Valqua Technology News

Winter 2019

No.36

VALQUA, LTD. HARD&SERVICE COMPANY H&S

http://www.valqua.co.jp

Greetings

Toshikazu Takisawa

Representative Director,
President & CEO

VALQUA, LTD.

I wish you a year filled with peace and happiness in the beginning of 2019.
Thank you for regularly reading the Valqua Technology News.

Looking back on last year, reflecting the depreciation of the yen, increased corporate profits, and the recovery of personal consumption, etc., Japan's economy steadily grew in the first half, but in the second half, with the effect of economic friction between the USA and China and the employment environment where there is a lack of workforce, the company outlook was not always positive. In such business environment, private companies strongly need to break out of the fixed mold that has continued from the past and create new innovation to provide added-value to their customers while being fully compliant and continuously striving towards improvement of quality.

As we have already announced through various media, our company's name has changed to VALQUA,LTD from October 1 of last year. Our company group has continued to work towards "Value" and "Quality" for over 90 years starting from the establishment until now, and supported the industrial foundations throughout the world as a pioneer of sealing engineering. We would like our readers to reconfirm that our new company name reflects our commitment to push towads developing our business globally with this "Sealing Engineering" as its main axis.
Our company group defines this name change as a chance for having a second chance for establishment and is highly committed to be reborn as a H&S company, develop total solutions consisting of products and services that consider the customer's viewpoint, and deliver these to our customers.

The "New Valqua Stage Eight (NV・S8)" management plan that started from last year is as already described in the previous paragraph, and it positions the "Sealing Engineering Service" solutions that were developed from our history in creative technology as its main axis and H&S activities aiming to provide new value for customers is positioned as the core for our group business's growth. To achieve this, we will try to avoid traditional ways of considering things, and try not to be trapped into abstract and uniform ways of thinking. We will understand the true needs of our customers by going back to the basics and conducting analysis and discussions regarding the challenges that surround our customers. We have a strong commitment to achieve healthy and continuous growth together with you by conducting technological development that creates "Creative Destruction".

We look forward to your continued support this year and wish all our readers the best in the coming year.

Greeting upon the Publication of 2019 Winter Issue

We wish you a Happy New Year 2019.
I would like to express my sincere gratitude to all of the readers of VALQUA Technology News.

We have entered the final year of the Heisei era and as we reflect back on the technological environment and trends of the past few years, the rapid changes and progress in information technology including IoT and AI has drastically changed the core value of the IT industry. For such technological innovation that brings impactful changes to the market, the keyword of "Connectivity" comes into play in innovative technology. Collaboration among companies from various fields and technologies is now achieved in the digital space using IT technologies along with the concept of open innovation.
In a world where new waves of technological innovation are surging forward, and as this year marks the 92th anniversary since the company's founding, our Group will further promote globalization and open innovation in technological development activities. We aim to combine our accumulated technological know-how with leading-edge technologies to create authentic customer solutions from the customer's perspective and to deliver them with speed. Throughout these activities, we would also like to value the "Connectivity" with our Group's customers and partnerships as well as our views for the environmental and economic sustainability when delivering products and technological solutions to customers as a result of our activities as "H&S Company".

This issue of Technology News consists of 3 parts which continues on from the previous issue: the real-life examples from "Customer Solution" which is provided by our Group, the articles that introduce our Group's technologies, and the introduction of new products. In the real-life examples of "Customer Solution," we introduce our predictive maintenance technology which detects abnormalities in marine equipment and delivers "safety and security" with a system that combines our proprietary sensing technology and material technology. This section also lists the contributions from customers who have experienced our Group's on-the-job training equipment and learning program on flange tightening. As for technical articles, we have picked up themes related to the characterization of large diameter flange tightening, processing technology and an evaluation method of lining tanks, and published them to provide readers with technical reviews for reference.
In addition, we provide information on new products—for example, new materials that show excellent characteristics even in severe environments such as high temperature steam environment—which will be useful for you to select products in the future.

We hope you will continue to enjoy the VALQUA Technology News this year as the new era begins.

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

Introduction of a System for Detecting Abnormal Vibration in Shipboard Equipment

~The Potential of Abnormal Vibration Detection Systems for Preventive Maintenance~

1. Introduction

The Japanese economy is supported by import/export trade and international sea transport accounts for over 90% of total import/export cargo. Transport by shipping is an extremely important method for conducting international trade.

With the expanding global economy and borderlessness, it is becoming apparent that global risk is intricately interconnected. Sea transport businesses are always at the brink of danger and they aim to prevent serious accidents. To conduct safe transport while maintaining a transport schedule, not only maintenance management to safely operate vessels, but also various efforts towards safe operation of the vessel and marine environment maintenance are being taken.

The important basics for maintaining safe operation of vessels are appropriate monitoring by the navigation officers and selection of an optimal route taking weather and sea conditions into consideration. Important equipment for operation such as the main engine that propels the vessel, power generator and auxiliary engines such as various pumps, fans and motors are located in the engine room, which is monitored by the engineer who also manages preventive maintenance.

To prevent serious damages beforehand, the operational state of the various engines and equipment in the engine room are patrolled and inspected daily to discover any abnormalities, and early actions such as overhaul inspections are extremely important.

In previous times, only the bare minimum of monitoring devices for equipment installed on vessels were available and during the patrol to inspect the engine room, the five human senses were mainly relied upon to find problems.

Recently, with the improvement in technology for temperature, pressure and vibration sensors, systems that automatically monitor various inspection items and issue warning on abnormalities are installed, but the actual situation is that not all the small behavioral changes and abnormal vibrations of onboard equipment could be automatically monitored sufficiently.

In this report, we would like to introduce a portable system which detects abnormal vibrations that was developed together by MOL Techno-Trade, Ltd. and Valqua as a collaboration.

2. Efforts toward preventive maintenance of equipment

2-1)Monitoring of status of onboard equipment

The operational status such as the temperature, pressure, rotation rate, etc., of each part of major equipment onboard, such as the main engine, power generator, boiler, etc., are automatically monitored at all times. This is periodically recorded in the data logger installed in the engine control room, and when an abnormality is detected, a warning is issued regardless of the time, which automatically slows down or initiates an emergency shut-down, and for equipment with a back-up function, the substitute equipment will start automatically to avoid any operational disruptions or major equipment damage.

However, small rotating equipment and motors that run fans and pumps are not equipped with sensors to monitor their operational status. Overheating, abnormal sounds and vibrations due to wearing out of motor

bearings are inspected by relying upon the five senses of the engineers during periodic patrols using touch and listening rods. If the discovery of abnormalities is delayed, this may lead to the burning of the motor due to damage to the bearing. The current situation is that preventive maintenance such as periodic opening maintenance based on operational time is conducted for main equipment onboard.

2-2) Use of big data onboard

Recently, the voluminous data obtained from status monitoring can be monitored around-the-clock on land by using a satellite link. Efforts towards improving safe operation are being conducted by combining this with weather and sea condition data, selection of an optimal route to decrease the burden on the vessel and propulsion engine, and utilization of optimal automatic navigation, etc.

Technical development on automatic operation of vehicles are being vigorously pursued by automobile manufacturers, and technical development of an autonomous navigation vessel (automated ship) has also started for ships. In the beginning of 2020, a test voyage to conduct actual validation is scheduled, so in addition to weather and sea condition information, various big data such as information on navigational meters (radar, collision prevention device, electronic marine maps) and status monitoring information within the engine room, etc. are becoming even more important elements to promote autonomous navigation. However, currently, not all onboard equipment is automatically monitored and a tool that can measure the status of equipment, confirm the presence/absence of abnormalities, and make decisions is anticipated. In particular, for onboard equipment, different from equipment installed on ground, the location itself where the equipment is installed may rock or be affected by vibrations from other installed equipment and in this environment, it is very difficult to measure and monitor abnormal vibrations of the equipment itself. The newly developed "System to detect abnormal vibrations in marine equipment" considered such environment which such equipment is placed in, and does not require any conversion to be used for all onboard equipment. It is an easy-to-use monitoring tool that can conduct wireless distance vibration measurements of equipment installed in places that are dangerous or in high places where access is restricted, and it has noise-cancelling features that enables it to eliminate disturbance vibrations that are generated from equipment other than the measurement target and has an addition of a wireless detection feature. The system composition is anticipated to be used not only for onboard equipment in vessels, but also widely used for preventive maintenance of equipment used in the track & field industry and industrial plant related equipment.

3. Summary of vibration detection maintenance system

3-1) Functions and characteristics of the vibration detection maintenance system

This system is currently undergoing validation on an actual vessel. As described above, it does not require conversion to monitor equipment status and it is currently undergoing validation as a system that can measure and monitor equipment vibration without being affected by vibrations due to rocking.

Figures1 and 2 show the external appearance of the vibration detection maintenance system and Table1 shows the major specifications of the main section of the system.

The sensor part for detecting vibration utilizes a fluorine resin and is intended to be used for locations with high temperatures such as pumps and has heat resistance in 100℃ environments. To enable easy installment regardless of the shape of equipment, it can be attached by tape and magnets.

The signal from the sensor is transmitted through the wireless dock and received by a tablet terminal located away from the equipment and whether there are abnormalities can be confirmed as chronological changes. It is also possible to directly connect the sensor and tablet with a cable for measurements.

On the functional side, it has a function that analyzes

the pattern of rocking of the vessel and equipment and the amplitude as vibration frequency. It reduces the vibration effect (disturbance vibrations) by rocking of the vessel, and by distinguishing it from vibrations of the equipment itself, it conducts continuous vibration monitoring of the equipment.

Figure1 External appearance of the vibration detection maintenance system
Left : Tablet
Upper right : Sensor (Approximately 2cm square)
Bottom right : Wireless dock (amplifier)

Figure2 Thin film fluorine resin organic piezoelectric element

Table1 Major specifications of the main section of the system

Display section	10-inch tablet (touch panel)
Ch No.	4ch or 2ch / amplifier Max. 12ch (wireless connection with 4 amplifiers)
Output	SD card slot (SDHC compatible, Max. 32GB)
Water resistant	IP54 waterproof equivalent
Use range	−10℃ to 50℃ , under 90% RH (with no condensation)
Size and weight	40 (H) x275 (W) x188 (D) mm 1200g (includes Li-ion battery, 280g)
[Scheduled]	Radio Law approved (Europe, US, China, Japan) CE marking, WEEE directive Chinese version of RoHS

3-2) Examples of validation experiments on reduction of disturbance vibrations

A validation using experimental methods was tried regarding the effects (disturbance vibrations) due to the navigational environment of onboard measurements, such as the wind and waves at the time of operation.

A vibrator device was used as the source for disturbance vibrations, and the motor was setup on a vibrating platform to confirm whether it would be possible to distinguish between disturbance vibrations and motor vibrations. The vibrator device was i240SA3M (manufactured by IMV) using 5Hz, 5mmp-p conditions to vibrate in the z-axis direction (up and down vibrations). The motor was a Superline single-phase motor (SC-KR-100W-4P-100V) under the condition of 1720 rpm (28.7 Hz) and was installed and fixed so the motor rotational axis was perpendicular to the vibration direction. Measurement results are shown in Figures3 and 4.

According to Figure3, motor vibrations are affected by disturbance vibrations and compared to when the vibrator is turned off, the signal intensity at 5 Hz, which is the additional vibration conditions, increases and significantly changes (approximately 50 dB) in vibration level. On the other hand, if disturbance vibrations are reduced, the increase in vibration

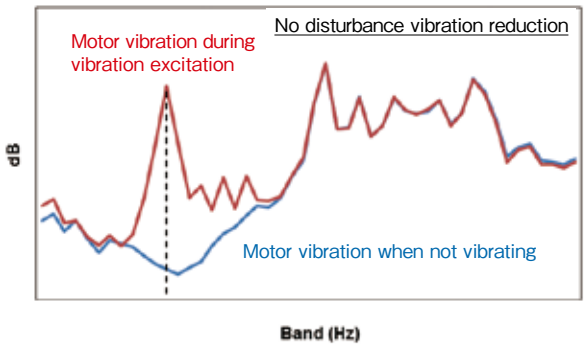


Figure3　Motor vibration band affected by vibrator vibrations

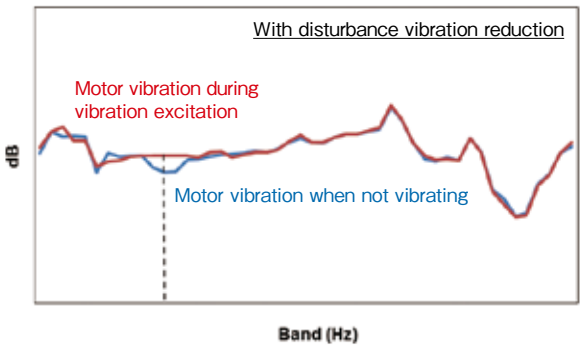


Figure4　Motor vibration band when effect of vibrator vibrations is reduced

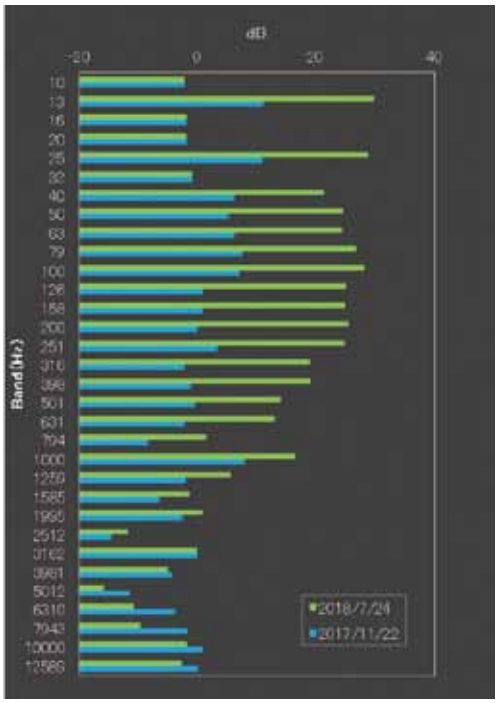


Figure5　An example of vibration measurement results on an actual vessel（seawater cooling pump）

intensity at 5 Hz was confirmed to be within 5 dB (Figure4). Similarly, the results of the effect of disturbance vibrations were under 5 dB even if measurements were under the conditions such as when the additional vibration amplitude was changed (5 Hz: 5,7, 10mmp-p) or the additional vibration frequency was changed (75 Hz: 0.03, 0.05mmp-p, 200 Hz: 0.005, 0.007 mmp-p). This suggests the possibility of reducing the effect of waves during navigation.

3-3)Measurement example on an actual vessel

Figure5 shows an example of measurement results of a seawater cooling pump on a coastal tanker (Technostar) owned by MOL Techno-Trade, Ltd. Temporal changes in the signal intensity can be seen. Measurements are to be continued while considering the effect of disturbance vibrations in preparation for the main validation study.

4. Summary

With the developed system, it was possible to confirm reduction of disturbance vibrations in the validation study at the laboratory level. In addition, a difference in temporal signal intensity was confirmed by measurement on an actual vessel.

However, in actual navigation, it will be necessary to measure the vibration status with everchanging surroundings and environment, such as main power output, loading conditions that differ between outbound and inbound trips, operational status of auxiliary equipment, etc.

Aiming for the main validation study, while confirming and considering the effect of a wide variety of disturbance vibrations, detecting the status changes in equipment vibration and setting the appropriate cut-off value are our future challenges.

5. Conclusions

It is considered effective for vessels operating on sea away from land to conduct appropriate maintenance management that includes keeping track of defects and breakdown trends of individual equipment and stocking maintenance parts. By continuing our validation study, we would like to produce a system that visualizes the states that differ from the normal state and deliver a predictive maintenance effect that would contribute to safety and security throughout the whole industrial field regardless of land or sea.

Makoto Haneda
Managing Director
MOL Techno-Trade, Ltd.

Hisataka Sato
Corporate Research and Development Group
Product Development Division I

Tetsuya Komeda
Corporate Research and Development Group
Product Development Division I

Yasushi Aburatani
Corporate Research and Development Group
Advanced Technology Reseach Division

Practical training Equipment for Flange Tightening Force Fluctuation due to Temperature Difference

1. Introduction

A countless number of flanges are used in petroleum refineries to connect pipes. Because there is little leakage of internal fluid from these flange connection parts, the plants are operated with little awareness of leakage of internal fluid from the flange. In addition, although we know as general knowledge that metal materials expand and contract due to temperature changes, it seems that knowledge and experience largely determine whether or not the operation is performed in relation to the flange tightening force.

Although veteran employees recognize that flanges leak from past failure experiences, young employees with little experience cannot imagine that leaks will occur from the flange connecting parts.

It is essential a the safe operation of the plant to learn that when a piping changes in temperature, the flange tightening force is affected, and in some cases, the internal fluid leaks from the decrease in the surface pressure, and this knowledge must be learnt by the personnel involved in the operation of a plant.

At this refinery, there have been past cases where flushing oil (light oil) leaked from the flange fastening part during the start-up operation. Leakage occurs when flushing oil (about 25 ℃) is introduced, a sudden temperature drop occurs at the connected hot pipe flange connection (about 200 ℃) , the surface pressure at the pipe flange connection decreases due to the change in the pipe's thermal strain.

From the above discussion, it is indispensable for safe operation of the plant to learn the decrease in surface pressure of the flange connecting part due to temperature change and the subsequent leakage of internal fluid through practical training and to know the mechanism. We asked Valqua Co., Ltd. to manufacture practical training equipment and develop a training program using that equipment.

In this paper, we are going to report the summary of the practical training program by using this equipment.

2. Overview of practical training equipment

2-1) Design specification

In examining the specifications of the practical training equipment, we adopted a fluid temperature (high temperature, low temperature) close to our case, and considered safety for use as training. The equipment was designed based on the training program, and both companies discussed the design proposal, and the equipment which reflected the result of the consultation was produced.

2-2) Outline of equipmentt

Outline of the completed equipment is shown in Figure1. The central part is a flange for monitoring the flange tightening force, and the tightening force of

Figure1 Educational hands-on training equipment
(The left side is the high temperature part, the right side is the low temperature part)

each bolt is displayed on the monitor on the left hand desk.

2-3) Training procedures (see Figure2)

① Set the fluid temperature on the high temperature side to about 200 ℃, monitor the flange tightening force online without the fluid on the low temperature side (about 20 ℃), and check the tightening status (balance) on the monitor.

②Introduce the low-temperature side fluid gradually, and visually check the level inside the pipe from the peephole (right flange in Figure1).

③Check how the flange tightening force (balance) changes by adding low-temperature fluid.

④Through this experience, each person will experience a decrease in flange tightening force that leads to leakage of internal fluid, and each person should be careful when operating the plant equipment in charge.

Figure2 Demonstration of practical training program by using new equipment
(Trainee in the front and lecturer in the back)

3. Training program

We asked STC Nara to install this practical training equipment and consider a training program that combines this training with the existing equipment and training program related to flange tightening. The training program is different for the manufacturing department and the construction department. (The manufacturing department allocates about one hour more for tightening flanges than the construction department because the gasket replacement and tightening of small-diameter pipes are carried out by the trainees themselves.)

3-1) Manufacturing Department

Lecture program 1.5 hours (see Figure 3)

- What is a gasket?
  (What is a seal/allowable leakage/ required characteristics, etc.)
- Type of gasket and Tightening
  (Tightening method/retightening, etc.)
- Failure cases
  (Poor tightening, selection mistakes, etc.)

Figure3 Trainees attending a lecture program

Practical training program 4.5 hours (see Figures4, 5 and 6)

- Flange tightening methods for gaskets
  (Compare the tightening force actually tightened by each trainee against the target tightening force, and determine their own skill.)
- Gasket creep relaxation, sealing performance, compression failure
  (Experience of defects due to creep phenomenon, which are the thermal characteristic of gaskets, excessive or insufficient tightening force.)
- Influence of bolt management
- Practical training using new equipment
  (mentioned above)

Figure4　Demonstration of practical training program by using existing equipment (Torque checker)

Figure5　Demonstration of practical training program by using existing equipment (Flange tightening equipment)

Figure6　Demonstration of practical training program by using existing equipment (Seal performance equipment)

3-2) Construction Department

Lecture program 2.5 hours

・What is a gasket?

・Gasket types, selection, and tightening

Practical training program 3.5 hours

・Fange tightening methods for gaskets

・Gasket creep relaxation, sealing performance

・Influence of bolt management

・Practical training using new equipment (mentioned above)

The training is conducted in small groups of four in order to reinforce the lecture program with the practical training program, and to enable each participant to think about and experience the purpose of practical training, and to fully understand the results. The participants are engaged in practical training with a sense of tension. In addition, although safety measures have been taken into consideration in advance, it is also intended that a small number of people will maintain a sense of tension and prevent accidental injuries.

The standard training hours are from 9:00 to 17：00, and it takes about 2 hours one way from our company in Yokkaichi to Nara Pref. (Valqua), and the work load for shift workers is particularly heavy. For this reason, lecture programs are held multiple time at Yokkaichi City (our company), and practical training programs are performed at Nara STC (Valqua).

4. Results of training

At the end of the training, VALQUA, Ltd. conducts a survey and the feedback from the participants is used in subsequent courses.

To summarize the results of our 12 participants' so far

①Overall satisfaction：Average 4.7
(5 levels of satisfaction　high 5 ⇔ low 1)

②Difference between initial expectation and actual content：Average 4.8
(5 levels of expectation as expected 5 ⇔ disappointing 1)

③Understanding of lecture program：Average 4.3
(5 levels of understanding well understood 5 ⇔ not understood 1)

④Understanding of practical training program：Average 4.7
(5 levels of understanding well understood 5 ⇔ not understood 1)

The average understanding level of the practical training program is 4.7, which is a high level of understanding.

Comments from the participants

"I was surprised at the faster change in tightening force due to flange quenching than expected."

"It was easy to understand because we were able to confirm the decrease in tightening force due to cooling in real time."

"By experiencing equipment that simulated an actual case it reinforced the dangers in me for the next 10, 20 years or more."

It seems that they had a favorable impression of the practical training equipment.

Most participants have the impression that they would like to introduce this training to their colleagues (especially junior colleagues) in the workplace. Because of the high level of satisfaction and understanding mentioned above, it is considered effective in strengthening management of flange tightening force by participating in this training, and the participation of those who have not yet participated in this training is planned as part of our educational program in the future.

5. Conclusion

We have installed piping and valve facilities on our premises, and as part of our training for new employees, we have taught them about the importance of gasket replacement and flange tightening by basic operations training such as flange tightening as voluntary maintenance activities. A decrease in surface pressure at the pipe flange connection may cause a leakage of the internal fluid which may lead to a major accident. On the other hand, even if you are in charge of the operation and maintenance of a refinery, you rarely have the opportunity to actually experience the mechanism of surface pressure reduction, and in many cases when trouble occurs you are reminded of its importance.

In this study, VALQUA, Ltd. developed practical training equipment and by developing a practical training program with the equipment it teaches the mechanism of reduction of surface pressure at the pipe flange connection part due to temperature-change which causes leakage of internal fluid and this is essential to the safe operation of the plant.

As a result of conducting employee education using the practical training equipment, its effectiveness could be verified, so we will continue to educate employees on the importance of managing flange tightening force utilising this equipment and the practical training program. In addition, we hope that many other companies will take this program to prevent similar trouble at their factories.

Finally, we would like to thank Valqua, Ltd. and Toyo Sangyo Co., Ltd., for manufacturing this equipment and for giving us the opportunity to publish our findings and experience.

6. Reference

1) Akira Muramatsu：Valqua Technology News No. 33, 15-18 (2017)

Kenichi Takamura
Engineering Department
SHOWA YOKKAICHI
SEKIYU CO.,LTD

Evaluation of Mechanical Properties and Sealing Performance of 24" Pipe Flange Connections with No.GF300 Gasket

1. Introduction

Gasketed pipe flange connections are used in many petrochemical plants, power, steel plants, etc. Asbestos gaskets are widely used because of their high heat resistance, sealing properties, high strength, easy handling properties, and economical with numerous studies having been conducted[1)-3)]. There have been numerous reports of human health hazards with asbestos gaskets published and regulations have been established in Japan since around the year 2000. However, this trend has been advancing in Europe and the United States for some time. Since 2008, asbestos gaskets cannot be used in Japan[4)].

There are two types of asbestos gaskets which are asbestos filled spiral wound gaskets and asbestos joint sheet gaskets. There were no major problems in replacing asbestos filler with expanded graphite filler of spiral wound gaskets. On the other hand, as alternatives for asbestos joint sheet gaskets, a non-asbestos joint sheet gasket containing aramid fibers, an expanded graphite sheet gaskets, and a PTFE compound sheet gaskets were developed and evaluated[5)]. Since the aramid joint sheet gasket contains a large amount of rubber, it hardens and cracks in a high temperature environment, and the bolts cannot be tightened. The expanded graphite sheet gasket is easily damaged and has poor handling properties. From this background, PTFE compound gaskets have become widely used in Japan. PTFE is excellent in heat resistance, chemical resistance, and sealing properties, and the problem of large creep has been greatly improved by improving the compounding formulation and manufacturing method. However, the PTFE compound gasket do not have a track record as asbestos gaskets do until now, and for this theoretical property study or research is required. We have been investigating the mechanical behavior of connection flange joints incorporating our PTFE compound gasket No. GF300 under normal and high temperature environments and under pipe bending[6)-8)].

It is known that gasketed connection flange connections have various nominal dimensions, and their characteristics change when the nominal diameters are different. In particular, it is said that the sealing property of the connections deteriorate as the nominal diameter increases. However, due to cost and time issues, most of the research on connection flange connections with gaskets has targeted relatively small diameter dimensions of 2 to 6 inches, and the characteristics of large diameter flange connections are yet to be clarified. Sawa et al. used a 20 inch sized pipe flange connection to characterize a spiral wound gasket connection, demonstrating that it differs from the characteristics of a small diameter pipe flange connection and that it is less sealable[9)-13)]. However, the ASME standard stipulates a 24 inch flange size with a larger nominal diameter, in addition, the mechanical properties and sealing properties of a large-diameter connection flange fastening body incorporating a widely used PTFE compounded gasket hanve not yet been investigated. Therefore, study of a pipe flange connection using such a gasket is necessary.

The purpose of this study is to evaluate the mechanical properties of the 24 inch tube flange fastener with No.GF300 by FEM analysis and experimentally. First, the basic characteristics of No.GF300 gasket are investigated in accordance with JIS B 2490[14)]. These basic data are to be used in the FEM-analysis to

calculate the axial bolt force variations and gasket contact-stress distributions. In addition, the amount of leakage from the pipe flange connection is estimated using the gasket contact stress distribution calculated from the FEM analysis and the leakage gasket stress relationship obtained from the experiment. Experiments will be conducted to show the validity of the FEM analysis, and the experimental results and the FEM analysis results will be compared and examined.

In the experiment, the amount of leakage from the pipe flange connection and the fluctuation of the axial bolt force are measured. The pipe flange connections used in this study were ASME class 300 24 inch-sized connections.

Our high-performance sheet gaskets containing PTFE, such as No.GF300 used in this research, are widely used because of their excellent heat resistance, chemical resistance, sealing properties, and handling property. In addition, since it does not contain any rubber, material deterioration does not occur at temperatures below 300℃ or over time and it is considered that mechanical properties can be evaluated with high accuracy in this study.

2. Experimental method

Figure1 shows the No.GF300 gasketed pipe flange connection equipment for measuring axial bolt force fluctuations and leaks. The pipe flange connection size is ASME class 300 24 inches, and the material is SUS304[15]. It is known that the characteristics of the pipe connector change greatly depending on the presence or absence of a pipe, and this device has a long pipe like the actual pipe connection. The size of the gasket is ASME class 300 24 inches, the thickness is 3.0 mm, and the bolt nominal diameter is M39.

Strain gauges are attached to the longitudinal axis of all 24 bolts, and the axial bolt force can be measured and recorded by connecting to a strain gauge. All strain gauges are pre-calibrated. The amount of leakage from the pipe flange connection is measured by the following equation (1) using the pressure drop method.

Figure1 Experimental equipment of 24-inch pipe flange connection

$$L = \frac{MV}{tRT_1}\left(P_1 - \frac{T_2}{T_1}P_2\right) \qquad (1)$$

Here, L : leakage amount, M : molar mass, V : internal volume of the apparatus, t : measurement time, R : gas constant, T_1 : temperature at the start of measurement, T_2 : temperature at the end of measurement, P_1 : internal pressure at the start of measurement, and P_2 : internal pressure at the end of measurement.

The initial internal pressure P_1 is set to 2 MPa, and the experiment is performed in ambient temperature environment. Tightening applies as initial axial bolt forces of 34.2kN, 68.5kN, 102.7kN and 136.9kN corresponding to mean gasket stresses of 10, 20, 30, and 40MPa. After tightening, helium is introduced, and the leakage is measured.

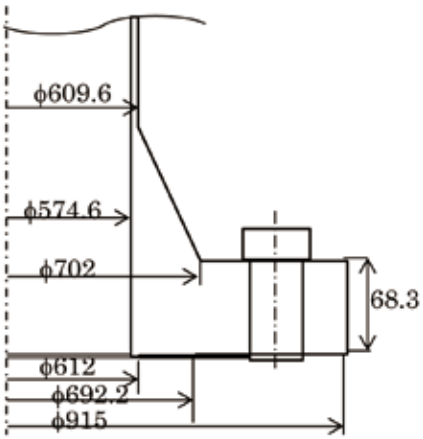


Figure2　Dimensions of 24-inch pipe flange connection

3. Gasket characteristics

The compression characteristics and leakage gasket stress relationship of No.GF300 gasket are measured in advance by experiments, and the measured values are used for FEM analysis.

3-1) Compression characteristics

First, the compression characteristics of the No.GF300 gasket at room temperature are measured using the experimental equipment shown in Figure 3. The size of the platen for compression test is JIS 10K 50A with raised face. A gasket is inserted between a pair of platens and compressed by a material-testing machine, and the amount of compression at that time is measured. Figure4 shows the stress-compression amount relationship (compression characteristics) obtained by the material test. Non-linearity and hysteresis are seen in the compression and decompression curves. These behaviors are also taken into consideration in the FEM analysis for calculation.

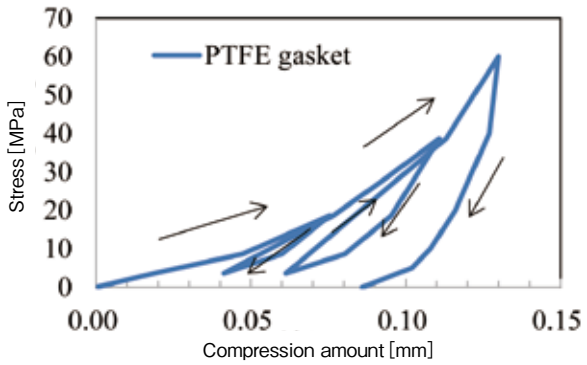


Figure4　Gasket compression characteristics

3-2) Sealing property

In the same manner as the compressive characteristics, a platen device shown in Figure 3 is used to measure the relation between gasket leakage and gasket stresses in accordance with JIS B 2490. The gasket is compressed in stages by a material-testing machine and the leak rate is measured when the material is loaded with helium at 2 MPa. The gas leaked from the gasket is collected by the rubber O-ring and sleeve, and measured using a soap membrane flow meter. Figure5 shows the measured leakage-gasket stress relationship. The vertical axis shows the logarithmic display of the amount of leakage, and the horizontal axis shows the gasket stress. It can be seen that the greater the gasket stress, the smaller the leakage. When the gasket stress was 30 MPa or more, the leakage was very small and could not be measured, so the data are not shown.

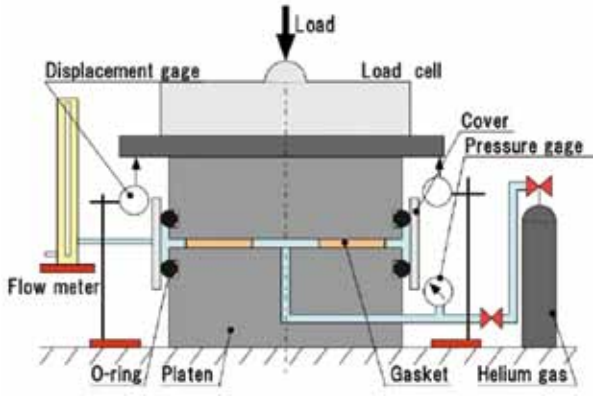


Figure3　Gasket characteristic measuring equipment

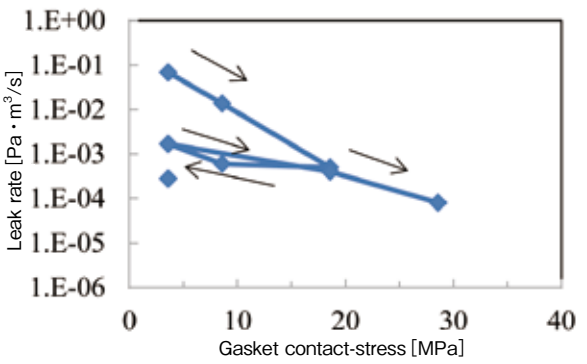


Figure5　Gasket leakage-stress relationship

4. FEM analysis

Figure6 is an FEM analysis model of a 24 inch sized gasketed pipe flange connection. A general-purpose code ABAQUS is used for the analysis and the number of elements is 2695 and the number of nodes is 4408. Considering the symmetry of the pipe flange connection, the 1/96 model (1/48 in the circumferential direction and 1/2 in the axial direction) is used. In this model, for simplification, the hexagonal nut has a circular shape with an equivalent cross-sectional area, and the screws are omitted. Figure7 shows the boundary conditions in the FEM analysis. All elements are constrained in each direction at the symmetric interface. An initial tightening force is applied to the bolt model by applying an axial load, and it is restrained when an internal pressure load is applied. The internal pressure exerts pressure on the flange and the inner surface of the pipe.

Elastic elements are used for flange and bolt models, and ABAQUS gasket elements are used for gaskets. This ABAQUS gasket element can take into account non-linearity and hysteresis characteristics. In FEM analyses, fluctuations in axial bolt force and gasket contact stress distribution are calculated.

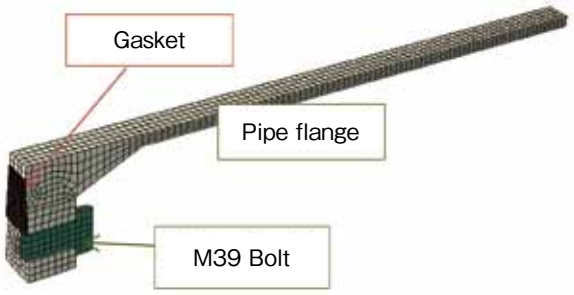


Figure6 FEM analysis model of pipe flange connection

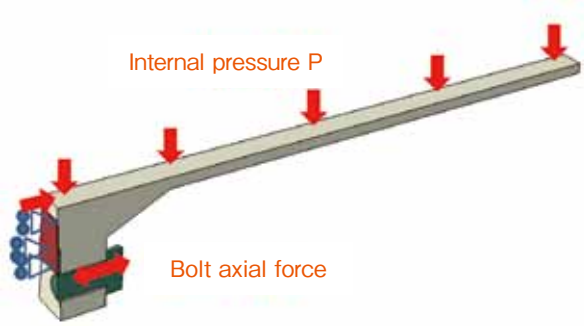


Figure7 Boundary conditions for FEM analysis

5. Experimental and FEM Analysis results

5-1) Axial bolt force

Figure8 shows the results of axial bolt force fluctuations reacting to internal pressure from experiments and FEM analysis. The horizontal axis is the internal pressure, the vertical axis is the axial bolt force, the solid line is the experimental result, and the broken line is the FEM result. The axial bolt force of the experimental results is the average value of 24 bolts. Initial tightening is applied as axial bolt forces 34.2kN, 68.5kN, 102.7kN, and 136.9 kN, which correspond to gasket contact-stresses of 10 MPa, 20 MPa, 30 MPa, and 40 MPa, respectively. Under all conditions, the axial bolt force decreased as the internal pressure increased. It is considered that this is because the flange rotation increases due to the internal pressure and the bolt axis contracts. Experimental results and FEM analysis are in fairly good agreement, indicating the validity of the FEM analysis.

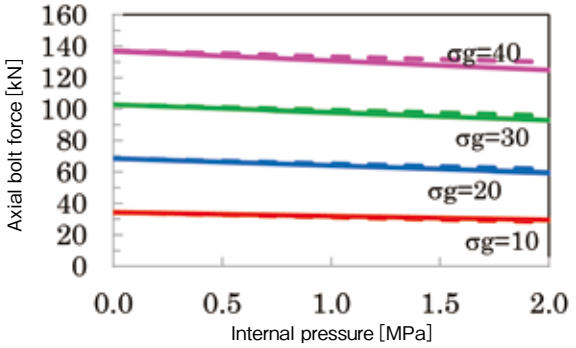


Figure8 Bolt axial force fluctuation during application of internal pressure

5-2) Gasket contact-stresses and leakage

Figure9 shows the gasket contact stress distribution at the time of tightening and at the time of applying 2 MPa internal pressure obtained from FEM analysis. The average gasket contact-stress at initial tightening is 10 MPa, 20 MPa, 30 MPa and 40 MPa. In all the contour diagrams obtained, it can be seen that the gasket outer

diameter is disengaged from the flange flat seat and is not in contact with the flange and that the contact stresses are zero. Looking at the data at the time of initial tightening, the contact stress becomes larger toward the outer diameter side due to the flange rotation. It can also be seen that the gasket contact-stress on the inner diameter is zero even when the mean gasket contact-stress is large. This is because the inner diameter of the gasket is separated from the flange by the flange rotation and is not in contact with the flange In addition, it was found that the change in the circumferential distribution of gasket contact stress was very small. When internal pressure applied, the sum of the gasket contact stresses decreases due to the thrust force in the axial direction.

Here, the leakage from the flange connections is estimated from the gasket contact-stress distribution obtained from the FEM analysis and the leakage gasket stress relationship also shown in Figure4 obtained by experiment[11), 12)]. Figure10 shows a comparison of the leak measured experimentally and the estimated leak. The vertical axis is the leakage per unit length by dividing the total leakage by the contact of the gasket at the outer circumference. It can be seen that the larger the gasket contact-stress, the smaller the leakage. In addition, the estimated leakage and the experimental results are in good agreement, demonstrating the validity of the leakage estimation method and FEM analysis.

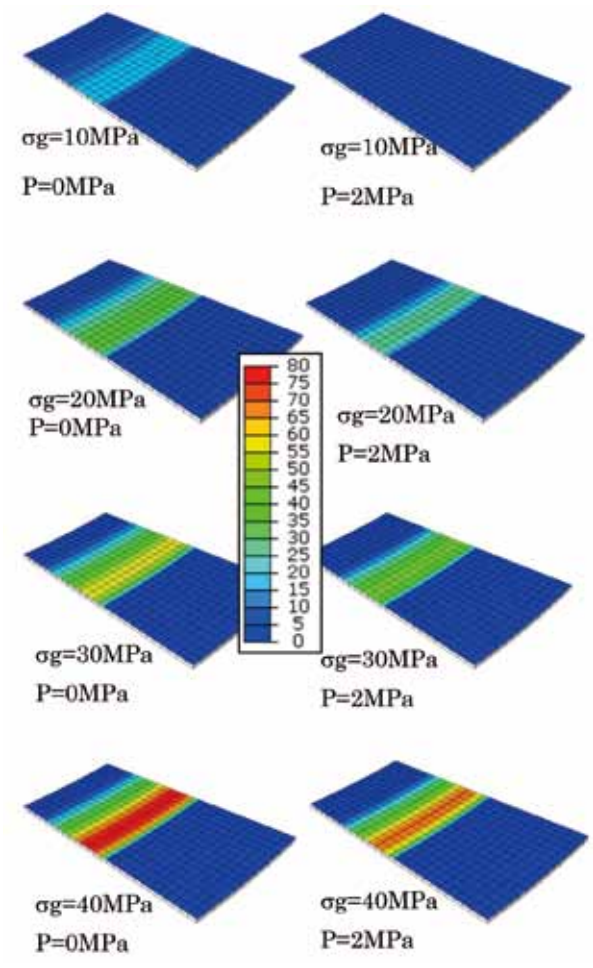


Figure9 Gasket contact-stress distribution obtained from FEM analysis

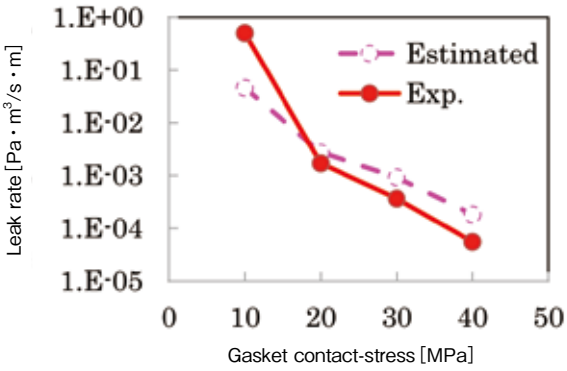


Figure10 Comparison of measured and estimated leaks from gaskets

6. Discussion

6-1) Effect of nominal diameter of pipe flange connection on axial bolt force fluctuation

Figure11 shows the values of the load factor when internal pressure is applied to the 2 inch, 4 inch, 8 inch, 12 inch, 16 inch, 20 inch, and 24 inch pipe flange connections incorporating the No.GF300 gasket calculated from FEM analysis. The average target gasket contact-stress is 20 MPa, and the internal pressure is set to 2 MPa. The load factor shown on the vertical axis is the increment rate of the axial bolt force when an external force (in this case, internal pressure) is applied. A positive value means that the axial bolt force increases, and a negative value indicates that the axial force decreases. It was found that the load factor tends to decrease as the nominal diameter of the pipe flange increases. This is because the larger the nominal diameter of the pipe flange, the smaller the bending rigidity of the flange ring, and

flange rotation is likely to be promoted when internal pressure is applied, and as a result, the bolt is easily contracted. Figure12 shows the gasket contact stress distribution for each nominal diameter pipe flange. The horizontal axis is the ratio of the gasket width and is dimensionless. Under all dimensional conditions, the gasket contact-stress decreased when internal pressure was applied, but this became more apparent as the nominal diameter increased. It is considered that the larger the nominal diameter, the larger the area for receiving the internal pressure, the larger the thrust force, and the larger the value of the load factor, so that the ratio of the loss of gasket contact-stress increases.

Figure13 shows the leakage estimated by the same method as the result in Figure10 for a 2 inch to 24 inch pipe flange connections. The average value of the target gasket contact stress is 30 MPa, and the leakage is the leak per unit length obtained by dividing the total leak by the gasket outer contact

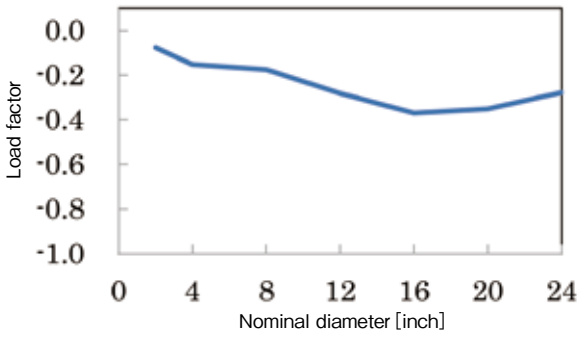


Figure11 Effects of nominal diameter on load factor in pipe flange connections

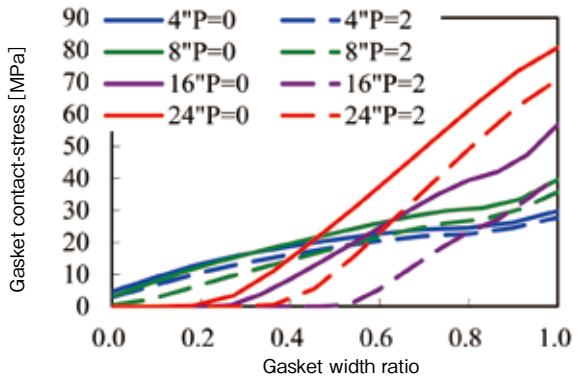


Figure12 Radial gasket contact stress distribution in the connection of each pipe flange nominal diameter

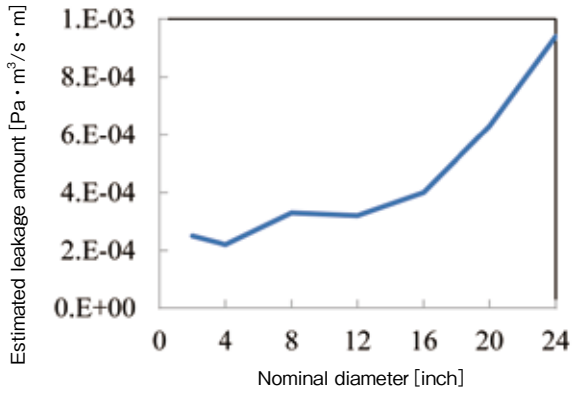


Figure13 Effect of pipe flange nominal diameter on leakage amount per unit length

circumference. As the nominal diameter of the pipe flange increases, the leakage per unit length increases, but the vertical axis is not a logarithmic scale but a linear scale, and the difference is not so large in reality.

6-2) Comparison of sealing properties of pipe-flange connections using No. GF300 and No. 6596V expanded graphite filled gasket

Figure14 shows the relationship between the leakage per unit length and the gasket contact-stress of the pipe flange connections using No. GF300 and No. 6596V expanded graphite filled gasket. As before, the pipe flange connection size is ASME class 300 24 inches and the internal pressure is 2 MPa. The validity of the FEM analysis method has been confirmed by comparing the FEM analysis and the experiment for the pipe flange fastener using No. 6596V. It was

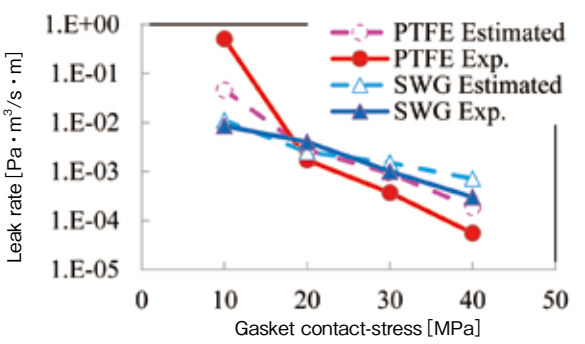


Figure14 Comparison of seal performance of each pipe flange connection using No. GF300 and No. 6596V

observed that when the gasket contact stress is smaller, the leakage rate is relatively large, but when the gasket contact stress is larger, the sealing property of the pipe flange connection using the No. GF300 is better than that of the pipe flange connection using the No. 6596V. The pipe flange connection using expanded graphite, which has the filler material of No. 6596V, exhibits good sealing performance even with relatively small stress. On the other hand, it is considered that the No. GF300 could not conform to the flange surface with a smaller stress, but was able to when the gasket contact-stress became larger, and exhibited a higher sealing property by compression of the material. From the strength calculations, some pipe flange connections are not applicable for spiral wound gaskets. However, it was found that in these locations, the sealing property of No.GF300 is same or better than that obtained from the spiral-wound gasket.

7. Conclusions

In this study, the mechanical properties of ASME class 3000 24 inch pipe flange connection with No. GF300 were investigated by experiment and FEM analysis, and the following conclusions were obtained.

(1) In accordance with JIS B 2490, the compression characteristics and leakage gasket contact-stress relationship of No. GF300 were measured.

(2) The leakage from the pipe flange connection was estimated from the above gasket characteristics and the gasket contact stress distribution results were obtained from the FEM analysis. In addition, both results were in good agreement with the experiment demonstrating the validity of the estimation method.

(3) Through FEM analysis and experiments, it was clarified that the axial bolt force decreases due to flange rotation when internal pressure is applied to the 24 inch pipe flange connection with No. GF300. It was also shown that the FEM analysis results are in good agreement with the experimental results.

(4) Using FEM analysis and basic gasket data, it was clarified that the larger the nominal diameter of the pipe flange, the smaller the load factor and the larger the leakage amount.

(5) It was clarified that No. GF300 exhibits higher sealing performance than a pipe flange connection using an expanded graphite filled spiral wound gasket when a recommended surface pressure of 35 MPa is applied. From the strength calculation, it was found that even in the pipe flange connection to which the spiral wound gasket cannot be applied, the sealing performance of GF300 is equal to or better than that when the spiral wound gasket is used.

8. References

1) T. TAKAKI, K. SATO, Y. YAMANAKA, T. FUKUOKA, "Effects of Flange Rotation on the Sealing Performance of Pipe Flange Connections", ASME PVP Vol.478, (2004) , pp.121-128.

2) T. SAWA, N. OGATA, T. NISHIDA, "Stress Analysis and Determination of Bolted Preload in Internal pressure", Transactions of the ASME, Journal of Pressure Vessel Technology, Vol.124, (2002) , pp.22-27.

3) T. KOBAYASHI, T. NISHIDA, Y. YAMANAKA, "Effect of Creep-Relaxation Characteristics of Gaskets on the Bolt Loads of Gasketed Joints", ASME PVP Vol.457, (2003) , pp.111-118.

4) Ministry of Health, Labour and Welfare, "Law for Partial Amendment of the Order for Enforcement of the Industrial Safety and Health Law", Cabinet Order No. 349 (2008) .

5) Nippon Valqua Industries, Ltd., GASKET, Catalogue No.YC08, (2016) .

6) K. SATO, A. MURAMATSU, T. KOBAYASHI, T.SAWA,"FEM Stress Analysis and Sealing Performance of Bolted Flanged Connections using PTFE Blended Gaskets under Internal Pressure", PVP 2015-45268, Proceeding of ASME PVP 2015 Conference, (2015).

7) K. SATO, T. SAWA, T. KOBAYASHI", FEM

STRESS ANALYSIS of Long-term Sealing Performance for Bolted Pipe Flange Connections with PTFE Blended Gaskets under Elevated Temperature" PVP2016-63372, Proceeding of ASME PVP 2016 Conference, (2016) .

8) K. SATO, T. SAWA, R. MORIMOTO, T. KOBAYASHI, "FEM Stress Analysis and Mechanical Characteristics of Bolted Pipe Flange Connections with PTFE Blended Gaskets Subjected to External Bending Moments and Internal Pressure", PVP2017-65332, Proceeding of ASME PVP 2017 Conference, (2017)

9) Y. TAKAGI, T. SAWA, H. TORII, Y. OMIYA, "Effects of Scatter in Bolt Preload on the Sealing Performance of Pipe Flange Connections Under Internal Pressure (Case Where the Nominal Diameter of Pipe Flange Connection is 20") ", PVP PVP2010- 25499, Proceeding of ASME PVP2010 Conference, (2010) .

10) Y. TAKAGI, T. SAWA, H. TORII, Y. OMIYA, "Effects of Scatter in Bolt Preload on the Sealing Performance of Pipe Flange Connections Under Internal Pressure (Case Where the Nominal Diameter of Pipe Flange Connection is 20") ", PVP2010-25499, Proceeding of ASME PVP2010 Conference, (2010) .

11) Y. OMIYA, T. SAWA, Y. TAKAGI", Stress Analysis and Design of Bolted Flange Connections under Internal Pressure", PVP2014-28606, Proceeding of ASME PVP 2014 Conference, (2014) .

12) Y. OMIYA, T. SAWA", Stress Analysis and Sealing Performance Evaluation of Bolted Pipe Flange Connections with Smaller and Larger Nominal Diameter under Repeated Temperature Changes", PVP2014-28730, Proceeding of ASME PVP 2014, Conference, (2014) .

13) A. MURAMATSU, K. SATO, M. U. KHAN, T.SAWA,"FEM Stress Analysis and the Sealing Performance evaluation of Bolted Pipe Flange Connections with Large Nominal Diameter Subjected to Internal Pressure", PVP2016-63407, Proceeding of ASME PVP 2016 Conference, (2016) .

14) Japanese Industrial Standards. JIS B 2490 "Test method for sealing behavior of gaskets for pipe flanges", (2008) .

15) ANSI/ASME B 16.5,"Pipe Flanges and Flanged Fittings", (1996) .

Kouji Satou
Corporate Research and Development Group
Product Development Division

Xing Zheng
China Research Institute
Seal Engineering Development Group

Toshiyuki Sawa
Hiroshima University,
Professor Emeritus

Lining Tank (Application)

1. Introduction

Following on from the previous article on "Lining Tank" (Basic version), this article will overview the "Application".

In the basic version, we have described the types and characteristics of fluoropolymers, the fluoropolymer sheet lining process, and the basic points to note in the design of fluoropolymer lining tanks, etc. This time, we will introduce the characteristics of our sheet lining process and the sheets for lining that we handle.

2. Characteristics of our lining processing method

This article describes the manufacturing process of our high-purity fluoropolymer lining tanks, characteristics of our processing technology.

2-1) Reformation and attachment of fluoropolymer lining sheet to the head part

Fluoropolymer lining tanks generally have a fluoropolymer sheet attached to the metal can of the outer shell. The sheets are rolled up and cut into strips for use. Strips of the sheet can be attached as is to the body part of the can, but the head part has a curved surface and it is difficult to attach strips of sheet, so the sheet is attached in several equal parts.

In our attachment method, the lining sheet of the head shape is heated and molded before use.

By processing the lining sheet for the head in advance, it is possible to:

- The combination of the vacuum attachment method described below and the reforming attachment of the sheet to the head reduces the amount of scraping to the sheet surface when attaching the sheet, and drastically reduces scratches on the surface and contamination of the sheet.
- The sheet before reformation is processed into a square, and there are few welding lines. This reduces the risk of problems such as broken welds.
- The reformation temperature is higher than the vulcanization temperature of the adhesive, so there is less residual stress in the sheet.

This reduces the risk of adhesive peeling problems.

The above three effects could be expected.

Figure1 Tanks made by other manufacturers

Figure2 Our liner

Figure1 shows a lining tank constructed by another company. There are many weld lines on the head at the bottom.

Figure2 shows the liner of the head part with our heating reformation and there are no weld lines.

The liner of a tank with an internal diameter of more than 1200 mm will have one or two welding lines as shown in Figure3.

Figure3　The liner in the head part of a large tank

The maximum internal diameter for head part reformation is ϕ2800. Three sheets are connected by 2 automatic welding lines and reformed. The connection between the head liner and the body liner is also welded automatically because the head liner reaches the body.

2-2) Vacuum attachment method with fewer scratches on the sheet surface

The vacuum attachment method is a method in which a flat sheet or a head molded sheet is placed along the body of a can, and the air between the back of the sheet and the body of the can is removed to create a vacuum, so that the lining sheet is pressed against the body of the can at atmospheric pressure and could be bonded without scraping.

In this attachment method：

- Reduces the scratches on the surface of the sheet and contamination of the sheet.
- Makes it possible to bond evenly and the bonding strength is stable.

The above two effects could be expected.

2-2-1) Appearance of head part attached by vacuum attachment method

Figure4 shows an image of the scraping attachment method used by other companies.

Figure5 shows an image of the vacuum bonding method which our company developed.

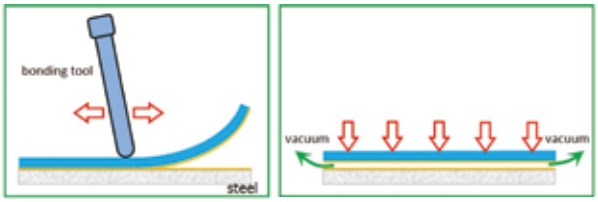


Figure4　Rubbing Attachment　Figure5 Vacuum Attachment

In the conventional method of attaching the sheet, a scraping jig press the liner against the tank. This causes abrasion scratches on the entire surface of the liner.

In vacuum bonding, it was realized that the sheet is pressed against the tank at atmospheric pressure, so only a small portion of the sheet, such as the edge of the sheet, is scraped, and the scraped area is greatly reduced.

Figure6 shows a photograph of the head part attached by the vacuum attachment method, and Figure7 is a magnified photograph.

Figure6　Head of a tank with liner attached by vacuum bonding

Figure7　Enlargement of the surface of our liner

2-2-2) Surface roughness after lining

The following are the results of comparing the liner surface of a tank head when “attachment by scraping” is used and “head reforming + vacuum bonding” is used to attach using M－PTFE sheets.

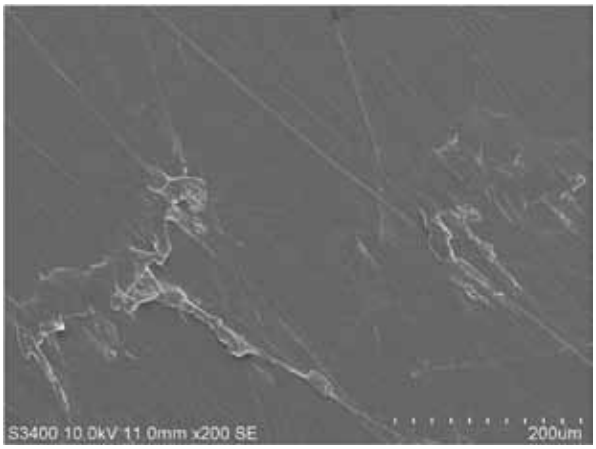


Figure8　Electron micrograph of the scraped area

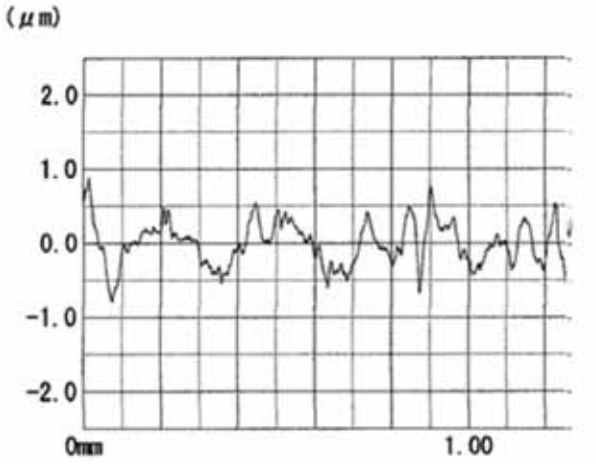


Figure9　Liner surface of our company (Ra 0.25μm)

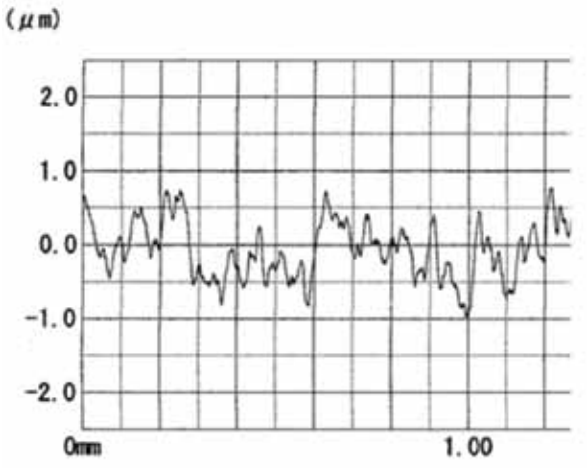


Figure10　Liner surface of another company (Ra 0.34μm)

Figure9 shows the surface roughness of the lining tank processed by the vacuum bonding method, and it was Ra 0.25μm.

Figure10 shows a graph of measurements of the surface of a sheet with conventional attachment, and it was Ra 0.34μm.

2-3) Stable quality by mechanized welding

Figure11 shows the cross-section of the welded part of the liner.

The liner of the lining tank is joined by PFA welding. There are two stages of welding: beveling at the end of the liner, followed by priming welding with PFA rods, and then band welding (reinforcement welding) using PFA strips.

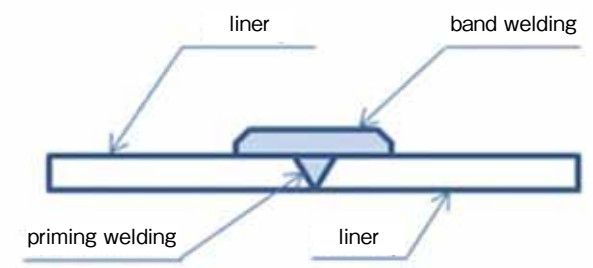


Figure11　Cross-sectional shape of band weld

We use self-propelled welders (automatic welders) for welding strips to stabilize "temperature", "speed" and "pressure", which are important conditions for welding. As a result, compared to manual welding by operators, the welding conditions were more stable and the strength variation significantly reduced.

In addition, it is now possible to weld strips with less undulation, meandering, and deformation of the welding line.

Furthermore, while other companies use a 14 mm width for manual strip welding, we have increased the strip width to 17 mm through mechanization to improve the welding strength and increase the welding part's reliability.

Figure12 Welding with an automatic welding machine

Figure13 Our product - Automatic welding (M－PTFE－ET)

Figure13 shows a strip weld done by automatic welding, which is wider and has less meandering.

2-4) Safety design of the component structure

2-4-1) Nozzle structure

The tube part of the nozzle is a part that has many problems with welding because it is difficult to adhere it tightly to the body of the can.

Other companies use a structure where the expansion and contraction stresses of the liner due to temperature changes are directly applied to the weld, as shown in Figure14. As shown in Figure15, the inside of the tank is also flare processed, and this flared part receives the stress, so the welding part is not subjected to expansion and contraction stress.

Figure14 Nozzle activity and loss examples due to temperature change

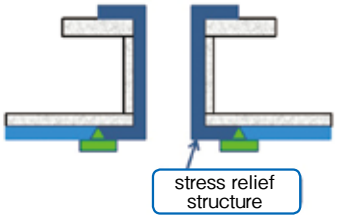


Figure15 Our nozzle construction method

2-4-2) Liquid collection cup structure

The structure of the liquid collection cup at the bottom of the tank is the same as that of the nozzle.

Figure16 Lining around the liquid collection cup is detached

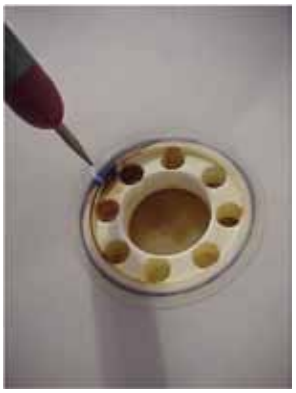


Figure17 The cause is damage to the weld between the collecting cup and sheet

Figure18 Examples of construction by other companies

Figure19 Our construction method

3. Selection of lining material

We use three types of materials of fluoropolymer lining sheets, PTFE, PFA, and M－PTFE. Two types of sheets are used for the adhesion method: chemical-etched sheets with fluoropolymer surface that is chemically processed and glass-backed sheets laminated with glass cloth sheet.

3-1) Functionality evaluation of our lining sheets

The following table shows an in-house evaluation of the five functionalities of our lining sheets on a 5-point scale.

Evaluated sheets

PTFE-ET : PTFE chemical-etched sheet

M-PTFE-ET : Modified PTFE chemical-etched sheet (PLP Sheet)

M-PTFE-GB : Modified PTFE glass-backed sheet

PTFE-GB : PTFE glass-backed sheet

PFA (NEW) -GB : PFA glass-backed seat

PFA (HP-PLUS) -GB : PFA glass-backed sheet

Evaluation details

Surface smoothness : Indicates the quality of dirt removal during washing.

Adhesion performance : Indicates the quality of the adhesive strength between the sheet and the adhesive.

Welding performance : Indicates the welding reliability of the sheet's connecting parts.

Permeation resistance : Permeation resistance to chemical solutions. Affects the life expectancy of chemical solution permeation.

Price : Indicates the quality of the cost of the sheet.

Table1 Functional evaluation of sheets for lining

evaluation: (excellent) 5・4・3・2・1 (poor)

lining sheet	surface smoothness	adhesion performance	welding performance	permeation resistance	price
PTFE-ET	3	3	3	4	5
M-PTFE-ET	4	3	4	5	4
PTFE-GB	3	3	3	2	3
M-PTFE-GB	4	3	4	4	2
PTFE-GB	5	3	5	3	2
PFA (HP-Plus) -GB	5	3	5	4	1

Note 1 ET: Etched sheet, GB: Glass Backing, M: Modified.
Note 2 Values are rated on a 5-point scale to indicate the quality.

3-1-1) Surface smoothness

The following is a photograph of the surface of three types of lining sheets made of different materials and surface roughness

Figure20 PTFE－ET×100

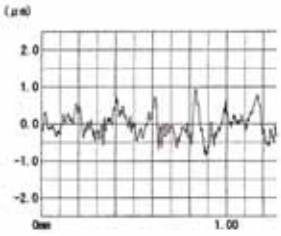


Figure21 Ra 0.29μm

Figure22 M－PTFE－ET×100

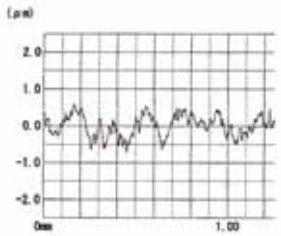


Figure23 Ra 0.24μm

Figure24 NEW PFA×100

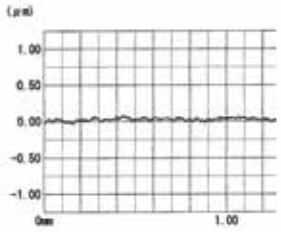


Figure25 Ra 0.03μm

PTFE : Highest surface roughness.

M-PTFE : Surface roughness is slightly lower than PTFE.

NEW PFA : The surface is the smoothest.

This measurement is at the stage of the sheets, and the surface roughness Ra after lining varies greatly due to the difference in lining construction methods described above.

3-1-2) Adhesion performance

Fluoropolymers are non-adhesive, so even if an adhesive is applied to a fluoropolymer sheet, it will not stick and peel off.

To add adhesiveness to fluoropolymer sheets in our etching processed sheets, chemical etching is conducted to add adhesiveness after the sheets are

manufactured.
On the other hand, glass-backed sheets are made by anchoring fluoropolymer sheets and glass cloth sheets by melting PFA between them to make them adhesive.

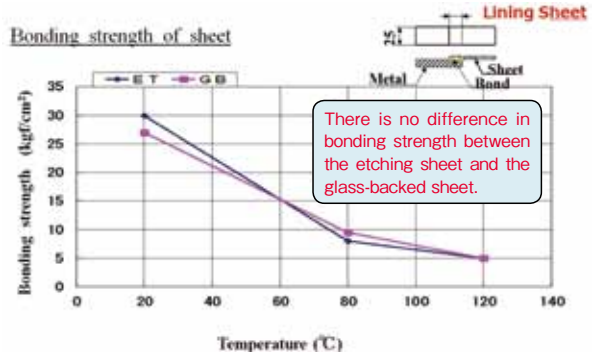


Figure26 Bonding strength (shear) of ET sheets and GB sheets

Figure26 shows the shear strength test results of ET sheet and GB sheet bonded to metal using rubber adhesive.
The peeled areas are all metal surfaces and have the same adhesive strength.

3-1-3) Welding performance

Figure27 shows a comparison of the weld strength of the lining sheets.

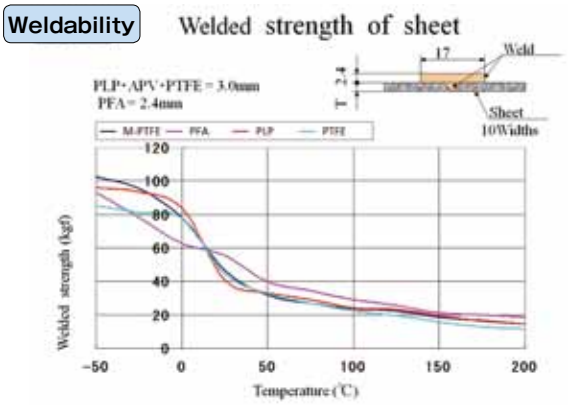


Figure27 Results of weld strength measurement

(PLP : this is a sheet of M－PTFE, but a sheet manufactured by our company with improved permeation resistance.)
There is no significant difference in the weld strength of all sheets in the temperature range where they are generally used. However, the PFA sheet, which is the same as the welding rod and strip material, could theoretically be said to have better fusion during welding and higher welding stability.
Guessing from the fluoropolymer material (molecular structure), the welding stability would be PFA> M－PTFE>PTFE.

3-1-4) Permeation resistance

It is known that the permeation of chemicals occurs mainly in the amorphous part inside the polymer.
Figure28 schematically depicts the crystal structure of a fluoropolymer sheet in the cross section.

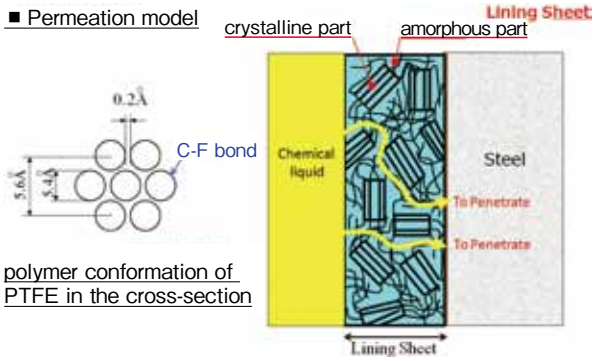


Figure28 Image of chemical permeation into fluoropolymer

The part where molecules are lined up orderly fashion is the crystalline part, and the part where molecules are intricately intertwined is the amorphous part.
The crystalline part is densely packed with molecules and has a high density.
The amorphous part has a low density due to the entanglement and random arrangement of molecules.
Therefore, the more crystalline the sheet, the greater the specific gravity.
The chemical permeates through the amorphous part and gradually diffuses through the sheet. Eventually, it reaches the body side of the can, which is the back side of the sheet with the adhesive surface.

Figure29 shows the specific gravity of fluoropolymer and the amount of hydrochloric acid permeation. The graph also shows the specific gravity of fluoropolymer sheets available on the market.

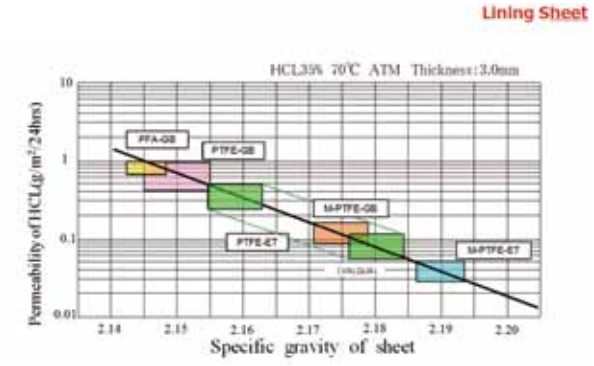


Figure29 Permeability against the specific gravity of fluoropolymers

This figure shows that the amount of chemical permeation decreases with the specific gravity.

PTFE gelate can retain its shape even if it exceeds the melting point. So it is possible to control the cooling conditions that affect crystallization. This characteristic can be used to control the degree of crystallization.

The specific gravity of PTFE generally available on the market, considering productivity is about 2.14 to 2.16. However the specific gravity of our sheets for lining is finished to about 2.18 to improve permeability. PFA is a molten polymer, and it is difficult to control the cooling conditions due to its molding method, so the specific gravity is generally in the range of 2.14 to 2.15.

Figure30 shows a cross-section of M－PTFE－GB sheet.

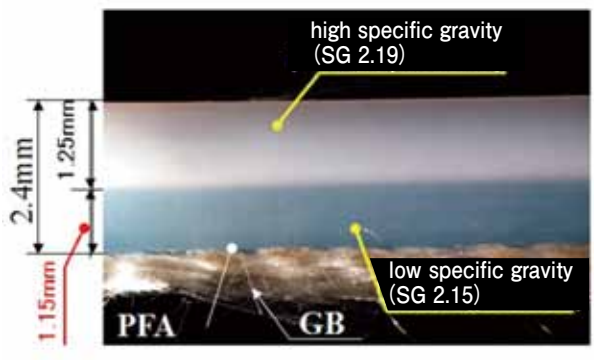


Figure30 Cross-section of M－PTFE－GB sheet.

It is necessary to gelate the sheet when laminating the glass cloth to the sheet to produce PTFE－GB and M－PTFE－GB sheets. Cooling is conducted after gelation, but the specific gravity decreases because of the difficulty of slow cooling.

The translucent part on the GB side is shown in the photo where the specific gravity has become low.

Figure31 shows a cross-section of our PLP sheet.

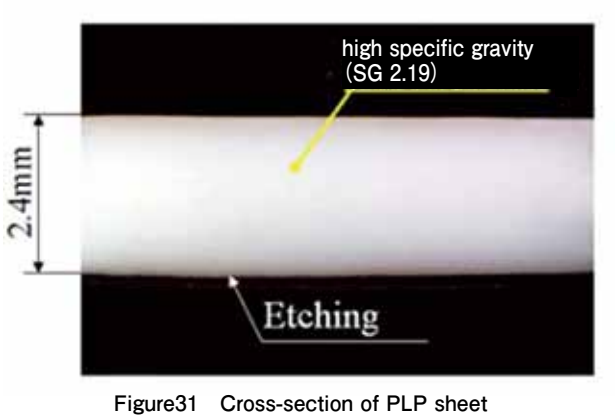


Figure31 Cross-section of PLP sheet

PLP sheet is a polymer that could be denser than PTFE, and since the etching process that does not require heat treatment that could gelate the sheet, without lowering the specific gravity.

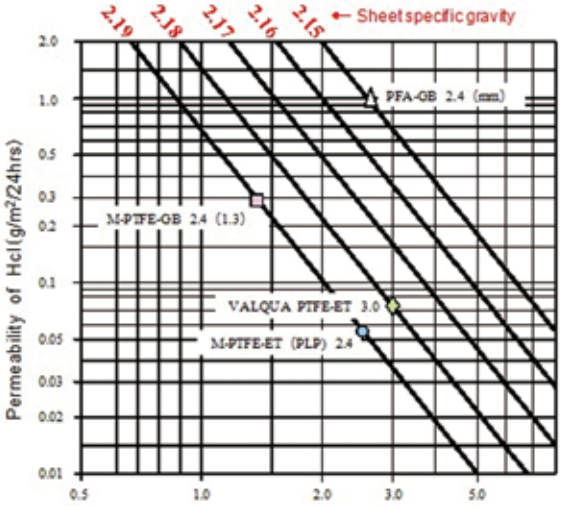


Figure32 Specific gravity, thickness and permeability of fluoropolymers

This figure shows that the thickness of the sheet is also an important factor in permeation resistance.

3-1-5) Price

Figure33 shows the relationship between the surface smoothness of the lining sheet and the market price of the lining sheet, and Figure34 shows a schema of the relationship between surface smoothness and

permeation resistance.
The right side of the horizontal axis indicates higher functionality, and the upper side of the vertical axis indicates higher cost.

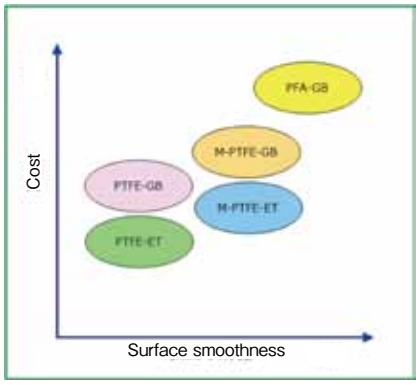


Figure33　Surface Smoothness：Cost

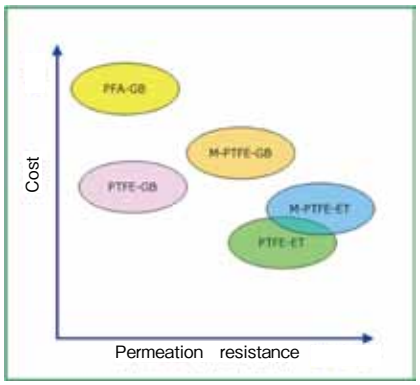


Figure34　Permeation Resistance：Cost

The cost of fluoropolymer raw materials is：
PFA＞M－PTFE＞PTFE
The cost of providing adhesion is ET＞GB.
The surface smoothness of the base sheet is PFA＞M－PTFE＞PTFE.
This is due to the different characteristics of the raw materials and the processing methods used to make the sheets. However, the method of lining attachment also needs to be considered.

4. Conclusion

Since the start of lining tank production, our company has responded with any queries from our customers regarding our product defects. We always inform our customers if there is any update regarding our production method. Although the causes of abnormalities differ, they could be roughly classified into three categories.
These are "chemical permeation," "unexpected structural defects," and "inexperienced construction techniques". We have been investigating the causes of each problem and making improvements.

For example, for chemical permeation, we have been working on selecting materials for lining sheets and increasing the density of the sheets. For structural problems, we have been working on design methods of the body of the can and improvement of the nozzle structure as described in the previous article. For construction technology, we have been working on the automation of welding strips.
With the rise of the semiconductor industry, cleanliness, which was not a requirement for chemical plants, has become more important, and the development of vacuum bonding and head liner molding technologies enabled us to reduce scratches to the liner surface as much as possible.
We will continue to strive to develop new technologies to meet the demands of the market.
Our next article will introduce an overview of the technologies we are currently working on and our future goals.

Takeshi Yokoyama
Assistant To High Performance Plastics
Product Manager

Long-Lifetime FEPM TOUGHUORO™

1. Introduction

Tetrafluoroethylene propylene rubber (FEPM) is a type of fluororubber (FKM). It is a copolymer of tetrafluoroethylene (TFE) and propylene (P) and has a different molecular structure compared to ordinary fluororubber (FKM; copolymer of vinylidene fluoride (VDF) and hexafluoropropene (HFP)).

Table1 shows the molecular structure of FEPM and FKM.

Table1 Molecular structure of FEPM and FKM

Type	Molecular structure
FEPM	$-(CF_2-CF_2)_p-(CH(CH_3)-CH_2)_q-$ TFE P
FKM (Copolymer)	$-(CF_2-CH_2)_p-(CF(CF_3)-CF_2)_q-$ VDF HFP

With this molecular structure, FEPM has characteristics such as superior steam resistance and chemical resistance which were weak points for FKM. FEPM is used as sealing for food and beverages facilities and sealing for tire vulcanizing devices.

However, with advancements in functionality of facilities and downsizing, the chemicals used for cleaning the facilities have become higher in temperature and concentration, and facilities are used in tougher environments, leading to more demanding properties for sealing material.

In this article, we will introduce the steam-resistant SS series and low compression set ZS series of TOUGHUORO™ that we have developed as a long-lifetime FEPM with improved heat resistance and steam resistance by utilizing our proprietary mixing design technology.

2. Characteristics of TOUGHUORO™

Compared to our existing FEPM, D0970 and D0890, TOUGHUORO™ is a material with significantly improved heat resistance and steam resistance. Below are the various characteristics of TOUGHUORO™.

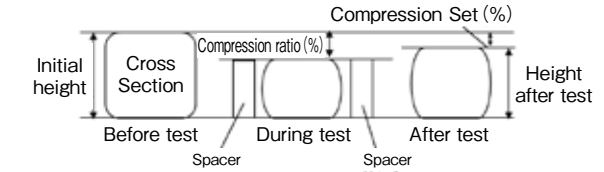
2- 1) Compression set characteristics properties

Compression set is used as an indicator for heat resistance in sealing material.

Under the same environment, a smaller compression set means the sealing material can be used favorably for a longer period of time.

Figure1 shows the measurement and calculation methods for compression set.

In general, compression set of 80% is considered as sufficient for life expectancy of material used for sealing[1)], but the compression set of TOUGHUORO™ showed better results than our existing FEPM and it is anticipated to have a 4-fold longer in air at 200℃.



$$\text{Compression Set (\%)} = \frac{\text{(Initial height)} - \text{(Height after test)}}{\text{(Initial height)} - \text{(Spacer height)}} \times 100$$

Figure1 Measurement and calculation methods for Compression Set

Figure2 shows the results for compression set in air at 200℃.

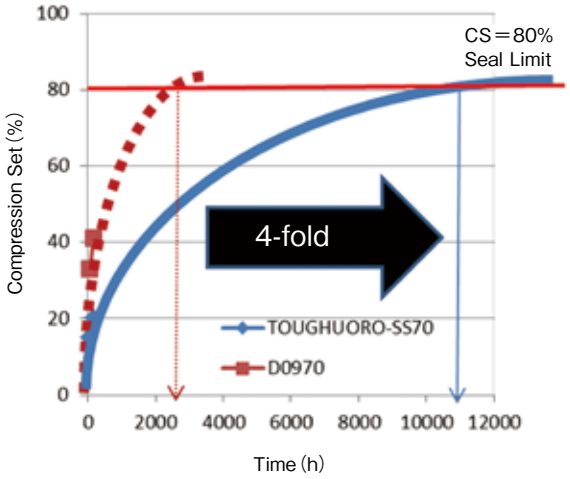


Figure2 Compression Set in air at 200℃

2-2) Steam resistance properties

Under steam conditions, HNBR and EPDM have been used conventionally to suppress foaming phenomenon called blister[2], but in conditions over 150℃, it was difficult to use these materials due to their characteristics. Our newly developed TOUGHUORO™ has improved mechanical strength as well and even under 230℃ steam conditions, no signs of blisters were confirmed, making it possible to use as a good sealing material. Figure3 shows the application area in stream of TOUGHUORO™ and various materials.

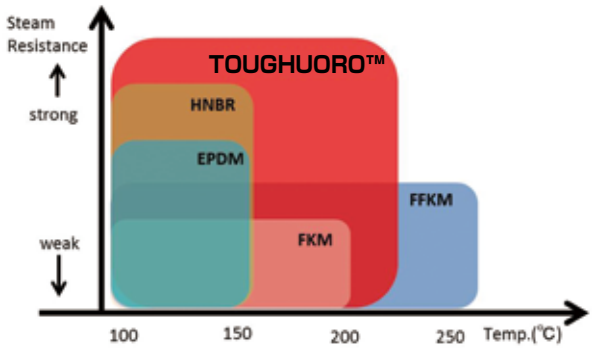


Figure3 Applicable area in steam of TOUGHUORO™ and various materials

Figure4 shows a cross-section of the sample after compression set test in steam at 230℃.

No bulister	bulister
TOUGHUORO™-SS70	D0970

Figure4 Cross section of specimen after Compression Set test in steam at 230℃

2-3) Acid resistance and alkali resistance properties

Regarding acid resistance and alkali resistance of TOUGHUORO™-SS70, it is equivalent or higher than that of D0970. Since heat resistance of TOUGHUORO™ has improved, it can be used under higher thermal conditions.

Figure5 shows the results for change in volume after the acid and alkali immersion test.

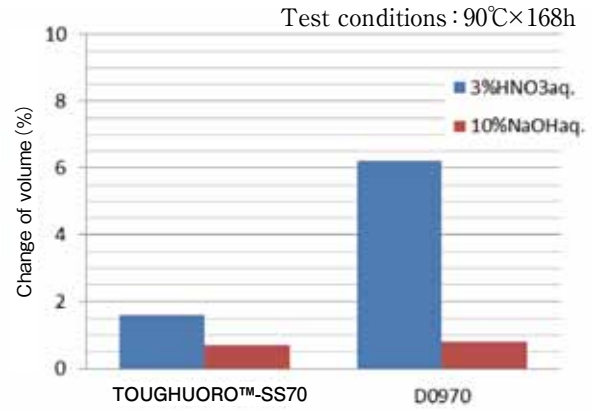


Figure5 Change in volume of TOUGHUORO™ after acid and alkaline immersion test

2-4) Water-glycol based flame-retardant hydraulic oil resistance properties

Resistance of TOUGHUORO™-SS90 to water-glycol flame-retardant hydraulic oil (HYDOL HAW, manufactured by MORESCO) is equivalent or higher than D0890.

The pass or fail judgment was made by stretch change ratio and volume change ratio (judgment criteria: within ±50% change in elongation, within +10% change in volume were judged as ○, those that

slightly exceeded the criteria were judged as △, those that clearly exceeded the criteria were judged as ×[3]). Table2 shows the resistance of TOUGHUORO™ to water-glycol based flame-retardant hydraulic oil.

Table2 Resistance of TOUGHUORO™ to water-glycol based flame-retardant hydraulic oil

	TOUGHUORO™-SS90	D0890
Change in Elongation	○	○
Change in Volume	○	○

Test conditions : 120℃×1000h

It was confirmed that TOUGHUORO™-SS90 is superior in regards to compression set and it is anticipated to enable use for a longer period. Figure6 shows the compression set after the water-glycol based flame-retardant hydraulic oil test.

Test conditions : 120℃×1000h
25%Compression、φ29×12.5h

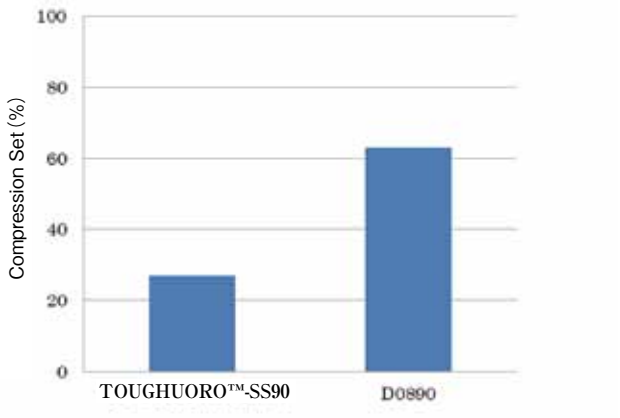


Figure6 Compression Set of TOUGHUORO™ to water-glycol based fire-retardant hydraulic oil

Table3 Material characteristics of TOUGHUORO™

Material name	Developmental products			
	Steam-resistant SS series			Low compression set ZS series
	TOUGHUORO™ -SS70	TOUGHUORO™ -SS80	TOUGHUORO™ -SS90	TOUGHUORO™ -ZS80
physical properties				
Hardness (ShoreA)	74	84	90	85
Tensile strength (MPa)	23.1	24.6	22.8	24.3
Elongation (%)	190	150	110	120
100% Modulus (MPa)	8.3	15.2	20.9	19.9
Compression set test_200℃×70h				
Compression set (%) in air	16	19	18	14
Compression set (%) in steam	14	20	18	11
Compression set test_230℃×70h				
Compression set (%) in air	22	26	27	21
Compression set (%) in steam	20	26	27	19

The values are measured values, not standard values.

2-5) Food Sanitation Act

TOUGHUORO™ is a material conforming to the criteria designated in the Ministry of Health, Labour and Welfare Notification No. 595 (Dissolution conditions: Used at temperatures over 100℃).

2-6) Product shape

TOUGHUORO™ can be manufactured into products with various cross-section shapes and large-diameters such as O-rings (No.4640), V packing (No.4631) and X-rings (No.4641).

2-7) Mechanical properties

There are two grades of TOUGHUORO™, the steam resistant SS series and the low compression set ZS series.

Table3 shows the physical characteristics and compression set in 200℃ air/steam for each grade.

3. TOUGHUORO™ applications

TOUGHUORO™ has superior heat resistance and steam resistance and the following uses are considered:

1. Mining market
   Bit seals
2. Steel market
   Rotary joint seals
3. Tire manufacturing market
   Sealing for curing press to car tire
4. Food and beverages market
   Sealing for food and beverages facilities
5. Nuclear power market
   High-temperature, dynamic seals

4. Conclusions

TOUGHUORO™ introduced in this article is a material that shows its best characteristics in high temperature steam conditions. In the future, higher demands may be placed on sealing material, but it is considered that this would be able to sufficiently answer those demands.

We would like to continue developing new materials and improving existing materials to correspond to the requests of our users.

5. References

1) Toshio Kawamura: Valqua Review, Vol26, No.6 (1982)
2) Hirofumi Zushi: Valqua Technology News, No.31 (2016)
3) Ken Suzuki: Valqua Technology News, No.24 (2013)

Hirofumi Zushi
Corporate Research and Development Group
Product Development Division

Low Torque & Long-Lifetime Swivel Joint LFR JOINT™

1. Introduction

The aging of the population, one of the major social issues in Japan, is currently causing a very serious situation in the manufacturing field as well. In particular, the aging of experienced workers in the manufacturing field has been progressing, but securing enough young engineers and the succession of techniques has not been keeping up with the speed of aging. The decline in technical ability in the field is already happening in the production field of every company. Additionally, the trend of aging population is rapidly spreading overseas, and this is also a significant issue from the global perspective.

In such situation, actions to streamline operating costs at each process are intensifying by considering all the various factors together including maintenance of facilities. This is because in order to gain maximum benefit with limited number of staff, streamlining with a more permanent perspective, which takes man-hour for maintenance and long-term reliability into account, is now required in addition to short-term cost reductions in purchasing facilities and materials. These issues are not only the matters imposed on the equipment that are the main force in a process, but also items such as sealing materials and joints, which have been considered as consumable supplies but have considerable roles to play.

LFR JOINT™, the swivel joint introduced in this issue of Valqua Technology News, is a solution-type of product developed while collecting customers' comments from the field.

We would like to introduce this product because it is a product which makes a significant contribution to our customers' maintenance cost reduction and productivity improvement of facilities using the techniques we have fostered as a manufacturer of seal products.

2. Issues of conventional swivel joints

A swivel joint is a collective term for a joint which has the ability of continuous rotation and oscillating movement at low speed. It is widely used as an important part which carries various types of liquids (such as hydraulic oil, air, water, etc.) considered as blood in each process.

Figure1　Cutaway model of LFR JOINT™

For example, swivel joints are applied as joints in the hose part of robots installed in automatic production lines of the aluminum diecasting process to reduce the load on the hose by eliminating twists caused by the robots' complicated movements and high frequency of operation.

However, swivel joints generally have high rotational resistance and the effect of load reduction on the hose is not sufficient, causing premature fractures in the hose. This has been an issue that considerably decreases productivity of the process.

As another example, under severe environmental conditions (high temperature, pressurized liquid, dust, etc.) such as in steel plants, there were some cases in which the interval between maintenance of the production line became shorter because the sealing material on swivel joints were quickly worn down.

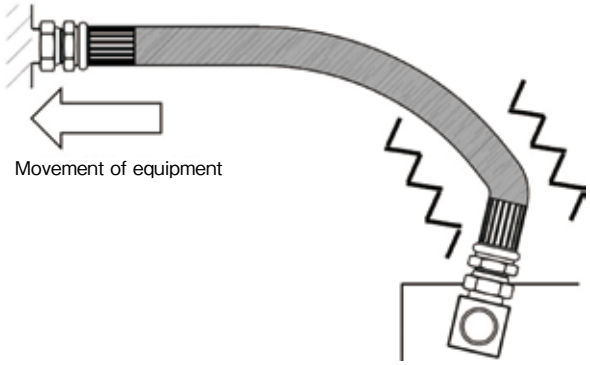


Figure2 Example of premature fractures in the hose

3. Cause of the issues

The two issues of swivel joints described above, 1) high rotational resistance and 2) short life, are largely due to the sealing material that is used.

O-rings, mainly made from rubber, are commonly used as the sealing material for swivel joints. During low-speed rotation or oscillating movement, this O-ring fills the gap by sliding against the rotational axis and prevents liquid leakage.

However, due to the characteristics of rubber material, frictional resistance when sliding against the rotational axis is extremely high. Furthermore, this tendency is even more significant when fluid pressure is high. These factors cause the swivel joint to have an extremely high rotational resistance and hinders the intended rotational and oscillating movement.

In addition, rubber is generally not a material which is resistant to abrasion. Therefore, O-rings are severely worn down, especially under adverse lubrication conditions at high temperature and high pressure, and this results in shortening the life of the swivel joints themselves.

4. Solution by LFR JOINT™

LFR JOINT™ is a swivel joint which solved the long-standing issues with swivel joints and realized both low-torque and long life.

Various innovative designs are applied to the sealing mechanism and also to peripheral aspects such as the seal groove. In this issue of Valqua Technology News, the sealing mechanism is explained.

5. Sealing mechanism of LFR JOINT™

In order to solve the issues of swivel joints, LFR SEAL™, a sealing material for rotational movement was specially developed for LFR JOINT™. Figure3 shows a cross-section diagram of LFR SEAL™.

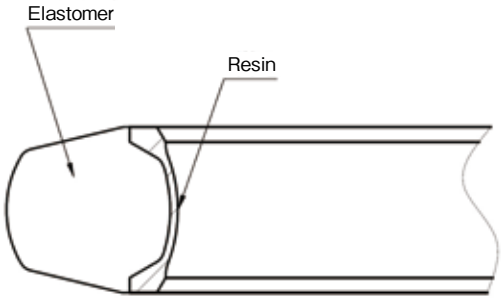


Figure3 Cross-section diagram of LFR SEAL™

5-1) Torque reduction

In order to reduce torque in swivel joints, it is necessary to reduce sliding resistance of the sealing material, but we considered that sliding resistance is related to friction coefficient, contact area with the other surface (rotational axis), and tension force. The

resulting design was produced by resolving each of these factors and is shown in Figure3.

Ⅰ.Friction coefficient

Resin of low friction coefficient was compounded with elastomer by forming them simultaneously inside the sealing where the other surface (rotational axis) comes in contact.

Ⅱ.Contact area

When fluid pressure is applied, a tilt generated by the tapered face of the non-pressurized side coming into contact with the groove face makes it possible to control the contact area of the arc sealing face that is in contact with the rotational axis. Thus, the increase in the contact area resulting from increased pressure can be suppressed as shown in Figure4.

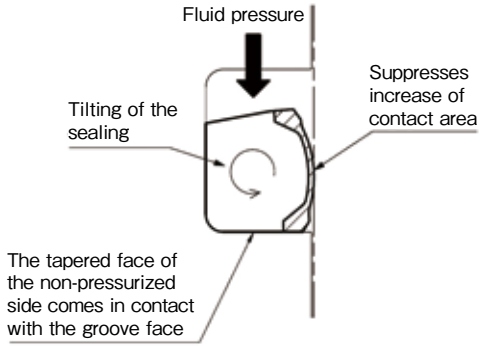


Figure4　Control of the contact area

Ⅲ.Tension force

The volume of external diameter of elastomer at the base was reduced and the inner face and the outer face that become the sealing face were designed to be arc-shaped to reduce tension force.

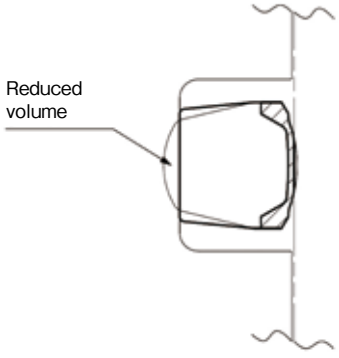


Figure5　Shape of external diameter of elastomer part

5-2) Life prolongation

It can be said that improving the durability of the sealing material is an effective means for life prolongation of the swivel joints because the life of swivel joints is deeply related to leakage from sealing material.

This sealing employs resin for the sliding face of the sealing and its durability is superior to an O-ring which slides on a rubber face. Also, as described in 5-1, the mechanism to reduce torque decreases friction heat generated during the sliding of the sealing and this reduces abrasion and fatigue of the sealing material.

6. Effects of LFR JOINT™

6-1) Increasing the life of accessories such as hose material

Figure6 shows a comparison of rotational torque of LFR JOINT™ and a conventional swivel joint with an O-ring. It shows that torque rises only slightly with LFR JOINT™, even if fluid pressure is increased.

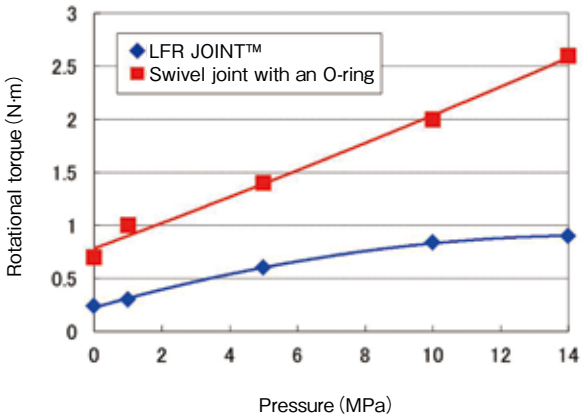


Figure6　Comparison of rotational torque

This considerably reduces the rotational load on accessories such as hose material.

In market performance, the lifetime of hoses was actually extended, and the life-prolongation effect even reached a maximum of ten times longer in some cases.

6-2) Life improvement of joints

Figure7 shows a product life comparison of LFR JOINT™ and a swivel joint with an O-ring, and Table1 shows the test conditions.

This shows that maintenance costs for joints can be reduced because the life of LFR JOINT™ is more than double when compared to our conventional joints.

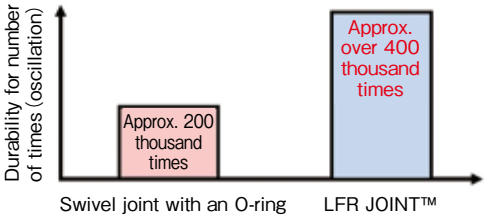


Figure7 Life comparison

Table1 Test condition for life comparison

Fluid	Air
Pressure	0.7 MPa
Temperature	120℃
Angle of oscillation	90 degrees
Diameter of rotational axis	ϕ42

Also, Figure8 shows a comparison of the cross-sections of the sealing material before and after life testing. The thinner line represents the cross-section before the test and the solid line after the test.

The O-ring for conventional swivel joints was severely worn away after approximately two hundred thousand times of oscillation and this abrasion caused leakage. On the other hand, LFR SEAL™ attached to LFR JOINT™ did not show any major abrasion even after approximately four hundred thousand times of oscillation and was still capable of continuous operation.

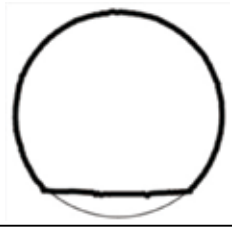
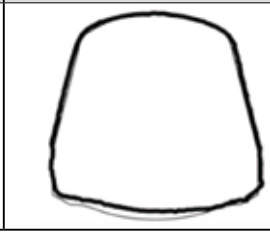
O-ring for conventional swivel joints (leakage after approx. two hundred thousand times of oscillation)	LFR SEAL™ attached to LFR JOINT™ (capable of continuous operation even after approx. four hundred thousand times of oscillation)
	

Figure8 Comparison of sealing cross-sections before and after life testing

7. Conclusions

The Valqua Group aims to evolve into an "H&S company" that provides not only sealing products but also peripheral services and this product is our first unit product that is a part of our strategy.

We will continue to develop products to meet market demand, but also dig out unmet needs together with our customers and work hard to provide true solutions by merging innovative technologies and services.

8. References

1) Akihiro Nagano, Valqua Technology News, No.30, 9-13, 2016

Ryosuke Nishi
Research and Development Headquarters
Product Development Division 1

Recent Technology News Back Issues

No.35 Summer 2018

Winter 2019

No.36

No.34 Winter 2018

【Customer Solution Feature】

Guidelines on Gasket Selection, Selection Troubles, and Countermeasures

Sales Group Technical Solution Division Asuka Matsushita

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

TORQUE SYSTEM Co.,Ltd. Managing Director Shinichi Kitahara

● **Business Introduction** H&S Demonstration Car H & S Business Group Hajime Nonogaki

● **Product introduction** Improved Seal Paste

Corporate Research and Development Group Product Development Division Ⅰ Masato Hamade

Multi-Purpose Gland Packing for Chemical Applications

Corporate Research and Development Group Product Development Division Ⅰ Syuuzi Sugawa

Corporate Research and Development Group Product Development Division Ⅰ Masato Hamade

●Recent Technology News Back Issues

No.33 Summer 2017

【Customer Solutions Special】

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

● **Technical Papers** Unsuitable Usage Conditions of Gaskets and Countermeasures

Sales Group Technical Solution Division Toshihiko Enishi

Evaluation of Basic Sealing Properties of the Pipe Flange Connection with Metallic Flat Gasket

Corporate Research and Development Group Development Division Kouji Satou

SHINKO PLANTECH CO., LTD. Yasuharu Kondou

Professor Emeritus at the University of Hiroshima Toshiyuki Sawa

Corporate Research and Development Group Satomi Takahashi

Troubles While Mounting Gaskets and Countermeasures

Sales Group Technical Solution Division Satoshi Akiyama

An Introduction and How to Use Seal Quick Searcher™(SQS) -Elastomer Version-

Corporate Research and Development Group Development Division Akira Ueda

Seal Training Center (STC) - Interactive Training for Sealing Operation

H & S BUSINESS GROUP Akira Muramatsu

● **Contribution** Management of Tightening of Flanged Fasteners at Plants

Mitsubishi Chemical Corporation Mizushima Plant Mechanical Group 2

Maintenance and Engineering Department Riichi Morimoto

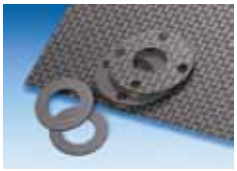
●Recent Technology News Back Issues

Aim for earth and people friendly production

Sheet Gasket

UNIVERSALHYPER ™(UF300)

This is a sheet gasket that enables gasket integration in chemical lines.
In addition to high temperature and long-term stability, chemical resistance has been improved, greatly expanding the range of applicable fluids.
It can be used for both strong acid and strong alkali lines.



BLACKHYPER ™(GF300)

It is a best-selling seat gasket with a high reputation for reliability and high cost performance, backed up by proven market experience.

■UF300, GF300
- Allowable temperature ranges : −200 to 300℃
- Maximum pressure : 3.5MPa

※Please refer to the product catalog and technical data.

VALQUA, LTD.

ThinkPark Tower 24F
2-1-1 Osaki, Shinagawa-ku, Tokyo 141-6024, Japan
Contact : VALQUA, LTD. http://www.valqua.com
TEL：(81)3-5434-7376 FAX：(81)3-5436-0562

VALQUA's Sales Network

■JAPAN
VALQUA, LTD.
【Main Number】 TEL : (81)3-5434-7370 FAX : (81)3-5436-0560
【Sales Group】 TEL : (81)3-5434-7380 FAX : (81)3-5436-0571

VALQUA SES CO., LTD.
TEL : (81)436-20-8511 FAX : (81)436-20-8515

VALQUA TECHNO, LTD.
TEL : (81)3-5434-7520 FAX : (81)3-5435-0264

■CHINA
VALQUA(SHANGHAI) TRADINGCO., LTD.
TEL : (86)21-5308-2468 FAX : (86)21-5308-2478

SHANGHAI VALQUA FLUOROCARBON PRODUCTS CO., LTD.
【Head Office】 TEL : (86)21-5774-1130 FAX : (86)21-5774-1244
【Jingansi Office】 TEL : (86)21-3253-5588 FAX : (86)21-3253-5568

■KOREA
VALQUA KOREA CO., LTD.
【Head Office】 TEL : (82)2-786-6718 FAX : (82)2-786-6719
【Ulsan Office】 TEL : (82)52-227-6717 FAX : (82)52-227-6719

■TAIWAN
TAIWAN VALQUA ENGINEERING INTERNATIONAL, LTD.
【Head Office】 TEL : (886)7-556-6644 FAX : (886)7-556-9907
【Hsinchu Office】 TEL : (886)3-572-0467 FAX : (886)3-573-7232
【Luzhu Office】 TEL : (886)7-696-2400 FAX : (886)7-696-7100

■SINGAPORE
VALQUA INDUSTRIES SINGAPORE PTE.LTD.
TEL : (65)6352-2650 FAX : (65)6352-2653

VALQUA TECHNOLOGY NEWS
No.36 Winter 2019

VALQUA, LTD.

ThinkPark Tower 24F
2-1-1 Osaki, Shinagawa-ku, Tokyo 141-6024, Japan
TEL : 81-3-5434-7370 FAX : 81-3-5436-0560
http://www.valqua.co.jp

■THAILAND
VALQUA INDUSTRIES(THAILAND), LTD.
【Head Office】 TEL : (66)2-324-0400 FAX : (66)2-324-0787
【Rayong Branch】 TEL : (66)38-026-136 FAX : (66)38-026-137

■USA
VALQUA AMERICA, INC.
TEL : (1)408-962-5030 FAX : (1)408-962-5031

VALQUA NGC, INC.
TEL : (1)713-691-1193 FAX : (1)713-691-4407

■VIETNAM
VALQUA VIETNAM CO., LTD.
【Head Office】 TEL : (84)220-357-0078 FAX : (84)220-357-0079
【Hanoi Branch】 TEL : (84)24-3222-2213 FAX : (84)24-3222-2216