the recovery amount were small. If the flange gap fluctuation is large due to thermal cycling, a spiral wound gasket with the best compression recovery characteristics isappropriate.

Table1 Compression recovery characteristics

	Compression [mm]	Recovery [mm]
	Contact gasket stress 5 MPa→100 MPa	Contact gasket stress 100 MPa→12.5 MPa
No.6596V t4.5	0.850	0.198
No.6540H t4.0	0.432	0.060
No.N520 t3.0 (Applied No.6)	0.918	0.079

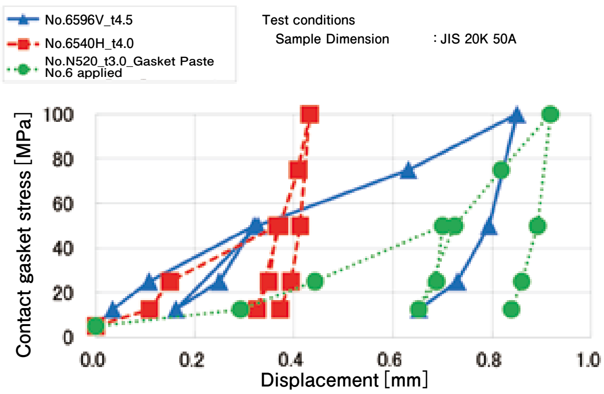

Figure2 Compression Recovery Characteristics

2-3) Sealing performance at high-temperature thermal cycling

For evaluation of sealing performance at high temperature, heating and cooling are repeated while the gasket was tightened to the flange and evaluation was carried out after cooling.

Figures3 and 4 show the sealing performance with the thermal cycle. The tightening contact gasket stress was set to 70 MPa for all samples, and the recommended tightening contact gasket stress for each gasket was also used. The heating temperature was 400℃ and 500℃.

From Figure3 and 4, the spiral wound gasket and the kammprofile gasket maintained stable sealing performance. On the other hand, in the case of the metal jacketed gasket, the leak amount before the heating was less than the measurement detection level, but the leak amount increased after the heating. This is thought to be due to the decrease in the resilience of the core material due to repeated thermal cycles.

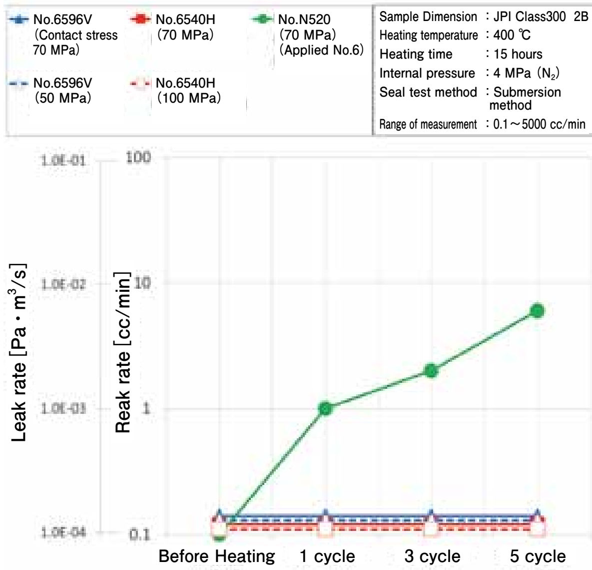

Figure3 Thermal Cycle Sealing Performance at 400℃

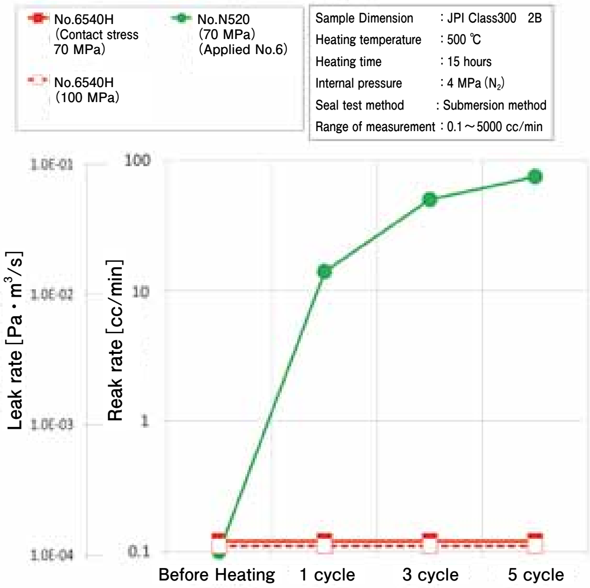

Figure4 Thermal Cycle Sealing Performance at 500℃

2-4) Selective use of semi-metallic gaskets

Spiral wound gaskets are the best semi-metallic gaskets in terms of performance. However, it may be difficult to use the spiral wound gasket, such as a large diameter which is difficult to handle and a shape witha narrow gasket width. Therefore, when the diameter of the gasket is less than about φ1000 mm and the seal width can be secured, the spiral wound gasket is appropriatee. On the other hand, when a large diameter (φ1000 mm or more) and seal width cannot be secured, or when working at high places, a kammprofile gasket or metal jacketed gasket isappropriate. Also, metal jacketed gaskets have the advantage that they can be processed into various shapes such as ellipses and rectangles and are more economical than kammprofile gaskets.

3. Kammprofile gasket series

3-1) Features

As previously stated, the kammprofile gasket is becoming increasingly spread in Japan in recent years. In response, we have developed a new profile gasket and expanded our product lineup. According to the usage conditions, it became possible to select the surface layer material to be bonded to the metallic serrated gasket.

Expanded graphite sheet laminated product (No.6540H) is a general-purpose product that can be used under various conditions. When used at 400℃ or higher which is a temperature range in which expanded graphite is liable to disappear by oxidation, the more heat resistant VALQUA HEAT RESIST SHEET™ laminated product (No.HR540H) is appropriate. PTFE sheet laminated product (No.7540H) is used at lower temperatures than the expanded graphite product, but it is appropriatefor lines where it is difficult to use expanded graphite due to the concern of contamination.

3-2) Characteristic evaluation

Heat resistance is one of a features of No.HR540H. Figure5 shows the thermal cyclic characteristics at 600℃ of a kammprofile gasket with a surface layer a VALQUA HEAT RESIST SHEET™ and an expanded graphite sheet.

From the results at 600℃, the leakage amount of No.HR540H did not change significantly even when the heating temperature was increased, but the leakage amount of No.6540H increased significantly. This is because expanded graphite disappears due to oxidation.Since the expanded graphite gradually oxidizes and disappears above 400℃, long-term sealability maintenance is a concern. Figure6 and 7 show the rate of weight loss over temperature and time for expanded graphite sheet and VALQUA HEAT RESIST SHEET™. Figure7 shows the evaluation result of up to 240 hours. However, the expanded graphite decreases even at temperatures of about 400℃ to 500℃, the sealing stability is a concern in the long term of 2 to 4 years. The VALQUA HEAT RESIST SHEET™ loses a little weight at the beginning of heating, and most of it remains unchanged in the long term. In addition, even if the heating temperature is raised, the rate of decrease remains unchanged, and the rate of decrease in the long term is also constant, resulting in stable sealing.

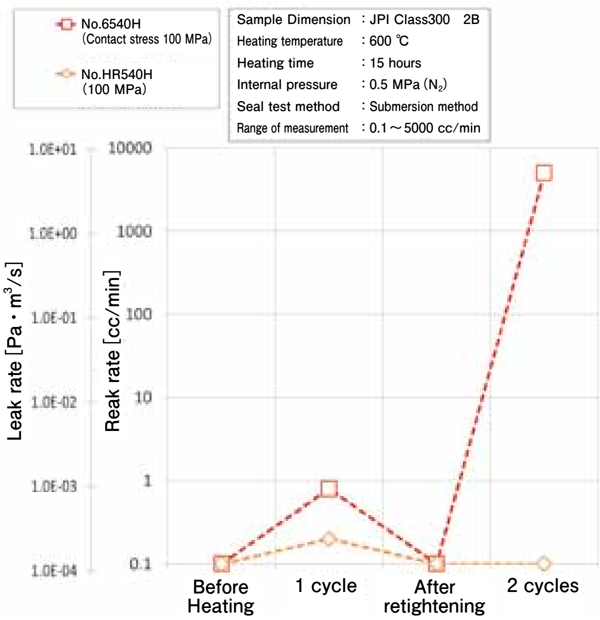

Figure5 Thermal Cycle Sealing Performance at 600℃

Large diameters pipe flange connections or equipment may be subjected to flange rotation, etc., and the gasket may have a load greater than the recommended tightening contact stress. Therefore, there is a concern that the metal part is exposed at the time of tightening and may damage the flange. Table2 and Figure8 show the evaluation results of kammprofile gasket's surface material which is cracked by applying excessive contact gasket stress. In No.HR540H and No.6540H, no metal exposure was observed even when a contact gasket stress of 200 MPa was applied, and there is a little risk of damaging the flange even if an excessive contact gasket stress was applied. In No.7540H, metal exposure was confirmed at a contact gasket stress of 140 MPa. This is probably because the PTFE sheet is easier to flow than the expanded graphite sheet. However, the recommended tightening contact gasket stress of No.7540H is 60 MPa, and even if a contact gasket stress twice as high as the recommended tightening contact gasket stress is applied, no metal is exposed and it is considered that there is no problem in use.

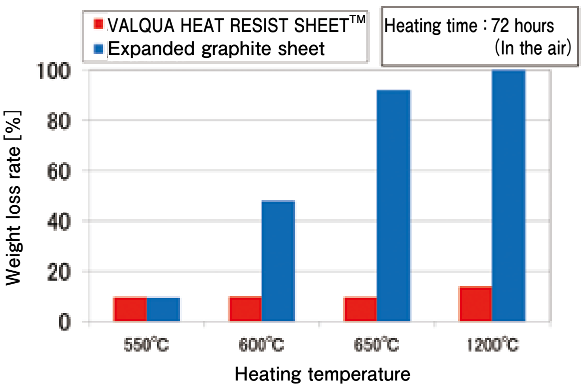

Figure6　Change in weight loss rate with temperatures

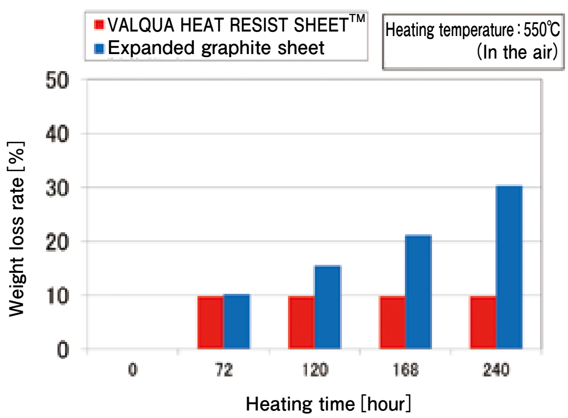

Figure7　Change in weight loss rate with times

Table2　Change in weight loss rate with times

Sample Dimension		Metal exposure
No.HR540H	VALQUA HEAT RESIST SHEET™	No metal exposure at 200 MPa
No.6540H	Expanded graphite sheet	No metal exposure at 200 MPa
No.7540H	PTFE　sheet	metal exposure at 140 MPa

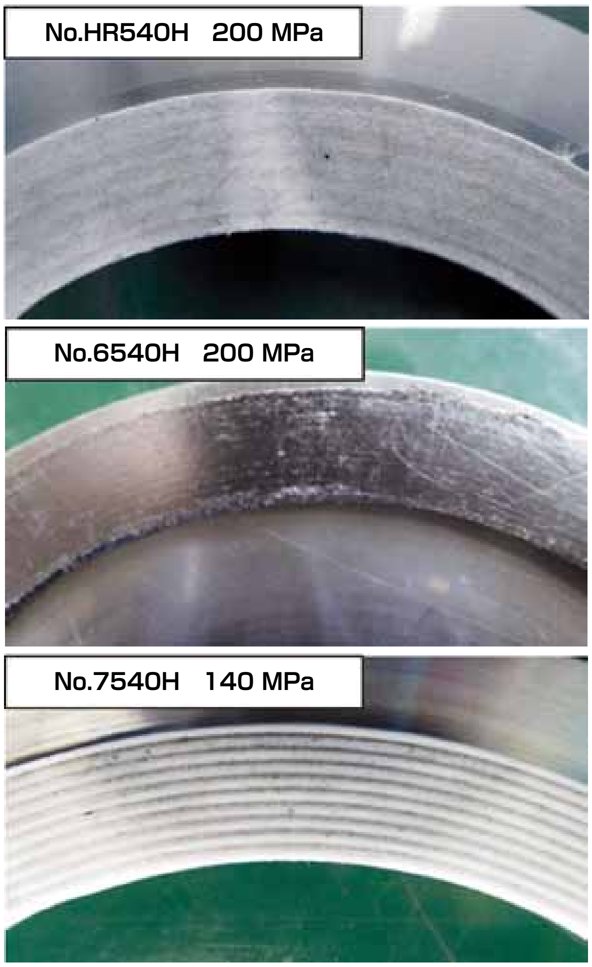

Figure8　Appearance after excessive contact gasket stress

4. Conclusion

In domestic petroleum refining and petrochemical plants, more stable sealing products are required due to the aging of plants and the prolonged periodic maintenance. We hope the performance comparison of these semi-metallic gaskets and the kammprofile gasket series will be an good option in selecting gaskets.

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Introduction of High-speed Opening and Closing Cylinder Valve

1. Introduction

Conventionally, ball valves and butterfly valves have been frequently used as automatic pneumatic valves which can be opened and closed in a short time and have low fluid flow resistance, but there have been difficulties in "durability and high-speed actuation".
Though these difficulties rarely become a problem in normal conditions, they sometimes become problematic in rolling line's cooling water switching valves in steel mills used in high frequency and high-speed operation. The problem is that the valve seat seal part is in sliding contact, and it is difficult to achieve good sealing for a long time because the valve seat is worn and damaged due to the accumulation of the operations. In addition, when the opening and closing operation time is short, the sudden increase in pressure on the primary side of the valve due to the water hammer phenomenon caused by sudden closing causes damage to the valve seat seal, valve support bearing, and operating stem and as a result, the valve may become inoperable.
In this report, we introduce the High-speed opening and closing cylinder valve, which was developed, and has been manufactured and sold about 40 years ago, has added value to solve these problems, and is still being selected by our customers.

2. Features

2-1) long sealing life

Since the valve seat seal is not in sliding contact, there is no deterioration in sealing performance due to friction.

2-2) Good operating reliability

Because of the internal structure is simplified and the number of moving parts is reduced, the occurrence of trouble is extremely low. In addition, since the entire valve has a cylindrical shape has sufficient strength to withstand a sudden pressure load due to the water hammer phenomenon and does not malfunction.

2-3) Compact and easy to handle

As the valve incorporates a drive unit and is integrated, it is compact, light, and easy to handle. Since the drive unit does not protrude, the space for piping can be reduced, and there is no limitation on the mounting procedure. Figure1 shows a sample image of a cylinder valve cut sample.

Figure1 Cylinder valve with built-in drive unit

2-4) High-speed operation

The moving parts are lightweight and have a short working stroke, enabling high-speed operation and good operability. Table1 shows a list of operating times for standard specifications.。

Table1 Standard operating time of cylinder valve

FLUID PRESSURE / OPERATION / NOMINAL SIZE	OPERATION TIME (SEC.) 0.98MPa OPEN→SHUT	0.98MPa SHUT→OPEN	1.96MPa OPEN→SHUT	1.96MPa SHUT→OPEN	USE AIR APPARATUS (MADE BY KONAN ELE.) SOLENOID VALVE	USE AIR APPARATUS (MADE BY KONAN ELE.) SPEED CONTROL VALVE
15A	0.10	0.10	0.10	0.10	453S202C	SC6-02-8A
20A	0.11	0.10	0.13	0.10		
25A	0.14	0.12	0.17	0.12		
32A	0.21	0.19	0.26	0.17	413S302C	
40A	0.21	0.19	0.26	0.17		
50A	0.33	0.28	0.43	0.26		
65A	0.30	0.26	0.36	0.25	413S603C	SC6-04-10A
80A	0.34	0.29	0.42	0.27		
100A	0.44	0.38	0.57	0.35		
125A	0.68	0.59	0.85	0.54		
150A	0.94	0.81	1.2	0.74		
200A	1.7	1.5	2.1	1.3	413S604C	SC6-04-15A
250A	2.4	2.0	3.1	1.8		
300A	2.6	2.1	3.5	1.9	413S806C	SC6-08-20A
350A	3.1	2.6	4.0	2.4		
400A	3.4	3.1	3.8	2.8		
450A	4.8	4.5	5.3	4.1		

2-5) Low air consumption

The effect of internal fluid pressure on valve operation is minimized, so the effective cylinder area is small. The amount of compressed air required for operation is less than the amount required to operate a ball valve of the same size.

2-6) Low fluid flow resistance

In a valve where the valve seat does not make sliding contact (eg a globe valve), the flow resistance is large because the flow direction of the fluid changes several times, but the flow direction of the cylinder valve is small. In addition, since the flow path is streamlined, the flow resistance is small and can be used for relatively large flow applications. Figure2 shows the relationship between the Cv value, differential pressure and flow rate of the two-way valve.

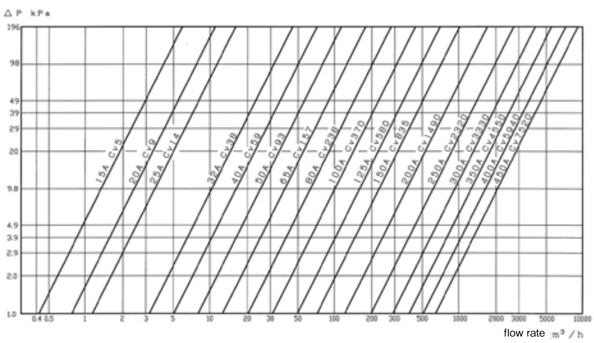

Figure2 Relationship between Cv value, differential pressure, and flow rate

3. Structure and Operation

The main components of the cylinder valve are the main body, the cap, and the piston, and the structure is such that the seal material for each joint and the movable part seal is used. Figure3 shows the cross-sectional diagram of the two-way cylinder valve. Also, a three-way cylinder valve can be made by attaching a T-shaped part to the primary side (body line flange side) of the two-way valve. Figure4 shows the cross-sectional diagram of the three-way cylinder valve.

The piston moves to the valve seat side or the non-valve seat side by switching the operating air pressure supplied to the cylinder (body). When the piston moves to the valve seat side, the tip of the piston is pressed against the valve seat packing, sealing the fluid flowing through the main body flow path and the inside of the piston, and the valve becomes "closed". Next, when the operating air pressure is switched and the piston moves to the opposite side of the valve seat, the space between the tip of the piston and the packing of the valve seat is opened as a flow path, and the fluid flows through the main body flow path and

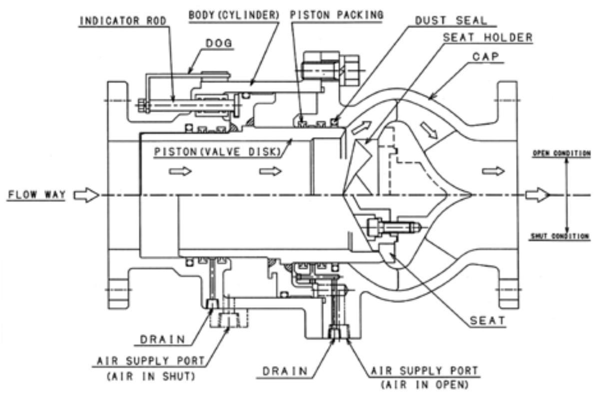

Figure3 Cross-section diagram of 2-way cylinder valve

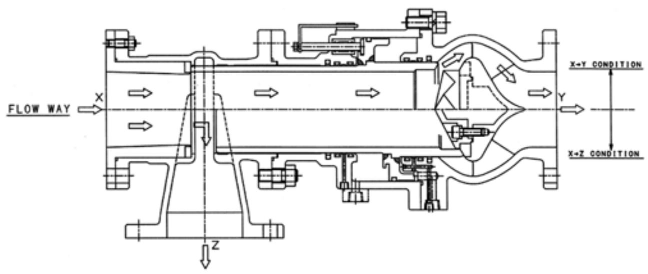

Figure4 Cross-section diagram of 3-way cylinder valve

the cap flow path through the piston inner part and the valves becomes “Open”.
The opening and closing state of the valve can be easily checked visually with an opening and closing indicator attached to the piston. In addition, by attaching an operation bar to the opening and closing instruction rod, it is possible to detect the opening and closing state using limit switches and proximity switches, and to attach a positioner and control valves.

4. Standard Specifications

The standard specifications of the cylinder valve are as follows.

■ Wetted metal material … SCS13, SUS304
■ Packing material… NBR, AU (Select others depending on the fluid)
■ Connection ……… JIS 10k, 20k flanges (CLASS 150 is also acceptable)
■ Size ……………… Nominal size 15 A～450 A
■ Sealing life ……… 500,000 cycles
■ Max. operating pressure …… According to Table2
■ Operation Air Pressure …… 0.4～0.7MPa
■ Operating temperature range
…… Depends on packing material (Consultation required)

Table2 Maximum operating pressure of cylinder valve

	NOMINAL PRESSURE	MAX.ALLOWABLE WORKING PRESSURE
2 WAY VALVE	10K	1.37MPa
	20K	3.33MPa
3 WAY VALVE	10K	0.98MPa
	20K	2.45MPa

Note : In case of 20k, 15A to 25A, both 2-way valve and 3-way valve are 1.97MPa.

5. Applications

5-1) Main application

The steelworks and PSA type nitrogen gas generator, which were the development purposes, are the main applications.

5-1-1) Steelworks (including non-ferrous metals)

Thick plate and hot rolling line product, cooling roll switching valve.
Customer needs: sealing life, operation reliability, high-speed opening and closing, automatic valve

5-1-2) PSA type nitrogen gas generator

Gas switching valve for PSA type large mounted nitrogen gas generator.
Customer needs: sealing life, sealability, high-speed opening and closing, automatic ON-OFF valve

5-2) Examples of new applications

Recent application examples are introduced below.

5-2-1) Theme Park fountain equipment

Used for shows including fountains in theme parks. Cylinder valves are used as ON-OFF and control valves for fountain effects. The fountain flow rate control with high-speed opening and closing contributes to a more expressive show than ever before.
Customer needs : operation reliability, high-speed opening and closing, automatic ON-OFF valve, control valve

5-2-2) Factory Wastewater Equipment Filter

Factory wastewater is discharged outside the factory when it meets the standards through a filter. The wastewater dust adheres to the filter and filtering ability may deteriorate if it is used continuously. Therefore, dust is removed by air blow, but if the ON-OFF valve is used frequently, air leaks inside and the line must be stopped to perform maintenance.
ON-OFF ball valves are usually used in the above applications, but the sealing life is short because the valve seat is sliding contacts. The adoption of a cylinder valve can contribute to improving the operation rate of wastewater facilities and reducing maintenance man-hours.
Customer needs : sealing life, automatic ON-OFF valve

6. Conclusion

In this report, we introduced the High-speed opening and closing cylinder valve, which solves the customer's difficulties / problems (= challenges) with our reliable seal valve technology solution (= provides value). We believe that our customers continue to use our products because our products maintain high quality. It is a realization of the fact that our name "Valqua" comes from "Value & Quality". We will continue to explore the potential needs of customers and provide solutions to build a win-win relationship with customers.

7. References

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2) Masahiro Kitazawa: Valve Technical Report No. 52, 80-81 (2004)

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Development of Spray Ball™ for Tank Cleaning

1. Introduction

In recent years, CIP (Cleaning In Place) with little or no involvement of workers has become the mainstream for assembling and removing of industrial tanks and pipes, etc.
This report focuses on cleaning nozzles for cleaning in tanks in various industries and introduces the Spray Ball™ (fixed type) and Rotary Spray Ball™ of our products and new Rotary Spray Ball™ of our developed products.
Cleaning validations are being implemented for facility equipment in critical processes in the pharmaceutical industry. Our Spray Ball™ has also been adopted as an important part of cleaning equipment, contributing to the risk management of our customers.

2. What is cleaning?

In this report, we define cleaning as removing the dirt (solid substance adhering to the surface) to the extent that there is no problem for the post-process treatment and processing.
In a broad sense, the cleaning also includes removing impurities in the gas or liquid, but it is excluded here.
The cleanliness of cleaning varies by purpose and use from a level of 100% removal of deposits to a level of acceptability when it is apparently reduced, and there is a wide range of demands from each industry.

3. Spray Ball™ (fixed type)

Fixed type Spray Ball™ is used for cleaning tanks such as reaction tanks, stirring tanks, and storage tanks in all industries, such as medical, chemical, and food products. Since the wetted part is PTFE having heat and chemical resistance characteristics, makes it possible to permanently install the product inside a tank. In addition, since the spraying position is designed according to the customer's tank nozzle orientation, efficient cleaning is possible in a short time and the consumption of cleaning liquid can be suppressed.
The holes are efficiently arranged by high-precision machining, and pressure is applied from a small hole to inject. If the fluid is flammable, conductive PTFE is recommended as the material. This is because static electricity accumulates during injection, which might cause firing.

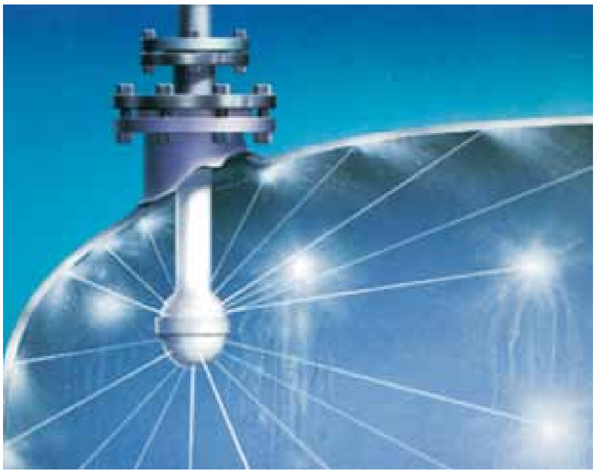


Figure1 Image of Spray Ball™ (fixed type)

Table1 The number of Spray Ball™ per tank volume

Tank volume	The number of Spray Ball™		
	Type	Vertical reaction tank	Vertical storage tank
～600ℓ	50	2	1
1～5m³	80	2	1
6～10m³	100	2	1

Note: The number of units used in the above table is an example.

Table1 shows the approximate required number of Spray Ball™.

If there are stirring shafts, baffles, etc. in the tank, it is recommended to increase the number of Spray Ball™ to clean the backside of the shaft.

The structure consists of ① upper ball ② lower ball ③ two-stage flanges as shown in Figure1 & 2. A two-stage flange is used to prevent misalignment so that the jet can be precisely sprayed to the intended cleaning point.

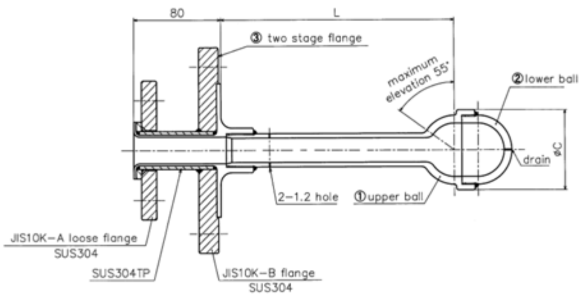


Figure2 Standard design of Spray Ball™ (fixed type)

Table2 shows the standard dimensions.

Table2 Standard dimensions

Type	Cleaning water vlume (L/min)	Flange combination	φC	L (maximum)	
				PTFE	Conductive PTFE
SB-50	15～40	25A×50A	46	400	300
SB-80	30～70	25A×80A	72	600	370
SB-100	70～100	40A×100A	97	500	370

When attaching the Spray Ball™ to a T-tube, etc., attach a joint or steady rest. This is to prevent the warpage due to the concentration of holes at certain locations and the application of spraying pressure.

For the flange combination, besides Table2, the size can be specified. The material of the flange is SUS304 as standard, but other materials such as SS400 can also be specified.

4. Rotary Spray Ball™

Figure3 Image of Rotary Spray Ball™

Rotary Spray Ball™ is similar in application and material properties to fixed Spray Ball™ but has the following features.

- Rotary Spray Ball™ is composed of ① body ② upper ball ③ lower ball ④ fixed ring ⑤ collar as shown in Figures4. The upper and lower balls rotate reversely. Since the cleaning water itself controls the rotation, there are no parts for rotation inside. Because of the simple structure, we can easily maintain this.
- Even at low pressure, we can clean efficiently because the spraying pattern makes a straight bar flow.
- The spraying pattern (angle) and flow rate (hole diameter/number of holes) can be changed depending on the customer specifications.

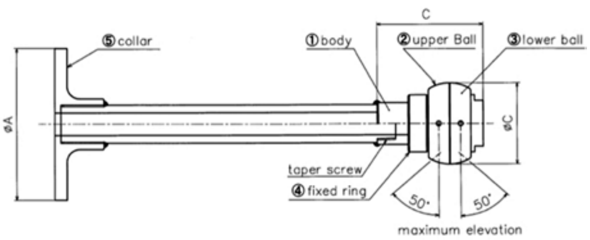


Figure4 Standard design of Rotary Spray Ball™

The mounting method is to insert the collar ⑤ between the nozzle of the tank and the nozzle on the piping side. This is because the Rotary Spray Ball™ needs

not to spray at the target point, unlike fixed type Spray Ball™.
Table3 shows the standard dimensions.

Table3 Standard dimensions

Type	Cleaning water vlume (L/min)	φA	φB	C	Taper screw
SB-50R	25	100	42	57	1/2"
SB-80R	90	130	64	86	3/4"
SB-100R	140	155	88	118	1"

5. Selection of fixed type or rotary type

So far, we have described Spray Ball™ (fixed type) and Rotary Spray Ball™, but we have received a lot of feedback about which one should actually be installed, so we compare the features of each one in a Table4.

Table4 Comparing fixed type and rotary type Spray Ball™

Type	Cleaning water vlume	Cleaning time	Spraying target	Maintenance	Cost
Fixed	○	○	○	△	○
Rotary	△	△	△	○	○

Regarding the amount of cleaning water, cleaning time, and point cleaning, since the fixed type targets the point for cleaning, it is possible to perform more efficient cleaning than scattering the cleaning liquid like a rotary type, to suppress the amount of cleaning water and cleaning time.
On the other hand, the rotary type is suitable for the rinse in the tank, and it is easy to disassemble and maintain because of the simple structure. In addition, since the hole diameter is large there is no concern about clogging.

6. Cleaning challenges

6-1) Background

The issue of tank cleaning is cleaning inside each nozzle.
Conventionally, if head of tank, manholes (hand holes), and lighting hole (through-lamp openings) in the tank were able to be cleaned, the cleaning inspection would have passed. But in recent years, it would have been judged to be unacceptable if it could not be cleaned to the inside of each nozzle, not limited to the particular industry.
In the background, small parts such as inside the nozzles that cannot be cleaned with Spray Ball™ have been cleaned manually by workers using brushes or cloths. As a result, cloth fibers and dust remained in the tank due to human intervention, causing serious damage to the post-process. This is so-called contamination problem.
Therefore, each industry has proposed CIP that requires no human intervention with the goal of eliminating contamination. Another advantage of CIP is that a certain cleaning effect can be expected so that the product quality can be stabilized and improved. Because of these factors, CIP became the mainstream, and cleaning nozzles attracted attention.

6-2) Solutions

First, the cleaning inside each nozzle was examined using a fixed type Spray Ball™. When cleaning with this product, it is possible to clean by increasing the length of the pipes as shown in Figure5 and spraying them into the nozzles from the downward direction. However, because the maximum elevation angle is 55°, as shown in Figure2, the area above the fixed type Spray Ball™ cannot be cleaned. In addition, designing the spraying point for each customer's tank nozzle orientation is a laborious work.
Next, Rotary Spray Ball™ is examined. When cleaning with this product, it is impossible to wash the inside of the nozzle because the maximum elevation angle is 50° as shown in Figure4 and only specific spray axes pass through.

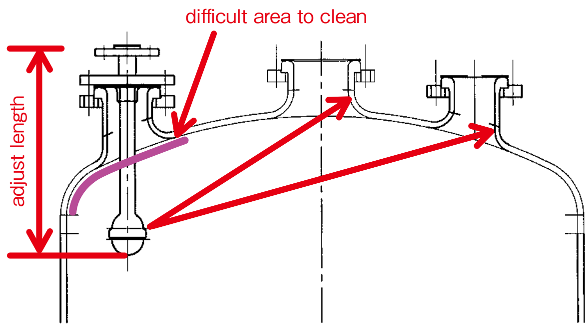


Figure5 Washing image of each nozzles

7. New developed product Rotary Spray Ball™

As described above, it takes time to design the Spray Ball™ (fixed type) and the inside of the nozzle cannot be cleaned with the conventional Rotary Spray Ball™. So we have newly developed a "Slit type" and a "Hole Pattern type" to meet customer requirements. Next, the features of each developed product are explained.

Figure6　New developed Spray Ball™

7-1) Slit type

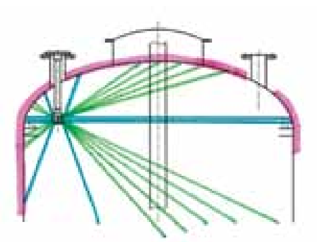


Figure7　Cleaning image of Slit type

The structure and material of the Slit type are the same as the standard products. The upper and lower balls rotate in the reverse direction and efficient cleaning is possible. Clean directly above and below the area where cleaning is impossible, using a straight bar flow, and clean manholes, lighting ports and nozzles with a wide area jet (slit). (Figure7)
The spraying pressure is slightly weaker than the hole shape due to the widened slit opening, but the spray is wider, so it is better at cleaning a wider area than the hole.

7-2) Hole Pattern type

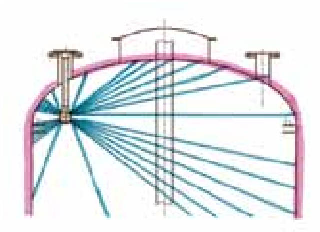


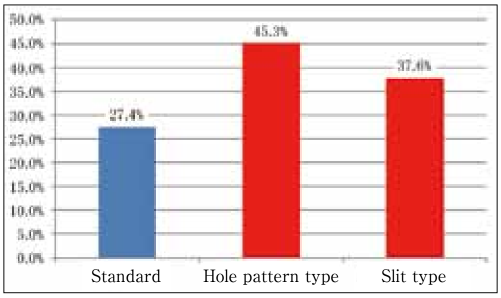
Figure8　Cleaning image of Hole Pattern type

The structure and material of the Hole Pattern type are the same as the standard products, upper and lower balls rotate reversely. It can clean directly above and below the nozzle tending to be unavailable for cleaning owing to the straight bar flow. And it can also clean the manhole, lighting hole, and each nozzle by small holes vertically arranged in two rows. This hole reaches the cleaning point while keeping water pressure, so it exhibits high cleaning power like fixed type Spray Ball™. The distance between the holes is made close by our unique design and processing, which makes it possible to enter each nozzle.
In addition, the efficient cleaning is possible, because the rotation speed is also low compared with the Slit type (Figure8).

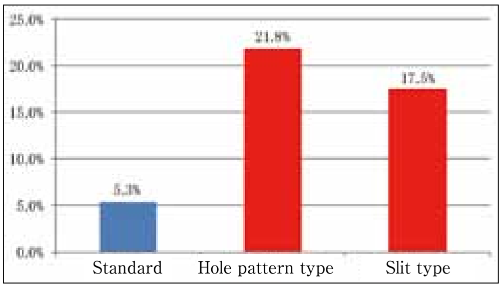
7-3) Comparison of cleaning rate between standard Rotary Spray Ball™ and newly developed Products

Figure9 shows the comparing the result of cleaning rate between the newly developed product as "Slit type" and "Hole Pattern type" and conventional Rotary Spray Ball™.
As observed from this result, the developed products as Slit type and Hole Pattern type are superior to the standard product in cleaning in the tank and in the nozzle. The Slit type can clean a wider area in a short time and the Hole Pattern type reaches the cleaning point while keeping strong pressure, so it is especially superior for cleaning in the nozzle.
This cleaning evaluation test is the result described in the following section 8 "cleaning evaluation test" devised by our company. The value in the graph is lower because the material having high adhesion and dirty is used to carried out the evaluation test under

severe conditions.



Cleaning rate of the tank inside



Cleaning rate of the nozzle inside

Figure9 Cleaning rate of the tank and nozzle inside

8. Cleaning evaluation test

Typical cleaning evaluation methods include visual inspection, solvent extraction using water, and sampling from the surface. When determining the cleaning evaluation method, it is necessary to first consider the general dirt related to the target equipment and select an appropriate cleaning evaluation method.

Table5 summarizes typical cleaning evaluation methods and their advantages and disadvantages.

Table5 Comparison of cleaning evaluation methods

Evaluation method	Advantage	Disadvantage
Visual inspection	・Easily implementable ・Surface dirt can be detected ・No need for analyzer	・Subjective ・Cannot detect the entire equipment ・Low concentration substances cannot be detected
Rinsing water sampling inspection	・Easily implementable ・Can detect detergents and other water-soluble substances ・Can be used for daily monitoring of the cleaning cycle	・Adhesive residue cannot be detected ・High precision analysis
Swab inspection	・Can be detect attached substances	・Depending on inspector results may vary ・It is necessary to enter or disassemble the equipment

The cleaning evaluation test method and inspection timing are specified in the operation manual of each company, and no particular standards are set in each industry.

Our customer may performt the cleaning evaluation test when delivering our Spray Ball™ products. The purpose is to attach Spray Ball™ to the customer's tank and check if cleaning at the level requested by the customer is possible. In this case, visual inspection is the mainstream. The method is to spray riboflavin or food coloring (viscosity is about 100cp), which looks like dirt was sprayed thoroughly into the tank and then operate the Spray Ball™ for about 1 to 2 minutes (depending on the customer). After that, visually check that the dirt has been removed. In the case of riboflavin, it is easy to find dirt because it is reflected by illuminating the black light, but care should be taken in handling because it has the property of being vulnerable to light. Food coloring is often used because they are available and handy. In the case of visual inspection, as shown in Table5, there is an advantage that it can be easily implemented and an analyzer is not required, but there is a disadvantage that the determination level is affected by the knowledge and experience of the assessor. Therefore, in order to eliminate such differences, a new method was devised for simply quantifying the cleaning evaluation test results. The advantage of this evaluation method is that a cleaning evaluation test can be easily performed at a low cost because special materials and analytical equipment are not required, and the result can be obtained immediately. Also, Since it is possible to quantify the value different from visual inspection, there is no concern that the judgment level is influenced by the judgment person. The challenge is that it is difficult to test the entire equipment and it is necessary to enter into the equipment.

Now, we are trying to improve this new method for practical application.

9. Conclusion

This report introduces the cleaning nozzle in the cleaning tank and a new cleaning evaluation test. So far, we had only two types of cleaning nozzle, fixed and rotary type, so it was difficult to respond to a wide range of customer needs.

The development of new cleaning nozzle "Slit type" and "Hole Pattern type" has made it possible to provide various spraying patterns. We hope that our customers will be able to select a cleaning nozzle suitable for each application in the future.

In addition, developing from conventional technology, we have successfully quantified the cleaning evaluation test. Starting with this research, we would like to try to further improve the cleaning rate and devise new cleaning methods and strive to develop services adapted to the times and the environment.

We will continue to pursue true customer needs and make efforts to provide new products and services.

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Recent Technology News Back Issues

No.37 Summer 2019

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Director, Managing Executive Officer CTO & CQO Mutsuo Aoki

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● **Customer Solutions**

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No.36 Winter 2019

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● **Introduction to Valqua Technology News No. 36 Winter 2019**

Senior Executive Officer Director of Corporate Research and Development Group Mutsuo Aoki

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● **Customer Solutions (Contribution)**

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