Valqua Technology News

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NIPPON VALQUA INDUSTRIES, LTD.

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【The 90th Anniversary Special Edition】

Greetings

Toshikazu Takisawa

President & CEO

NIPPON VALQUA INDUSTRIES, LTD.

First of all, we would like to sincerely thank our valued readers for your continuing interest in our Valqua Technology News. Thanks to your support, we are able to celebrate our 90th anniversary this year. We promise to expand our seal engineering legacy, to strive harder to create innovative technology with novel value, and to contribute to achieving a sustainable society. To mark our 90th anniversary, this issue covers projects that demonstrate our technological commitments in an easy-to-understand manner. We hope you enjoy the Valqua Technology News.

Last year, the world witnessed political upheavals including Brexit, the U.S. presidential election and highly volatile resource prices for petroleum and natural gas in particular. Due to these events, exchange rates and stock prices on many markets fluctuated greatly, so it was difficult to predict the business environment. Amid the global situation, the Japanese market enjoyed a moderate recovery over the year-end thanks to some strong industries, mainly semiconductor equipment manufacturers. However, unfair practices including falsification of fuel economy tests in the car industry and a road collapse near Hakata Station reminded us of the huge social responsibilities of companies and the importance of risk management. The year 2016 also witnessed accelerating technological progress, such as autonomous driving technology and the introduction of AI in various industries.

Under such business environment, the VALQUA Group is working on its seventh medium-term management plan, New Valqua Stage Seven (NV・S7), by optimally restructuring its business framework with a broader perspective. Through the plan, we aim to strengthen how we manage global risks. One of our challenges is to promote technological development, particularly our seal engineering technology. In the global markets, we are also reinforcing the creation of novel value in products and services, which are the two major components of H & S*. Through such activities, we aim to transform the VALQUA Group into an H & S company.

One of our value-creating commitments is training sessions. Since we believe that our seal engineering can provide our customers with "safety and security" through our products, we offer training session services based on the H & S concept in the worldwide markets, which are receiving positive feedback from numerous customers. In this issue, "Valqua Technology News" features a wide range of troubleshooting cases as examples of our customer-oriented solutions.

Again, we thank our valued customers for your continued support, which has allowed us to celebrate this 90th anniversary. We would greatly appreciate your further guidance and encouragement and we wish you a long and successful future.

* The term "H & S" means working to maximize customer value through "H (hard = products)" and "S (seal-engineering service)."

Greetings upon the Publication of the 90th Anniversary Special Issue

First of all, we would like to sincerely thank our valued readers for their continuing interest in our Valqua Technology News as a means to understand how we are dealing various technological challenges.

We are pleased to celebrate the 90th anniversary of Nippon Valqua Industries this year. We take pride in our contribution to industry development through our fundamental technologies; namely, seal engineering and fluorocarbon polymer processing technologies. Today, various industries are pursuing technical innovation: higher integration and performance in the semiconductor industry, utilization of hydrogen energy to achieve a low-carbon society in the energy industry, and introduction of autonomous driving technology and AI in the information and communications industry. Since our seal and material-processing technologies are closely related to these industries, we have been making great effort to keep pace with technological development and to provide product with value desired by our customers.

We are thankful for the many people who have helped us realizing our technological achievement, and some of them contributed articles to this spring issue illustrating our technological transition from past to present, and our current technologies resulting from the continuous development activities up to today. We have always provided customers with seal products and fluorocarbon polymer products of high value, as well as solution services, through which we have made many technological achievements. As for the technology feature article this issue, like previous one, we introduce these technological achievements mainly from the standpoint of solving customers' problems.

One of our achievements of special importance is that, as the pioneer in seal engineering, we initiated to address the problems of asbestos and totally replaced it with non-asbestos based products ahead of other companies. We have also led the industry in technologies for reliability evaluation and product-lifetime prediction to enhance the safety of non-asbestos products. Through such activities, we have also accumulated deeper technological knowledge and capabilities, and based on these assets together with our seal engineering services expertise, we, offer our customers new value as the H&S

company.

This issue introduces the Seal Quick Searcher®(SQS) service, and the "Evaluation of High-Temperature and Long-Term Properties of Fastening Bodies with PTFE Gaskets," a reliability evaluation method for enhanced safety in using seal products. This issue also features case reports how we solved customer`s problems utilizing the solution services related to fluorocarbon polymer processing and seal technologies. We hope you find these reports interesting and useful.

We will continue to monitor current trends and develop unique technologies to offer products and services that meet the needs of our customers. Again, we thank you for your support and hope to continue serving you in the future.

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

Upon the Publication of the 90th Anniversary Special Issue

Introduction

This special issue of *Valqua Technology News* celebrates the 60th anniversary since the first publication of its predecessor, *Valqua Review*. We sincerely thank all our valued customers and readers who have supported us through the years, and would like to tell you about our history upon the publication of this 90th anniversary special issue.

1. Historical background leading to the publication of *Valqua Review*

Nippon Valqua Industries was the first Japanese specialized manufacturer of seal products. At that time, industries were growing since World War I and needed to manufacture industrial products within Japan. In line with this trend, Nippon Valqua Industries was established for the domestic production of seal products.

Japan's petrochemical industry was also starting to grow at that time. However, major seal products were being imported from Europe and the U.S. due to the lack of technologies and related technical information in Japan. Determined to produce seal products in Japan, we studied and learned from imported products. As a manufacturer, we aimed to communicate with customers to meet their needs and build their trust in seal products. Over the years, we have helped to revitalize industries under this policy and the spirit of value and quality, from which our company derives its name.

Under a contract with the Ministry of International Trade and Industry, we undertook several research projects to develop Japanese technologies, including high-temperature and high-pressure steam packings, packings for industrial use (asbestos joint sheets), aircraft packings primarily made from silicone rubber and Teflon®, and methods for manufacturing and processing tetrafluoroethylene resin. Our research produced some excellent results.

During the same period, we established a research association on fluororesin. Fluororesin was gaining popularity and eventually became widely used in various industries.

In contrast, seal products were not well known. According to reports at that time, "Although packings are important for maintaining the airtightness of fixed and moving parts of machinery and preventing leakage of processing fluid in a wide range of production plants, their value is overlooked due to their inconspicuous nature."

With this background, we decided to produce a technical journal as a 30th anniversary project, to raise awareness of packings that was then called “obturators” through theoretical and academic content. We also wanted to disseminate information about packings and encourage universities and industrial high schools to offer courses on packings.

In December 1957, the first issue of *Valqua Review* technical journal was published.

2. *Valqua Review*

2-1) Inauguration of *Valqua Review*

The president at that time, Toshihisa Takizawa, explained the purpose of *Valqua Review* as follows: “We want to communicate with each valued customer, to learn from their honest feedback on our products, to improve based on their feedback, and thus to repay customers for their support. We also ask academic and industry experts to contribute articles to our journal. We want to introduce new ideas and information to our readers, in addition to information on our current and upcoming products.”

The background leading to the inauguration of the journal and its role were described by Mr. Takizawa as follows: “Nippon Valqua Industries has more than a 30-year history as a packing manufacturer. Our product line has always centered on packings but has also expanded to include other industrial goods. Thanks to our customers’ support, we are celebrating our 30th anniversary. During the postwar period, we provided various chemical products including fluororesin packings ahead of other companies. The excellent electrical properties of the resin allowed us to expand our business to heat-resistant and high-

frequency-resistant insulating materials. Thus, the journal articles cover a wide range of industrial goods including machinery, chemicals, and electrical products.”

Under such policy, for 44 years since its inauguration, *Valqua Review* has consistently been issued monthly; approved for third-class mail as a technical journal; distributed to customers, universities, academic institutions, and libraries to raise awareness of seal technologies; and actively welcomed contributions from external parties since it is not an in-house journal.

At the time of its inauguration, the journal received supporting contributions from academic and industry experts including Dr. Matake Kurokawa, then director of the Agency of Industrial Science and Technology; Dr. Masao Yamagata, then academic dean of the Faculty of Engineering at the University of Tokyo; Dr. Uichi Hashimoto, then chairman of the Japan Society of Mechanical Engineers; and Dr. Shunichi Uchida of the Tokyo Institute of Technology. This wide range of contributors represented the high expectations for the journal.

Dr. Kurokawa expressed his expectations as follows: "This journal provides an appropriate framework at a time when few periodicals cover topics related to packings and insulating materials, which are important for industry. However, it is not easy to understand their characteristics and use them appropriately because they are made from various materials including metals, inorganics, and organics. Packings and insulating materials have become very diverse with the development of synthetic resin materials. I am pleased to see the inauguration of this journal, and I hope it will help overcome such issues."

The same year that the journal was inaugurated, 1957, the Petrochemical Industry Association (predecessor of the Japan Petrochemical Industry Association) started its activities. In the previous year, 1956, the Hydraulic Machinery Industry Association (predecessor of the Japan Fluid Power Association) was inaugurated. Since there was little knowledge of seal technology at that time, the need for systematic information on seal products started to emerge. *Valqua Review* emerged to meet those expectations.

2-2) Transition of articles in *Valqua Review* (December 1957 to June 2000)

From its inauguration in 1957 to the 1960s, the journal featured articles to raise awareness of seal products. The articles ranged from basic research on fluororesin and the introduction of overseas technologies to contributions written from the viewpoint of seal users, such as "Accurate Utilization and Selection of Seals," practice-based articles and eventually articles based on in-house data.

At the time, seals were manufactured in various forms and used for high-temperature and high-pressure fluids. Thus, the demand for products changed from the time when those had been called "obturators." That is, the recognition of leaks changed from simply a loss of energy to problems which hindered the manufacturing environment. Along with the raised awareness of packings for preventing leaks, seal manufacturers gradually started to resolve the problems.

In the 1960s, basic research was actively conducted worldwide, and in the 1970s, many polymer molecules were synthesized. In the field of fluororesins and synthetic rubber, new materials were developed one after another. Accordingly, *Valqua Review* featured articles on ways of developing systems to meet the emerging needs with new materials.

In the 1970s, the Japanese economy suffered turbulent times with the Nixon Shock, Oil Shock, and High-Growth Period. This led Japan to change its economic path from the pursuit of high growth to the pursuit of stable growth. The era witnessed remarkable developments in export industries including the auto, ship and vessel, and steel industries. Also, developments in the emerging atomic, space, and information industries were expected.

As industries pursued product development, systemization, and informatization, we shifted from the management of leaks to the following missions: systematization of seal products as seal engineering or technologies for machine elements and expansion of solution services by introducing diverse seal-related products. Thanks to many contributions from external parties, articles in *Valqua Review* were categorized by elemental technology and edited as a series of technical data. Valqua aimed to help create not only in-house technologies but also a cross-sectional consortium. The resulting achievements were published as books by Kindai Henshu-sha: *O-Ring*, the O-Ring Society, 1969; *Gasket*, the Gasket Society, 1974; and *Air-Pressure Seal*, the Air-Pressure Seal Society, 1977. These greatly contributed to standardization of the industry.

The journal began to feature articles on various fields including electrical insulating materials using fluororesins, vacuum seals including bellows, and building materials using glass fiber. *Valqua Review* became a reputed technical journal and was highly evaluated as a technical resource.

When our company was founded, there were no sales engineers. However, as we grew, we started to hire and train sales engineers in the 1970s.

There have been many interviews with external experts in the journal since it was started. These articles covered topics ranging from prospects for technology to prospects for the future, including *New Year Random Talk - What future lies ahead in the 1980s* (January 1980) and *New Year Random Talk - Perspectives on China in the 1980s* (January 1981) .

The specialty series of *Valqua Review* was serialized starting with *Bochu-Kanwa* (*talks during the breaks in one's work*) in April 1977 and ended as *Kanchu-Kanwa (a talk in free time) in May 2000.* The writer Tatsuya Imoto talked about his experiences as an engineer and garnered many readers, and readers looked forward to the series. A total of 188 articles were published in two independent books.

In the 1980s, industries started to focus on the following: streamlining, improvements in controllability and operability, improvements in safety, environmental protection and disaster prevention, and compliance with Japanese and international standards such as JIS and ISO. In addition, work began on advanced technologies that would support the coming economic system, leading to developments in biotechnology, space, semiconductor/electronics, and new-energy industries.

Valqua Review started to run lecture articles on seals. The journal increasingly featured articles on fluororesins and fluororubbers to reflect trends in new energies including those in their use in the atomic-power industry and their use at low temperatures in the LNG industry as well as semiconductor-associated trends in their use for chemical-liquid processing.

On the other hand, environmental regulations were being tightened and requirements for new registration of chemical substances were becoming stricter. Therefore, the pace of new-material development slowed and the materials used for product development started to be controlled. *Valqua Review* increasingly featured research on non-asbestos trends, polymer alloys, composite-making, and sophistication of compounding techniques.

In the 1990s, industries became more globalized. The semiconductor and electronics industries, which became major players, expanded through the digital revolution and fluctuations of these industries started to greatly affect the economy. Environmentally, regulations on chlorofluorocarbons were introduced to curb global warming, the problems of dioxin that is associated with waste incineration as well as endocrine disrupter received much attention, and the first asbestos regulation was legislated in Europe ahead of other countries.

Valqua Review reported many studies on elastomers in the early 1990s, featuring hydraulic-pressure seals and tribology. Among the feature articles, Shinzo Koujiya, a professor of Kyoto University at that time, contributed a five-year series *Introduction to the Science of Rubber*, which was published by Nippon Valqua Industries in 1995. Regarding seals, the journal reported research on vacuum seals including spring-energized metal C-ring seals. For semiconductors, the journal systematically reported research on tank linings.

Along with diversifying needs and globalization, the journal started to report on efforts to enter new fields, and included technical reports associated with individual needs in the late 1990s. As the articles became more diverse and specialized, the contents of the journal became less consistent. Therefore, in the first year of the new medium-term plan New Valqua Stage 1, along with a renewal of the management philosophy The Valqua Way, the concept of *Valqua Review* was reassessed, leading to the rebirth of the journal as *Valqua Technology News*.

Some 488 volumes of *Valqua Review* containing 1,707 reports were published. Of the 1,707 reports, 1,061 were technical papers. A total of 824 external contributors, including 280 academics, wrote articles for the journal. We sincerely thank all contributors for their invaluable support.

3. *Valqua Technology News* (From Autumn of 2001 to present)

Valqua Technology News was inaugurated in the autumn of 2001 as a quarterly journal, focusing on articles. The goal of the renewal was to promote our unique skills to the public more clearly. Upon its inauguration, Toshikazu Takizawa, the president of Nippon Valqua Industries, commented, "We will strive to introduce our excellent technologies, particularly our core area of seals, in an easy-to understand manner, and to offer customers diverse solutions."

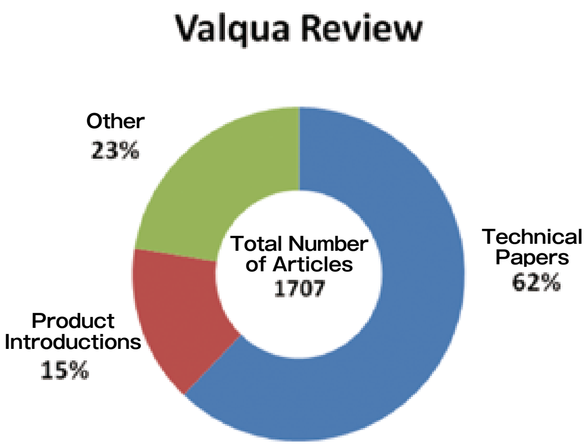
To date, a total of 32 volumes including this issue have been published, including f 182 articles and 79 technical papers. Since the journal focuses on reporting Valqua's technologies, the number of external contributions has decreased. Nevertheless, there have been articles from 15 contributors including 9 academics.

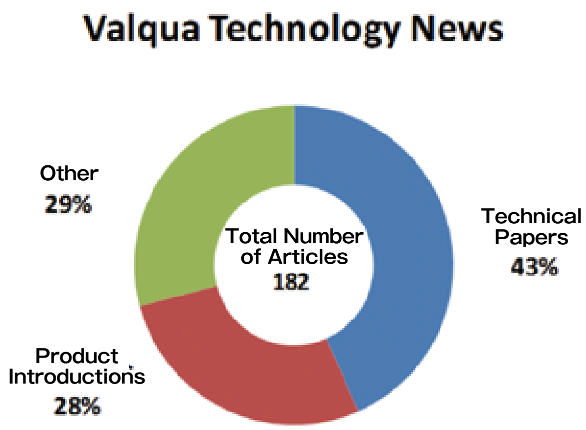
The 2000s was a significant transition period regarding measures to address global environmental problems and global procurement/international specialization. In industry, miniaturization of semiconductors, enlargement of liquid crystal displays, increase in information technology capacity, introduction of clean energies, and life-science and nanotechnology started to flourish.

Valqua Technology News aims to clarify the company's direction through its articles. Its reporting covered performance-assessment research on non-asbestos gaskets of various types; development of highly functional elastomer series suitable for the miniaturization of semiconductor devices; and the development of vacuum technologies for the nano-development environment. We have worked to increase the value of our products for society through modularization and 'componentization.' The journal has also reported our work on vacuum components, hydraulic systems as a next-generation power source, membrane filters, millimeter-wave products, waste-fluid recycling systems, and reticle automated transportation systems.

The period since 2010 is difficult to describe. However, rapid social developments have created social challenges including environmental problems, resource problems, and urbanization. These problems are started to interact with each other on a global scale. To resolve the challenges, open innovation through collaboration among academia and industry is certainly appropriate.

In this environment, the journal is increasingly featuring articles on the existential meaning of Nippon Valqua Industries as a seal-engineering manufacturer. Finite element analysis (FEA) technology comprehensively analyzes the varying life of seals on the basis of experimental data. Progress in FEA technology allows customers to intuitively understand issues through visualization. The technology has also been used to write many articles. The technologies have been integrated to offer solution services on the basis of users' comprehension of the system. We are endeavoring to expand our business to technical training which integrates hard and soft aspects to meet the demands of the times, and to enter the field of trouble prevention diagnosis. The journal covers all these areas.





4. Conclusion

In this 90th anniversary year since Nippon Valqua Industries' inauguration, we looked back at our history spanning from *Valqua Review* to *Valqua Technology News*. The publication has always maintained its original spirit of contributing to industry. We hope you will understand how that spirit has been inherited. We will strive hard to keep providing the technical information sought by our valued readers. We look forward to continuing to serve you with future editions.

Editorial board of the 90th anniversary special issue of *Valqua Technology News*

Transition of Valqua's technologies and customer value Looking back at the history of *Valqua Technology News* and *Valqua Review*

Since its founding in 1927, Valqua has focused on the research, development, and manufacture of sealing products and sealing materials based on technologies developed in-house.

In the 19th century, Japan imported most of high-class sealing products. After that, mineral oil started to be used as hydraulic oil to replace vegetable oil. Given that synthetic rubber was considered more suitable than natural rubber for use in mineral oil, we developed compounding technologies for synthetic rubber, to allow us to domestically produce sealing products. In this way, we have consistently worked behind the scenes to support domestic industries since before World War II.

Just after World War II, we discovered the existence of fluororesin and decided to utilize its excellent chemical resistance for consumer use. With the goal of domestically molding fluororesin, we imported the powder material in 1951 and started research and testing on processing methods. We proceeded with research and developed our own technologies, marking the first success in fluororesin research in Japan. In the 1950s, the chemical industry started introducing fluororesin widely. We are proud to have supported the growth of the Japanese semiconductor industry as well.

Valqua's products are basic parts of machinery and their range of application expanded rapidly in the postwar period, and yet our products could rarely be seen in action. However, we wanted more people to know about our technologies and products, which we believed would contribute to industrial development in Japan. Therefore, in 1957, we issued *Valqua Review*, a monthly technical journal, as a 30th anniversary project.

Valqua Review aimed to widely disseminate information on our technologies and contribute to social development. Thus, we published articles written by various contributors ranging from customers to academic experts. The journal introduced sealing technologies and various new materials including fluororesin and elastomer. The journal contents attracted considerable attention from readers, especially plant engineers working mainly in the petrochemical industry, which led the post-war industrial recovery, and the publication was highly evaluated.

Thereafter, diverse materials have been created along with developments in various industries, and we too have developed a range of products for different industrial applications. In the 1970s, expanded graphite was introduced as sealing material, and was mainly used for gland packing. Later, it was widely used as a filler for spiral wound gaskets along with fluororesin filler. Following the growth of the petrochemical industry, the semiconductor industry rapidly developed. Fluororubber O-rings, which are resistant to high temperatures in the baking process, were introduced in the semiconductor manufacturing process. Material prices were rising. In parallel, rubber compounding technologies were gradually standardized, and, regarding seals including gaskets, the basic composition was established. In a sense, the technologies reached maturity.

Therefore, for sustained growth it was necessary to expand into growing markets and to develop novel technical concepts.

Regarding semiconductor manufacturing processes, a type of fluororubber that emits less gas and is resistant to varying ambient plasma was required in line with improved equipment performance. To meet this need, a novel elastomer seal "ARMOR CRYSTAL®" was developed; it was introduced to the semiconductor market in 1998.

At that time, material technologies were significantly changing to meet environmental regulations, particularly those for asbestos.

Consequently, Valqua revamped *Valqua Review* and produced the new quarterly technical journal *Valqua Technology News* in the spring of 2002. The renewal aimed to transform the journal into a better source of information and to offer more customers technical information in new fields and markets including developments in the semiconductor market and various devices, and information on technologies related to the changing social environment.()

New products have new functions that accommodate new technology trends. In response to these technological changes, not only conventional material technologies but also technologies for evaluating the new functions were needed. That is, reliability assurance technologies were required for the new fields and markets.

Conventional products had been supplied based on performance history premised on conventional technologies. However, due to changes such as regulations on asbestos, which forced manufacturers to radically replace main materials and produce alternative products, the alternative products could not be supplied based on performance history, because these new products had no performance history. So, it was necessary to gain social and technical recognition of these products. New technologies were required to replace performance history, namely reliability evaluation technologies for clarifying the essential functions expected of products, evaluating these functions, and assuring their long-term reliability.

In 2006, Valqua launched the general-purpose, non-asbestos sheet "GF300". The development of "GF300" was accomplished thanks to Valqua's legacy technologies: fluororesin processing technologies that Valqua had accumulated over the years and reliability evaluation technologies, in which Valqua had pursued developments in advanced technology fields including the atomic power and aerospace industries.

Recent years have seen a rapid transition not only in product development and functional evaluation, but also toward a safer society. Under such circumstances, the supply of highly reliable products is not enough; more detailed technical information regarding the selection and use of products should be offered to customers. To do so, we should not rely on only conventional technologies and skills transfer, but should establish more systematic training systems for further dissemination and utilization of our fundamental technologies. Regarding long-term reliability evaluation, we need to expand the application of analysis methods to new areas in the future.

Therefore, Valqua decided to become an "H & S company" to drive future growth: "H & S" stands for "H (hard = products)" and "S (soft = seal engineering service)."

Maximization of customer value is essential for transforming into an H & S company. In doing so, we should not prioritize only "hard" technologies. We should also expand our services to even the smallest aspects in the product life cycle including elements closely associated with the product. In doing so, we believe we can transform into a more rounded seal engineering company.

One example is the Seal Training Center (STC). In 2014, STC was at our Nara Office (Nara) and MRT Center (Machida, Tokyo).

Malfunctions of bolted flange joints due to improper selection of gaskets and improper tightening of bolts remain unresolved. As generations change, problems associated with the transfer of techniques and skills from skilled engineers or workers to younger generations are emerging. Each plant is taking actions to tackle these problems, but providing education and training within each company also poses various challenges to be solved.

To solve these problems, we should strive harder to disseminate sealing technologies. In addition, regarding personnel training, we should offer systematic education and lectures including practice training to personnel ranging from operators to operation managers and supervisors. This will enable us to maintain and improve acceptable technologies and technological levels.

Personnel training based on these ideas has already become the norm in Europe and the U.S. The bolt tightening method for bolted flange joints was standardized as EN1591-4 in Europe and ASME PCC-1 in the U.S. Also, a technical certification system for bolt-tightening based on these standards is being started. Our Seal Training Center (STC) observes these standards, and offers hands-on training for seal operations. It also incorporates novel technical findings both in Japan and overseas.

Such approaches attract the attention of many users and are also highly evaluated by plant owners and people in the engineering field.

Our future corporate mission is not only to develop new products and supply them to the market but also to offer various solution services for sealing and practical applications.

We will continue to provide the latest technical information to meet the needs of all customers through *Valqua Technology News*.

Senior Fellow　Takahito Nishida

Contribution: Congratulations on the 90th Anniversary Special Issue of Valqua's Establishment

Let me express my sincere congratulations on the 90th anniversary special issue. I have enjoyed reading this journal since 1993 when the journal's name was different from the current Valqua Technology News (VTN). At that time, I met an engineer of Valqua for the first time, when he came to my workplace at University of Yamanashi to learn about the trends of gasket and sealing technologies in Europe and the U.S. I am also honored that VTN has published my articles several times.

At that time, non-asbestos gaskets were being developed in the U.S., Canada, the U.K., and France, but fugitive emissions occurred when the working fluid was a gas. Therefore, researchers were requested to urgently do the following: introduce new gasket factors, collect data, and, using the gasket factors and collected data, establish methods for designing bolted flange connections which met the standard leakage rate.

From 1989, I made presentations on my paper at the Pressure Vessels & Piping (PVP) Conference of the American Society of Mechanical Engineers (ASME) every year. I also participated in the Bolted Flange Connection Committee (BFC) of the Pressure Vessel Research Council. So, by chance, I grasped the global trends and direction of research. The chairperson of BFC at that time was Dr. K. H. Hsu, and I had kept a summary of his resume (on a slide), so I gave a copy to the engineer. After exchanging information with the engineer several times, I asked Mr. Jim Payne, a central figure in BFC's research of bolted flange connection design, about the employee's questions while at the PVP Conference in 1994. He gave me his answers which I simply conveyed to the engineer.

Before asbestos regulations were introduced in 2008, asbestos gaskets had been the most widely-used gaskets in Japan. Although I don't precisely remember the R&D situation for non-asbestos gaskets at that time, Japan was probably isolated and in a very different environment from that in Europe and the U.S. However, amid such environment, the staff at Valqua studied new technologies in the U.S. based on the information summary which I had handed to the engineer and they prepared for the development of non-asbestos gaskets in Japan.

Around 1997, I was appointed chairman of the Flange-Gasket Committee of the High Pressure Institute of Japan, so I had more opportunities to learn about research on the sealing performance of gaskets and bolted flange connections. In 1996, 1998, and 2000, engineers of Valqua participated in the PVP Conference and gave presentations on their work. Mr. Payne of the U.S. had high expectations for their presentations on gasket technologies. I also conducted several joint researches with Valqua during my tenure at University of Yamanashi and Hiroshima University.

Valqua also received the attention of researchers from a major US petroleum company when Valqua more recently presented papers at the PVP Conference related to our joint research on the analysis of the mechanical behavior and sealing performance evaluation of bolted flange connections with PTFE gaskets, as well as the stress analysis and sealing performance evaluation of bolted flange connections with larger nominal diameter.

The major research trends in Europe and the U.S. at present appear to be as follows: to develop techniques for detecting fugitive emission amounts at levels ranging from 10^{-7} to 10^{-9} Pa m^3/s and, due to environmental problems, to establish methods for the design and construction of bolted flange connections. In addition, research and technological development of not only gaskets but also overall bolted flange connections for establishing the following methods are required: a method to design bolted flange connections and to develop gaskets for high-temperature environments when a combined external load is applied; an efficient and reliable multiple-bolt-tightening method; and a method for preventive design and assembly for bolted flange connections with larger nominal diameter. That is, the design and assembly of bolted flange connections including a more reliable bolt tightening method than the standard leakage rate is required.

I believe that Valqua will continue to lead the world in the development and expansion of sealing technologies.

Professor Emeritus at the University of Hiroshima Toshiyuki Sawa

Contribution:Evolving Gasketing and Sealing Technologies

Let me express my congratulations on the 90th anniversary year since the establishment of Nippon Valqua Industries, Ltd. I greatly respect everyone who has supported industry through the development and manufacturing of seal products for as long as 90 years. Valqua's long history shows the importance of seal products, and gaskets in particular, for industry.

I started research on gaskets about 20 years ago when I was transferred to the National Institute of Technology, Numazu College. At that time, research and standardization of the fugitive emissions of gaskets was led by the Pressure Vessels Research Council in North America. This is when I started a joint study on the leakage characteristics of gaskets together with Mr. Nishida, currently a senior fellow, Mr. Asahina, currently an executive officer, and others. In the course of the study, we discovered that the leakage amount of a gasket is closely associated with its compression amount. It was already known that the amount of leakage differs at the time of compression and unloading of gaskets even when the same contact pressure is applied to the gasket. However, we found that the correlation between a gasket's leakage amount and compression amount can be uniquely determined. Our finding was a significant achievement for evaluating the leakage characteristics of a gasket.

We presented the results of this study at domestic and international academic conferences. Also, Valqua Technology News featured our results in 2005. Our method for determining the leakage amount of a gasket by using its compression amount was incorporated in JIS B 2490 "Test method for sealing behavior of gaskets for pipe flanges" in 2008. I am proud to have contributed to society through the inclusion of our collaborative results in JIS.

Today, asbestos is no longer used in gaskets; gaskets are mainly made from heat-resistant fluororesin. These gaskets have excellent sealing performance and the leakage amount is much less than that of joint-sheet gaskets. Fluororesin gaskets can dramatically reduce gas emissions from flanged joints of piping systems in plants including chemical plants into the environment. This low-emission property contributes to environmental protection. Methods for designing flanged joints were developed around 1940, and are still based on gasket factors. Although problems associated with the gasket factor (m, y) have been pointed out, the gasket factor is still used most frequently. However, the design method is now transforming into a more reasonable design method for flanges which appropriately takes the gasket's leakage characteristics into account.

I am sure Valqua will continue to develop highly functional gaskets and prosper also as a supplier of comprehensive sealing technologies for flanged joints toward the coming 100th anniversary.

Professor at Mechanical Engineering, National Institute of Technology, Numazu College

Takashi Kobayashi

Contribution: Congratulations on the 90th Anniversary Year of the Founding

Valqua Review was inaugurated in 1957 to promote and introduce our technologies under our core principle of value and quality, from which our company derives its name. We take pride in our technologies and have worked hard to develop various seal products ahead of other companies.
In this 90th anniversary issue, I would like to share with our valued readers a summary of the products we have developed.
I joined Valqua in 1958 as Japan was emerging from the post-World War II era and as the economy and society were starting to prosper. At that time, the energy source was switching from coal to oil. Accordingly, petrochemical complexes were built all around Japan and the production of petroleum derivatives started, creating a need for new seal products.

• Fluororesin Products
Fluororesin was developed in the U.S. and has unconventional heat and chemical resistance. We noted the benefits and aimed to incorporate fluororesin products into our product lines. To achieve this goal, we sent our employees to the U.S. in 1956, where they learned processing techniques, then we started to process fluororesin in our Atsugi plant for the first time in Japan. Thereafter, we started to develop and market chemically resistant fluororesin lining pipes and lining vessels. Also, we made use of the electrical characteristics of fluororesin, especially its high-frequency properties, to produce electric parts, and started manufacturing and marketing these parts.
However, since fluororesin is a resin, it was difficult to use it on its own as a seal product. So, we combined fluororesin with rubber, felt, and metal; designed the shapes of fluororesin products; and then produced and marketed seal products (including envelop gaskets). We received DuPont's prestigious Plunkett Award for our remarkable development of fluororesin products, and received the award again later.

• Lineup of Rubber Products
Regarding rubber, which is a seal material, new types of rubber material were developed and marketed one after another. Accordingly, training sessions on these newly developed rubbers and rubber additives were held, taught by various academics. We were lucky to attend such sessions to learn about techniques for rubber. To fully investigate whether each of these various rubber materials was suitable for use as a seal material, we combined each rubber material, vulcanized the combined products, soaked them in various chemical solutions, analyzed the changes in swelling rate and physical properties, and tabulated the results to determine whether the material could be used or not.

• Alternative Product to Asbestos
The major seal material since before WW II had been asbestos. Thanks to its heat resistance, chemical resistance, and low cost, asbestos had been used not only for various seal materials but also as a construction material. However, it was found that asbestos damages the respiratory organs, so its use started to be banned. The ban was then extended to the seal industry, so we needed to

develop non-asbestos products. The staff in our development department struggled to find appropriate substitutes for asbestos for joint sheet, Valquatight Gasket (spiral wound gasket), gland packing, and others. But thanks to their efforts, substitute materials were found including carbon fiber, foamed carbon, and aramid fiber. After repeated development and testing, our lineup of alternative products was finally completed.

• Products Associated with the Nuclear Power Industry

Around 1970, nuclear power stations started to be built throughout Japan under the energy policy of that time. Accordingly, seal materials for the nuclear power industry were developed one after another. Metal bellows, flectors, rubber boots, foamed-carbon products, inflation seals, and other products were developed. Other industries then started to use these products; flectors were often used as flexible joints for ducts of desulfurization equipment and NOx removal equipment.

• Automobile Industry

We have manufactured industrial braking systems since our establishment. As automobile technologies changed, we led the way and developed unique products including a clutch facing for automobiles, sealing-rubber products for electrical components (seals for harnesses), and oil sheet gaskets.

• Mechanical Seals

As a pioneering company, we have also developed and manufactured industrial mechanical seals domestically, and have focused on developing the main seal materials including mechanical seal materials for car coolers. We have also produced seal materials with excellent sealing properties which can be used instead of gland packings.

• Valve Production

We have long produced piston valves which used packings as seal materials. After the production of fluororesin started, we developed ball valves which used fluororesin as a seal material for the chemical industry and other industries, and started production. Many chemical firms have since used our ball valves. Also, for highly corrosive chemical solutions, we developed various lining valves made from fluororesins, and also developed our unique, long-life, cylinder-type valves which can open and close rapidly. These valves have been used in many iron-making machines and gas generators.

• Development of Corrosion-resistant Seal materials

Seal materials always come in contact with metals. When metal-corrosion problems at the contact surface occurred in Japan, the need for corrosion-resistant seal materials emerged. So, we worked with universities and other institutions to develop corrosion-resistant gaskets and packings. During these projects, we identified corrosive elements in seal materials and optimized the mix of ingredients and sealing properties ahead of other companies. Our pioneering achievements greatly influenced the concept of seal materials thereafter.

• Development of Seals for Construction Machinery

During the construction boom, construction machinery was produced one after another. Most machines were hydraulic-driven, and seals were used for most of the hydraulic machinery. Conventionally, such seals used to be fabric-filled packings, in which rubber had been reinforced with canvas and other fabrics. However, after the development of high-pressure-resistant urethane rubber, urethane U-packings became the main type. Urethane rubber has extraordinary mechanical strength and abrasion resistance and is ideal for high-pressure hydraulic packings. So, we conducted functional tests of urethane packings and decided to produce and market the product as an alternative to fabric-filled packings. At that time, we established Japan Elastollan Co., Ltd., a urethane manufacturer, to produce urethane. Urethane rubber has rubber elasticity and can be used for injection and extrusion molding. So, it started to be used for various purposes, including sport shoes and machine parts. Around 1955, even a new plant had no experience in developing seals, so functional and verification tests were required in order to develop seal materials. We could not build a plant only for these tests, so we made a testing machine to conduct basic tests. However, eventually we needed to conduct verification tests at actual plants. Fortunately, customers in those days let us conduct the final tests at their plants and collect data. Thanks to their cooperation, we could establish our seal products. We are deeply grateful for their steady support and will continue to appreciate them.

This article described the transition of our seal product lineup and development activities since around 1955. I hope it was interesting.

NIPPON VALQUA INDUSTRIES, LTD. former Managing Director (Technical Manager)

Takao Iwane

Contribution: Congratulations on the Publication of the 90th Anniversary Special Issue of *Valqua Technology News*

Let me express my congratulations on the publication of the 90th anniversary special issue of *Valqua Technology News* to all the staff of the technology-development department of Nippon Valqua Industries, Ltd. I used to work in that department, and so I am happy to see this anniversary.

In the research and development department, I used to study fluororesin. At that time, fluororesin was introduced as a material for Valqua's seal products. I also conducted basic research, although I probably spent longer in applied research and development.

In this article, I would like to share some of my experiences while working on application development.

Thanks to its distinguished characteristics, fluororesin is used in many industrial fields including for semiconductor manufacturing equipments, chemical plants, and automobile-related and electronic components. Also, domestically manufactured fluororesin electric cable (Valflon electric cable) was used to explore locations for geothermal power generation, a new energy.

In development studies for geothermal power generation, cables for underground surveys are required. These cables are used in volcanic areas, and so naturally, excellent heat resistance is required to tolerate the high temperatures found underground during exploration. At that time, the best cable for this purpose was tetrafluoroethylene resin electric cable.

However, despite its excellent functions, tetrafluoroethylene resin was difficult to process, so we worked hard to devise a way to manufacture cables of several thousand meters. After great difficulties, we adopted tape-wrapped cable.

We attached various sensors to the end of the cable. Then, along with electricians and the cable, we explored trackless mountains in a volcanic zone. After safely arriving at the planned location for generation, we measured the temperature of hot hydrothermal water present several meters below the ground along with the staff at the geological survey station. This was all a long time ago (about 40 years?) .

I also experienced on-site development activities. Once, we worked on developing components including a chemical-resistant heater and solving problems at a production line of a major semiconductor manufacturer which went on to lay the foundation of the current IT society. On another occasion, we were posted to a steel-manufacturing site, where we were surrounded by strong acids and alkalis contained in tanks lined with chemical-resistant fluororesin, piping inspectors lined with chemical-resistant fluororesin, and other equipment. We proceeded with development in this tough environment. These hard experiences now provide good memories.

Thanks to the support from many technology-development staff, we could carry out various application development projects. As a result, we received the Plunkett Award four times. DuPont, an American manufacturer which was the first to start producing fluororesin, gives the award to a group which has done excellent work in application development. Our achievement was the culmination of continuous efforts by our excellent R&D staff and related parties, so I was delighted to win the awards.

As we celebrate the prosperous 90th anniversary year, I look forward to further achievements from the technology-development department which will help Valqua to expand toward the coming 100th anniversary.

NIPPON VALQUA INDUSTRIES, LTD.　former Managing Director (Technical・Business　development)
Yoshiaki Mori

Contribution: Memories of My Tenure as CTO

Since joining Valqua as an executive officer in charge of development of products and merchandise in November 2003, I have been working here for as long as 15 years including the last couple of years as a technical adviser. During my 15-year career at Valqua, I worked as CTO for 4.5 years from April 2010. Dr. Igarashi, my predecessor, has a broad knowledge and insight in chemistry ranging from basic to applied chemistry. I am grateful for all his advice during my CTO days. Since I was focused on practical techniques, his advice was invaluable. As his style as CTO was easygoing, I felt huge pressure when I was appointed as CTO. That was the first time I truly realized and admired his elegant business style as CTO.

One of my most impressive memories is my first business trip to the Nara Office on my first working day at Valqua. The president at that time asked Mr. Joya, a managing director, to show me around the office. I also had a chance to give a 'policy' speech in front of all the staff of the office. I remember that I emphasized how R&D should contribute to company earnings. These days, the idea that company R&D should contribute to company earnings has become common, but at that time, it was considered that R&D should be pursued with a medium- to long-term vision. This approach was like that of public-sector research institutions. This situation was not limited to Valqua; many companies had the same idea. So, when I emphasized profit-oriented R&D in my first policy speech, the researchers were reluctant to accept it. My idea was too audacious at that time.

Meanwhile, the business trip was just one day, and I remember it well. Because the Nara Office is located in the countryside, I had to change trains at Kyoto to the Kintetsu Line to get to the Nara Office (it's quicker to visit Shanghai!). Thereafter, during my tenure as CTO, I visited Nara many times, but unfortunately I have never visited the area near the office other than Kashiharajinguu. I hope to have the chance to travel there again.

In R&D, the creation and utilization of human networks are important along with personnel training. Especially, in China, close cooperation with academics is indispensable in research and development. At that time, I had conducted joint studies with universities in Japan and Western countries, but not with Chinese academics. In Japan, there was much discussion as to the roles of researchers at public institutions including universities in terms of contributing to society. So, we came to stipulate very specific results for the joint studies in advance. In contrast, there was no such discussion in China. When we explained the expected results to Chinese academics and tried to set goals for an R&D program, they balked. This made me realize that we need to seriously consider social and cultural backgrounds.

Recently, widely-applicable technological seeds are increasingly likely to come from totally different fields than in the past. So, it is important for us to open the door for research and to deepen communication with other companies and other R&D institutions. This gives researchers a global perspective which allows research institutions to continue evolving into organizations which can create great value. Such a pursuit of continuous evolution is our never-ending challenge.

NIPPON VALQUA INDUSTRIES, LTD. former CTO **Hiroyuki Kuroda**

Types and Application of Filler-added PTFE Materials

1. Introduction

Among plastic-based materials, PTFE offers diverse benefits including heat resistance, chemical resistance, insulation, non-stick, and low friction. Its scope of application is broad: it is used in various fields including semiconductor devices, chemical plants, automobiles, office equipment, and home appliances.

However, PTFE suffers from inadequate abrasion resistance and creep resistance, which are serious disadvantages leading to severe self-damage in the case where PTFE is used in sliding parts like shaft bearings and large deformation in the case where one is used in load-bearing parts. The addition of a different material, namely, filler, can alleviate these problems.

This report described the types, features, and applications of typical fillers.

2. Features

2-1) Modifiable Features

The addition of filler can modify features including abrasion resistance, creep resistance, thermal conductivity, and coefficient of linear expansion. Modified PTFE has approximately 1000 times stronger abrasion resistance, twice the creep resistance, and up to twice the thermal conductivity of pure PTFE. The optimal filler should be selected depending on the desired modification.

2-2) Types of Filler

Typical fillers include inorganic fillers such as glass fiber, graphite, molybdenum disulfide, and bronze. Organic fillers are also used.

The features of each filler-added PTFE are described below.

○ Inorganic fillers

● Glass fiber

Glass fiber has little effect on chemical and electrical properties. Glass fiber-added PTFE has approximately twice the compression creep resistance and approximately 1000 times better abrasion resistance than pure PTFE. These features make glass fiber-added PTFE ideal for improving abrasion resistance. The color is white, which makes it easy to use. However, it might break a counterpart shaft when used for shaft bearings.

● Graphite

Graphite improves creep resistance and reduces initial wear and starting resistance of PTFE. Graphite-added PTFE has excellent thermal conductivity and chemical resistance. It is less abrasive to the counterpart material, so it is economically efficient, although its abrasion resistance is not excellent.

● Carbon fiber

Carbon fiber-added PTFE has excellent compressive

Table1 Types and features of fillers [3)]

Filler type	Identifying symbol	Characteristics
Glass fiber	15%…2K0 20%…2N0 25%…2T0	Excellent abrasion resistance Excellent electrical characteristics Attached by alkali Poor abrasion resistance in water
Glass fiber + graphite	20%+5%…2N1	Excellent creep resistance Improves sliding properties
Glass fiber + MoS_2	15%+5%…2K7	Excellent creep resistance and compression strength Improves sliding properties Excellent electrical insulation
Graphite	15%…1K0	Excellent sliding properties Does not attach to soft opposite materials
Bronze	60%…3M0	Excellent creep resistance and compression strength Excellent heat conductivity
Bronze + carbon fiber	3U8	Excellent sliding properties in oil
Carbon graphite	25%…6T0 33%…6P0	Excellent creep resistance and load bearing properties at high temperatures
Carbon fiber	10%…8H0	Excellent sliding property in water Excellent creep resistance
Organic filler	9A1 9A2 9B1	Does not attach to soft opposite materials Stable sliding properties Excellent creep resistance and compression strength

Table2 List of filler-added PTFE properties [3)]

Item	Unit	ASTM measuring method	Filler identifying symbol										
			Pure PTFE	2K0	2N0	2T0	2N1	2K7	1K0	3M0	6T0	6P0	8H0
Filler content	Amount %	–		Glass fiber 15%	Glass fiber 20%	Glass fiber 25%	Glass fiber 20% Graphite 5%	Glass fiber 15% MoS2 5%	Graphite 15%	Bronze 60%	Carbon/ graphite 25%	Carbon/ graphite 33%	Carbon fiber 10%
Specific gravity		D792	2.1	2.23	2.24	2.26	2.23	2.29	2.17	3.91	2.10	2.05	2.09
Tension	MPa	D638	30.9	23	20.6	18.6	14.7	18.5	16.0	18.5	17.5	13.5	20.0
Stretch	%	D638	400	320	300	280	235	280	230	215	55	15	200
Compression creep 60min MD	%	D621 (23℃ 13.7MPa)	–	6.6	6.0	5.2	5.8	4.6	5.2	3.2	3.4	1.9	6.8
Compression creep 60min CD	%	D621 (23℃ 13.7MPa)	–	10.3	9.4	8.3	7.0	5.4	5.8	3.5	3.6	2.6	9.0
Compression creep 24h MD	%	D621 (23℃ 13.7MPa)	14.3	9.6	8.7	7.9	8.0	6.5	6.9	4.5	4.5	3.7	9.4
Compression creep 24h CD	%	D621 (23℃ 13.7MPa)	16.7	14.3	13.1	12.4	9.8	7.8	8.0	4.9	4.9	3.7	13.2
Compression creep Permanent deformation (after 24 hours) MD	%	D621 (23℃ 13.7MPa)	7.9	5.3	4.9	4.5	3.9	3.0	3.3	2.0	2.0	1.7	5.1
Compression creep Permanent deformation (after 24 hours) CD	%	D621 (23℃ 13.7MPa)	8.4	7.6	7.5	7.5	5.2	4.0	4.5	2.3	2.3	1.8	7.1
Compression creep 60min MD	%	(150℃ 19.6MPa)	51.8	52.4	51.3	50.7	36.8	45.5	43.0	40.4	35.0	32.4	33.7
Compression creep 60min CD	%	(150℃ 19.6MPa)	–	–	–	–	–	–	–	–	36.1	35.6	38.7
Bending strength 0.2% offset CD	MPa	D790	5.6	3.9	4.1	4.2	8.3	8.5	6.0	8.0	9.6	–	8.3
Bending strength Modulus of elasticity CD	MPa	D790	340～620	1,550	1,730	1,900	1,540	1,690	–	1,380	1,190	–	1,030
Compression strength 0.2% offset MD	MPa	D695	7.6	11.6	12.3	13.1	10.0	12.9	10.2	11.9	11.2	–	8.7
Compression strength 0.2% offset CD	MPa	D695	–	8.9	8.9	8.9	10.1	12.7	10.7	12.2	8.4	–	9.6
Compression strength Modulus of elasticity MD	MPa	D695	410	690	760	830	980	970	–	770	1,050	–	770
Compression strength Modulus of elasticity CD	MPa	D695	–	600	650	700	960	830	–	800	840	–	770
Hardness	Durometer "D"	D2240	55	60	62	63	64	65	61	70	67	68	64
Impact strength (izod)	J/m	D256	155	144	129	117	154	159	140	10.5	–	–	168
Heat conductivity	W/(m·K)	Cence Fitch	0.24	0.37	0.40	0.45	0.20	0.33	0.45	0.47	0.43	–	0.19
Linear expansion coefficient 25～90℃ MD	10^{-5}/℃	D696	–	14.2	13.4	12.6	13.5	15.0	12.6	9.7	8.5	–	13.4
Linear expansion coefficient 25～90℃ CD	10^{-5}/℃	D696	12.2	10.6	10.2	8.3	9.0	6.3	7.9	7.8	7.2	–	9.9
Linear expansion coefficient 25～150℃ MD	10^{-5}/℃	D696	–	15.1	14.2	13.2	13.1	15.8	13.5	10.3	9.4	–	14.5
Linear expansion coefficient 25～150℃ CD	10^{-5}/℃	D696	12.6	10.9	10.3	8.6	9.0	6.4	8.5	7.9	7.7	–	10.0
Linear expansion coefficient 25～200℃ MD	10^{-5}/℃	D696	–	16.3	15.4	14.4	13.9	17.3	14.6	11.4	10.6	–	15.7
Linear expansion coefficient 25～200℃ CD	10^{-5}/℃	D696	13.7	12.3	11.4	9.7	9.9	6.9	9.2	9.0	8.5	–	11.1
Linear expansion coefficient 25～260℃ MD	10^{-5}/℃	D696	–	18.5	17.7	16.8	15.9	20.0	17.6	14.0	13.5	–	18.2
Linear expansion coefficient 25～260℃ CD	10^{-5}/℃	D696	16.4	14.8	13.4	11.9	11.7	8.0	10.8	10.4	9.7	–	13.1
Water absorption rate	%	D570	0	0.015	0.014	0.013	0.016	0.010	0	0	–	–	–
Limit PV value 0.1m/s	MPa·m/s		–	0.6	0.7	0.7	0.8	0.8	0.9	0.6	1.0	1.0	0.9
Limit PV value 0.5m/s	MPa·m/s		–	0.7	0.9	0.9	1.4	1.5	1.4	1.0	1.4	1.5	1.5
Limit PV value 5.0m/s	MPa·m/s		–	1.1	1.2	1.2	1.8	1.8	1.3	0.6	1.8	1.9	1.8
Coefficient of abrasion (in air, after 50 hours)	$\frac{cm \cdot s}{MPa \cdot m \cdot h} \times 10^{-5}$	Measuring with Matsubara-type test instrument	7,100	5	7	7	7	6	9.8	13	8	13	6
Coefficient of abrasion (in water, after 50 hours)	$\frac{cm \cdot s}{MPa \cdot m \cdot h} \times 10^{-5}$	Measuring with Matsubara-type test instrument		5,500	–	5,100	–	–	470	–	20	26	20
Coefficient of dynamic friction (after 50 hours)		P=0.69MPa V=0.5m/s	–	0.39～0.42	0.29～0.35	0.50～0.54	0.30～0.32	0.29～0.31	0.22～0.25	0.12～0.17	0.31～0.37	0.31～0.35	0.27～0.30
Coefficient of static friction		P=3.4MPa	0.05～0.08	0.10～0.13	0.10～0.13	0.10～0.13	0.08～0.10	0.08～0.10	0.08～0.10	0.08～0.10	–	–	–

strength, creep characteristics, and abrasion resistance. These features are significantly improved in the high-temperature region above 200°C. It also has excellent sliding characteristics and good chemical resistance in water. It offers excellent sliding characteristics in fluids of low lubricity including acid and alkaline fluids.

● Molybdenum disulfide

Molybdenum disulfide-added PTFE has improved creep resistance and lubrication. It does not degrade electrical insulation, so it can be used for electrical usages. However, molybdenum disulfide is rarely added to PTFE as a single filler; it is added along with glass fiber and bronze.

● Bronze

Bronze-added PTFE has significantly improved abrasion resistance, compressive strength, creep resistance, hardness, and dimensional stability. It tends to retain oil on sliding surfaces, and has excellent abrasion resistance under oil lubrication, so it can be used for oil lubrication usages. However, it is important to note that bronze-added PTFE is not suitable for electrical and chemical applications.

○ Organic fillers

● Polymide-based resin

Polymide based resin-added PTFE is beneficial in the case where soft metal moving parts that are likely to be damaged by carbon-added or graphite-added PTFE are used as a counterpart material.

● Polyphenylene sulfide-based resin

Polyphenylene sulfide-added PTFE has creep resistance and dimensional stability.

● Aromatic polyester-based resin

Aromatic polyester based resin-added PTFE has improved mechanical characteristics including compression and bending, as well as stable sliding.

Like these examples, there are many types of filler. An appropriate filler should be selected depending on the usage conditions including load, sliding speed, lifespan, frictional conditions, counterpart material, linear expansion, corrosion resistance, and electrical properties.

Although pure PTFE is white, some fillers turn PTFE black or dark brown. These conditions should be considered depending on the position of use and the application.

3. Conclusion

PTFE has excellent chemical characteristics, sliding properties and non-stick, making it suitable for shaft bearings and sliding parts. In the case where filler is added to PTFE, the PTFE gains improved frictional and creep characteristics, making it suitable for mechanical purposes.

The type of filler determines the improvement in characteristics of PTFE. We hope the above explanation of various fillers will help our readers when selecting a material.

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Accuracy and Mold Direction of PTFE Products

1. Introduction

In general, the accuracy of PTFE product is not easy to control because its coefficient of linear expansion is higher than that of metals, and its one of volume transition temperature is around room temperature causes volume changes approximately 1 to 2%. Moreover, thin-walled PTFE products are known to be difficult to machining because not only PTFE is flexible and elastic material, but also residual stress remains after molding sometimes deform due to frictional heat generated during the machining process or due to aging after machining. Such deformation could influence dimensional accuracy.

Regarding processing accuracy, PTFE products are sometimes required the same permissible dimensional tolerance as for a metal material. In such cases, the characteristics of PTFE described above could cause troubles between users and manufacturers. With this background, this report explains the processing accuracy of PTFE.

2. General Permissible Dimensional Tolerance

Table1 shows "General Tolerance for Polytetrafluoroethylene (Machine Cut)" stipulated in JIS K 6884-1971.

This standard stipulates dimensions ranging from 1 mm to 1000 mm for when the material of a PTFE molded product is machined through compression or extrusion molding. The term "general" used in this standard means that the standard can be applied when a blueprint shows no figures or symbols.

When measuring the processing accuracy of PTFE, the following essential characteristics of PTFE should be taken into account:

1. PTFE has low thermal conductivity.
2. PTFE has a high coefficient of linear expansion.
3. PTFE's volume changes markedly (by approximately 1 to 2%) at around 23°C.
4. PTFE is elastic.
5. PTFE sometimes has residual stress.

Table1 General tolerance for polytetrafluoroethylene (machine cut)

Unit: mm

Categories of nominal dimension			Tolerance	
			Grade 1	Grade 2
1	up to	16	±0.1	±0.3
More than 16	up to	40	±0.2	±0.6
More than 40	up to	63	±0.3	±0.8
More than 63	up to	100	±0.4	±1.0
More than 100	up to	160	±0.5	±1.2
More than 160	up to	250	±0.6	±1.4
More than 250	up to	400	±0.7	±1.7
More than 400	up to	630	±1.0	±2.0
More than 630	up to	1000	±1.5	±2.5

From the above, PTFE's dimensional minimum tolerance is approximately ±0.05 mm or half the value stipulated in JIS K 6884 (grade 1), although PTFE's machining accuracy depends on the size and shape.

However, because of PTFE's elasticity, an accurate value could be varied if the end of a measuring device is pushed strongly against a PTFE specimen. For example, a difference of at least 0.1 mm in measured values sometimes occurs depending on how a micrometer is pushed against a PTFE specimen. Users and manufacturers should consider this point.

3. Effects of Annealing Treatment

Usually, free sintering (baking) process is applied to PTFE after compression molding. During sintering, PTFE's internal stress could be decreased compare with molded products with coining process (a process in which a material is sintered in a mold and then cooled under pressure) whose outer layer is quenched. However, annealing* treatment is applied to the material in case high dimensional accuracy is required or the product shape is complex.
Eliminating the internal stress generated during molding process is an effective way to improve dimensional accuracy and to prevent from its change over time.

*Annealing: A procedure in which molded products are slowly cooled at a given temperature to remove internal stress generated by heat or mechanical stress.

4. Surface Roughness

As stipulated in General Tolerance for Polytetrafluoroethylene (Machine Cut), material characteristics should be taken into account when setting a surface-roughness value.
Since resin is affected by heat during machining on the surface and has elasticity, the surface-roughness value could not equal to the machined metal surface.
Generally, a difference in the finish of surface roughness is caused by the machining conditions including rotational and feeding speed and cutting tools (blades).

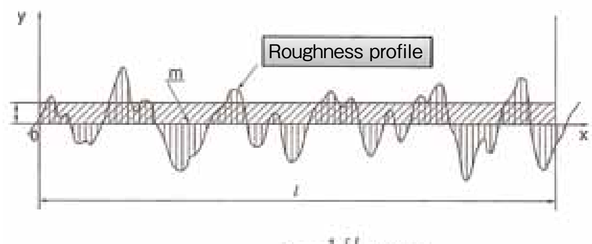
Table 2: Standard values of surface roughness of PTFE
Figure 1: Calculated average roughness (Ra)
Figure 2: Maximum peak (Rmax)
Figure 3: A machining method for round bars and sleeves
Figure 4: A machining method for sheet (plate material)

Table2　Categories of roughness

New JIS symbol		Former JIS symbol		Applicability standard for machining
Symbol	Arithmetical mean roughness	Symbol	Maximum roughness	
√	12.5 to 25 a	▽	50 to 100 S	Acceptable
√	3.2 to 6.3 a	▽▽	12.5 to 25 S	Acceptable
√	0.4 to 1.6 a	▽▽▽	1.6 to 6.3 S	(Conditionally acceptable, in the case of sheet)
√	0.012 to 0.2 a	▽▽▽▽	0.05 to 0.8 S	Unacceptable

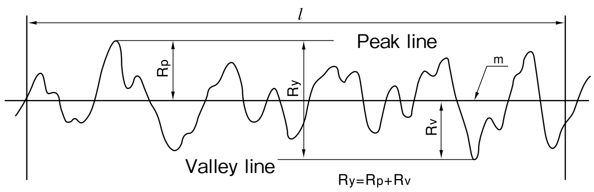
(Unit: μm)

The comparison of the two symbol types (new and former JIS symbols) shown in Table 2 is not strictly precise; it is shown for convenience. Even today, many companies continue to use the former JIS symbols.
The former symbols were introduced approximately 60 years ago, and so are well known. It will take time for the new symbols to become known among peripheral manufacturers. In addition, in the case of functional parts, existing techniques tend to be followed. Therefore, it is important to understand the relationship between the new and former symbols.



$$R_a = \frac{1}{l}\int_0^l |f(x)|\,dx$$

Figure1　Type of surface roughness: calculated average roughness (Ra)



Note: In calculating Ry, only the average roughness profile area in reference length should be used, because too high or low peaks might be caused by abnormal reason such as scratch.

Figure2　Type of surface roughness: maximum peak (Rmax)

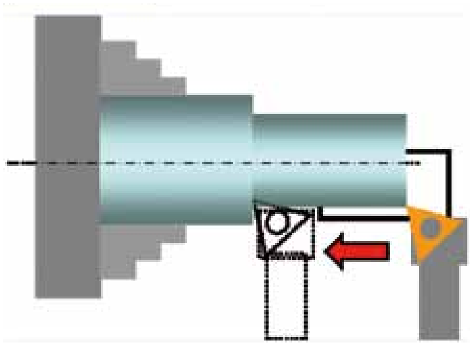


Figure3 Machining of outside diameter

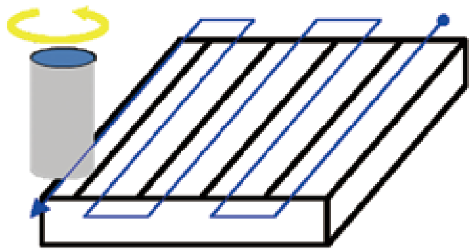


Figure4 Machining of a surface

5. Direction of Molded Products

Molded PTFE products have various directions depending on their molding methods, and the direction influences the physical properties. One of the common molding methods for PTFE is the compression molding method, as shown in Figure 5.

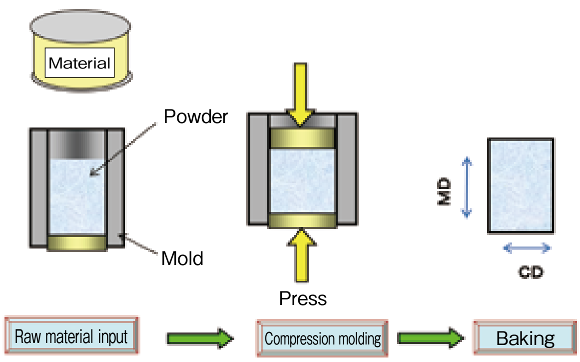


Figure5 The compression molding method

In the compression molding method, the material is placed in a mold and force is applied from both above and below the mold to press the material together. This generates directionality. The direction toward the compressed side in the material at the time of molding is called the molding direction (MD), while the direction perpendicular to MD is called the cross-sectional direction (CD).

Some PTFE materials are filled PTFE whose material is mixed with filler. Since fibrous filler orients during molding, and has markedly different physical properties from those of PTFE, filled PTFE should be designed and used with caution.

The following are characteristics that are changed in filled PTFE.

Compression-creep characteristics:

The MD value becomes greater than the CD value.

Tensile strength and elongation:

MD tensile strength becomes greater than CD tensile strength. CD elongation becomes greater than MD elongation.

Coefficient of linear expansion:

The MD value becomes greater than the CD value.

When material shapes are sleeves and rods, the molding direction can be visually confirmed, and so the processing can be started based on the direction. However, when the material shapes are plates and complex processing is required, it is necessary to visualize the direction including marking the direction during the initial processing stage.

6. Conclusion

PTFE is chemically inactive, has excellent chemical resistance, can be used at a wide range of temperature, and has the lowest friction coefficient among solid materials, and so has been used for various purposes. Also, PTFE is much easier to machine than metals. It is also relatively softer than other resins and has good affinity when combined with other materials for use.

Recently, many PTFE products have also been used in the precision-instrument industry, and so stricter dimensional accuracy is required. We will develop machining techniques in line with the accelerating progress of machine tools and industrial tools. To do this, we will ask users and manufacturers for their requests for dimensional accuracy and tolerances according to their intended uses.

7. References

1. *Valqua Handbook*, Technology Ver., September 2010
2. *Fluororesin DuPont™ Teflon Handbook*, Du Pont-Mitsui Fluorochemicals Company, Ltd.
3. JIS K 6884-1971

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Correction and apology

VALQUA would like to announce and apologize for a partial correction to "Explanation on PTFE Linear Expansion Coefficient," 3. Example calculation for dimensional correction in VALQUA Technology New Summer No. 31.

Incorrect: Dimensional change

Incorrect: Dimensional change $= 1000 \times (100 - 0) \times 20 \times 10^{-5} = 20$

Correct: Dimensional change $= 1000 \times (0 - 25) \times 20 \times 10^{-5} = -5$

Therefore, the length at 0° C is 995 mm (shrunk).

Introduction and Utilization of Seal Quick Searcher® (SQS) - Gasket Version -

1. Introduction

In 2014, we launched Seal Quick Searcher® (SQS) on our website, which is used to search for available seal products. Through SQS, customers can select industrial seal products and find troubleshooting methods. The website search system is designed for engineers who do not have expertise in gaskets, to allow them to easily find necessary technical information. The website also provides technical information in the desired format.

Since SQS was launched, we have received very positive feedback from customers. The search system is now available in not only Japanese but also English and Chinese.

2. What is Seal Quick Searcher® (SQS) ?

Seal Quick Searcher® (SQS) is a search service that enables users to find our recommended seal products in various ways. When searching for industrial seal products, users can set certain search conditions including not only fluid group & type, temperature, and pressure but also keywords and industries. We have also put our accumulated know-how online in a Frequently Asked Question (FAQ) format. Through SQS, users can calculate bolt tightening force, select an appropriate pressure rating, and search for items equivalent to non-Valqua products, catalogs, and *Valqua Handbook* in real time.

In addition, users can select gaskets based on actual usage conditions. If they use SQS and search for solutions to troubles that have happened at their workplace, the website can offer troubleshooting suggestions. Of course, the system fully covers inquiries about products and conditions, and engineers from all industries can use this service. Basic instructions on how to use SQS are given below; please refer to them when using our website and system.

3. How to Use Seal Quick Searcher® (SQS) ①Search by Fluid Group & Type, Temperature, and Pressure

One of SQS's key functions is the ability to search recommended seal products which meet specified conditions. By using this function, anyone can select gaskets based on fluid group & type, temperature, and pressure. The following pages describe how to search recommended products.

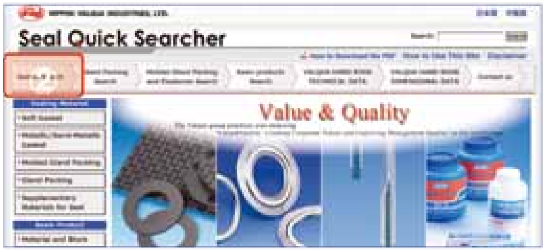
3-1) How to Access Seal Quick Searcher® (SQS)

Click the "Seal Quick Searcher®" button on our website.

①Click the Seal Quick Searcher button.

3-2) How to Access "Gasket Search"

Click the "Gasket Search" button on the "Seal Quick Searcher® (SQS)" page.



②Click the [Gasket Search] button.

3-3) How to Access "Search by Fluid, Temperature, and Pressure"

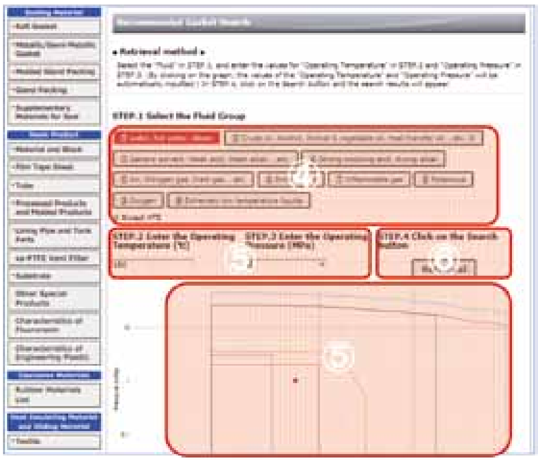
Click the "Search by Fluid, Temperature, and Pressure" button on the "Gasket Search" page.

③ Click the [Search by the Fluid, Temperature and Pressure] button.

3-4) How to Set Search Conditions

Select a fluid group and type, and input temperature and pressure on the "Recommended Gasket Search" page.

Through this intuitive setting of conditions, users can repeatedly search for products with simple mouse operations.



④Select a fluid group.

Note:Inverted red display represents the selected fluid group.

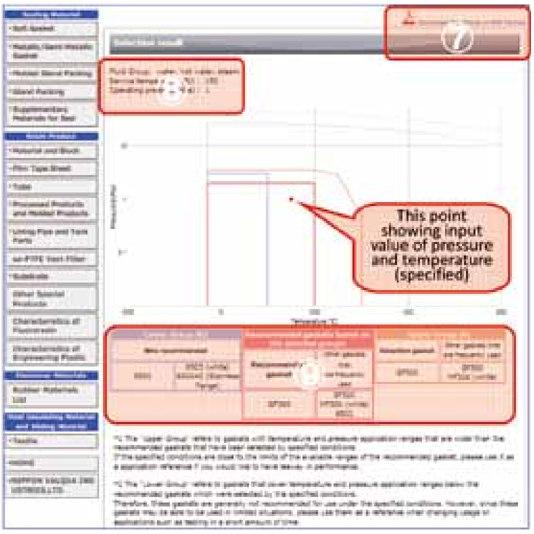
⑤Input temperature and pressure.

Note:To automatically input temperature and pressure, click the desired temperature point on the graph.

⑥Finally, click the [Retrieval] button.

3-5) How to Retrieve and Confirm the Selection Results

After clicking the "Retrieval" button, product search results are displayed below the graph.



⑦The results can be downloaded in PDF format.

⑧The search conditions are displayed.

⑨Recommended gaskets are extracted on the basis of the search conditions. Then the recommended products and its upper and lower groups are displayed.

Refer to the following explanation regarding upper and lower groups.

After clicking the product number displayed in the "Selection Results" section, the page switches to a new page displaying detailed information on the selected product.

Explanation

The term "upper group" represents a group of gaskets covering a wider range of temperature and pressure than the recommended gaskets extracted on the basis of designated conditions. When the designated conditions are near the usable limit of the recommended products and sufficient margin is desired to ensure proper functioning, the upper-group information is a useful reference.

The term "lower group" represents a group of gaskets covering a narrower range of temperature and pressure than the recommended gaskets extracted on the basis of designated conditions. Therefore, generally, lower-group products should not be used when the product is used under the designated conditions. However, a lower-group product may be used under limited conditions, such as for a short period including trial operation or when a change in conditions is planned. The lower-group information may then be a useful reference.

4. How to use Seal Quick Searcher® (SQS) ②Find an Item Equivalent to a non-Valqua Item with Product Number

Users can use information for a non-Valqua product to find the equivalent Valqua gasket.

4-1) How to Access "Equivalent Item Search"

Click the "Equivalent Item Search (Including Product No.)" button on the "Gasket Search" page.

①Click the  button .

4-2) How to Set Search Conditions

Set search conditions on the "Search for items equivalent to Valqua's gasket from other company's products" page.

Either the "Search by entering a key word" or "Search from a product number from a list of other manufacturers" is available.

② The search can be conducted by entering a key word (partial key words are acceptable) .

③ Also, a search can be conducted by selecting a product number from a list of other manufacturers.

Note: "Gasket Search results" displays "Recommended" and "Suggested" products. Each type of product is recommended on the following basis.

Recommended product: A product with similar materials and usable range

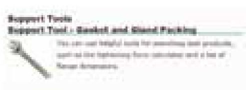
Suggested product: A product which has a partly different color tone and usable range, but can probably be used.

5. How to Use Seal Quick Searcher® (SQS) ③Calculation of Gasket Tightening Force

Seal Quick Searcher® (SQS) provides various information and useful tools for using our products. This section introduces one such tool and explains how to use it to calculate the tightening force.

5-1) How to Access "Support Tools"

Click the "Support Tools" button on the "Seal Quick Searcher® (SQS)" page.

①Click the  button.

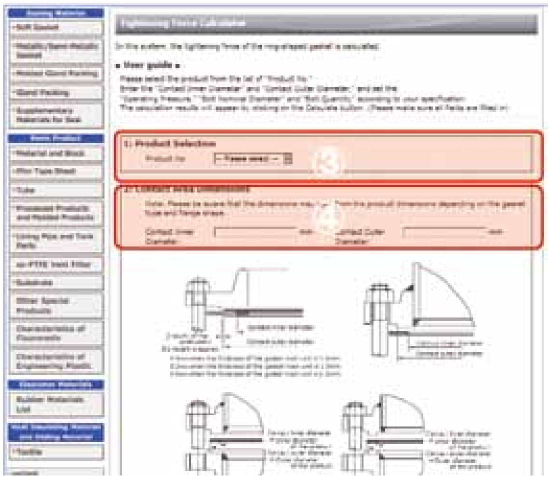
5-2) How to Access the "Tightening Force Calculator"

Click the "Tightening Force Calculator" button on the "Support Tools" page.

②Click the  button.

5-3) How to Set Calculation Conditions ①

Select a product and input the dimensions on the upper part of the "Tightening Force Calculator" page.



③Select the product number of the product which is to be calculated.

④Refer to the illustration and input the internal and outside diameters of the contact zone.
Especially, in the case of spiral wound gaskets, attention should be paid to the position of the gasket's outside diameter when measuring the diameter.

5-4) How to Set Calculation Conditions②

Input the operating pressure, bolt nominal diameter, and bolt quantity, which are to be calculated, on the lower part of the "Tightening Force Calculator" page. Then, click the "Calculation" button.

⑤Input the operating pressure, bolt nominal diameter, and bolt quantity, which are to be calculated.

⑥Finally, click the  button.

5-5) How to Display Calculation Results

The results of the tightening-force calculation are displayed as follows.

Also, the results can be downloaded as a PDF.

⑦The value calculated through the following processes: Wm1 and Wm2 stipulated in JIS B8265 are used in this calculation, are compared, and the higher value is displayed.

⑧The value calculated based on our recommended gasket stress is displayed (in the case of a liquid seal).

⑨The value calculated based on our recommended gasket stress is displayed (in the case of a gas atmospheric seal).

⑩The value calculated based on the allowable gasket stress of the gasket is displayed.

⑪The value calculated through the following processes: The value is calculated according to JIS. Then the obtained value is compared with our recommended stress and the higher value is displayed as the final calculation result.

6. Conclusion

This report introduced some of the functions of our Seal Quick Searcher® (SQS). We hope you will use SQS for your business. We will continue to improve the functions to meet our valued customers' needs.

Toshihiko Enishi
Sales Group
Technical Solution Division

Causes of and Countermeasures for Allophone Trouble in a Piston Seal System for Cylinders

1. Introduction

In recent years, to accommodate requests regarding hydraulic machinery, hydraulic systems have been streamlined by increasing the operating pressure and temperature and reducing the size and weight of hydraulic systems. Accordingly, the performance requirements of hydraulic cylinders including packings for hydraulic cylinders have changed, and so the performance of various packings has been improved.

We have developed a seal system for high-pressure cylinders as a maintenance kit for cylinders for hydraulic shovels in the construction machinery industry. When evaluating actual equipment during the development stage, we found that allophone (stick-slip phenomenon) occurs in cylinders under certain conditions. During allophone of the cylinder, a stick-slip phenomenon occurs at the contact zone of a reciprocating packing, causing abnormal noise and oscillation while the cylinder is moving. Such allophone is a problem of hydraulic cylinders.

This report describes an allophone trouble and its solution. In this particular case, we considered that the allophone trouble was caused by the defective formation of an oil film at the contact zone between the packing and its opposing face, so we designed the packing to improve its ability to absorb the oil film.

2. Example of Packing Structure for Hydraulic Cylinders

Generally, several packing and parts are used in high-pressure cylinders including cylinders for hydraulic shovels. Figure1 illustrated the structure of a high-pressure cylinder.

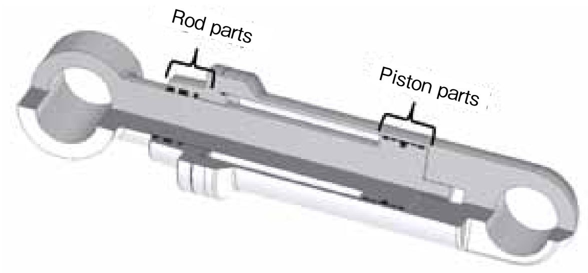


Figure1 Structure of a hydraulic cylinder

2-1) Structure of Seal System in the Rod Segment

The packing used in the rod segment plays an important role in preventing external leakage, and is an important function of cylinders. Figure 2 illustrated the structure of the seal system in the rod segment. Table1 showed the component parts.

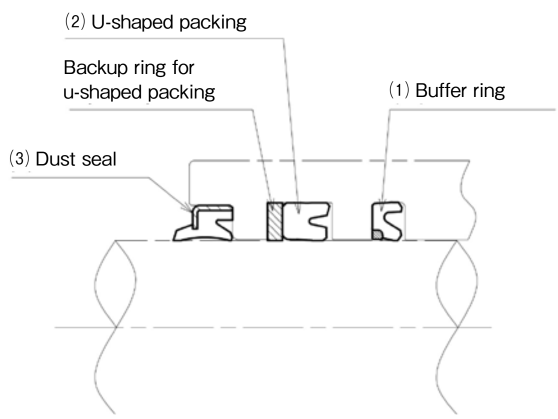


Figure2 Structure of seal system in the rod segment

Table1 List of component parts of the seal system in the rod segment

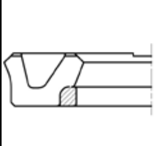
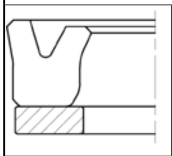
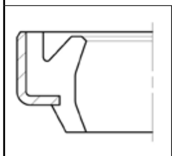
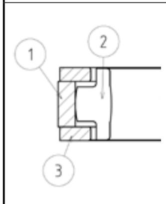
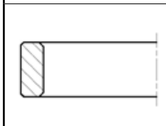
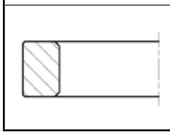
(1) Buffer ring	
	Absorbs the initial high pressure to reduce the strain on the u-shaped packing. The pressure resistance is enhanced by the use of the backup ring in reinforced plastic.
(2) U-shaped packing	
	The main sealing component to prevent fluid leakage. The pressure resistance is enhanced by the use of the backup ring in reinforced plastic.
(3) Dust seal	
	This packing prevents the infiltration of external contaminants such as sand and gravel. It also helps to ensure the prevention of minor leakage from the u-shaped packing.

Table2 List of component parts of the seal system in the piston segment

(4) Piston seal	
	The main component that maintains the oil pressure inside the cylinder for operation. Its components are as follows: ① : Sliding ring to enhance the tribological properties ② : Rubber back ring to ensure tight sealing ③ : Backup ring to support the pressure resistance
(5) Wear ring	
	Functions as a bearing when the piston is in motion. Typically made of cloth-reinforced phenolic plastics.
(6) Sliding ring	
	Prevents the contaminants in the oil from infiltrating the piston seal. Typically made of Polytetrafluoroethylene (PTFE).

2-2) Structure of Seal System in the Piston Segment

The packing used in the piston segment retains hydraulic pressure and provides appropriate thrust and load-retention ability to move the cylinder.[2] Figure 3 illustrated the structure of the seal system in the piston segment. Table 2 showed the component parts.

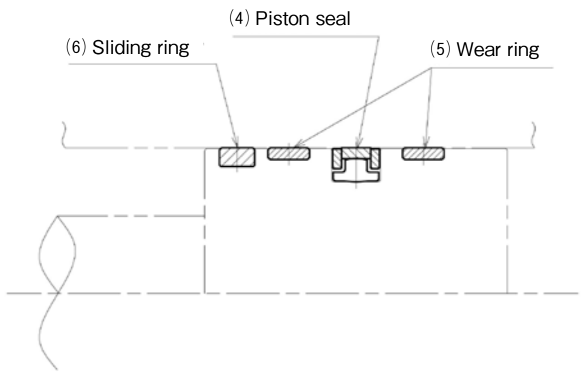


Figure3 Structure of seal system in the piston segment

3. Allophone (Stick-slip Phenomenon)

Static and kinetic frictional forces act on the contact surface between the packing and the opposing face; the two forces are closely interrelated. Sticking is the condition in which static frictional force (starting resistance) acts on the contact surface, and slipping is the condition in which kinetic frictional force (sliding resistance) acts on the contact surface. The stick-slip phenomenon is when both stick and slip conditions occur instantaneously and cyclically on the contact surface.[2,3]

This phenomenon occurs in hydraulic cylinders mainly at low speed, and sometimes causes troubles such as noise and oscillation. This noise is called allophone.[2,4]

4. Evaluation of Allophone

We have developed a seal system for high-pressure cylinders. We mounted actual equipment in a cylinder of a hydraulic shovel to conduct an operation test of the cylinder. As a result, allophone (stick-slip phenomenon) occurred in the cylinder when the shovel was operated at low speed and when the oil temperature was high. However, we did not confirm allophone at the lab evaluation during development. This meant that the operating conditions of the actual equipment had not been recreated, and revealed the difficulty of evaluating allophone.

4-1) Lab Evaluation

We conducted lab evaluation (stick-slip test) of a seal system for high-pressure cylinders during the development stage under the conditions shown in Table 3. The test results showed no allophone or stick-slip phenomena.

It is difficult to conduct a quantitative assessment of the stick-slip phenomenon; we need to precisely replicate the usage conditions and environment in order to fully understand the characteristics of the packing, and then to plan and conduct a test.[4] However, in the lab evaluation, the operating conditions including the cylinder's transverse load and high oil temperature had not been replicated.

Table3 Conditions for stick-slip test

Parameter	Testing conditions
Oil temperature	Ambient temperature (temperature without artificial control: approximately 40° C)
Velocity	0.01 m/sec
Weight	25 kg
Lubricant	Hydraulic lubricant (kinetic viscosity at 40° C: 46.0 mm^2/sec)
Verification method	Verification is based on the wave form depicted in the accelerometer measuring the up/down movements of the cylinder.

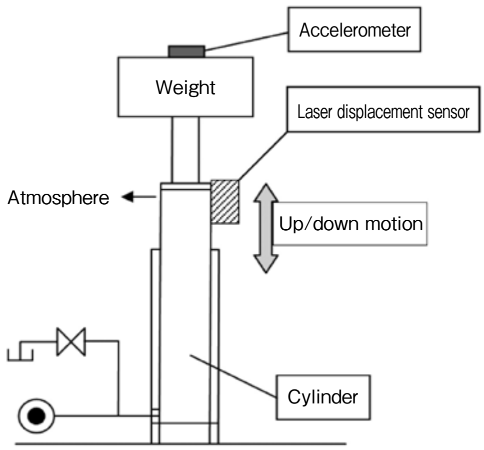


Figure 4 Equipment for stick-slip test

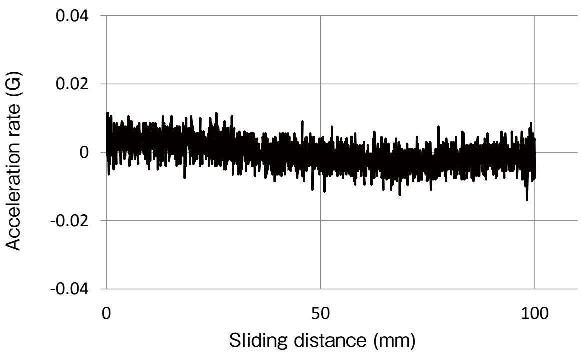


Figure5 Results of stick-slip test

5. Relationship between Stick Slip and Oil Film on Packing

Poor lubrication and frictional resistance at the contact surface affect the stick-slip phenomenon on packing. That is, periodical and recurring cycles of sticking and slipping at a contact surface cause the phenomenon. In the sticking condition of the cycle, the packing deforms itself to remain in the original position, and tries to return to its original shape when it is forcefully slipped by an external force, etc. The stick-slip phenomenon of the packing is affected by various factors including temperature, speed, pressure, surface roughness, viscosity of hydraulic oil, and oiliness. Although these factors have not been quantitatively investigated, qualitatively, the low viscosity of hydraulic oil often causes rupture of the lubricating film when equipment is operated at low speed under high pressure and when insufficient lubricant is applied.[5]

To alleviate the stick-slip phenomenon of a packing, the overall frictional resistance is sometimes lowered. One way to do this is to improve the retention of oil film between the opposing face and sliding surface.[2]

5-1) Formation of Oil Film on Packing

Regarding retention of an appropriate oil film on the sliding surface of a common reciprocating packing, the pressure gradient of the pressure pattern on the side of the fluid inlet and the same pressure gradient on the side of atmosphere are closely interrelated.[6] Absorption or scraping of the oil film may occur depending on the angle of the pressure gradient; this absorption and scraping affects the thickness of the oil film and sealing properties.

In the process of developing a high-pressure rod seal (U-packing), we focused on the shape of the packing on the heel side and the pressure gradient of pressure patterns in the heel segment. We verified that a seal with excellent absorbability could be developed by setting both the shape and the pressure gradient to optimal values.[1]

5-2) Application of Forming Method of Oil Film to a Piston Seal System

In the cylinder in which allophone occurred, the rod seal system of the cylinder used a U-packing developed by Valqua, and an appropriate oil film was retained between the opposing face and sliding surface. Taking these conditions into consideration, we assumed that allophone occurred in the piston seal system.

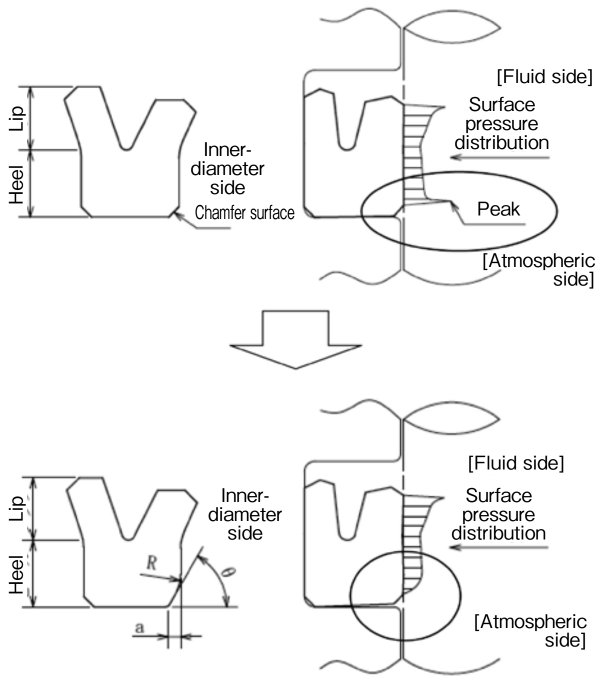


Figure6 Technique to absorb oil film used in the developed product

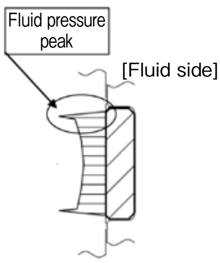
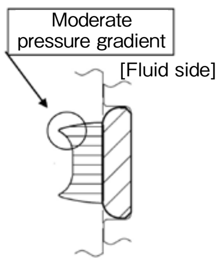
The results of allophone evaluation of actual equipment suggested that allophone occurred both when the viscosity of the oil was low due to high oil temperature and when transverse load was applied to the piston seal system. When transverse load was applied to a shaft bearing, wear ring of the shaft bearing was strongly pushed to the opposing face, and then the contact pressure reached its maximum value. As a result, the pressure gradient of pressure patterns is presumed to have become sharper, too. Therefore, we consider that allophone was caused by higher frictional resistance due to scraping of the oil film by the wear ring.

To verify this hypothesis, the pressure pattern of the wear ring was confirmed by finite element analysis (FEA). As a result, greater peak contact pressure and a sharper pressure gradient were confirmed in the C-chamfer at both ends.

It was found that the developed U-packing had functions of both scraping and absorbing the oil film. As a countermeasure against problems associated with the C-chamfer, the U-packing was applied to the system to make use of the two functions. Table4 shows the results of the analysis and investigation of the countermeasure.

The absorbability of the U-packing was used in shaping both ends of the wear ring into an R-shape to form an appropriate oil film on the sliding surface. No allophone was confirmed in an allophone evaluation of actual equipment in which this wear ring was provided. Based on this result, we consider that an appropriate oil film was formed.

Table4 Results of analysis of wear ring and investigation on countermeasure

Parameter	Analysis outcomes	Alternative product evaluation results
Edge form	Chamfering (edge) Chamfer surface 	Round 
Surface pressure distribution of sliding surface	Localized surface pressure peaks appear in the chamfer surface of the edges.  [Piston seal side]	Reduces the pressure gradient by applying rounded chamfering on the edges.  [Piston seal side]
Material properties	Glass-fiber reinforced nylon. It is stronger and more cost effective than conventional materials such as PTFE and cloth-reinforced phenolic plastics. It is inferior to PTFE in its frictional characteristics. Thus, some products have the sliding surface treated with knurling.[2)]	Based on the cost factor, the raw material will not be replaced.

6. Allophone Evaluation of Cylinders of Actual Equipment

An allophone evaluation was conducted with an actual hydraulic shovel before and after taking the countermeasure described above. Figure7 showed the frequency of the allophone sound. No allophone wave shape was confirmed in the evaluation after taking the countermeasure.

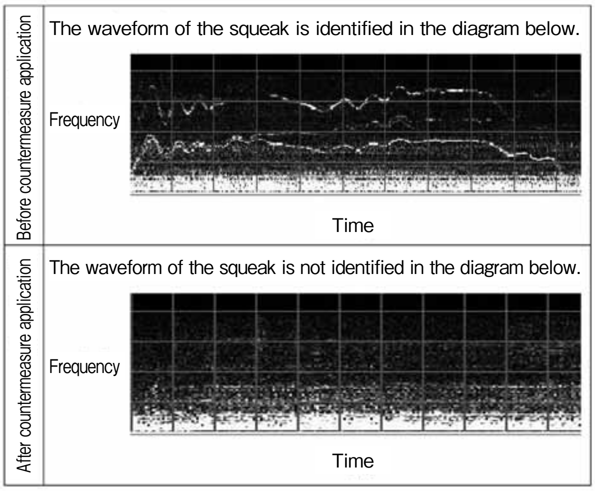


Figure7 Allophone evaluation of cylinders

7. Conclusion

This study verified that retention of an appropriate oil film alleviated allophone in packings for hydraulic cylinders.

To retain an appropriate oil film, the functions of scraping and absorbing the oil film are essential. By understanding these functions, this technique can be applied to other products to reduce allophone and frictional resistance. However, we still do not have a quantitative understanding of usage conditions, appropriate thickness of oil film for each product, and other factors, and many challenges remain. Therefore, further product development is needed for verification.

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1) Yamashita, J., *Valqua Technology News* No. 30, 2016, pp. 3–8

2) Ando, T., *Hydraulics & Pneumatics*, May 2003, pp. 28–33

3) Nakano, K., *Journal of the Society of Rubber Science and Technology*, Vol. 80, 4th issue, 2007, pp. 134–139

4) Takamure, T., Tsuji, K., Muramatsu, A., and Yoshida, T., *Hydraulics & Pneumatics*, May 2003, pp. 34–37

5) Akai, *H., Hydraulics & Pneumatics*, May 2003, pp. 13–20

6) Kaneda, S., *Journal of the Society of Rubber Science and Technology*, Vol. 72, 4th issue, 1999, pp. 194–201

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Development Division

Sticking Troubles of O-Rings and Countermeasures

1. Introduction

The rubber O-ring is a seal used for both static seal products (gaskets) and dynamic seal products (packings). It is made with soft elastomer, and so fits well to opposing faces and allows sealing with little tightening force. The O-ring also has the following other benefits:

- It can be used in various conditions, from high pressure to low pressure.
- It requires little space for mounting.
- The structure of the mounting section is simple, making mounting easy.
- It is standardized, readily available, and low cost.

Thanks to these benefits, the rubber O-ring is the most widely used general seal product in various equipment and devices in a wide range of industries including the automobile, hydro-pneumatic, machine-tool, food, semiconductor, and aerospace industries.

Rubber is an inherently elastic material and so recovers to its original shape. In addition to elasticity, rubber has non-slip, sticky properties. With these useful characteristics, rubber is used to produce tires, hoses, belts, and so on. On the other hand, these characteristics could cause malfunction cases when handling products, such as difficulties in mounting and dismounting. In the case of the rubber O-ring, these problems cause products to stick to each other and to stick to their opposing faces.

This report describes the causes of O-ring sticking and countermeasures, and introduces the products that Valqua has developed to reduce sticking troubles.

2. Sticking Phenomenon and its Causes

2-1) Sticking of O-rings

When a rubber O-ring contacts with its opposing face, such as a metal surface, under pressure, it sometimes sticks to the face. When the sticking strength of this phenomenon is small, the phenomenon is sometimes called adhesion. Depending on the usage condition, it may stick sufficiently strongly to cause material destruction of the rubber upon removal. In the case of static seal products, the sealing properties themselves rarely cause problems even if sticking occurs. However, sticking may result in a) a very large force required to open flanges at changing O-rings, and b) in the case of a large-bore O-ring, the flanges cannot be opened due to the large contact area with the opposing face, which creates substantial sticking force. Also, maintenance problems may occur, such as cleaning difficulties if the sticking rubber ruptures: the ruptured rubber sticks to the grooves and opposing faces when flanges are opened.

On the other hand, in the case of dynamic seal products, sticking may cause O-rings to detach from a groove and directly affects their sealing properties. In addition, sticking may cause equipment to malfunction, including operational delays, abnormal noise, and abnormal oscillation. Thus, sticking may directly result in equipment malfunctions.

2-2) Mechanism of Sticking

Sticking is considered to occur by the following process: when rubber contacts its opposing face, molecules of a rubber segment spread and stick to the opposing face, forming an interface through secondary bonds (including hydrogen bonds and Van der Waals force). Thereafter, the initial sticking (physical sticking) occurs. There are no clear categories of sticking, and there are various theories about sticking. However, it is sometimes called adhesion when the degree of sticking is small. Also, the initial sticking may be affected by the anchor effect, vacuum effect, and so forth. It is considered that primary bonds (including chemical bonds) subsequently start to form at the interface and the sticking strength gradually increases, leading to strong sticking (chemical sticking + physical sticking).[1,2]

2-3) Factors Affecting Sticking

The sticking strength varies depending on the type of rubber and the material of the opposing face. However, other major factors affecting sticking strength include the hardness of rubber, temperature and humidity conditions, and the surface roughness of the rubber and its opposing face. Other factors affecting sticking strength have been reported.[3] Based on these reports, major factors are categorized as follows:[4]

- Sticking strength decreases with increase of hardness of rubber.
- Sticking tends to occur with increasing temperature, although this is not always true.
- The effects of humidity vary depending on the combination of rubber and its counterpart material.
- Sticking strength decreases with increasing roughness of the surface of both rubber and metal. Contact area affects this phenomenon.

3. Sticking-prevention Methods

Simple methods of preventing sticking include greasing and lubrication. However, these processes can contaminate products and mounting sections. To shorten the operation time as well to as prevent contamination, O-rings which inherently prevent sticking are required.

Major methods of preventing the sticking of O-rings are categorized in Figure 1.

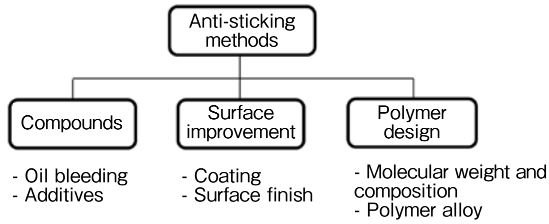


Figure1 Categorization of sticking-prevention methods

3-1) Sticking-prevention Using Material Combination

This method reduces sticking by mixing a combination of the following selected internal additives to rubber: solid lubricant including PTFE, lubricating components, releasing components, or other chemicals. Generally, these formulated chemicals affect the physical properties of rubber, compression set, and others, so the characteristics of each additive should be balanced.

3-2) Sticking-prevention Using Surface Modification

This method reduces sticking by making the surface of the rubber resistant to sticking. There are two approaches for doing this: coating to form a sticking-resistant thin film on the surface of rubber, and surface treatment using chemical immersion or plasma/radio irradiation. The types of coating include the following: a coating that physically adheres to the surface and a coating that forms a thin film through reaction with the surface of the rubber to enhance adhesion to the base rubber. The thin film should exhibit chemical affinity with the base rubber. A typical surface treatment is surface hardening: rubber is immersed in chemical solution containing a vulcanizing agent and then heat is applied for hardening. However, the area modified by this approach is limited to the area close to the top surface, and frictional wear of the modified layer results in the loss of this preventive effect. This approach should be used with care when applied to dynamic seal products.

3-3) Sticking-prevention Using Polymer Design

This method reduces sticking by improving the material polymer of the O-ring itself. Generally, polymers with high molecular weight are considered to stick less, as well as polymers with fewer side chains and end groups (including -COOH, -OH, and >CO).

Also, this method can be performed by giving a polymer a structure which inhibits molecular-chain motion (e.g. a structure with a high glass transition point). However, it is difficult to develop a polymer which has a structure to reduce sticking while retaining the elasticity of rubber. Further molecular-design investigations are expected by new polymer design and polymer alloys with new structures.

Valqua has developed various methods to prevent and reduce sticking in its products. Some of our key products are outlined below.

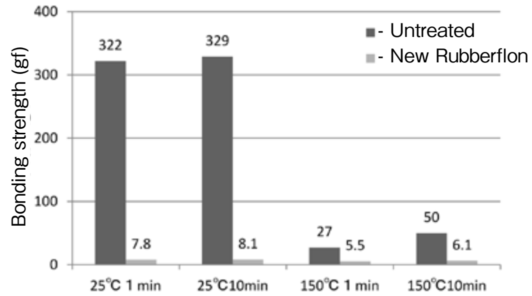
4. New Rubberflon

New Rubberflon (Rubberflon is our registered trademark) is an example of our products that are designed to prevent sticking.

New Rubberflon is produced using the surface-modification method, not just a coating. Because of reactive treatment, the treated surface layer adhere with matrix rubber, thus not easy to remove. Moreover, the method does not affect the physical properties of the base rubber, so most rubber materials such as nitrile rubber and fluororubber except for silicone rubber can be processed with this method. New Rubberflon offers both low sticking and friction. Thus, the product not only prevents sticking between products or to the opposing face, but also reduces insertion friction when mounting O-rings including cylindrical-surface seals.[5, 6] Figure2 showed values obtained by experiment to measure New Rubberflon's sticking strength. Figure3 showed values obtained by experiment to measure friction coefficient.

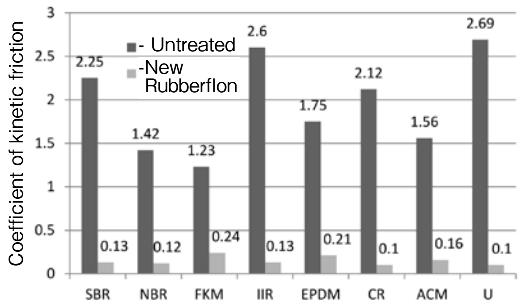
The treatment of O-rings with New Rubberflon is expected to provide the following benefits:

- Prevention of sticking between O-rings
- Prevention of sticking to the opposing face
- Improvement in fit of O-rings (greaseless)
- Prevention of twisting and damage in O-rings



Test method: tack testing device
The strength required to detach the probe from the test pieces, after being in contact under certain conditions, is measured.
Test piece: acrylic rubber sheet of 2 mm thickness; weight: 100 gf; probe: stainless probe, Φ 5 mm; velocity of probe removal: 600 mm/min

Figure2 Sticking strength of a rubber treated with New Rubberflon



Test method: ball indenter test, testing velocity: 60 mm/min
Test piece: rubber sheet of 2 mm thickness, weight: 200 gf, ball indenter: SUS Φ 6
SBR: styrene-butadiene rubber; NBR: nitrile rubber;
FKM: fluorocarbon rubber; IIR: isobutylene-isoprene rubber;
EPDM: ethylene propylene rubber; CR: polychloroprene rubber;
ACM: acrylic rubber; U: polyurethane rubber

Figure3 Coefficient of dynamic friction of a rubber treated with New Rubberflon

5. D2370, a Non-adhesive Fluororubber

Fluororubber has excellent heat and chemical resistance, and so is used in a broad range of industries. Generally, fluorine is considered to be an adhesion-resistant, slippery material. However, contrary to expectations, fluororubber often sticks to the opposing face, and so is not an adhesion-resistant material.

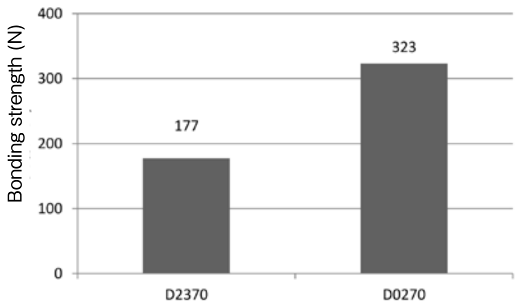
D2370 was developed using our unique compounding technique. The product reduces sticking while maintaining the characteristics of conventional fluororubbers including heat resistance and physical properties.

Table1 showed the physical properties of D2370, and Figure4 showed its sticking strength measured by experiment.

Table1 List of physical properties of D2370 (a non-adhesive fluororubber)

	D2370 Non-adhesive fluorocarbon rubber	D0270 Standard Valqua fluorocarbon rubber
Hardness (Shore A)	70	71
Tensile strength (MPa)	14.0	13.9
Stretch (%)	190	230
Compressed permanent deformation rate (%)*)	14	16

*) 200° C/70 hours, 25% compression, Φ 29 mm disc
The values in the table are observed values, not standard values.



Test method: The test piece was placed in contact with the counterpart under certain conditions and cooled in an ambient environment for 4 hours, then the strength required to detach the counterpart from the test pieces is measured.
Test piece: rubber sheet of 2 mm thickness; contact pressure: 5.88 MPa; heating conditions: at 120℃ for 20 hours
Counterpart: ring-shaped SUS 304 of Φ 25 x Φ 19; detaching velocity: 50 mm/min

Figure4 Sticking strength of D2370 measured by experiment

D2370 can be used as an alternative to common fluororubber in various valves which use a common fluororubber O-ring including for door seals and gate valve seals. We consider that D2370 can reduce operational malfunctions at opening and closing points by decreasing sticking strength of seal materials. In addition, the product is expected to prevent sticking to the opposing face including flanges.

6. Conclusion

This report explained sticking factors and methods for preventing the sticking of O-rings, and introduced our sticking-prevention products.
In the case of static seal products, sticking is one of important factor which affects maintenance seriously. However, there also are cases where sealing properties are sometimes retained and extended because of the sticking characteristics of O-rings in site of beyond limitation for sealing by permanent deformation of O-ring. In such cases, prevention sticking might not an only way to solve problems but also prevention methods while considering various operating conditions were required.
Also, various factors including the usage environment and conditions affect sticking, so it is difficult to solve sticking problems only with seal materials. Therefore, it is important to precisely identify the conditions in which O-rings are used.
We welcome feedback and honest opinions from users, to help us make full use of the characteristics of rubber materials, develop high-value-added products, and introduce new products.

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Evaluation of the Bolted Flange Connection with PTFE-blended Gasket under High-temperature and Long-term condition

1. Introduction

The bolted flange connections with gasket have been used under high temperature and long-term conditions in oil plant, chemical plant, power plant and so on. In Japan, various asbestos gaskets used to be widely used because of excellent heat resistance, sealing performance, strength, ease of use, and low cost till 2008. The many studies for asbestos gaskets[1-5] have been conducted, clarifying the characteristics of the connection with asbestos gasket such as sealing performance. In Japan, the use of asbestos products was restricted in 2008, requiring non-asbestos products to be used.[6] As a result, non-asbestos gaskets have been developed and improved.

The asbestos gaskets are categorized into two major types: the spiral wound gasket containing asbestos filler and the compressed asbestos fiber sheet gasket. For the substitution of asbestos, asbestos for spiral wound gaskets was replaced with flexible graphite, and it caused no major problems. On the other hand, the compressed aramid fiber sheet gasket, the flexible graphite sheet gasket and the PTFE-blended gasket have been developed[7]. The compressed sheet gaskets containing aramid fibers shows low resistant to heat because they contained a lot of rubber, and the flexible graphite sheet gaskets are so fragile and easy to scratch. Therefore, in Japan, the PTFE-blended gasket was improved further and is now widely used. The former PTFE-blended gaskets showed poor creep characteristics, whereas the newly developed PTFE-blended gasket offers improved creep characteristics. However, the mechanical characteristics including the stress–strain curve of gasket, fundamental leakage characteristics (JIS B 2490), and creep characteristics for these gaskets have not been available. In addition, there has been insufficient verification as to whether this connection with PTFE-blended gasket has superior sealing performance compared with the conventional connection with asbestos gasket.

Previous studies have investigated the connection with PTFE-blended gasket for its sealing performance at room temperature, flange hub stress, change in axial bolt force (load factor), and the contact gasket stress distribution. The results showed that the sealing performance of the PTFE-blended gasket is quite superior to that of connections with the compressed asbestos fiber sheet gasket.[8] However, its performance at high temperatures is not well known.[8] Therefore, research on the mechanical properties of the connection including creep characteristics and sealing performance under high temperatures and long-term condition are required.

The objective of the present paper is to examine the mechanical characteristics of bolted pipe flange connections with PTFE-blended gaskets under elevated temperature using FEM calculations and experiments. Firstly, the fundamental characteristics of the PTFE-blended gasket such as stress–strain curves, thermal expansion coefficient, and fundamental leakage characteristics are measured. In addition, the creep characteristics at high temperatures are measured. In FEM calculations, the change in axial bolt force, the flange hub stress and the contact gasket stress distribution of bolted pipe flange connection with PTFE-blended gasket at some temperature are calculated. And then, the leak rates ware estimated from the contact gasket stress distribution and relationship between the leak rate and contact gasket stress. For verification of the FEM method, the experiments to measure the change in axial bolt force, the flange hub stress and the leak rate at each temperature are carried out.

In this study, the test gasket is No.GF300 in Nippon Valqua Industries, ltd.. The No.GF300 includes no rubber and no material degradation occurs in high temperature and long-term conditions.

2. Experiment set up

Figure 1 shows the experimental setup for connection. The change in axial bolt force, the flange hub stress and the leak rate are measured using this set up. The nominal size of pipe flange is ASME/ANSI class300 2inch and the flange material is Stainless Steel 304 [9]. The connection is heated 3℃/min using electric cartridge heaters. The flange temperature is measured and controlled using the thermocouple and the flange hub stress is measured using the strain gage. The axial bolt force was measured using the strain gages attached to shank of bolt. The tightening is performed according to JIS B 2251:2008 "Bolt tightening procedure for pressure boundary flanged joint assembly".

Leak rate was measured using the pressure drop method and calculated by equation (1)

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

where, L is leak rate (Pa・m³/s), M is molar mass (kg), V is volume within equipment (mm³), t is measurement time (s), R is gas constant (J/kg・K), T_1 is initial temperature (℃), T_2 is measurement temperature (℃), P_1 is initial internal pressure (MPa) and P_2 is measurement internal pressure (MPa).The nominal size of gasket is ASME/ANSI class 300 2 inch with thickness of 1.5mm. The internal pressure is 2MPa, the flange temperatures are chosen as room temperature, 100℃ and 200℃. The initial axial bolt force is 16.4kN correspond to mean contact gasket stress 35MPa.

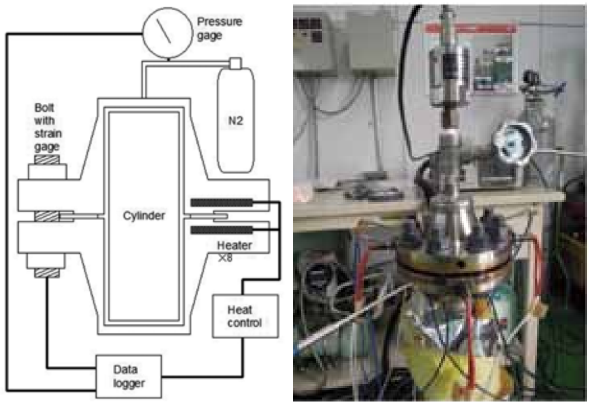

Figure1 experimental set up for connection

3.Gasket property measurement

Prior to FEM calculations, the gasket properties such as stress-strain curve, fundamental leak rate, thermal expansion coefficient and creep are measured.

3-1) Stress-Strain curve

Figure2 shows the schematic of experimental setup for measuring the sealing performance of the gasket (JIS B 2490). It can be heated by electric cartridge heaters. Figure3 shows the stress-strain curve at room temperature, 50℃, 100℃, 200℃ and 300℃ measured. The strain increases as test temperature increases and it can be seen the temperature dependency. It is because that the gasket material was softened in high temperature.

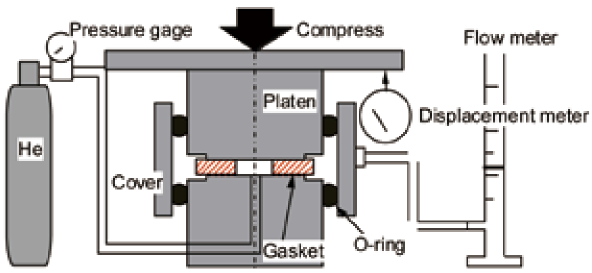

Figure2 Schematic of experimental setup for measuring the sealing behavior of the gaskets (JIS B 2490)

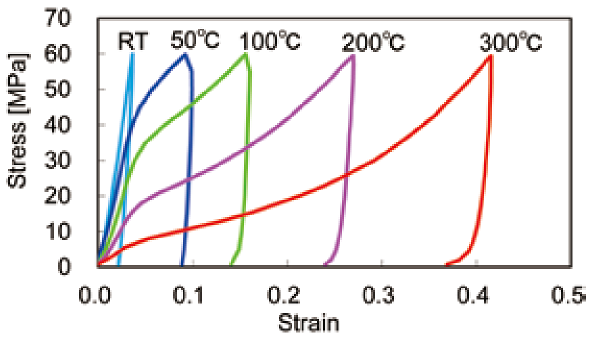

Figure3　Stress-strain curves of gasket

3-2) Sealing performance

The relationship between the fundamental leak rate and the contact gasket stress at room temperature and only re-load step at 200℃. The experimental setup was shown in Figure2 and the test gas is helium gas 2MPa.

Figure4 shows fundamental leak rate at room temperature obtained from the experiment. When the contact gasket stress is 20MPa or greater, it can be measured because that the value was less than lower limit of 5 x 10^{-5} Pa･m^3/s.

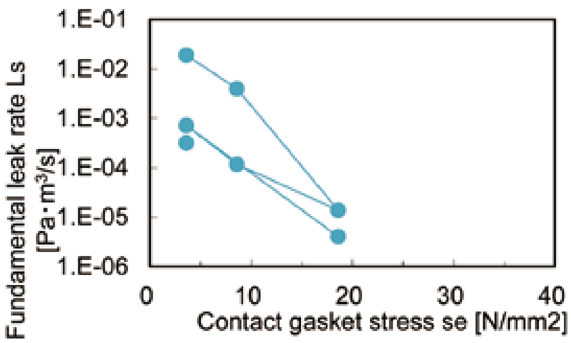

Figure4　Relationship of gaskets between leak rate and contact gasket stress at room temperature in a platen test

Figure5 shows the leak rate in unloading process at 200℃, the initial contact gasket stresses are chosen as 19.8MPa, 25.5MPa and 35.0MPa. From comparison between results of Figure4 and Figure5, it can be seen that the sealing performance at high temperature is better than at room temperature. The result indicates that sealing performance increases as the temperature increases. This is suggested that because the softened gasket material is able to fill the micro gaps of flange faces at high temperature.

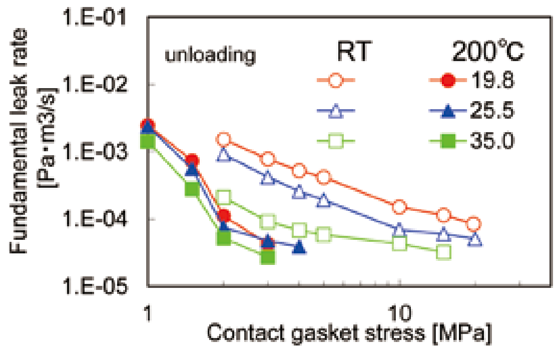

Figure5　Measured relationship between the fundamental leak rate and the contact gasket stress in unloading step at RT and 200℃

3-3) Thermal expansion coefficient

Figure6 shows thermal expansion coefficient measured by thermal mechanical analysis (TMA). It can be said that the thermal expansion coefficient increases with higher temperature.

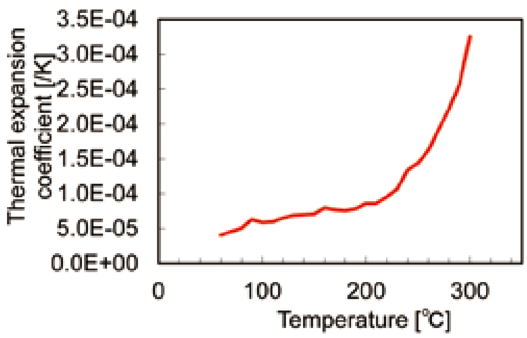

Figure6　Thermal expansion coefficient of gasket

3-4) Creep

The creep characteristics of gasket are measured by the setup shown in Figure7, for evaluation of gasketed connection in long-term condition. The dimensions of test gasket are ϕ22mm and ϕ58mm, test gasket stresses are chosen as 12.5MPa, 25.0MPa, 35MPa, and the temperature is 200℃. Figure8 shows the measured creep strain behaviors of the gasket. The abscissa is elapsed time, and the ordinate is creep strain. This figure indicates that the creep strain increased over time. So creep strain increases as gasket stress increases and it show the stress dependency. This behavior was formulated to equation 2 and inputted to FEM calculations.

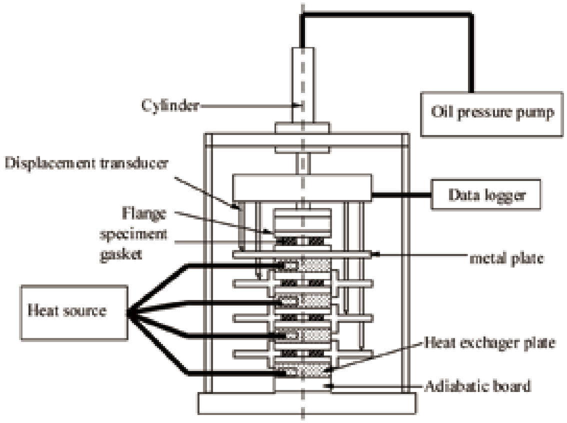

Figure7 Equipment for testing the creep of gaskets

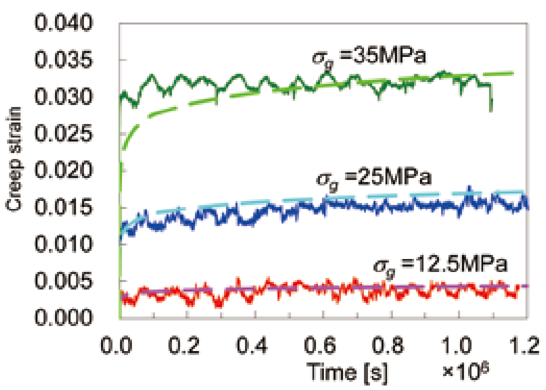

Figure8 Measured creep strains of gaskets

$$\overline{\varepsilon_c} = a \cdot \sigma^n \cdot t^j \quad (2)$$

where $\overline{\varepsilon_c}$ is creep strain rate (/s); σ is stress (MPa); t is measurement time (s); and a, n, and j are constants obtained by experiment (a = 1.61×10^{-5} (/MPa), n = 1.25, j = −0.915).

4. FEM calculations

The FEM calculations are conducted using ABAQUS. Figure9 shows the FE model for bolted flange connection with gasket. Taking into account the symmetry of the connection, 1/32 part (1/2 in axial direction, 1/16 in circumferential direction) of connection is analyzed. Bolts and nuts are united, and screws are omitted. Also, nut shape is simplified from hexagonal to circular.

Figure10 shows the boundary conditions. The uniform bolt stress is applied to the cross sectional area in the bolt at initial tightening. In Step 2, heat and internal pressure are applied to the inside of the connection. Flanges and bolts/nuts are modeled with elasticity-heat transfer elements. The gasket is modeled with elasticity-plasticity-heat transfer-viscosity elements. Table1 shows the characteristics of each material.

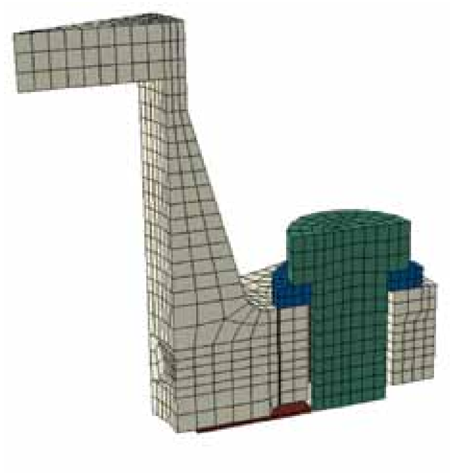

Figure9 FE model for pipe flange connection with gasket

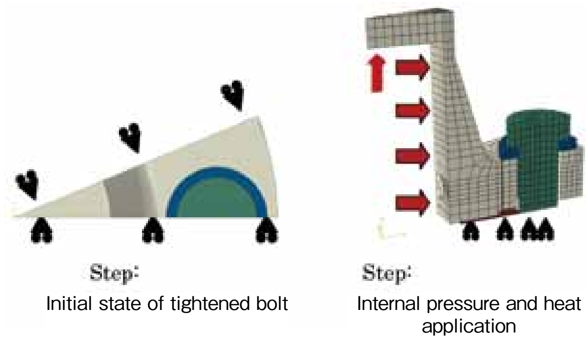

Figure10 Boundary conditions

Table1 The characteristics of each material

	Flange	Bolt	Gasket
Modulus of longitudinal elasticity [GPa]	200	200	Fig.3
Poisson's ratio	0.3	0.3	0.45
Linear expansion coefficient [/K]	1.12 E-05	1.09 E-05	Fig.6
Heat transfer coefficient [W/m·K]	4.4 E-02	1.1 E-02	2.5 E-05
Specific heat [J/kg·K]	500	500	1000
Density (room temperature) [kg/m^3]	7800	7800	2.3

5. Experiments and Results of FEM Analysis

5-1) Changes in Axial Bolt Force

Figure11 and 12 show the changes in axial bolt force obtained by FEM calculations and experiments at 100°C and 200°C respectively. The solid lines show the FEM results, the dotted lines show experimental results. And the change in flange temperature is shown in same figure. The initial axial bolt force is chosen as 16.4kN. The flange is heated, kept for 24 hours, cooled to room temperature. The heated and cooled cycles are 4 times.

From figure 11 and 12, it can be seen that the change in axial bolt force are influenced from temperature of the connection. In initial heating, the axial bolt force decreases substantially, because the gasket strain increases due to the temperature dependency of stress-strain curve of gasket material, that is, the gasket thickness decreases. Axial bolt force increased and decreased in accordance with increasing and decreasing temperature due to the difference in thermal expansion coefficient between each component. In heating at 200℃, the change in the axial bolt force is larger than that at 100℃ and also the reduction in the axial bolt force is larger in cooling. In cooling, the axial bolt force is reduced to 2kN, by which the average gasket stress is 4.3MPa. However, no leakage is observed.

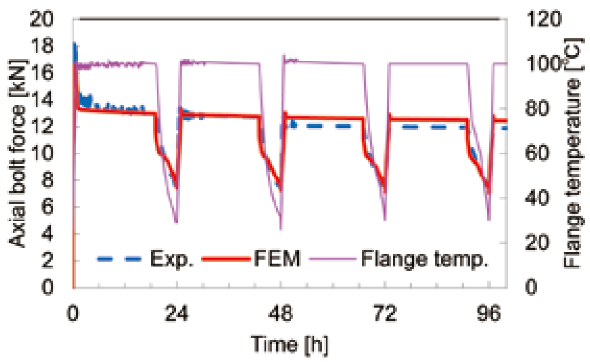

Figure11　Changes in axial bolt force at 100℃

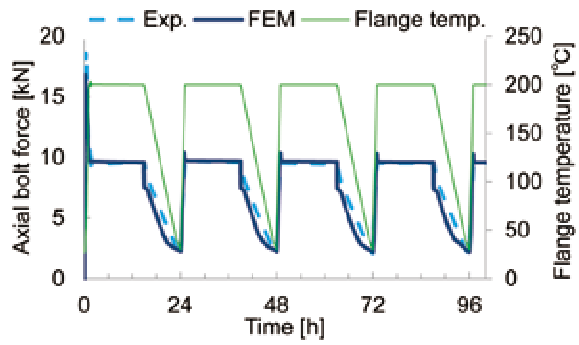

Figure12　Changes in axial bolt force at 200℃

5-2) Hub Stress of Flanges

Figure13 shows the flange hub stress at initial tightening and under high temperature. The figure also shows value calculated according to the Boiler & Pressure Vessel Code, Section VIII, Division 1.[14] The measured results are fairly good agreement with the FEM results, the method of FEM calculations are verified.

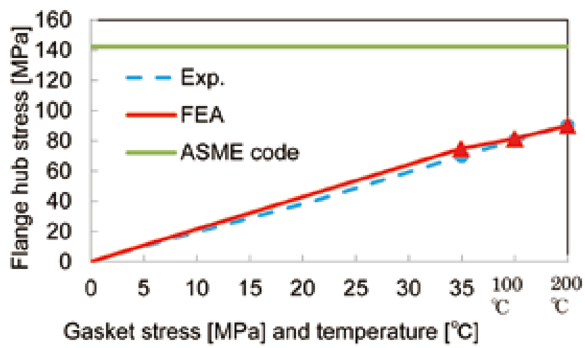

Figure13　Flange hub stress

5-3) Contact Gasket Stress Distribution and Leak Rates

Figure14 shows the obtained contour figure of contact gasket stress distribution for the gasket in initial bolt tightening, and the cases where the connection is heated to 100 and 200℃, respectively. The around outside of gasket did not contact the flange face. So the contact gasket stress is zero.

In these figures, it can be said that the change in contact gasket stress distribution in the circumferential direction is negligible. As the result, the contact gasket stress increases at the outer edge of the gasket because the flange rotation occurs. The results at the elevated temperature, show that the outside of gasket is deformed by compression due to the heating and a contact force by a bolt.

Figure15 shows the leak rate from the gasket interfaces is estimated using the contact gasket stress distribution obtain from the FEM and the fundamental leak rate shown in Figure4 and 5 [12)13)]. The abscissa is contact gasket stress, the ordinate is the amount of gas leakage per unit contact diameter. A fairly good agreement between the estimated results and the experimental results is observed. This confirms the validity of the method for estimating the amount of leakage from the FEM calculations and the fundamental leak rate.

5-4) Estimation of the sealing performance in long-term condition

The bolted connection with gasket is used in high temperature and long-term condition, so it is important to evaluate the sealing performance in high temperature and long-term condition. Figure16 shows the change in contact gasket stress in ten years estimated from results of FEM calculations. The leak stress (when allowable leakage is 1.7×10^{-4} Pa·m³/s) is also shown in same figure, the leakage occurs when the contact gasket stress decreases less than that value. The connection size is ASME/ANSI class 300 2inch, the fluid temperature is 200℃ as above evaluations. The shutdown is every two years, so it is considered in FEM calculations. When the initial contact gasket stress is chosen as 25MPa, the contact gasket stress fall down less than leak stress, and then it is estimated that the leakage occur. On the other hand, when the initial contact gasket stress is chosen as 35MPa, the contact gasket stress keep over leakage stress, it can be considered that the sealing is kept.

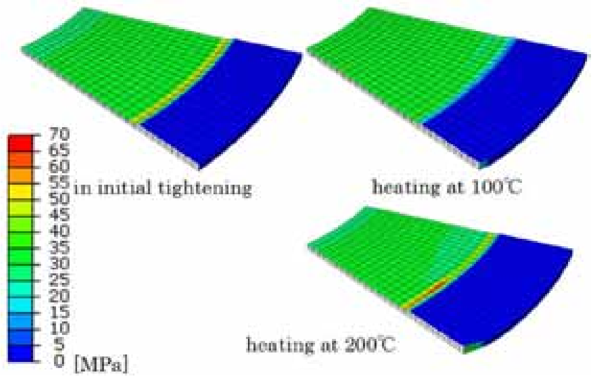

Figure14 Contact gasket stress distributions obtained by FEM calculations

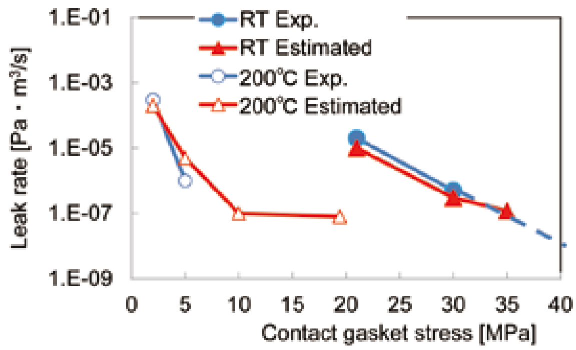

Figure15 Comparison of leak rates of connections between the experimental results and estimated results.

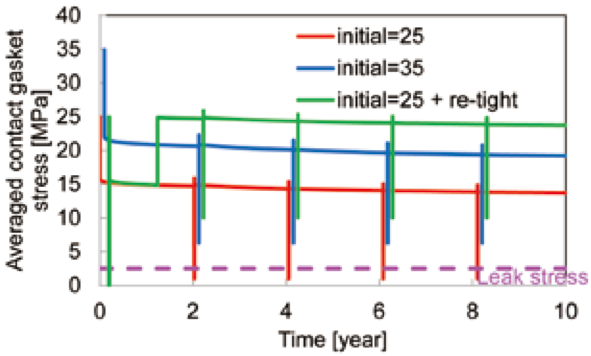

Figure16 Change in contact gasket stress of connection in ten years estimated by FEM calculations

6. Conclusion

In this present paper, it is shown that bolted pipe flange connection with PTFE gasket (No.GF300) keep good sealing performance in high temperature and long-term condition by using experiments and FEM calculations. The results obtained are as follows.

(1) The fundamental characteristics of PTFE-blended gasket were measured experimentally such as the relationship between gasket stress and displacement and its temperature dependency, the relationship between the leak rate and contact gasket stress, thermal expansion coefficient and creep property.

(2) The change in axial bolt force of bolted connection with PTFE-blended gasket is effected substantially by heat cycle and the connection with No.GF300 gasket shows the good sealing performance in 200℃ heat cycle condition. In addition, the flange hub stress was lower than the value calculated using ASME code.

(3) The leak rate from the connection with PTFE-blended gasket was estimated from the contact gasket stress distribution obtained by FEM calculations and the relationship between leak rate and contact gasket stress obtained by experiments, and compared with the experimental value to verify the robustness of our prediction method.
(4) It is proposed the method to estimate the long-term behavior of bolted flange connection with PTFE-blended gasket (No.GF300) under high temperature. And it is shown that the connection with No.GF300 gasket keeps safety for 10 years when the initial contact gasket stress is 35MPa, and also that re-tightening resulted in additional safe.

7. References

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Kouji Satou
Corporate Research and Development Group
Development Division

Year	VALQUA's Technical History
1927	Founded NIPPON BRAKE LINING SEISAKUSHO for manufacturing of brake linings for automobiles and various high-speed machines.
1929	Started research of Compressed Asbestos Sheet and various gaskets.
1930	Started manufacturing of clutch facings.
1931	Started manufacturing of asbestos braided gaskets. Started manufacturing of high-test lining.
1932	Started manufacturing of asbestos spiral gaskets. Started research and prototype manufacturing of cloth-inserted rubber molds. Started manufacturing of laminated compressed sheets.
1933	Received a request from the Imperial Japanese Navy Technical Department to research special high-temperature and high-pressure metal gaskets. Started manufacturing of laminated Compressed Asbestos Sheet (No. 902, 305, and 1000).
1934	Completed research on special high-temperature and high-pressure gaskets (No. 1250). Registered special high-temperature and high-pressure gaskets in the Navy Purchasing List.
1935	Installed Japan's first manufacturing equipment for large Compressed Asbestos Sheet (for 120-inch sheets). Started manufacturing of prototypes of large Compressed Asbestos Sheet.
1936	Started research work on fabrication of synthetic rubber.
1937	Had synthetic rubber gaskets installed in KAMIKAZE as the first Japanese product in a round-the-world flight. Started manufacturing of grease (No. 1).
1939	Obtained polysulfide synthetic rubber, HITACOLE,*1 and started research work on oil resistance gaskets.
1941	Started manufacturing of synthetic rubber gaskets for aircraft and asbestos compression sheets.
1943	Appointed by the Army Fuel Plant for research on gaskets for oil refining equipment. Started manufacturing of aircraft gaskets. Following the National General Mobilization Law (Article 25), ordered to conduct research tests for power-generating high-temperature and high-pressure gaskets. Started manufacturing of metal gaskets for fuel and industrial use.
1947	Started manufacturing of piston valves.
1949	Completed a molding processing method for polyvinyl chloride resin and started sales. Started research work on a new braiding method for asbestos mole-braided gaskets. Commissioned by the Ministry of International Trade and Industry for research on high-temperature, high-pressure, and superheated steam gaskets.
1950	Successfully completed research work on new braiding methods and started manufacturing mole-braided (latticing) gaskets. Completed research work on high-temperature, high-pressure, and superheated steam gaskets commissioned by the Ministry of International Trade and Industry.
1951	Completed research work on synthetic rubber oil seals for bearing oil prevention. Started research work on silicon rubber processing. Imported Teflon powder*2 from the United States and started research work on the Teflon molding method. Started research work on O-rings.
1952	Completed research work on the fabrication of Teflon and started sales as VALFLON®. Started manufacturing of synthetic rubber oil seals. Completed research work on metal spiral gaskets and started manufacturing and sales as VALQUATIGHT™.
1953	Completed MECHANICAL SEAL for rotators and started manufacturing and sales. Received subsidiary aid from the Ministry of International Trade and Industry for research on the performance of aircraft gaskets made mainly of silicon or Teflon.
1954	Started manufacturing and sale of O-rings.

Year	VALQUA's Technical History
1955	Received subsidiary aid from Ministry of International Trade and Industry for fabrication and manufacturing technology of polytetrafluoroethylene.
1956	Started manufacturing and sale of Teflon-coated adhesive tape. Imported Teflon extruders and started research work on thin-walled tubes, hoses, and coated cables. Started manufacturing and sale of fluorocarbon rubber. Synthetic rubber gaskets used for fighter jets (F-86) for the first time in Japan.
1957	Completion of industrialization tests for fabrication and manufacturing technology of polytetrafluoroethylene approved by the Ministry of International Trade and Industry. Released technical report, VALQUA REVIEW.
1958	Started manufacturing and sale of Combined Drip-Ring Gaskets (No. 2800).
1959	Started manufacturing and sale of screw joint seals, TAPE SEAL™.
1960	Started manufacturing and sale of VALFLON® glass cloths (No. 7920). Started manufacturing and sale of ball valves.
1962	Started manufacturing and sale of ultrahigh molecular weight polyethylene (HOSUTAREN GUR*3) products. Product name: VALREN.
1963	Started manufacturing and sale of Teflon grease SPRAY WAX (UNON S).
1964	Developed Japan's first Teflon fiber and started manufacturing and sale. Completed the world's largest (400 mm) VALFLON® large-diameter pipes.
1965	Founded NIPPON ELASTON, CO. as a joint venture with the German company ELASTOMER AG and started manufacturing and sale of thermoplastic polyurethane, ELASTORUN.*4 Started manufacturing and sales of Cordseal<Soft>™.
1966	Entered a technologically cooperation with the American company DURA METALLIC and started manufacturing and sale of DURA SEAL.
1967	Newly developed fire-resistant coating material, REF-LIGHT, received certification by the Ministry of Construction. Jointly developed valve seals with the American company DINNER CO. Started manufacturing and sale of high-temperature metal coating, VALFLON® BELLOWS.
1968	Started manufacturing and sale of carbon fiber-braided gaskets (No. 97-CT, Current No. 6232). Completed standardization of mechanical seals for mixers and started manufacturing and sales.
1969	Started manufacturing and sale of PURE VALFLON® PASTE. Started manufacturing and sale of flexible duct connectors, FLECTOR™.
1970	Started manufacturing and sale of metal hollow O-rings.
1971	Started manufacturing and sale of VALFLON® powder gaskets, PHLOROTIGHT. Received approval to display the API (American Petroleum Inst.) certification mark for ball valves meeting API Standard 6D. Started manufacturing and sale of VALFLON® Lining Ball Valve. Started sale of DOH and MS-type gas removal apparatuses. Started manufacturing and sale of heat transfer spiral gaskets with twigs, HEAT TRANSFER VALQUATIGHT™ WITH TWIG. Started manufacturing and sale of fire-safe ball valves.
1972	Started sale of flexible tubes for air conditioners, VALFLC. Started manufacturing and sale of ELASTORUN Laminated Films. Started manufacturing and sale of Gasket Cutter in new design. Started manufacturing and sale of VALFLON® FLAWLESS GASKET.
1973	Developed completely wet spraying VALQUA WET and started accepting orders. Started sale of gasket tools in new design. Started manufacturing and sale of VALFLON® THERMAL CONTRACTION TUBE.
1974	Started manufacturing and sale of gland gaskets with braided carbon fibers, CHEMSEAL™.

Year	VALQUA's Technical History
1974	Started manufacturing and sale of soundproofing construction material, NOISE DAMPER.
1975	Started manufacturing and sale of Japan's first completely unlubricated gasket, NORPACK™. Received development subsidiary paid from the Ministry of International Trade and Industry, Agency of Industrial Science and Technology for research on non-contact seal applications. Developed anti-corrosive Compressed Asbestos Sheet (No. 1500AC, No. 1501AC, and No. 921AC) and started manufacturing and sales. Jointly developed steel-fiber-mixed lightweight concrete slabs with Kajima Corporation. Entrusted by the Research Development Corp. of Japan with the development of manufacturing technology for heat and alkali-resistant glass fibers.
1976	Developed acid-proof Compressed Asbestos Sheet made from chrysotile (No. 1000) and started manufacturing and sales. As an important technology research and development project, received subsidiary aid from the Ministry of International Trade and Industry, Agency of Industrial Science and Technology for industrialization tests for manufacturing of heat-resistant and fireproof building materials with Shirasu glass fibers. Terminated contract with the British company TBA INDUSTRIAL PRODUCTS LTD. for technical cooperation for dust laying asbestos cloth.
1978	Terminated contract with the American company FLUOROWARE INC. for cross-licensing of fluorocarbon resin PFA injection molding, transfer and compressing molding techniques.
1979	Started manufacturing and sale of fused fluorocarbon resin PFA wafer carrier containers and jigs for semiconductor manufacturing.
1982	Started manufacturing and sale of Compressed Non-Asbestos Sheet. Started sale of metal-coated spring gaskets, TRYPACK™.
1983	Started sale of Oil Sheet. Started sale of gland gaskets for aramid fiber rotation shafts.
1984	Started sale of VALFLON CRYSTAL RUBBER™.
1985	Promoted development of various non-asbestos products. Started sale of GREENTIGHT.
1990	Started sale of VALFLON® Semi-rigid Coaxial Cable.
1993	Received the Plunket Award from the American company DU PONT for ALL FLUOROCARBON RESIN BAR CODE. Established Nara Works in Gojo, Nara, and started manufacturing of highly functional rubber products.
1994	Started sale of CLEANTIGHT®.
1995	Received the Plunket Award from the American company DU PONT for PFA tubes for copying machine rolls. Started sale of large-capacity, site-construction-type VALFLON® Sheet Lining Tank.
1997	Received the Plunket Award from the American company DU PONT for site-construction-type VALFLON® Sheet Lining Large-CapacityTank.
1998	Started sale of high-purity fluorocarbon rubber seals for liquid crystal/semiconductor devices, ARMOR® series (4 types).
1999	Started sale of rectangular gate valves for semiconductor or FPD manufacturing device manufacturers.
2001	Started publishing quarterly issues of VALQUA Technology News to pass down most of the roles of the VALQUA REVIEW.
2002	Received the Plunket Award from the American company DU PONT for electrode films of electric double-layer capacitors.
2004	Started sale of heat-resistant non-asbestos sheet gaskets, BLACKHYPER®. Founded the Fluorocarbon Resin Search Institute and VALQUA Seal Research Institute in Shanghai, China.
2005	Completely terminated manufacturing of asbestos products.
2006	Completely terminated sale of asbestos products.

Year	VALQUA's Technical History
2006	Started sale of high-temperature VALFLON® jacket gaskets, No. N7030 (H) SERIES.
2008	Integrated the Fluorocarbon Resin Search Institute and VALQUA Seal Research Institute into the VALQUA China Research Institute (newly established in Shanghai).
2010	Founded J/V VALMEI Corporation (headquartered in Tokyo) to reinforce Expanded Fluoroplastics (sa-PTFE™) business. Founded China Membrane Institute in VALQUA China Research Institute in Shanghai, China. Launched enhanced China operations through an operational and capital tie up with Daikin Industries, Ltd. Started sale of PTFE sheet gaskets with white filler, BRIGHTHYPER®.
2011	Established the China Functional Resign Research Institute in Shanghai VALQUA Fluoroplastics Corp. Ltd. as a technological development base.
2012	Started sale of CRYSTALLINE SILICA FREE SERIES using amorphous silica instead of crystalline silica as an environmental measure.
2013	Founded ADVANCE FLON TECHNOLOGIES (SHANGHAI) CO., LTD. as a joint venture with Guarniflon S.p.A., Italian company, in China. Started sale of PTFE sheet gaskets with filler, UNIVERSALHYPER®. Started sale of earthquake-proof countermeasure gaskets No. 6596A.
2015	Published "New Gaskets and Gasketing Technology" (by Takahito Nishida, senior fellow at VALQUA).
2016	Started sale of RCF FREE SERIES using materials other than ceramic fibers as an environmental measure. Opened APPLIED R&D INSTITUTE in South Korea. Started sales of improved seal paste, classified as non-dangerous goods with a safe, environmental, carcinogen-free combination.

＊1 HITACOLE is the name of a product manufactured by HITACHI, LTD.
＊2 Teflon is the name of a fluorocarbon resin product manufactured by DU PONT.
＊3 HOSUTAREN GUR is the name of a product manufactured by HOECHST.
＊4 ELASTORUN is a trademark of BASF Polyurethanes GmbH (Gesellschaft mit beschränkter Haftung).

Recent Technology News Back Issues

Earth-friendly, Human-friendly Manufacturing

New Gaskets and Gasketing Technology

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

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