Valqua Technology News

Winter 2018

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NIPPON VALQUA INDUSTRIES, LTD.

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【Customer Solution Feature】

Greetings

Toshikazu Takisawa

President & CEO
NIPPON VALQUA INDUSTRIES, LTD.

I wish everyone much happiness in the new year, 2018.
First of all, we sincerely thank our valued readers for your continuing interest in our magazine.
Thanks to your support, Valqua Technology News, our technical journal, recently celebrated its 60th anniversary.
On this occasion, we greatly thank everyone, including all our consumers and readers who have supported us for a long time.
We expanded our unique technological legacy to develop "seal engineering service." Based on this, we will strive harder to create innovative technology with novel values, and to contribute to achieving a sustainable society. We will also do our best to make Valqua Technology News easier to understand and use for our readers.

In reviewing the Japanese economy in 2017, company earnings appeared to improve, reflecting a recovery in exports, led mainly by the IT industry, and brisk personal consumption.
Overseas, the following trends were observed: 1) The U.S. economy showed a mild recovery trend, supported by capital investment which was primarily driven by domestic demand, and 2) In developing countries, economic growth slowed down due to structural reform of the Chinese economy, the strained geopolitical situation, and other factors.
Meanwhile, the Japanese manufacturing industry suffered scandals including fraudulent quality inspection systems, which form the foundation of manufacturing. Such scandals highlighted the importance of corporate social responsibility and risk management. On the other hand, various industries actively utilized new technologies including AI and IoT in 2017.

Under such conditions, the Valqua Group completed its 7th medium-term management plan New Valqua Stage Seven (NV･S7). At the same time, Valqua is promoting technological development, which is based on seal engineering service, for the next stage, NV・S8. Through the technological development, we will expand our business to create novel values in the global market.

We would greatly appreciate your continued guidance and encouragement, and we wish everyone many more successful years.

Introduction to Valqua Technology News No. 34 Winter 2018

Let us begin by wishing everyone a Happy New Year, and sincerely thanking our valued readers for your continuing interest in our magazine.

The year 2017 witnessed many environmental changes. IoT and AI technologies have entered practical use such as for automated driving and the home-connected Internet. The conventional market is undergoing a complete structural change and new market opportunities are emerging. On the other hand, due to increased global awareness of environmental issues and accelerating technological development in both the public and private sector, the range of conventional products is transforming so quickly and drastically that the traditional approach to product lifestyle cannot cope. For example, the auto industry is experiencing dramatic changes in product lineups, and such transformations are emerging in various markets. Therefore, as a company, we must seriously examine how to respond to such changes.

Amid this environment, Valqua, a leading seal engineering company with a history of 90 years, will continue to contribute to social sustainable development through our unique and creative technologies based on our corporate philosophy of "The Valqua Way." In order to develop unique and creative technologies, we are determined to expand our role as a provider which takes customers' viewpoints into account to provide new solutions in various fields.

This issue features technical papers and businesses which contribute to industrial safety and security under various conditions and special environments. These include a paper which was awarded ASME PVP Award (best paper award) from the Computer Technology & Bolted Joints Technical Committee of ASME PVP; a paper on the behavior of flange connections at the time of an earthquake; a paper on countermeasures against severe accidents; and a paper on countermeasures against seal troubles. Regarding our hard & seal engineering service (H&S) business, this issue introduces a contributed article and Valqua's approaches. All the articles in this issue feature technical information which is unique to Valqua. We hope you will find it useful.

We will continue to provide technical information which meets the needs of the times, and hope that you will continue to use Valqua products.

Senior Excutive Officer Director of Corporate Research and Development Group **Mutsuo Aoki**

ASME PVP 2016-Awarded Paper

1. Introduction

In 2016, we contributed and presented the paper "FEM Stress Analysis and the Sealing Performance Evaluation of Bolted Pipe Flange Connections with Large Nominal Diameter Subjected to Internal Pressure," which examines the mechanical behavior of flange connections with large nominal diameter, at the Pressure Vessels & Piping Conference (PVP). PVP is a technical divisionof the American Society of Mechanical Engineers (ASME).

ASME's PVP, which consists of 12 committees, holds a professional meeting annually, at which various papers are presented. Among the papers presented, approximately 10 are nominated and receive awards of excellence. Our paper received an award from the Computer Technology & Bolted Joints Technical Committee, one of the 12 committees.

Figure1 shows a picture of the commendation ceremony; Figure2 shows the certificate of commendation given at the ceremony.

This article introduces the paper's contents and the future prospects for basic research regarding this theme.

A Valqua staff member receives a commendation from Mr. Trevor G. Seipp, Honors and Awards Chair (left).

Figure1 Commendation ceremony

Figure2 ASME PVP AWRD

2. Approaches to basic research

Seal engineering is our core technology. Using this technology, we are developing and expanding our services associated with flange working methods to suit the needs of customers' plant operation.

The tightening force of a bolt varies depending on the size of the flange. Therefore, different tools should be used to fasten bolts depending on the flange size. We propose optimal tools that suit the customer's usage environment, and such proposal work is one of our services.

These services have been gradually recognized in the market, and so we began to receive inquiries not only about tool selection but also flange working methods, including optimal fastening procedures, regarding the fastening of flanges with large nominal diameters.
However, more bolts are used in fastening flanges with large nominal diameters, and under such conditions, a marked phenomenon unique to flange tightening, called elastic interaction, occurs. In elastic interaction, axial bolt force, which secures the sealing performance of the gasket, is greatly affected by the tightening force of the neighboring bolts. Therefore, more leakage troubles are known to develop regardless of the gasket's performance. For this reason, basic research is essential in order to propose optimal flange working methods. Based on such research, the mechanical behavior associated with flange connections will be elucidated and bolt tightening methods will be established.
Therefore, we built 24-inch flange connections as shown in Figure 3. The 24-inch flange connection is the largest of the standard flanges. We then conducted stress analyses using the finite element method (FEM) to predict the flange's seal performance. As a result, we established the method and published a paper on it.
Stress analysis using the finite element method (FEM) involves calculating the deformation behavior of a structure based on its mechanical characteristics in order to predict changes.

Figure3　24-inch flange connection

3. ASME PVP 2016-awarded paper

In this study, stress analyses using the finite element method (FEM) were conducted to propose a method to evaluate the sealing performance and develop a bolt-tightening method.
When gaskets are compressed, internal stress develops. Since the sealing performance of a flange connection is considered to be determined by this internal stress, stress analyses using the finite element method (FEM) were conducted to calculate the flange connection's contact pressure when pressure is applied to the internal side of the flange connection through fluid after the gaskets are compressed using bolts. In the analyses, spiral-wound gaskets containing foamed carbon filler (No. 6596V) and joint sheet (No. 6500), and the analysis code ABAQUS were used.
Figure4 is a model of a flange connection under inner pressure (P).
Figure5 shows an FEM model of element decomposition. In the finite element analysis, we took the symmetrical properties into account to divide the model in half in the axial direction and in 1-bolt length in the circumferential direction.

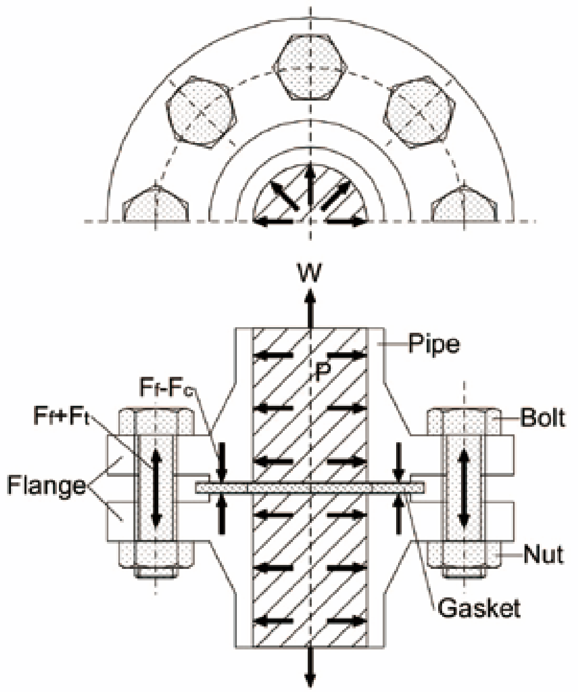


Figure4　FEM model of a flange connection

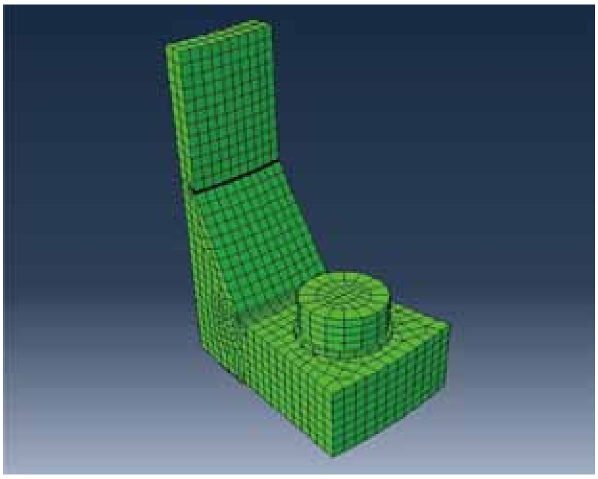


Figure5 FEM model

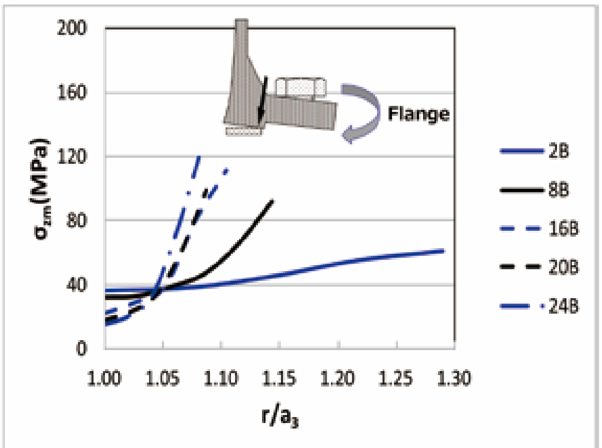


Figure6 contact gasket stress distribution of the spiral-wound gasket in the radial direction

Figure6 shows the contact gasket stress distribution of a spiral-wound gasket in the radial direction. The horizontal axis indicates dimensionless numbers. The number was calculated by dividing the length between the center and the pressure point in the radial direction by the gasket's internal diameter. On the assumption that two flanges were tightened in parallel with each other, this study was conducted under the condition that the contact gasket stress does not change much in the circumferential direction, but only in the radial direction.

This figure indicates the trend that the larger the flange, the greater the contact pressure on the side of the gasket's outside diameter. This trend indicates that, after bolt tightening, the application of pressure through fluid generates rotation which deforms flanges in the circumferential direction.

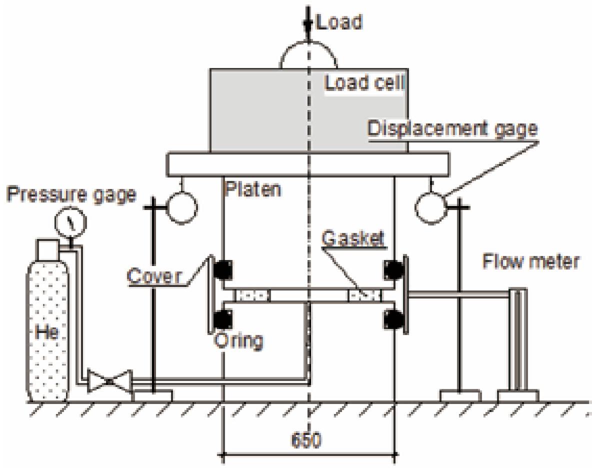


Figure7 Outline illustration of the test equipment stipulated by JIS B 2490

The basic leakage amount of the gasket was calculated according to JIS B 2490.

Figure7 illustrates an outline of the test equipment stipulated by JIS B 2490.

Figure8 shows the results from a test conducted according to JIS B 2490; the bold line indicates the basic leakage amount of the gasket, which was calculated as the leakage amount plotted against the gasket's contact pressure on unloading.

This basic leakage amount of the gasket was compared with the leakage amount obtained by an experiment, in which the leakage amount of the flange connection was calculated based on the average contact-pressure pattern of the gasket shown in Figure6.

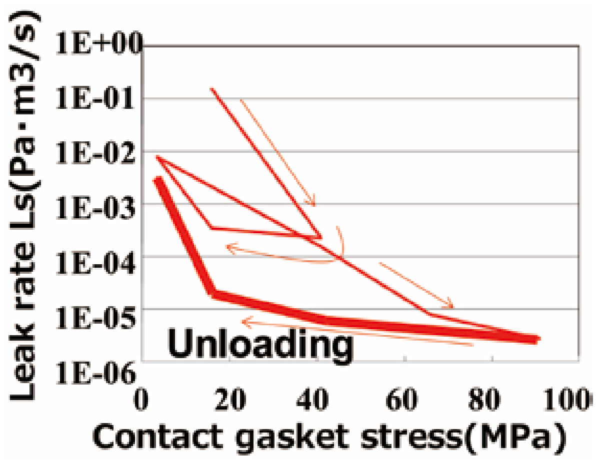


Figure8 Measurements of basic leakage amount of spiral-wound gaskets

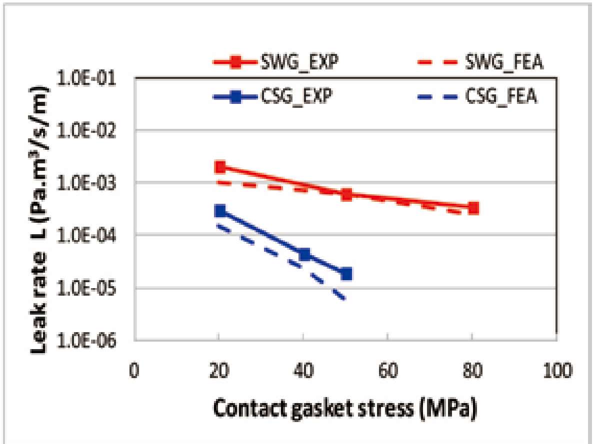


Figure9 Comparison of the results from the experiment with the analysis results

Figure9 compares the results from the experiment with the analysis results.

The red line represents the spiral-wound gasket and the blue line represents the joint sheet; both gaskets had less leakage when the gaskets' contact pressure increased. The experimental and analysis results matched closely, indicating the validity of the analytical method.

With this analytical method, it is possible to predict the leakage amount of a flange connection. Also, the results indicate that setting a higher initial tightening force of the bolts is effective for reducing the leakage amount.

4. Future prospects

Currently, we are studying how to apply these results to our proposal services regarding flange working methods, and are now introducing these services. In the long run, we believe that application of the results of this basic research will allow us to evaluate and analyze working methods, which are difficult for customers, and then propose the optimal working methods.

Receiving an award for this paper showed that our study is highly evaluated in the United States, where sealing technology is actively studied. This high evaluation not only raises the brand profile of Valqua but also verifies our evaluation methods and working methods regarding flange connections. We received an inquiry regarding tightening methods for flanges with large nominal diameters from a major U.S. oil company soon after presenting this paper, indicating strong interest in this theme. This quick reaction indicates that even major oil companies have problems regarding tightening methods for flanges with large nominal diameters and wish to collaborate with companies which possess advanced sealing technology. Cooperation with major oil companies might be achieved by strengthening Valqua's technological foundation using the results of this study.

5. Conclusion

In this study, an ideal flange connection was established as an ideal model, assuming the flange and bolts had no scratches and the gasket was tightened uniformly.

However, in actual working conditions, we cannot fasten such ideal flanges; for example, gaskets are compressed unevenly. In future, we aim to determine the effects of such uneven fastening on the sealing performance of flange connections, and to establish solutions to on-site problems.

In addition, since the thermal burden and external force can affect actual piping, we intend to take these effects into account in further studies.

Akira Muramatsu
H&S BUSINESS GROUP

Evaluation of the Mechanical Behaviors of Pipe Flange Connections with PTFE Gaskets Subjected to Bending Moment

1. Introduction

The pipe flange connection with gasket is widely used at petroleum-refining, chemical, and power-generating plants. In Japan, asbestos gaskets were widely used and intensively researched, since those were low-cost and offered excellent heat resistance, sealing performance, durability, and ease of handling. [1)－3)] However, a regulation[4)] on the use of asbestos was implemented in 2008 due to its effects on human health.

Asbestos gaskets can be categorized into two major types: the spiral-wound gasket containing asbestos filler, and the compressed asbestos fiber sheet gasket. When the asbestos regulation was introduced, replacing the asbestos of the spiral-wound gasket with flexible graphite filler did not cause any major problem. However, regarding compressed sheet gaskets, it was difficult to replace the material for several reasons, and so the compressed aramid-fiber sheet gasket was developed as an alternative to the compressed asbestos fiber sheet gasket. However, it required a higher rubber content, which caused challenges for heat resistance. While the flexible graphite sheet gasket had no problems in heat resistance, the gasket surface is vulnerable to scratches because the material is brittle. Therefore, the improved polytetrafluoroethylene (PTFE) blended gasket came to be widely used. This gasket has excellent chemical resistance as well as heat resistance, and the conventional problems of creep characteristics were overcome by devising formulation and production methods. Therefore, the improved PTFE blended gasket came to be used in many connecting parts.[5)] However, the following mechanical behaviors of pipe flange connections with PTFE gasket are not well defined: gasket contact stress distribution, sealing performance, changes in hub stress and axial bolt force, and other behaviors.

The authors previously studied the abovementioned mechanical behaviors of pipe flange connections with PTFE gasket at room temperature and high temperature and found that the connections with PTFE gasket are superior to the compressed asbestos fiber sheet gasket. [6), 7)]

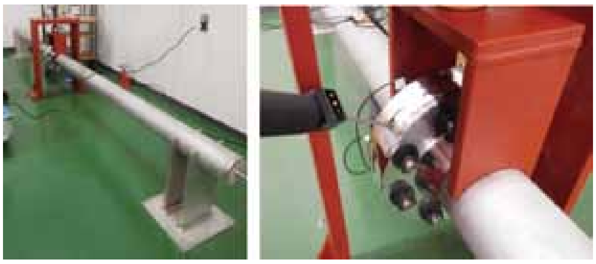
Japan is prone to earthquakes: recent ones include the Hyogo-ken Nanbu Earthquake in 1995, the Niigata-ken Chuetsu-oki Earthquake in 2007, the Tohoku Pacific Offshore Earthquake in 2011, and the Kumamoto Earthquake in 2016. In addition, according to some, the Nankai Megathrust Earthquake is expected to occur within the next 10 years. There are many plants and buildings located near the postulated seismic center, which would likely suffer serious damage. In the Hyogo-ken Nanbu Earthquake, liquefaction caused bending on pipe flange connections, resulting in leakage of LP gas and the issuance of an evacuation advisory to 70,000 people. Therefore, countermeasures against earthquakes are essential for plants. Sawa et al. studied the mechanical behaviors of the flange connection with spiral-wound gasket when subjected to bending moment.[8)-10)] At the Tightness Testing and Research Laboratory of Ecole Polytechnique de Montreal (Canada), the characteristics of change in axial bolt force when flange connections with expanded PTFE gasket are subjected to bending moment were studied.[11)] Meanwhile, Koves et al. described a method to evaluate the effects of bending moment using equivalent internal pressure.[12)-16)] However, there have been no studies on the pipe flange connection with PTFE gasket subjected to bending moment and internal pressure. As PTFE-blended gaskets are widely used, countermeasures for disasters including earthquakes are required, and so it is important to evaluate the mechanical behavior of pipe flange connections with PTFE gasket.

This study aimed to determine the mechanical behaviors of the pipe flange connection with PTFE gasket subjected to bending moment and internal pressure using FEM stress analyses and experiments. Firstly, the fundamental characteristics of a gasket were measured according to JIS B 2490. In finite element method (FEM) stress analyses, axial bolt force, hub stress, and the gasket contact stress distribution were calculated. In addition, leak rate was estimated based on the gasket contact stress distribution and fundamental characteristics. To verify the method of FEM stress analyses, the FEM results were compared with those from experiments on axial bolt force and hub stress. In the experiments, leak rate from connections, axial bolt force, and hub stress were measured.The connection size was ASME/ANSI class 300 4-inch. The gasket used was the No. GF300, which contains no rubber and so suffers no chemical degradation due to heat and deterioration over time. Accordingly, it is possible to conduct a precise mechanical evaluation with the No. GF300.

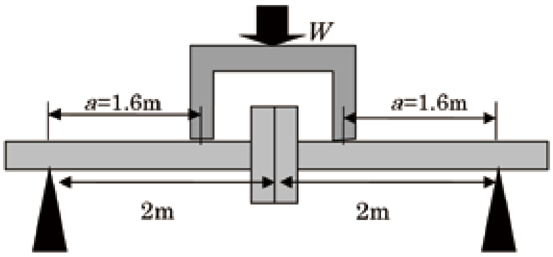
2. Experimental method

Figure1 (a) shows the experiment equipment used to study the effects of bending moment on the pipe flange connection; Figure1 (b) outlines the equipment. Through four-point bending, bending moment was applied to the pipe flange connection. In addition, internal pressure could be applied to the piping through a connected helium gas cylinder. The connection size was ASME/ANSI class 300 4-inch; the flange and pipe material was SUS304.[17)] Each pipe was 2 m long, and the total length of the equipment was approximately 4 m. To match the connection, the nominal diameter of the gasket was ASME/ANSI class 300 4-inch with a thickness of 1.5 mm.

Flange hub stress and axial bolt forces were measured using the strain gauges; the leak rate was measured with a helium leak detector according to the sniffer method. The initial bolt tightening was conducted according to JIS B 2251 "Bolt tightening procedure for pressure boundary flanged joint assembly."[18)] After bolt tightening, four-point bending moment and inner pressure were applied and then flange hub stress, change in axial bolt force and leak rate were measured. M, which is the bending moment acting on the connection, was calculated using the equation $M = W/2 \times a$, where a is the effective pipe length (= 1.6 m). The initial axial bolt force was 11.1 kN per bolt to give an average gasket stress 10 MPa; the internal pressure applied on the connection was 2 MPa.



(a) Equipment



(b) Outline of the equipment

Figure1 Experiment equipment used to measure the mechanical behaviors of a pipe flange connection subjected to four-point bending moment

3. Gasket characteristics

For FEM stress analyses, compression and sealing characteristics of gaskets were evaluated.

3-1) Compression characteristics

The stress-strain curve of gasket at room temperature was evaluated. Figure2 shows an outline of the experimental equipment used for the evaluation.[19)] The size of the flange raised face is equivalent to the size stipulated in JIS 10K 50A; the raised face was compressed in a compression tester. Figure3 shows the stress–strain curve of No. GF300 gaskets obtained from the experiments. The strain value was calculated by averaging the indicated values of three displacement gauges to obtain the amount of compression, and then dividing the compression amount by the initial thickness to obtain the strain value.

3-2) Sealing performance

The sealing performance of gasket was evaluated using the equipment shown in Figure2 according to JIS B 2490. The pressure of the helium gas supplied from the cylinder was increased to 2 MPa, then the leak rate from the gasket, which was collected using a sleeve, was measured with a soap-film flowmeter. Figure4 indicates the relationship between the leak rate and gasket contact stress obtained from the experiment.

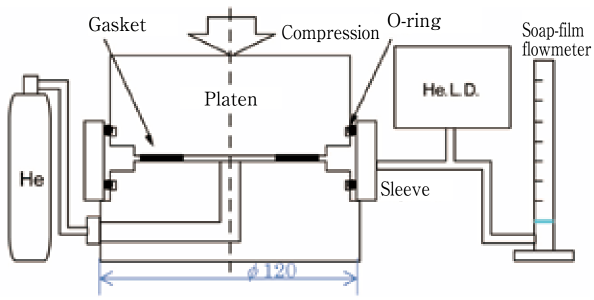


Figure2 Outline of test equipment used to evaluate gasket characteristics

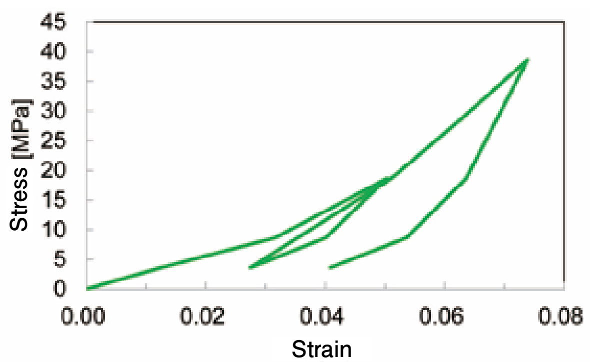


Figure3 Stress–strain curves of No. GF300 gasket

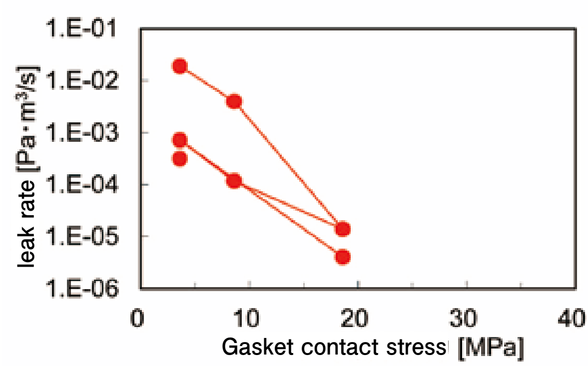


Figure4 Relationship between leakrate and gasket contact stress

Even though the gasket contact stress was increased to approximately 40 MPa, the leak rate was too small to be measured when the contact stress exceeded 20 MPa, so no data is shown in the graph.

4. FEM stress analysis

Figure5 shows the FEM model of the pipe flange connection with gasket subjected to four-point bending and internal pressure as shown in Figure1. In consideration of symmetry, the model was arranged at 1/4 scale (axial direction = 1/2, circumferential direction = 1/2) . The threads of bolts and nuts were omitted, and the nut shape was simplified from hexagonal to circular having the same cross sectional area. Figure 6 shows a boundary condition for the FEM stress analyses. In the illustration, the condition was replicated in the following manner: 1) Symmetric faces were fixed, and 2) Regarding bolt tightening, tension equivalent to the axial force was applied to each bolt model. Regarding four-point bending after tightening the piping ends, a load of $W/2$ was applied to jigs located around flanges. The effects of internal pressure were replicated by applying pressure to the internal side of the pipe flange vessel. Flanges and bolts were modeled using elastoplasticity elements; gaskets were modeled using ABAQUS gasket elements. In the FEM analyses, axial bolt force, flange hub stress, and the gasket contact stress distribution were calculated.

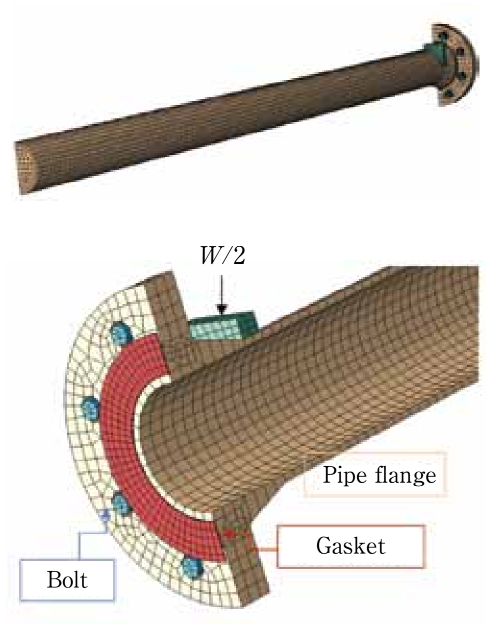


Figure5 FEM model of a pipe flange connection

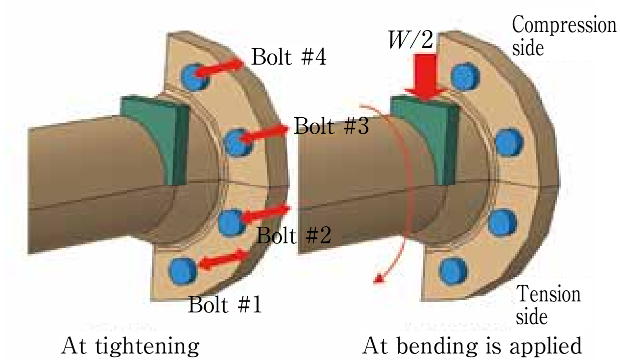


Figure6 Boundary conditions in FEM stress analyses

5. Results of FEM stress analyses and experiments

5-1) Change in Axial bolt force

Figure7 shows changes in axial force for the four bolts shown in Figure6. The values were obtained by FEM stress analyses and experiments. The abscissa represents the bending moment M; the ordinate represents axial bolt force; the solid line represents the results of experiments; the dashed line represents the results of FEM stress analyses. The axial force values of bolt #1 and #2 increase with increasing bending moment, whereas those of bolt #3 and #4 decrease. The contact surface of the flange opens due to bending moment on the piping. The opening applies tension to the bolts, resulting in increased axial force. The increased tension on the side of bolt #1 and #2 is due to this increased axial force. On the other hand, the contact surface of the flange closes. The closing compresses bolts, reducing axial force on the side of bolt #3 and #4. The results of the FEM analyses and experiments matched well, verifying the robustness of the FEM stress analyses.

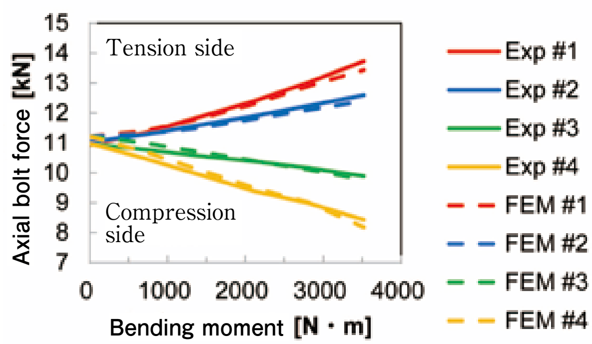


Figure7 Changes in axial bolt force when bending moment is applied to the pipe flange connection (The bending moment was calculated from FEM stress analyses and experiments.)

5-2) Gasket Contact stress distribution

Figure8 shows contour figures of the gasket contact stress distribution at the following timings: when the flange was initially tightened; when a bending moment of 3500 N/m was applied to the pipe flange connection; and when a bending moment of 3500 N/m and internal pressure were applied to the pipe flange connection. The contact gasket stress is found to be zero at the non-contacted gasket area, that is, at the most outer radius part of the gasket. The gasket contact stress distribution at initial tightening indicates increasing contact stress in the radius direction of the outside diameter due to flange rotation. In the circumferential direction, the contact-stress gradient is negligible.

When a bending moment of 3500 N/m was applied, part of the gasket's contact stress significantly decreased (left figure); when internal pressure was applied, the gasket's contact stress decreased further.

Figure9 shows the gasket contact stress distribution in the outermost diameter contact area (r = 46.05 mm) in the circumferential direction at each step. The graph indicates marked changes in contact stress distribution due to opening of the flange's contact surface; the opening was caused by the bending moment applied to the flange.

Next, The leak rate from the connection is estimated using the contact gasket stress distribution obtained from the FEM and the fundamental leakage performance shown in Figure4[20)−21)]. Figure10 shows the estimated leak rate and the experimental results. As the bending moment increases, the leak rate gradually increases; when the bending moment exceeds approximately 3000N/m, the leak rate substantially increases. As Figure8 shows, part of the gasket's contact stress became zero due to bending moment; this zero stress appears to have caused the substantial increase. The estimated leak rate and the experimental results matched well, indicating the validity of the FEM analyses and the method of estimating leak rate.

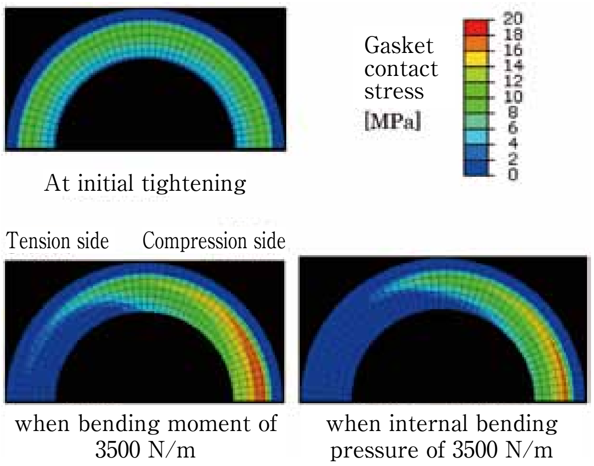


Figure8 Gasket Contact stress distribution obtained from FEM stress analyses

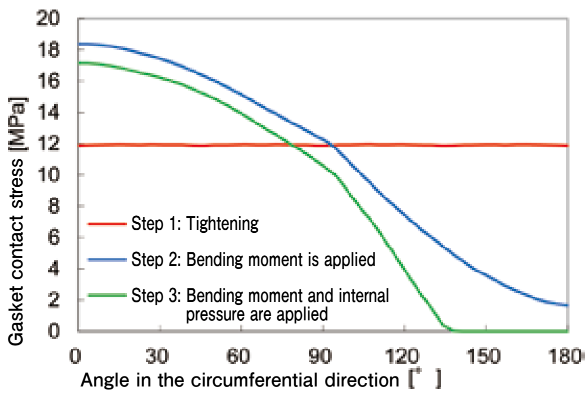


Figure9 Gasket Contact stress distribution at each step

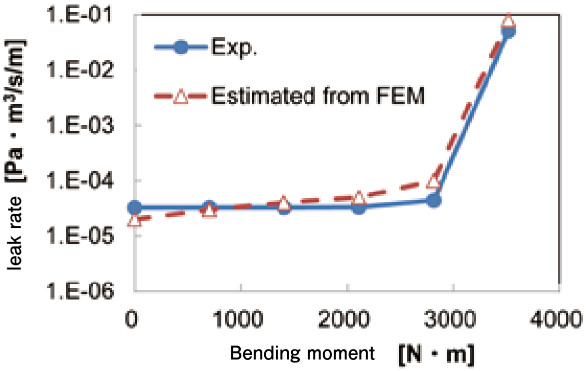


Figure10 Comparison of leak rate from connection when bending moment is applied

5-3) Flange Hub stress

Figure11 shows the relationship between the maximum principal stress in the axial direction, which occurs at the flange hub, and bending moment. The graph also shows values calculated using an ASME Boiler & Pressure Vessel Code Section Ⅷ Division 1 "Rules for construction of Pressure Vessels" App.2, (2004). (in this case, ASME values were calculated under the condition of zero bending moment).[22)] This graph indicates that as the bending moment increases, hub stress, which was evaluated from the experiments and FEM stress analyses, increases. The results of the experiments and FEM stress analyses matched well, indicating the validity of the analyses.

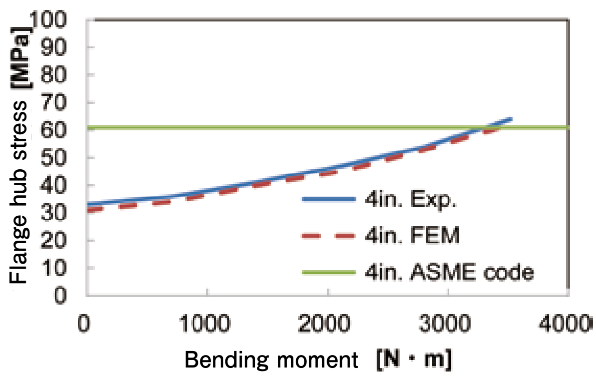


Figure11 Effects of bending moment on hub stress

6. Discussion

6-1) Effects of nominal diameter of connection on axial bolt force behavior

The effects of nominal diameter on the axial force behavior of the bolts in the connection were studied by FEM stress analysis. Figure12 shows the greatest changes in the increase and decrease of axial bolt force when bending moment was applied to a pipe flange connection with a No. GF300 gasket. The nominal diameters were chosen as 4, 8, 12, 16, 20, 24 inches and internal pressure was not applied. The ordinate represents the axial bolt force ratio (=(Ff+Ft)/Ff) ,where Ff is bolt preload and Ft is an increment in axial bolt force; the abscissa represents the bending moment per bolt. the initial mean gasket contact stress was 10 MPa; the maximum bending moment *M*, which was applied to the flange, was 3500 N/m, indicating the following: the bolt number *N* increases when nominal diameter is greater, reducing the maximum *M/N*. The solid line represents data for bolts subjected to tension by bending moment; the dashed line represents the data for bolts subjected to compression (contraction) by bending moment The figure indicates the trend that the smaller the nominal diameter, the greater the effects of bending moment on axial bolt force. Thus, for the equivalent bending moment applied to the flange, the sealing properties are safer when the nominal diameter is greater.

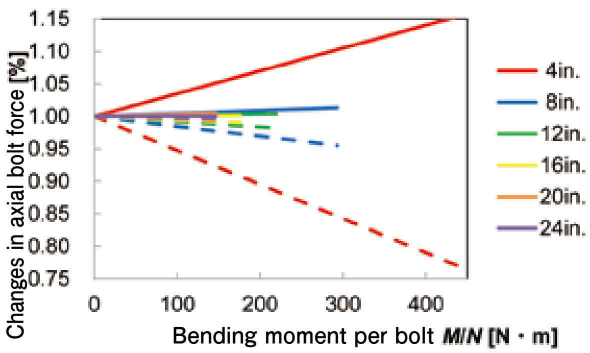


Figure12 Effects of nominal diameter on behaviors of change in axial bolt force in pipe flange connections subjected to bending moment

6-2) Effects of the order in which bending moment and inner pressure are applied

Figure13 shows the effects on the leak rate of the order in which bending moment and inner pressure are applied. The graph shows the results of leakage tests which were conducted in the following two orders: Step 1: tightening, Step 2: bending-moment application, Step 3: internal pressure application (solid red line) ; and Step 1: tightening, Step 2: internal pressure application, Step 3: bending moment application (solid blue line) . The ordinate represents the leak rate and the abscissa represents the bending moment. When the bending moment exceeds 3000 N/m, the order of "Step 2: internal pressure application, Step 3: bending moment application" is associated with slightly larger leak rate; however, the difference in leak rate was small and almost at the level of error. In the experiments, the order in which bending moment and internal pressure were applied showed no substantial effects on leak rate.

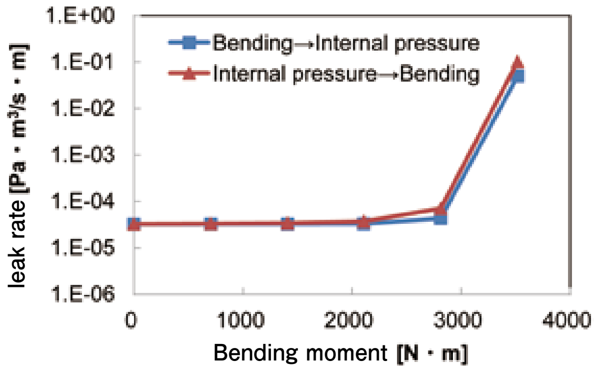


Figure13 Effects on sealing performance of the order in which bending moment and inner pressure are applied

6-3) Effects of action point of bending moment on leakage volume

As sown in Figure14, the effects of applying bending moment at different points of bolt configuration were studied. In Figure14 (a) the bolts were arranged in a vertically symmetrical manner; this configuration is widely used (pattern A) . In Figure14 (b) , two bolts are placed on the vertical line (pattern B) . Figure15 shows the relationship between leak rate and bending moment for each pattern.

The results show that pattern A was associated with smaller leak rate than pattern B. Placing bolts at the position where the opening is largest was thought to alleviate the reduction in contact pressure and sealing performance; however, the commonly-used pattern A was associated with greater sealing performance. In pattern A, four bolts resist the opening force, whereas in pattern B, only three bolts resist the opening force. Therefore, in total, the opening appeared to be greater in pattern B.

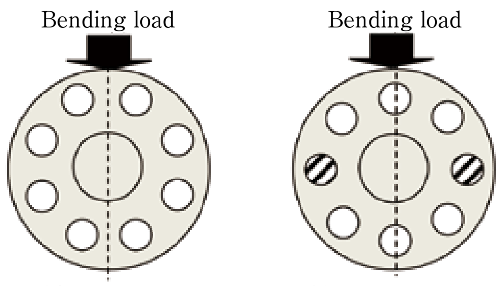


Figure14 where bending moment is applied

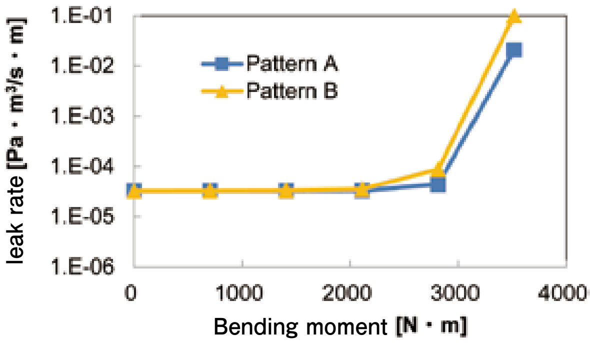


Figure15 Effects of where bending moment on sealing performance

7. Conclusions

In this study, experiments and FEM stress analyses were used to study the mechanical behaviors of axial bolt force, hub stress, and sealing performance of the pipe flange connection with PTFE gasket subjected to bending moment. The following conclusions were obtained.

(1) FEM stress analyses were used to calculate the gasket contact stress of a 4-inch pipe flange connection subjected to bending moment and internal pressure. When bending moment was applied, the contact stress decreased on part of the gasket contact surface. When the bending moment reached approximately 3500 N/m, the contact stress became zero, causing a rapid increase in leak rate.

(2) The results of the experiments and FEM stress analyses were used to evaluate the axial bolt force when bending moment was applied to the flange. The evaluation results indicated that the results of the FEM stress analyses and experiments matched well. In addition, when bending moment per bolt as M/N, the evaluation revealed the trend that the greater the nominal diameter, the stronger the resistance to bending moment.

(3) The gasket contact stress distributions were obtained from the FEM stress analyses; the relationship between the leak rate and contact stress was obtained from the experiments. Using the two results, leak rate was estimated. The estimated and experimental values matched relatively well, indicating the validity of both the methods of analyzing FEM stress and estimating leak rate.

(4) The effects on sealing performance of the order in which bending moment and internal pressure are applied were studied. The results indicated that the order does not significantly affect leak rate.

(5) The effects of the action point of bending moment on sealing performance were studied. The results indicated that the common bolt arrangement (pattern A) is associated with greater resistance to bending moment on the piping than is the arrangement in which two bolts are arranged on the vertical line (pattern B).

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Performance Evaluation of Improved EPDM Material under High-temperature Environments

1. Introduction

In the case of a severe accident (hereafter, SA), the primary containment vessel (PCV) is surrounded by high-temperature steam at 200°C and high radiation dose of several hundred kGy. Therefore, the PCV requires a sealing material that can maintain sealing performance even under an SA environment. For such cases, we evaluated the performance of our improved EPDM material (No. H3070) under high-temperature environments.

Previously, silicone rubber and fluororubber, which generally have excellent heat resistance, have been used as sealing materials for PCV. However, in an environment with high-temperature steam of 200°C and high radiation dose of several hundred kGy, the structural weaknesses of polymers cause the progression of reduction in molecular weight due to hydrolysis and due to exposure to high energies including γ rays. This is likely to lead to the loss of sealing performance, and so a new material was considered necessary.[1)]

The improved EPDM material was developed on the assumption that it would be used in high-temperature steam, and we have proposed the new material for such applications. We have been conducting various evaluations to confirm its sealing performance, using a steam environment at a high temperature of 200°C and atmospheric pressure of 0.854 MPa as basic conditions which properly allow a PCV to contain radioactive material in the event of SA. Various tests were conducted under these conditions and the improved EPDM material was confirmed to have adequate sealing performance.[2)]

Figure1 schematically illustrates the characteristics of the improved EPDM material and existing silicone rubber and fluororubber sealing materials, based on previous evaluation results of each material. The horizontal axis represents steam temperature and the vertical axis radiation dose. The figure shows that silicone rubber and fluororubber cannot maintain sealing performance in the event of SA; on the other hand, the new EPDM material maintains sealing performance even in high-temperature steam of over 200°C and γ ray irradiation of over 800 kGy.

Thus, the improved EPDM material was confirmed to offer adequate environmental performance in the event of SA, and was determined to be used as a new sealing material for PCV. For this application, it was crucial to confirm the following two matters: confirmation of the limit conditions under which the improved EPDM material can maintain sealing performance, and verification of the improved EPDM material's superiority under SA environments. Therefore, an evaluation under a high-temperature

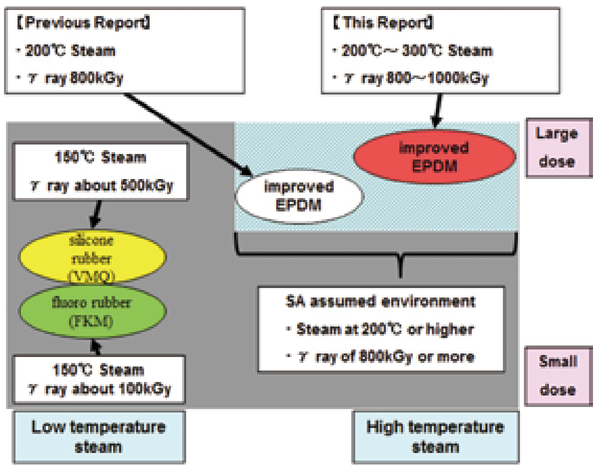

Figure1 General characteristics of sealing material

environment in which the temperature significantly exceeded SA temperatures was conducted.

Regarding the evaluation method, the following tests were conducted to confirm sealing performance: compression-set tests, which are effective for verifying the lifespan of the seal, and leakage tests using small flanges, which imitate flanges installed on actual equipment.

2. Evaluation

2-1) Preliminary test to set the evaluation temperature

This evaluation aimed to confirm the limitation of sealing performance of the improved EPDM material; the evaluation was conducted at temperatures up to the temperature at which the improved EPDM material showed no significant material changes. Thermogravimetric analysis was used as the evaluation method. In Figure2, the purple line represents the rate of weight loss due to heat. Weight loss begins to occur at a temperature of over 300°C. No major change was found to develop in the main backbone structure at temperatures up to 300°C. Therefore, the performance was evaluated at temperatures up to 300°C.

2-2) Evaluation method

2-2-1) Compression-set test

Two evaluation methods were used to confirm the performance at 300°C, one of which was the compression-set test, which is very effective for confirming the lifespan of a seal.

The method of measurement conformed to JIS K 6262:2013 "Rubber, vulcanized or thermoplastic – Determination of compression-set at ambient, elevated or low temperatures." The JIS large specimen (cylindrical specimen with a diameter of ϕ29 mm and thickness of 12.5 mm) was used as the sample shape; the compression rate was 25%.

Plastic deformation which occurs at high temperatures and under compressed conditions (but not only high-temperature conditions) was quantified. The quantification was defined as follows: 0%: the original shape is completely restored; 100%: no shape restoration occurs. Rubber deterioration can be considered to be a chemical reaction. Therefore, the time taken to reach a given deformation can be estimated by plotting a graph with time on the horizontal axis and compression-set rate on the vertical axis as shown in Figure3.

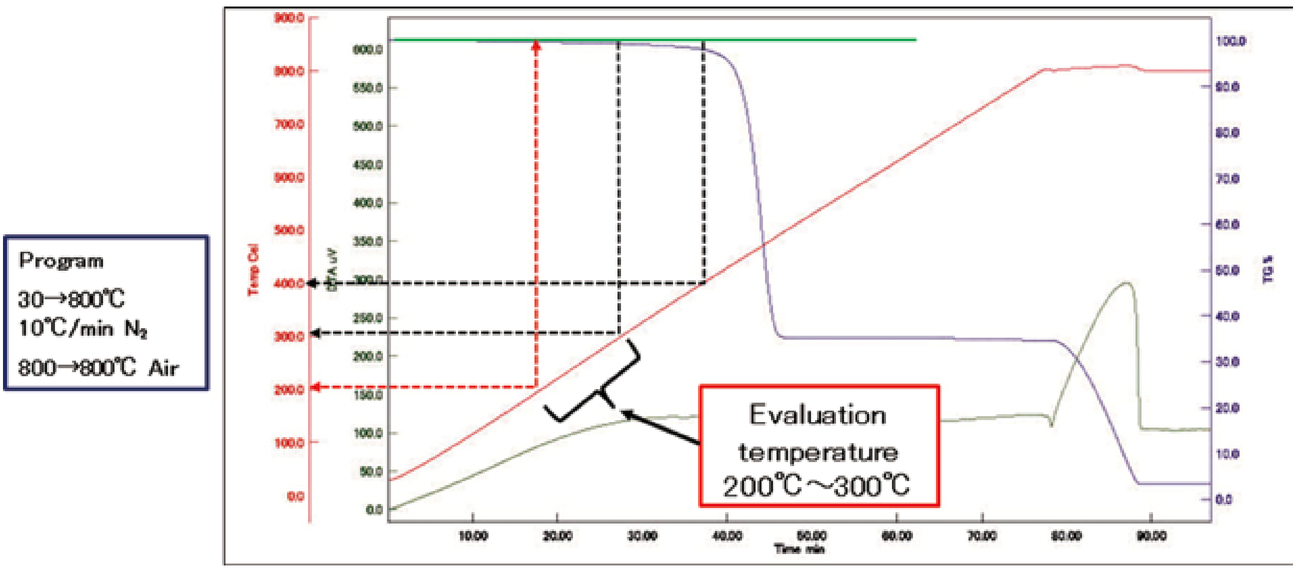

Figure2　Results of thermogravimetric analyses

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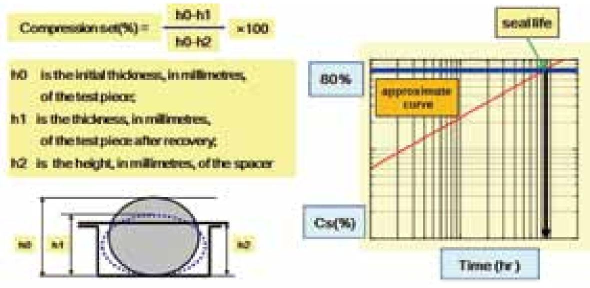

Figure3 Compression-set test and expected lifespan

Table1 shows the evaluation conditions. To take the conditions in the event of SA into consideration, the evaluation was conducted under the following conditions: atmosphere: saturated steam environment, exposure dose of γ rays: 800 to 1000 kGy, temperature: 200 to 300°C. Regarding the environment within a PCV in the event of SA, the maximum atmospheric pressure was assumed to be 0.854 MPa. On the other hand, this evaluation was conducted under a saturated steam environment, resulting in much greater pressure applied to the specimens (saturated steam pressure at 200°C: 1.6 MPa, at 300°C: 8.6 MPa). Therefore, the environment is much more severe than in a PCV in the event of SA.

2-2-2) Leakage tests using small flanges

Leakage tests using small flanges were conducted as the second evaluation method. Small flanges, which imitate the flanges installed on actual equipment, were used to confirm whether the sealing performance could be maintained at the temperatures and pressures of SA. Figure4 schematically illustrates the small flange and Table2 shows their sizes. The cross-sectional shape and size of the flange's groove are equivalent to those of the actual equipment; the cross-sectional shape and size of gaskets were also equivalent to those of the actual equipment. In the event of SA, the flanges of the PCV open due to inner pressure. To imitate this phenomenon, an adjusting shim was inserted into the smooth part in the small flange, and the opening area was then adjusted. After the adjustment, He gas was used to apply pressure to the inside of the small flange. This pressurization enabled leakage tests to be conducted under conditions imitating those in the actual equipment.

As Table3 shows, the test conditions were as follows:

Table1 Conditions for compression-set tests

Test	Radiation dose	Environ	Temp	Time
No.	kGy	-	℃	hr
1-1	800	Steam	200	24
1-2	800	Steam	200	72
1-3	800	Steam	200	168
2-1	800	Steam	225	24
2-2	800	Steam	225	72
2-3	800	Steam	225	168
3-1	800	Steam	250	24
3-2	800	Steam	250	72
3-3	800	Steam	250	168
4-1	1000	Steam	265	72
4-2	1000	Steam	265	168
4-3	1000	Steam	265	336
5-1	1000	Steam	280	168
6-1	1000	Steam	300	24
6-2	1000	Steam	300	72
6-3	1000	Steam	300	168

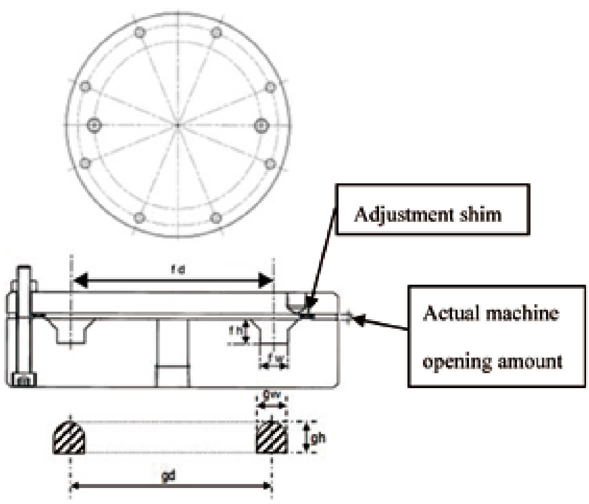

Figure4 Outline of a small flange

Table2 Sizes of small flanges

	Seal material dimensions			Groove dimensions			Opening amount
	Center diameter (gd)	Width (gw)	Height (gh)	Center diameter (fd)	Width (fw)	Height (fh)	
Small flange	Shrink actual machine	Same dimension as actual machine	Same dimension as actual machine	Shrink actual machine	Same dimension as actual machine	Same dimension as actual machine	Actual machine opening amount

Table3 Conditions for leakage tests

Test No.	Radiation dose	Heating				
		Exposure environment			Test environment	
		Environ	Temp	Time	Environ	Temp
	kGy	-	℃	hr	-	℃
7-1	1000	Steam	280	168	Dry	280
8-1	1000	Steam	300	168	Dry	300

After the flange temperature reached a given temperature, He atmosphere of 1 MPa was used to pressurize the inside of the flange for 10 minutes. After the pressurization, the presence of leakage was confirmed. If He gas leaks in this test, the leakage can be confirmed from the outside of the flange. Therefore, the leaked He gas was collected through water as a substitute to calculate the hourly leakage rate of He. Figure 5 outlines the test equipment.

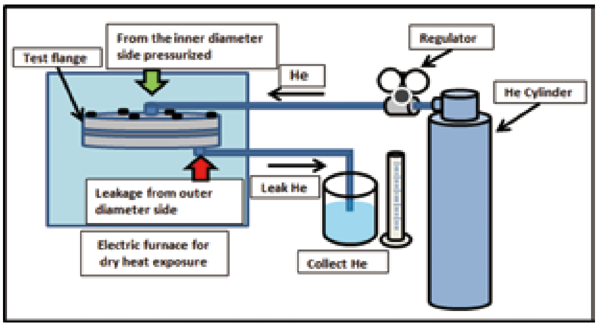

Figure5 Outline of test equipment to determine leakage from a small flange

3. Evaluation results

3-1) Compression-set test

Table4 shows the results of the compression-set tests. In the table, Cs represents the compression-set rate. The following trends were confirmed: under a constant temperature, the compression-set rate increases over time; within a given time period, the compression-set rate increases with increasing temperature.

Table 4 Results of compression-set tests

Test No.	Radiation dose kGy	Environ -	Temp ℃	Time hr	Cs %
1-1	800	Steam	200	24	10
1-2	800	Steam	200	72	11
1-3	800	Steam	200	168	16
2-1	800	Steam	225	24	10
2-2	800	Steam	225	72	15
2-3	800	Steam	225	168	18
3-1	800	Steam	250	24	13
3-2	800	Steam	250	72	16
3-3	800	Steam	250	168	22
4-1	1000	Steam	265	72	25
4-2	1000	Steam	265	168	34
4-3	1000	Steam	265	336	38
5-1	1000	Steam	280	168	53
6-1	1000	Steam	300	24	47
6-2	1000	Steam	300	72	67
6-3	1000	Steam	300	168	84

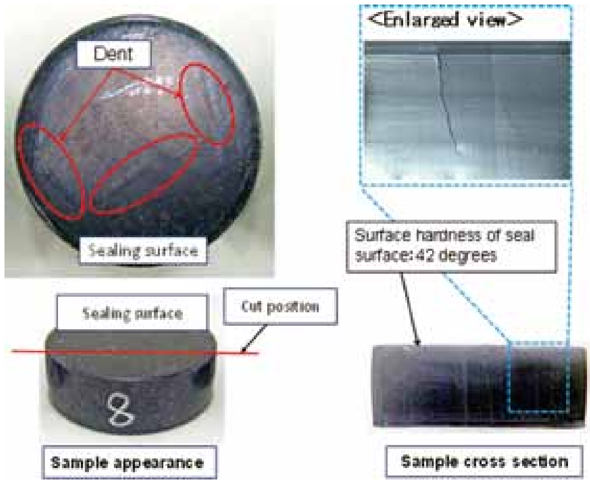

Figure6 Specimen after Test No. 6-3 test

Figure6 shows an external view of a specimen tested under the most severe conditions with a temperature of 300°C and duration of 168 hours (Test No. 6-3). Although no abnormality was found on the side face, dents were found around the center of the sealing surface. Therefore, the specimen was cut and the cross section was checked. Although the dents were caused by a crack that had developed inside, the crack was confirmed not to have penetrated into the sealing surface. The cause of the crack appeared to be a rapid expansion of compressed steam while the pressure was being reduced under highly-pressurized saturated steam. To be more specific, the crack is considered to have developed as follows: 1) Steam pressure of 8.6 MPa was applied to flanges for the evaluation under a saturated steam environment at 300°C. 2) The steam pressure also compressed steam contained in the rubber. 3) After the evaluation was completed, the highly-pressurized steam was released from the pressure container. 4) During steam release, rapid decompression occurred. 5) The rapid decompression caused steam, which had been compressed in the rubber, to expand rapidly. 6) The rapid expansion caused the crack in the rubber.

In this evaluation, the crack was caused by a physical factor stemming from the evaluation equipment. On the other hand, in the event of SA, the maximum pressure is expected to be 0.854 MPa, and so it is considered that no crack will develop in actual

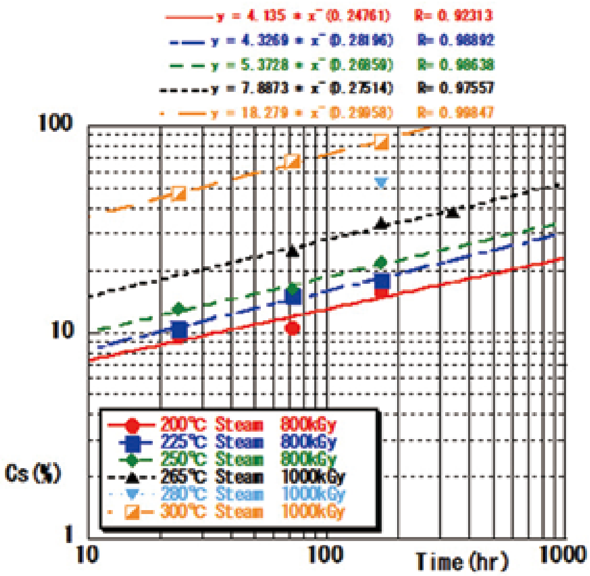

Figure7　A plot of the results of compression-set tests

equipment in the event of SA.

Figure7 illustrates the results of the compression-set tests. The horizontal axis represents time; the vertical axis represents compression-set rate. Under such conditions, the resulting data were plotted to produce an approximation curve for each temperature. As Figure7 shows, each curve shows a very high correlation coefficient, and the slopes of the respective approximation curves are approximately the same. Figure8 is an Arrhenius plot of the results of the Arrhenius equation under the following conditions: 1) Sealing performance can be secured at the

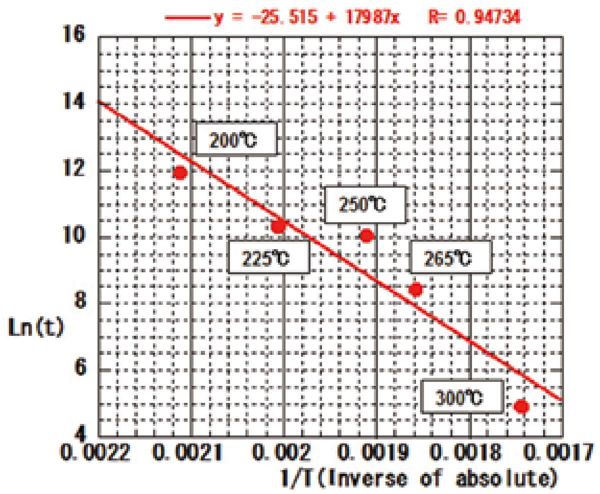

Figure8　Arrhenius plot based on data at temperatures of 200 to 300°C

compression-set rate of 80%.[3] 2) Time duration was set such that a compression-set rate of 80% could be achieved within the time duration. 3) Each temperature was arranged according to the time duration. As a result, the plot demonstrates that a collinear approximation can be made with very high correlation coefficients.

Since thermal deterioration is a chemical reaction, the progress of deterioration varies depending on the amount of thermal energy which is applied to the material. Therefore, regular deterioration behaviors are likely to be detected provided that the temperature range does not significantly exceed the thermal limit for the material and the evaluation environment is not unstable.

Therefore, in this evaluation, which was conducted under a saturated steam environment of 200 to 300°C, the deterioration had developed according to the chemical-reaction theory, and was not likely to cause sudden and abnormal deterioration. Therefore, lifetime estimation was confirmed to be possible with this deterioration.

3-2) Leakage test using small flanges

The results from leakage tests using small flanges showed that no leakage occurred from the specimen which had been exposed to the saturated steam environment at 280°C and 300°C for 168 hours.

After the evaluation had been completed, the small flanges were dismantled to check the appearance of the gaskets. Figure9 shows a photograph of a specimen which was exposed to 280°C for 168 hours; no abnormality was found in the appearance. Similarly, regarding a specimen which was exposed to 300°C for 168 hours, cracks were confirmed on part of the gasket in the direction of the outer circumference; however, no cracks or damages, which affect leakage, were confirmed in the direction of inner or outer circumference. Regarding the abovementioned cracks, like the internal cracks in the compression-set tests, rapid expansion of compressed steam due to rapid decompression appears to have caused the cracks.

Therefore, at 168 hours after the initiation of exposure

Figure9　Specimen after Test No. 7-1 leakage tests

under saturated steam environments at 280°C and 300°C, no significant defect of sealing material was confirmed. Therefore, the sealing performance appears to have been maintained.

4. Summary

The results of the compression-set tests and leakage tests using small flanges under high-temperature saturated steam environments were as follows.

- The mechanism of deterioration of our improved EPDM material (No. H3070) appeared to be the same at temperatures ranging between 200 and 300°C; the possibility of sudden abnormal deterioration developing due to temperature changes is low.
- The results of the leakage tests using small flanges showed no leakage when the flanges had been exposed to saturated steam at 300°C for 168 hours.
- These results indicate that the improved EPDM material can be used in a stable manner under saturated steam environments at temperatures up to 300°C.

5. Conclusion

In this evaluation, the improved EPDM material was confirmed to maintain its sealing performance even under the very severe environment of 300°C, provided the environment was limited to that used in this evaluation. This finding highlighted the importance of continuing with development and verification based on unconventional, free-thinking without bias, as well as listening to users' requests. We will continue to strive hard to produce such reports in the future.

Note that this report is an edited version of a paper presented at the autumn academic lecture session of the Atomic Energy Society of Japan in 2017.
Lastly, we sincerely thank the staff of Chubu Electric Power Co., Inc. for their assistance in publishing this report.

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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.

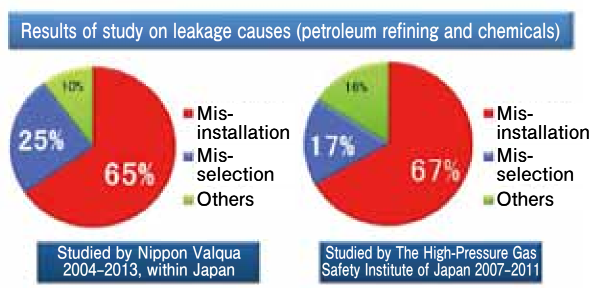

Figure 1　Statistics from study of leakage causes

2. Guidelines on gasket selection

2-1) Issues regarding gasket selection

Gaskets are used under <u>various conditions</u> and so <u>a wide range of conditions</u> 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

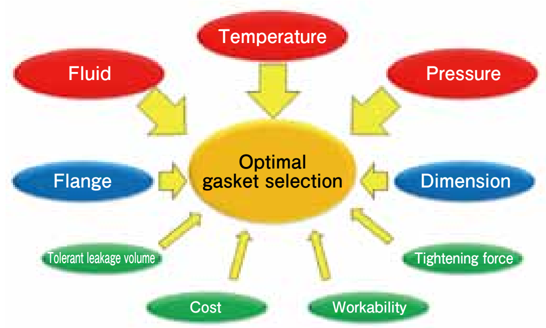

Figure2　Selection conditions for gaskets

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.

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:

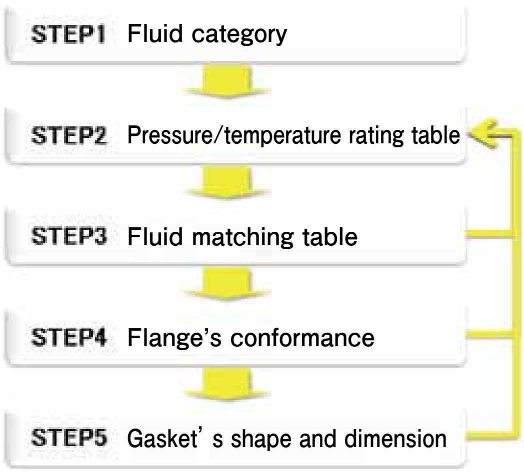

Figure3 Selection conditions for gaskets

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 water 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.

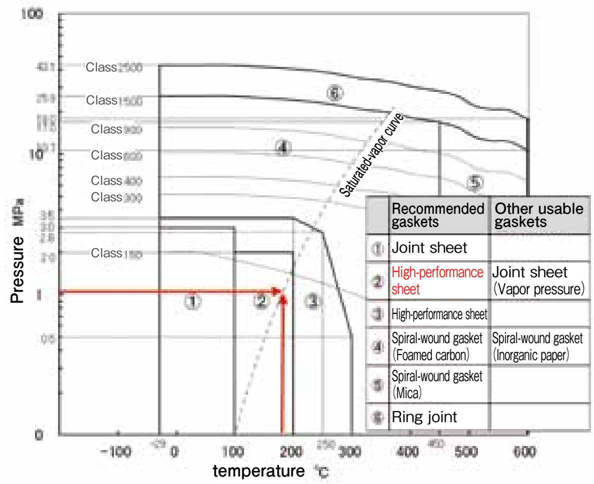

Figure 4 Temperature/pressure selection graph for water, hot water, water vapor

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	High-performance sheet MF300	High-performance sheet GF300	High-performance sheet 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		Flange-seat type			
Type	Shape	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 inner and outer rings	Raised face (flat face)	With inner and outer rings	With inner and outer rings	With inner and outer rings
With inner and outer rings	With outer ring(1)(2)		With outer ring(1)(2)	With outer ring(1)(2)	With inner and outer rings
With inner ring	With inner ring	Male-and-female shape	With inner ring	With inner ring	With inner ring
With inner ring	Basic shape(3)		Basic shape	Basic shape	With inner ring
Basic shape(3)	Basic shape(3)	Groove shape		Basic 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

Figure7　Deformation of a spiral-wound gasket

inner and outer rings is recommended.

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.

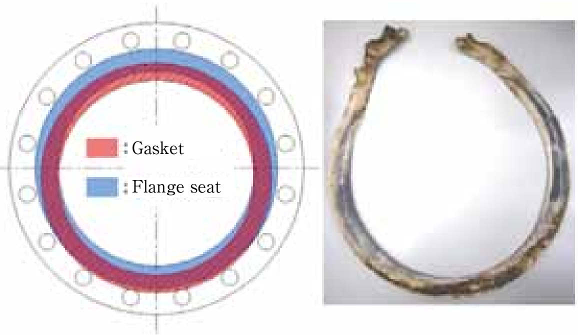

Figure8　Deformation due to gasket misalignment

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^{TM}, 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.

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Considerations for Tool Selection and Installation of Fastening Bolts for Flanges with Large Nominal Diameters

1. Introduction

Various tightening tools are used for fastening bolts. Correctly selecting the optimal tools depending on the usage environment and required fastening precision and properly using such tools reduces the workload and improves fastening precision, work efficiency, and safety.

Bolt fastening is required not only during plant construction but also maintenance and inspection. However, bolt fastening is difficult to control and so even now it still depends on the operator's instincts and experiences. In addition, as the number of skilled operators decreases, bolt fastening is becoming a major cause of leakage accidents and fires at plants. Despite this situation, training on bolt tightening, including the systematic selection of fastening tools and their usage, is rarely provided. In recent years, a certification system for a flange-fastening qualification[1)] has been introduced in other countries, and has helped to reduce leakage. However, especially in Japan, efforts to prevent leakage are left to the discretion of facility owners and engineering companies.

Regarding large bolts, which are difficult to fasten by manpower alone, we sell and rent out tools for such bolts. We also offer on-site supervision on shop floors where fastening skills vary among the different operators who perform fastening.

We have accumulated useful knowledge and information about fastening from on-site experience, and would like to share tips on fastening regarding tool selection and considerations for installation.

2. Selection of optimal tools

Firstly, using tools offers the following benefits:

<u>Benefits associated with installation quality:</u>

- Correct fastening force can be applied to bolts.
- Gaskets, flanges, and bolts are not overloaded.
- Tightening will be consistent if it can be managed based on torque values and axial force values.

<u>Benefits associated with operation:</u>

- Work time can be decreased by reducing staff number and operation time.
- Heavy manual work can be eliminated, reducing the burden on operators.
- Tightening can be executed even in narrow areas where there is little space around equipment.

To obtain such benefits, it is crucial to select tools that meet the on-site conditions. Below, we explain the important factors for selection.

① Fastening-torque value or axial-tension value

When the fastening torque is known, select a tool which can apply that torque at no more than 70% of its maximum output.

【Point】Consider the tool's fastening performance.

As a guide, a tool should be selected from tools which have maximum torque output equal to 1.5 times the target torque. If the axial-tension value (bolt elongation) is the target value, the tightening is managed by using a bolt tensioner or a hydraulic torque wrench & ultrasonic axial force meter as shown in Figure1.

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Figure1　Measurement of bolt elongation value using an ultrasonic axial force meter

② Shape and number of bolts and nuts

Since the types of tools that can be used are limited depending on the shapes of bolts and nuts, such as all-screw bolts, tap-end bolts, hexagon headed bolts, and cap nuts, select tools which match such bolts and nuts.

【Tip】Check whether the selected tool matches the shapes of bolts and nuts.

When the long part of a bolt protrudes from the nut's top face, the bolt cannot be fitted with a hexagonal socket. Therefore, center-hole tools and center-hole bolt tensioners should be selected.

【Tip】Consider the tool's operational speed.

Since the operation time per bolt should be shortened, consider selecting a tool with a high fastening speed, fastening bolts concurrently using several tools, and other strategies.

③ Clearance around the target bolt and equipment environment

Check the clearance around bolts to be tightened and the equipment environment.

【Tip】Check whether there is space in the axial direction of bolts.

Large spaces in the axial direction are required for pistol-type tools including air torque wrenches. On the other hand, hydraulic torque wrenches

Table1　Characteristics and evaluation of each tool

	Booster wrench	Battery-type torque wrench	Air torque wrench	Hydraulic torque wrench	Bolt tensioner
Applicable bolt	M16–36	M20–48	M20–56	M30–76	M30 to over M100
Torque range	300–2,000 N・m	500–4,000 N・m	500–6,000 N・m	1,000–30,000 N・m	Managed using axial tension (kN)
Major characteristics	Very strong torque can be applied with light force.	Easy cordless operation using a pistol-type tool	Easy operation using a pistol-type tool	Smallest and lightest among tools with the same torque	No scoring on screws Several screws can be fastened concurrently.
Advantages	No need for power source	Handy for anyone High speed	Handy for anyone High speed	Highly precise torque Wide torque range	Highly-precise fastening No co-rotation
Disadvantages	Takes time in fastening.	Regular charging is required.	Need for stable air supply	Need for pumps and hydraulic hoses	Troublesome setting Heavy tool
Power source	Unnecessary (Manpower)	Rechargeable battery	Compressed air 500 kPa -	Compressed air 500 kPa -, Power supply 100 V, 200 V	Compressed air 500 kPa -
Explosion-proof	○	×	○	○Depends on pump's function	○
Condition for application 1	Space of at least 250 mm is required in the axial direction of a bolt.	Space of at least 500 mm is required in the axial direction of a bolt.	Space of at least 500 mm is required in the axial direction of a bolt.	Space can be minimal in the axial direction of a bolt.	Space of at least 300 mm is required in the axial direction of a bolt.
Condition for application 2	A reaction-force point should be secured on the neighboring bolt or other area.	←	←	←	Bolt's head should protrude from nut's top face by at least 1d (d: diameter).
Management method	Input torque wrench	Digital pre-setting	Air pressure	Hydraulic power up to 70 MPa	Hydraulic power up to 150 MPa
Concurrent fastening	N/A	N/A	N/A	Available (up to 4 bolts)	Best (2 bolts to half the total number of bolts)
Operator No.	1 operator/tool	1 operator/tool	1 operator/tool	1–2 operators/tool	0.5–1 operator/tool
Nut fitting	Socket	Socket	Socket	Socket or direct fitting	Prybar
Speed	☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆	☆☆
Precision	☆☆	☆☆☆	☆☆☆	☆☆☆☆	☆☆☆☆☆
Operability	☆☆	☆☆☆☆☆	☆☆☆☆☆	☆☆☆☆	☆☆
Lightness	☆☆☆	☆☆☆☆	☆☆☆	☆☆☆☆☆	☆
Concurrent multiple-bolt fastening	☆	☆☆☆	☆☆☆	☆☆☆	☆☆
Applicability to various sizes	☆☆☆	☆☆☆☆	☆☆☆☆	☆☆☆☆	☆☆
Introduction cost	☆☆☆☆☆	☆☆☆	☆☆☆	☆☆	☆☆☆

are compact and can be widely used. Care should be taken, if space is tight, such as under piping elbows.

【Tip】Check the orientation in which tools are applied.

When tools are heavy, especially when used from underneath, workability is greatly affected by the tool's weight, so the tool's weight is an important factor. When a tool weighing over 10 kg is used upwardly from underneath, some measure to support the tool or prevent it from falling is necessary.

④ Available power source

Check the type of power source available.

【Tip】Secure a power supply of 200 V or stable compressed air.

If there is no power supply, a booster wrench or a battery-type torque wrench should be selected (the wrench should be charged). Also, bolt tensioners can be pressurized using a hand pump. By considering the above factors and comparing them with each tool's characteristics as shown in Table1, the candidate tool types can be identified. Especially, the bolt tensioner uses a different fastening mechanism from the torque method: the bolt tensioner applies axial force to a bolt by directly pulling the bolt. Therefore, the bolt tensioner is rarely affected by the friction coefficient of the contact surface, and so offers highly accurate fastening and does not scratch the flange's surface. However, many devices are designed without assuming that the bolts are fastened using a bolt tensioner; in some cases, part of the device must be remodeled, including changing the bolts, in order to use a bolt tensioner in existing facilities.

3. Considerations of assembly

3-1) Maintenance of bolts and nuts

The next important factor is maintenance of bolts and nuts. Especially, in the case of torque fastening, the axial tension applied to bolts varies depending on the maintenance condition, so maintenance is very important, which includes the following:

① Removing rust and scale
② Repairing damaged screw threads
③ Applying lubricant to the nut seat and threaded portion
④ Smoothing the flange's surface (when impossible, use a washer)

We have checked the maintenance conditions at many sites and found that although 1) and 2) are conducted properly, 3) is often inadequate. In the case of torque control, the axial-tension value of the nut seat surface, which is greatly affected by friction, varies significantly when a lubricant is applied to the surface. When the surface condition of a flange is poor, inserting a washer may improve the condition. We have seen many such cases.

In the case of the all-screw bolt, when lubricant is not applied to the fastening side and opposite side of the nut seat surface, co-rotation is less likely to occur.

3-2) Fastening procedures

When fastening a flange's bolts while uniformly compressing the gasket, fastening should be conducted in a stepwise fashion, as described in JIS B2251[2] and JPI-8R-15.[3]

In practice, these standards are rarely observed, and they show procedures only when using one tool for fastening. The proper procedures vary depending on the number of tools used, so it is desirable to set

Figure2 Parallel fastening using two hydraulic torque wrenches

efficient procedures which are tailored to the number of tools used.

Among the proper procedures, we especially recommend parallel fastening as shown in Figure2. In parallel fastening, at least two tools are placed diagonally for fastening.

This requires less work for one bolt until fastening is completed in a shorter time period, and the gasket is compressed evenly. Therefore, this fastening method can prevent malfunctions resulting from uneven fastening. Valqua's Seal Training Center[4] has facilities where you can experience parallel fastening of flanges with large nominal diameters, so we encourage you to take advantage of these facilities.

3-3) Considerations on reaction-force point

In torque fastening, in principle tools should apply force from a reaction-force point. Securing a stable reaction-force point directly results in accurate fastening force and safety. Therefore, the following procedures are important when fastening nuts: 1) Draw a horizontal line extended from the center of the nut to be fastened. 2) On the horizontal extended line, set a position where a reaction-force arm is fixed. 3) Tightly secure the reaction-point arms on the position in such a manner that the arm is securely fixed to the position when force is applied to the arm. Regarding common flanges, reaction-force points can usually be secured by using the neighboring nut. However, in other cases, it is necessary to carefully check in advance whether a reaction-force point can be correctly secured.

3-4) Efficient operation

After tool selection, the actual work will start; a little preparation in advance can reduce the working time, so we recommend preparing the following items.

① Backup wrench

Figure3 shows some backup wrenches. A backup wrench is set on the nuts on the fastening side and on the opposite side to prevent co-rotation. In addition, backup wrenches can be removed easily. If backup wrenches are not used, co-rotation must be prevented by using slogging wrenches and chisels, but it takes longer to remove the wrenches than when fastening nuts.

Figure3　Backup wrench

② Hydraulic pump with large discharge volume

The speed of the hydraulic torque wrench and bolt tensioner depends on the pump's discharge volume; the discharge volume makes a significant difference especially when a large tool is used. However, large tools are less portable. Therefore, take on-site conditions into account when selecting appropriate tools.

③ Not-too-long hydraulic hose

If the hydraulic hose is too long, it is obstructive on the scaffold, and makes tools not only cumbersome but also slower. The standard length is 5m.

④ Nut splitter

Figure4 shows a hydraulic nut splitter. Although this phenomenon occurs only when a nut is

Figure4　Nut splitter

loosened, if the nut adheres to a bolt too strongly the nut does not rotate. In this case, hydraulic power can be used to cut a nut quickly to remove a bolt.

4. Conclusion

This article introduced considerations for tool selection and installation when fastening the bolts of flanges with large nominal diameters.

Our first priority is to resolve on-site problems and challenges in bolt-fastening operations. To achieve this goal, we have developed products which are useful on shop floors; selected tools which meet the requirements of each shop floor and promptly procured these tools; created on-site guidance on handling; and performed fastening management using an ultrasonic axial force meter.

Through these experiences, we have encountered many cases in which ignoring small details resulted in problems. Two decades ago, there were many skilled workers and we witnessed their excellent hammering works. However, when an ultrasonic axial force meter was used to measure the fastening conditions of the bolts which they had fastened, the meter showed that the bolts had been fastened too strongly. Over-fastening was probably performed because the gaskets of many flanges did not function as intended.

Valqua offers various services at its Seal Training Center, to provide proper knowledge and significantly reduce the risks stemming from users' ignorance.

Leakage at the bolted flange joint is mainly due to poor assembly, which may be due to bolt-tightening problems. We offer products and services for bolt-tightening, to accumulate on-site experience which cannot be gained from studying theories, and provide useful information for those who need it, ranging from designers to operators. To achieve this goal, we are establishing a system and offering support for all procedures ranging from seal selection to bolt tightening.

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TORQUE SYSTEM Co.,Ltd.
Managing Director

H&S Demonstration Car

1. Renewed demonstration car

We set one of our goals—becoming an H&S company—based on our core principle of "maximizing customer value." As an H&S company, we aim to provide not only seal products (hardware) but also overall seal engineering.

As part of our efforts, in 2014 we opened a Seal Training Center (STC), which is a hands-on training center for sealing work, and have since been offering training services. To promote the value and effectiveness of the STC, in 2015 we started using an STC demonstration car, which is fitted with STC training equipment. This car enables simple hands-on demonstrations to be conducted at a customer's premises.

Such approaches are greatly appreciated by many customers, and are highly evaluated by plant owners as well as engineers. The number of STC training sessions continues to rise year by year, and we are honored and humbled to receive such positive feedback.

During the two years of its operation, the STC demonstration car has helped to achieve one of our goals, which is to promote the value of the STC. Accordingly, we have completely renewed the STC demonstration car to create an "H&S demonstration car," and started using it in autumn 2017 to increase advertising and promote various H&S service packages.

Figure1 H&S Demonstration Car

2. Concept

The concept of the H&S demonstration car is not only to attract attendees to the STC training sessions but also to visually and physically promote the value of the H&S solutions. To do this, we installed part of our service packages, which we newly developed and started using in relation to our H&S solutions centering on seal engineering, on the car and gave customers the opportunity to try out these solutions.

In addition, the full-scale renewal allowed us to promote the values of the new H&S service package to customers, for whom we had performed work and given demonstrations in the past.

3. Outline of equipment installed on the demonstration car

3-1) Mobile Seal Training System (MSTS)

Mobile Seal Training System (MSTS) is a service package which integrates both equipment and lecturer-training services. In MSTS, some of STC's training facilities are installed on the car to make a mobile/assembly type training facility, which allows customers by themselves to give seal training to on-site operators at their sites.

In addition, the demonstration car features training equipment for flange tightening and training equipment to acquire a sense of torque, which are especially appealing. With this equipment, operators have the chance to experience training.

Figure2　Mobile Seal Training System (MSTS)

3-2) Flange Solution Tool

To ensure robust sealing, it is important to select not only optimal seals but also optimal operation management. When the positional relation of different piping flanges is not optimal, correction is dangerous and requires many workers and much time. Accordingly, we started to offer Flange Solution Tool, which allow these operations to be executed safely and efficiently.

On the demonstration car, a large demonstration flange unit is installed. This unit is used for demonstrations on how to adjust the misalignment of a flange. In addition, actual bolt-fastening tools

Figure3　Flange Solution Tool

including hydraulic wrenches and bolt tensioners, are exhibited.

3-3) Rust-proofing service

Various plants and ships & vessels are located and operated mainly in coastal areas of Japan to facilitate distribution. Coastal areas are convenient for distribution, but involve the challenges of salt damage (equipment rusting) to the devices and piping of plants and ship & vessels.

To help solve these challenges, mainly rust-proofing painting is applied. However, such painting involves various issues regarding life cycle, application period, smartification, and other challenges. Therefore, new rust-proofing technologies are needed.

Commonly-used rust-proofing paints have poor adhesion. Therefore, if a gap or space develops between equipment and paint, it leads to separation, requiring re-painting every 2 to 3 years. When re-painting, scraping to remove the degraded coating film is also required. Therefore, in plants which need to avoid combustion risk, operations should be conducted within a limited period during shutdown. However, re-painting requires many procedures such as drying.

A rust-proofing management service using a special rust-proofing resin material can resolve these problems. The material has the following characteristics:

① Long-term anticorrosion
- Oil exuding from within resin blocks oxygen and fluid.
- Since the exudation period is long, long-acting blocking is expected.

② Paint application is possible during plant operation
- Unlike common paints, no scraping using tools is needed.
- Painting can be conducted even on areas where scraping cannot be performed (painting cannot be performed) .

③ Excellent post-painting workability
- Since the special rust-proofing resin material can be cut with a cutter, overhaul inspection is simple.

The demonstration car contains a special rust-proofing operation unit. This unit is used to demonstrate the application of special rust-proofing resin, highlighting the differences from conventional painting.

Figure4　Special rust-proofing operation unit

Pre-treatment

Post-treatment

Figure5　A case of rust-proofing treatment

4. Conclusion

This report introduced an H&S demonstration car, which aims to improve the advertising and appeal of H&S solutions. We will revise the range of equipment installed on the car in turn depending on the customers' needs, status of new development, and handling. We dispatch the car all over Japan to help our customers.

Hajime Nonogaki
H&S Business Group

Improved Seal Paste

1. Introduction

When seal paste is applied to gaskets, the scratches in flanges are filled with the paste, improving the sealing properties. Therefore, seal paste has long been used for gasket connection.
Although there are no problems with the conventional seal paste, user demands for safety and the environment are getting stronger, so we developed an improved seal paste.

2. Product summary

The improved seal paste is a light brown paste based on a special, non-drying, oil-based bond formulated with inorganic filler and a small amount of solvent. The formulation is an improvement over the conventional seal paste, as it contains no carcinogenic substances. In addition, it is categorized as a non-hazardous material under the Fire Service Act. Thus, the product is safer and more environment-friendly.

Figure 1　Improved seal paste

3. Characteristics

① The product does not contain crystalline silica, which is carcinogenic, nor organic solvent including highly hazardous dichloromethane and toluene. The product is safe and environment-friendly.

② Since the product contains a solvent with a high flash point, it is categorized as a non-hazardous material (combustible solids under the designated combustibles*) .

③ The new product has similar properties to the conventional seal paste. When applied to gaskets, it works as a sealing adjunct, protects the flanges from rusting, and prevents gaskets from adhering to the flanges.

④ A brush is attached to the cap, making it easy to apply to gaskets and other objects.

Note : Combustible solids under the designated combustibles: Products whose speed of combustion expansion is fast in the case of fire, or whose combustion is difficult to suppress. Petroleum asphalt and some other products fall into this category. When the amount of such a product exceeds a designated amount (3,000 kg) , it is categorized as a combustible solid under the designated combustibles; when used or stored in amounts lower than 3,000 kg, it is categorized as a non-hazardous material.

4. Applicable fluid

The improved seal paste is applicable to water, air, gasoline, kerosene, lubricating oil, natural gas, LPG, cold water, and hydrogen sulfide. The paste can be used when hydrocarbons including ethylene, butane, and ethane are handled, and helps prevent deposit corrosion on the surface of stainless-steel flanges.

5. Service temperature range

−50 to 300°C

6. Product form

730 g of paste in a capped metal can with a brush

7. Performance data

These performance data demonstrate that the improved seal paste has properties equivalent to those of the conventional seal paste.

7-1) Test to check sealing properties at room temperature

To evaluate the sealing properties of each paste, various low contact pressures were applied to gaskets to which the improved seal paste or the conventional seal paste was applied. As a result, leakage from gaskets using the improved seal paste stopped at a contact pressure of 7.5 MPa, the same as leakage from gaskets using the conventional seal paste. This result demonstrates that the improved seal paste has properties equivalent to or better than those of the conventional seal paste.

Table1 Test conditions for checking the sealing properties at room temperature

Gasket	No.GF300
Gasket dimensions	JIS 10K 50A t=1.5mm
Fluid	Nitrogen gas, 3.5 MPa
Gasket stress	5、7.5MPa
Type of paste	Improved seal paste Conventional seal paste
Amount of paste applied	Approximately 0.7 g on both sides

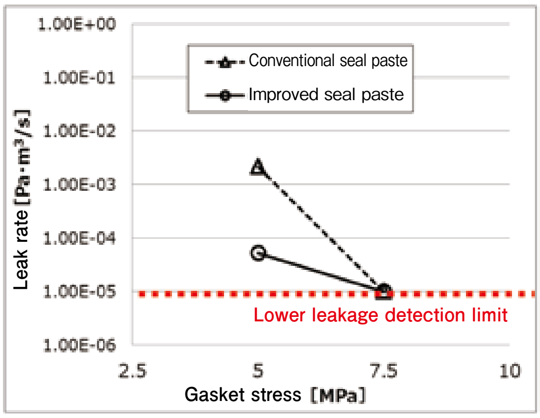

Figure2 Test results of checking the sealing properties at room temperature

Table2 Test conditions for checking compression fracture

Gasket	No.6500
Gasket dimensions	ϕ100×ϕ64 t=3mm
Gasket stress	70、100MPa
Amount of paste applied	Approximately 1.75 g on both sides

7-2) Test to check resistance to compression fracture

Contact pressures of 70 MPa and 100 MPa were applied to gaskets to which either the improved seal paste or the conventional seal paste was applied, to evaluate the contact pressure at which compression fracture occurs.

No abnormalities occurred at contact pressures of up to 70 MPa, neither with the improved seal paste nor with the conventional seal paste. Compression fracture occurred at a contact pressure of 100 MPa with both pastes, verifying that the two pastes have equivalent properties. Figures 3 and 4 show enlarged photos of

Figure 3 Compression-fracture test of conventional seal paste
Compression fracture was confirmed at 100 MPa.

Figure 4 Compression-fracture test of improved seal paste
Compression fracture was confirmed at 100 MPa.

gaskets which suffered compression fracture.

8. Conclusion

Since legal regulations on toxic substances and dangerous substances are becoming stricter due to social demands regarding safety and the environment, customers increasingly need products that meet such social requests. Accordingly, we will continue to develop safe and environment-friendly products for users.

Masato Hamade
Corporate Research and
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Product Development Division I

Multi-Purpose Gland Packing for Chemical Applications

1. Introduction

To date, various types of carbon-fiber products, which have heat and chemical resistance, have been used as gland packings for chemical applications. However, for a particular product, different types of packing should be used depending on how the product is used. When several types of packing are taken from stock and used, there is a risk that the wrong type of packing might be used, possibly causing damage to plant operation and incurring safety risks.

We have developed a new product based on carbon fiber like the conventional product, but when used in a single product, different types of packing are not required depending on how the single product is used. The new product can also be used under diverse conditions in a single product, and offers the same heat, pressure and chemical resistance. Therefore, the new packing improves the stability and safety of operation, and helps reduce inventory.

2. Composition

No. 6137 series is based on gland packing manufactured as follows: (1) Carbon fiber is treated with PTFE dispersion. (2) The cross section of the treated carbon fiber is braided into a square shape. (3) The shaped carbon fiber is finished with PTFE dispersion and graphite particulate. Both oil-containing and oil-free types are available. The three types, No. 6137, No. 6137-O, No. 6137-SO, can be selected depending on the application.

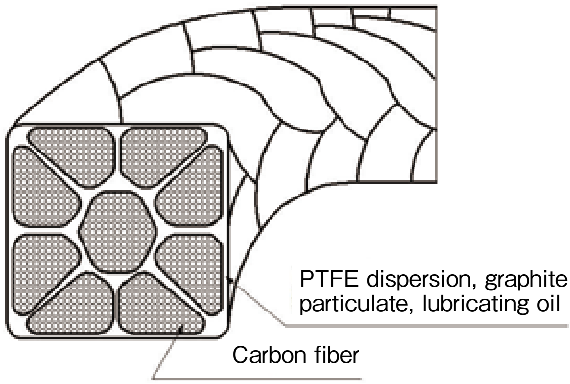

Figure1 Outline illustration of No. 6137 series

Figure2 External view of No. 6137 series

3. Characteristics

① No. 6137 series is suitable for a wide range of applications, including valves, pumps, equipment, and others.

② The main materials of No. 6137 series are carbon fiber and PTFE dispersion, which have excellent chemical resistance. Therefore, No. 6137 series can be used for most fluids except strongly oxidizing fluids.

③ No. 6137 series is suitable for a wide range of applications, resulting in excellent cost performance (inventory reduction).

4. Applications

・Common applications of No. 6137 series
No. 6137 series can be used for valves, pumps, packings of seal devices, etc., all of which handle chemical fluids (except for oxidizing acids and oxidizing agents including concentrated sulfuric acid and concentrated nitric acid).

・No. 6137 can be used in valves and devices for applications designated as oil-free processing, requiring no contamination by lubricating-oil, and for prevent softening and loosening of the packing due to lubricating-oil reduction.
・No. 6137-O can be used for valves and devices as well as high-speed pumps including turbo pumps, all of which require low torque and gas-sealing performance. It can also be used as a substitute for No. 6232 and No. 6262 (thus reducing inventory through part-number integration).
・No. 6137-SO can be used for high-speed pumps such as turbo pumps, which need greater heat resistance than No. 6137-O in devices which require low torque and gas-sealing performance.

5. Usable range

Table1　Product specifications

Application	Valve	Pump	Device
Maximum service temperature	260 ℃		
Maximum service pressure	15.5 MPa	1.6MPa	9.8MPa
ANSI rating	Class 900	—	—
Maximum service speed	—	20m/s (1)	5m/s (1)
PV tolerance	—	14.7MPa·m/s (1)	—
pH range	0～14		

Note (1): Maximum service speed and PV tolerance are applicable to No. 6137-O and No. 6137-SO.

6. Specifications

Nominal dimension: □ 3.0–25.0 mm
Packing unit: 3 m (Ring-shape molding is also available.)

7. Results of functional tests

7-1) Evaluation of basic characteristics

Basic-characteristics tests are conducted to evaluate compressive-strain characteristics, sliding characteristics, sealing characteristics in valves, and use as gland packing.

Test conditions:

Table2　Test conditions

Gland packing	No.6137-O, No.6232 (1)
Test equipment	Refer to “Figure 3. Outline illustration of basic-characteristics test equipment.” Evaluation of basic characteristics
Packing dimension	$\phi 20 \times \phi 33 \times 6.5^{H}$
Packing qty	6 rings
Stem radial clearance	0.5mm
Packing stress	4.9～58.8 MPa
Fluid	Nitrogen gas
Fluid pressure	1.0～9.8 MPa

Note (1): No. 6232 is used for valves and reciprocating equipment.

Outline of the test method:
① Mount the gland packing in a test jig.
② Fasten the packing under a given contact pressure using a compression tester.
③ Measure the height and stem torque of the packing.
④ Load fluid pressure on the packing and measure the leak rate.
⑤ Increase the packing stress in a stepwise fashion, and repeat steps ② to ④.

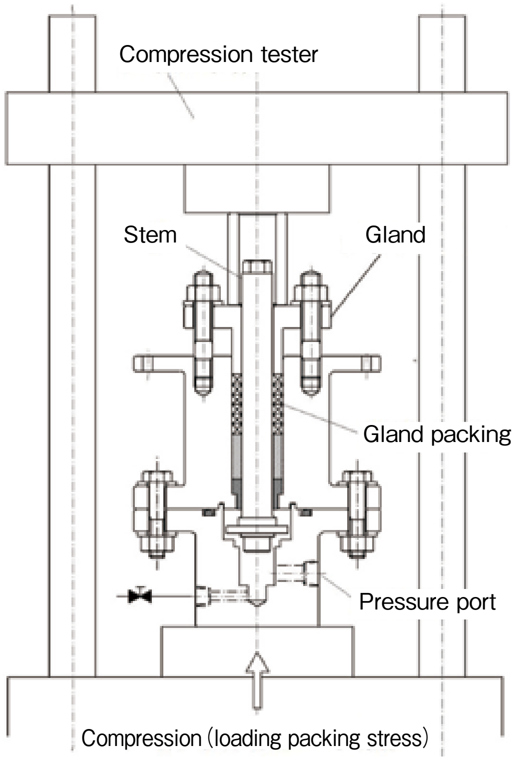

Figure3 Outline illustration of basic-characteristics test equipment

Test results:

The results of the basic-characteristics evaluation are shown in Figures 4 to 7.

No. 6137-O had a slightly lower compression ratio, weaker stem resistance, which is a sliding characteristic, and improved performance than the conventional product No. 6232. Regarding sealing properties, both specimens showed equivalent results.

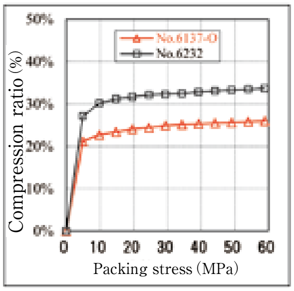

Figure4 Compression characteristics

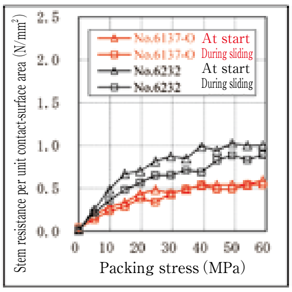

Figure5 Sliding characteristics

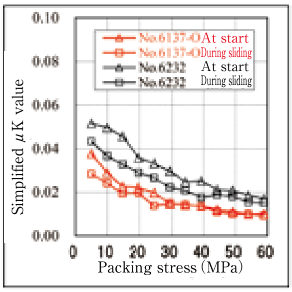

Figure6 Sliding characteristics (μk value)

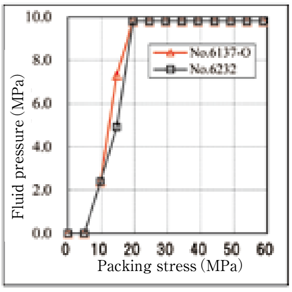

Figure7 Sealing properties

7-2) Reciprocation-tolerance test

Reciprocation-tolerance tests are conducted to evaluate the sliding-resistance characteristics and sealing characteristics against reciprocating motions of the gland packing for valves.

Table3 Test conditions

Gland packing	No.6137-O, No.6232 (1)
Test equipment	Refer to "Figure 9. Outline illustration of a reciprocation-tolerance tester."
Packing dimension	$\phi 20 \times \phi 33 \times 6.5^{H}$
Packing qty	8 rings (2 rings + lantern ring + 6 rings) × 2
Packing arrangement	
Fluid	Water and heated water
Test temperature	260℃
Stem radial clearance	0.7 mm (inner diameter = ϕ21.4)
Sliding number	1000 reciprocations × 3 cycles (3000 reciprocations)
Packing stress	Initial packing stress: 39.2 MPa Additional packing stress: 39.2 MPa
Stem operating conditions	Stem stroke: 50 mm Stem speed: 25 mm/sec Stem stop: 1 sec
Fluid pressure	On heating: 10.2 MPa When withstanding pressure at room temperature: 11.0 MPa

Note (1) : No. 6232 is used for valves and reciprocating equipment.

Test results:

Figure 10 shows the results of the reciprocation-tolerance tests.

No. 6137-O had a weaker stem resistance, which is a sliding characteristic, and improved performance than the conventional product No. 6232. Regarding sealing properties, both specimens showed equivalent results.

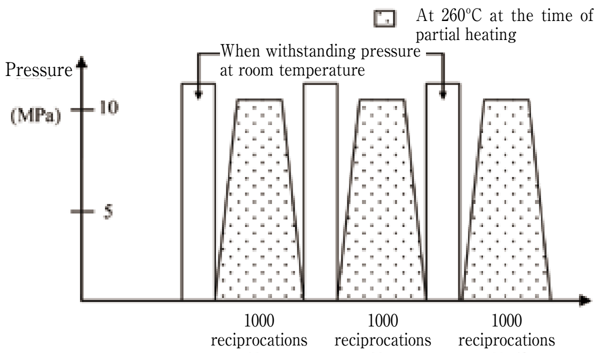

Figure8　Outline of test cycles

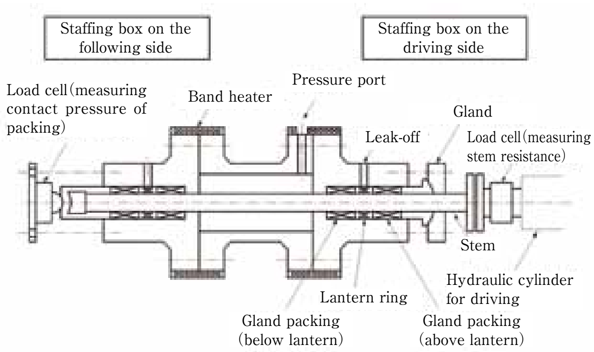

Figure9　Outline illustration of a reciprocation-tolerance tester

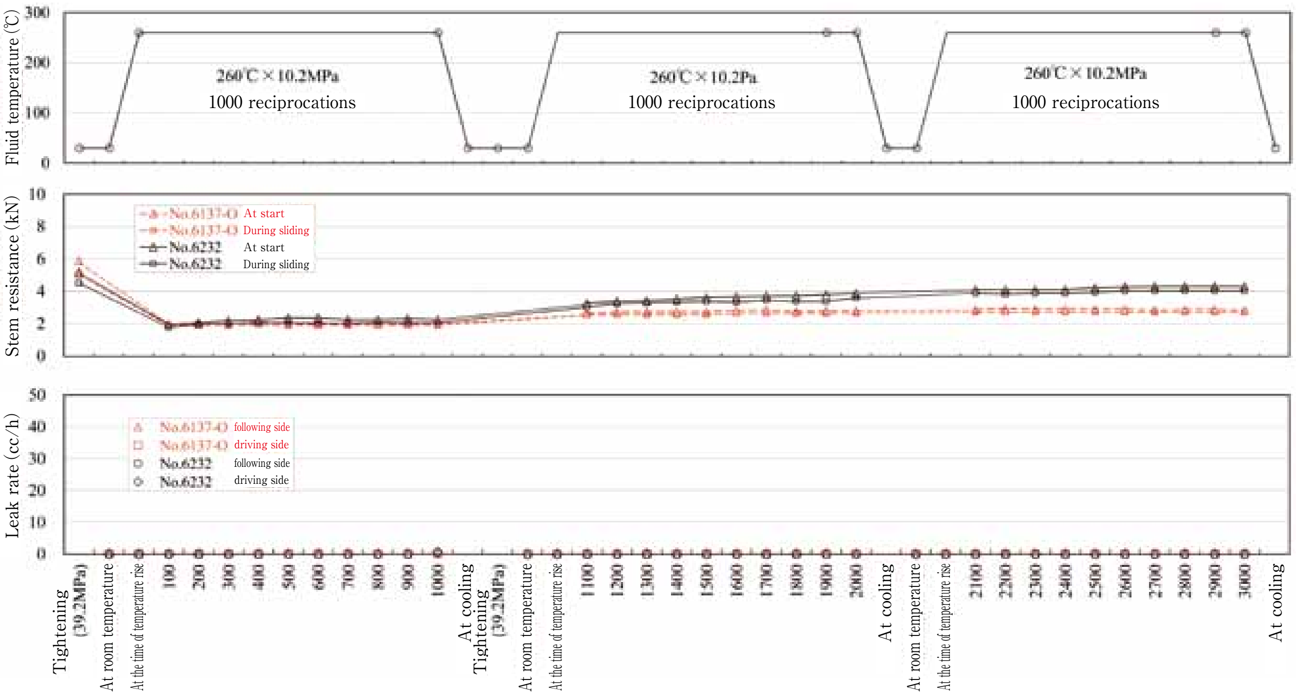

Figure10　Results of reciprocation-tolerance tests

7-3) Large-bore pressure test

Large-bore pressure tests are conducted to evaluate the pressure tightness of a gland packing.

Table4　Test conditions

Gland packing	No.6137-O
Test equipment	Refer to "Figure 11. Outline illustration of large-bore pressure tester."
Packing dimension	$\phi 80 \times \phi 112 \times 16.0^{H}$
Packing qty	6 rings
Stem radial clearance	1.2 mm (inner diameter = ϕ82.3)
Packing stress	39.2 MPa
Temperature	Room temperature
Fluid	Water
Fluid pressure	15.5 MPa, 19.4 MPa, 23.3 MPa (Maximum, ANSI Class 900 × 1.5)

Outline of the test method:

① Mount the gland packing in a test jig.

② Use a torque wrench to tighten the gland packing to a given packing stress.

③ Apply a given fluid pressure to the sample using a water-pressure booster.

④ After keeping the pressure for 30 minutes, check whether the fluid penetrates through the packing or leaks.

⑤ ncrease the fluid pressure in a stepwise fashion, and repeat the check of step ④.

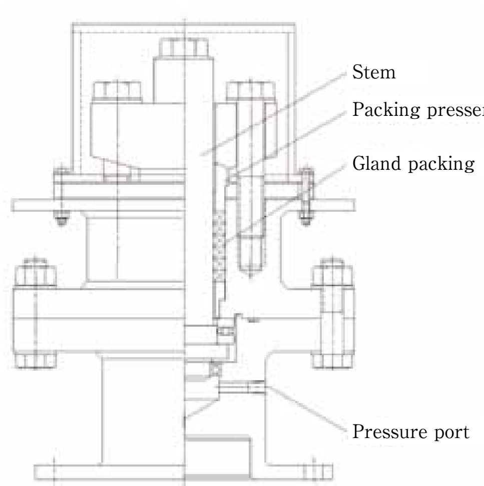

Figure11 Outline illustration of a large-bore pressure tester

Test results:
Table 5 shows the results of the large-bore pressure test.
Pressure tightness was improved from the diameter of ANSI Class 600 for the conventional product No. 6232; No. 6137-O can be used at the diameter of up to ANSI Class 900.

Table5 Results of large-bore pressure tests

Fluid pressure (MPa)	19.4	23.3
ANSI rating	Class 900 × 1.25	Class 900 × 1.5
Penetrating	None	None
Leakage	None	None

7-4) Test to evaluate long-term durability against inverter using an actual equipment pump

In inverter-tolerance tests, the rotation of a rotary pump's motor is switched alternatingly between 60 Hz and 30 Hz using an inverter in the pump of actual equipment. Through the alternate switching, the peripheral speed and discharge pressure are varied, creating much more severe conditions than under regular operation. Under such conditions, the leak rate and stem-torque characteristics were evaluated.

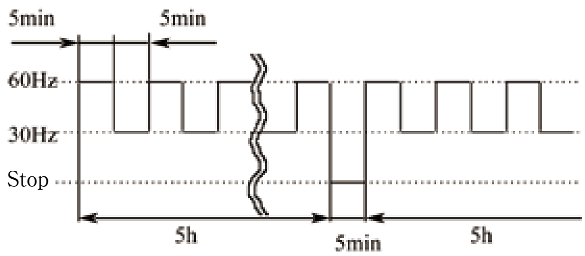

Figure12 Inverter activation cycle

Test pump : General-purpose, single-suction centrifugal pump
Motor : 4-phase, 200 V (60 Hz) , 4 poles, 5.5 kW
Pump bore : 65 × 50

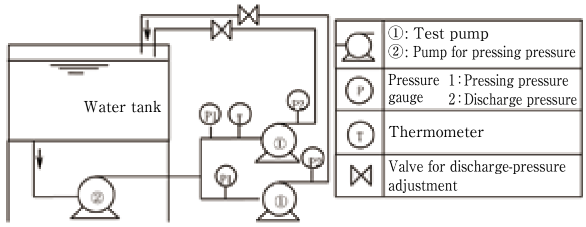

Figure13 Outline illustration of a long-term inverter-tolerance tester

Table6 Test conditions

Test equipment	Refer to "Figure 13. Outline illustration of a long-term inverter-tolerance tester."	
Gland packing	No.6137-O, No.6262 (1)	
Packing dimension	$\phi 35 \times \phi 51 \times 8^{H}$ (4 rings)	
Fluid	Water	
Temperature	Course of events	
Pushing pressure	0.5MPa	
Test frequency	60Hz	30Hz
Rotation	1800rpm	900rpm
Peripheral speed	3.30m/s	1.65m/s
Discharge pressure	0.8MPa	0.6MPa
PV value	2.64MPa・m/s	0.99 MPa・m/s

Note (1) : No. 6262 is used for rotary pumps and rotary devices.

Test results:
Tables 7 and Figure 14 show the results of the inverter-tolerance tests.
In the tests, varying pressures and peripheral speeds were applied to the samples through inverter operation of a rotary pump of actual equipment. Under varying pressures and peripheral speeds, No. 6137-O showed stable tolerance and had equivalent leak rate and sliding resistance to the conventional product No. 6262.

Table7 Results of inverter tests

Operation time		Approximately 1000 hours			
Fluid temperature (1)		Course of events			
Gland packing		No.6137-O		No.6262 (3)	
Frequency		60Hz	30Hz	60Hz	30Hz
Leak rate (2) (cc/min)	Minimum value	6	6	9	9
	Maximum value	18	15	90	90
	Average	14	13	26	26

Note (1) : Fluid temperature fluctuates depending on packing's frictional heat and piping resistance.
(2) : Leak rate just after inverter activation
(3) : Test results do not include time for running-in and initial adjustment.

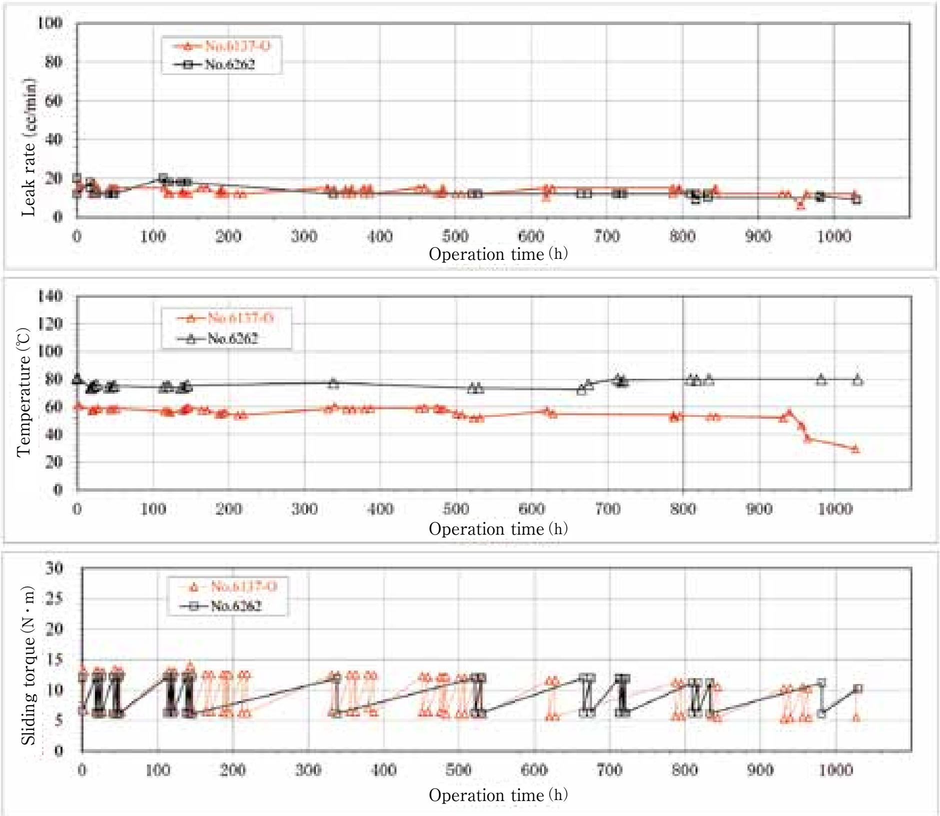

Figure14 Results of inverter tests

8. Conclusion

With the products described here, different types of products do not need to be selected depending on the application, thus improving the efficiency of the inventory management and reducing the risk associated with product mis-selection.

We will continue to develop new products to satisfy the varying needs of individual users.

Syuuzi Sugawa
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Masato Hamade
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Recent Technology News Back Issues

No.31 Summer 2016

[Customer Solutions Special]

Earth-friendly, Human-friendly Manufacturing

New Gaskets and Gasketing Technology

Recent environmental regulations have led to a major transformation in the different types of gaskets and their materials. Likewise, we are also seeing major changes in the design standards for bolted flange connections.
In response to this technical situation, JISB0116 "Glossary of Terms for Packings and Gaskets" was completely revised for the first time in 37 years.
The recently published "New Gaskets and Gasketing Technology" is the first handbook that both covers the technical background leading up to this JIS terminology standards revision and explains the technical basics of gaskets and bolted flange connections in an easy to understand manner. As such, we feel it will serve as a reference for many of those involved in gaskets.

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