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Valqua Technology News
Greetings

We thank you for regularly reading the Valqua Technology News.

We have now entered the middle of 2021, but the global spread of COVID-19 that has been continuing since last year is still with us. Advances in vaccination and other measures have meant that we are now seeing signs of progress towards a return to normal, but we must still remain vigilant. On the other hand, even in such a difficult situation, it is necessary for society as a whole to be able to respond appropriately to changes in the international situation and to environment-related issues. I assume that readers are also making various efforts to steer a new direction in this completely different "New Normal" business environment.

Our company has designated this year as the first year of our corporate transformation (CX) and we are implementing a number of initiatives aimed at achieving the targets we have set forth. This includes the growth targets in our three-year medium-term management plan "New Frontier 2022" (NF 2022), which was launched last year, and the major targets we have set for 2027, which will be the 100th anniversary of our company. The goal of these activities is to evolve into an H&S company that not only provides hardware, but also delivers services to the customers which provide added value. This is something we started from the time of NV･S7, the mid-term business plan before last. Furthermore, in the CX activities in NF2022, we are incorporating leading-edge technologies from Japan and overseas as we promote activities to advance our company's traditional seal engineering and peripheral technologies into next-generation technologies. The aim of this is for the service technology products incorporating digital solutions that our company offers to trigger innovative digital transformation (DX) in total business with our customers. I also hope that the development results generated by these activities will make a significant contribution to labor-saving in operations, as this is an area where the coronavirus crisis has triggered accelerating needs in all industries.

Another major challenge facing industry around the world is initiatives to suppress climate change, which are expressed by terms such as carbon neutrality and the circular economy. For this problem, our company is also working to appropriately fulfill our responsibility as part of the industrial world. We are striving to reflect these challenges in the contents of our R&D activities, so that they are also results that should be created by our technology development activities. The promotion of such activities is consistent with our company's endorsement of TCFD, which has already been widely reported in the media. We expect that the results of these activities will enhance our company's ESG value and lead to business results that satisfy our stakeholders.

Against this background, in this issue of Technology News, the main topics examined are themes introducing products such as highly distinctive high performance seal products that are expected to become increasingly important in specific fields in the future, systematization products that are expected to be deployed in predictive maintenance technologies utilizing IoT, and seals that are expected to bring significant benefits to facilities related to hydrogen, which is attracting increasing attention as a new energy material.

I thank you in advance for your continuing support of the products and services of our company, as well as for reading the Valqua Technology News.

Director & CTO　Mutsuo Aoki

Precautions when considering usage and troubleshooting (Flector™)

1. Introduction

Expansion joints, a type of pipe joint, have been widely used in various plants since the past. An expansion joint is a component that absorbs the effects of mutual displacement between structures, and is indispensable for the safe operation of various plants. Therefore, it is crucial to carefully select them, because installing and operating an incorrectly designed product can lead to equipment damage and possibly a major accident. There are metallic and non-metallic expansion joints. The non-metallic expansion joint manufactured by our company is called Flector™.

This report provides a brief product overview of Flector™, precautions to be taken when considering its usage, as well as usage troubles and their countermeasures.

2. Product overview

2-1) No.FLEX (Flex)

This product is a combination of metallic parts (flanges, etc.) and a non-metallic cover (Figure1). The cover part is made of integrally molded rubber and reinforcing fabric, therefore eliminating any joints and providing excellent airtightness, long-term flexibility, and radiation resistance.

Major applications: Ventilation equipment in nuclear power plants.

2-2) No.XP-221

This product is a combination of a cover and metallic parts (flanges, etc.) formed by sewing and bonding organic and inorganic cloth, film, etc. (Figure2). It is used in a wide range of industries due to its high

Figure1 Photograph of external view of No.FLEX

Figure2 Photograph of section view of No.XP-221

Figure3 Photograph of external view of No.PRBT

degree of freedom in design and high versatility.
Major applications: Exhaust gas, boiler and dust collector lines in various plants, etc.

2-3) No.PRBT (Rubber boots)

This product is made of the same cover material as No.FLEX, and is installed by wrapping a fan-shaped cover with fasteners sewn on both ends around the pipe penetration area, closing the fasteners, sealing the area with an amorphous sealing material, and then fixing both ends with metallic bands (Figure3). This product is specially designed to seal the gap between the pipe at the pipe penetration area and to absorb pipe displacement.
Major applications: Pipe penetrations in walls and floors of power plants.

3. Precautions when considering usage

Figure4 shows a product specification sheet. The items colored in pink are the minimum necessary information. If there is insufficient or incorrect information, it will have a significant impact on the performance and longevity of the product and therefore caution is required. In this section, the reasons why this is necessary will be explained in detail for each item.

Valqua Flector Specifications

Date

Dealers				Sales Office Name of Contact Person	
Customer Name				Quantity	
Sales channels				Usage Examples	Yes - No /Date of previous use
(Required for export)					(Previously use o/#)
Inclusion of venues					
Nominal size	If there are specific dimensions, please indicate them separately on the drawing.				
Terms of Use	Purpose of use				
	Name of facility or equipment				
	Installation point			Installation Location	Indoor / Outdoor
	Fluid name (Ingredients)	Dust: Yes (amount) ・ No			Corrosiveness: Yes ・ No
	Design conditions	Temperature (° C)		In operation	Temperature (° C)
		Pressure (kPa)			Pressure (kPa)
		Displacement	Axis direction (X)		
			Axis vertical (Y)		
			Axis level (Z)		
	Flow rate			Mounting length	
	Flow direction	Horizontal/vertical (top to bottom, bottom to top) Other			
Materials	Flange (non-contact gas part)			Inner tube (gas contacting part)	
	Bolts for mounting			Gasket	
	Restricted materials			Other	
Coating	Pretreatment				
	Undercoat				
	Middle coat				
	Top Coat				
	Finish color				
Other matters					

Figure4 Product specification sheet

3-1) Nominal dimensions (Mounting dimensions)

It is critical that the mounting dimensions are correct, otherwise the product cannot be installed. There might occur a problem of discrepancy between the drawings and the actual site due to lack of management of revision and abolition. Therefore, it is important to confirm the current status.

3-2) Installation location and fluids

If installed outdoors, it is necessary to implement appropriate measures because the surrounding environment is harsher than indoors, including rain, ultraviolet rays, and temperature differences. As for fluids, the presence or absence of corrosiveness and dust will lead to determining whether a cover configuration or inner cylinder will be necessary, and this is important because it has a significant impact on longevity.

3-3) Design conditions, flow velocity, flow rate, and distance between mounting surfaces

Temperature and pressure are important criteria for cover selection. Optimum design can be achieved by checking both design parameters and operating conditions. Since there exists a correlation between the amount of displacement and the space between the mounting surfaces, there is a possibility that one or the other cannot be addressed depending on the combination.

3-4) Flow direction and mounting position

The cross-section of the design may change depending on the flow direction and mounting position. Since the flow direction will also be printed on the product, it is necessary to provide this information.

4. Examples of troubles and their countermeasures

Examples of troubles due to insufficient information, incorrectinstallation, etc. will be outlined, as mentioned above.

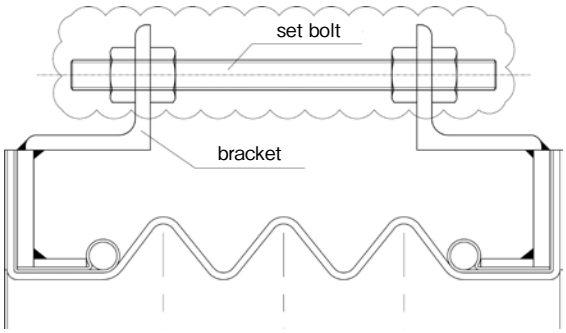

Figure5 Half-sectional view of XP-221 equipped with a set bolt

4-1) Omitting removal of set bolts

A half-sectional view of the XP-221 equipped with a set bolt is shown in Figure5. Set bolts are installed to maintain the structure of the product during transportation and storage. Although instructions are given to remove the set bolts when the product is installed, it may happen that the product is operated without removing them. Since the primary role of expansion joints is to absorb displacement through expansion and contraction, it is pointless to leave the rigid set bolts in place.

Occasionally, mounting is done with the bolts slightly loosened, but the maximum displacement cannot be absorbed with the set bolts in place, so they must be removed after the product is installed.

In principle, we make sure that the removal of the set bolts is clearly indicated on the delivery drawings provided by our company.

4-2) Dust accumulation problem due to insufficient information regarding mounting position

Normally, if there is no specific instruction, the product is designed to be installed parallel to the ground. In this example, the design included an inner cylinder because the fluid was powder. Figure6 shows an image of the XP-221 with the inner cylinder during shutdown. Since it was installed perpendicular to the ground, powder accumulated between the cover and the inner cylinder during shutdown. This happened because there was no information about the mounting direction and negative pressure. If powder accumulates between the cover and inner cylinder, it will affect the absorption of displacement of the cover, and the powder will scrape against the cover during displacement, leading to damage to the cover.

Countermeasures include filling the gap between the inner cylinder and the cover with heat insulating material or installing both inner cylinders in order to eliminate the gap where fluid can enter.

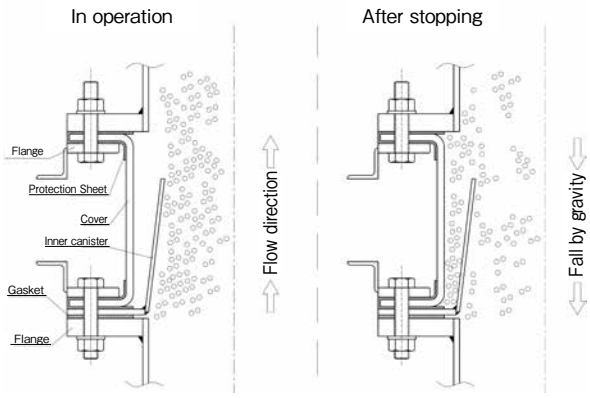

Figure6 Image of the XP-221 with inner cylinder during shutdown

4-3) Installation of thermal insulation on the outside of the product

Although we do not recommend the application of thermal insulation to the product, there have been cases where it was wrapped around the expansion joint as well, in order to maintain thermal efficiency of the equipment. Figure7 shows a half-sectional view of the XP-221 equipped with thermal insulation. When insulation is applied, heat from the fluid is trapped without hardly being dissipated to the outside air. Wrapping insulation around can lead to a loss of elasticity and heat-induced deterioration of the cover, eventually damaging the product. If thermal efficiency is a priority, shortened product lifetime and damage must be considered in advance.

As a countermeasure, considering outside installation, CR tarpaulin, which has good weather resistance, was selected as the most outmost layer, but since its heat resistance is low, in this case, we applied a cover made of heat-resistant inorganic cloth and PTFE film.

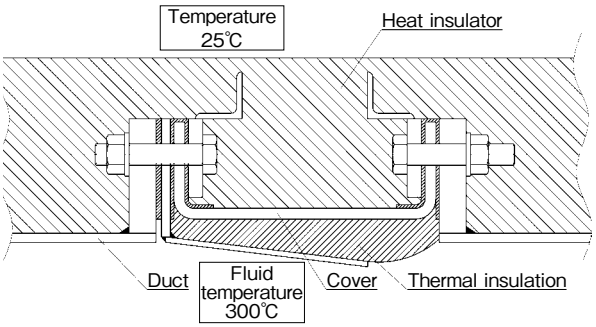

Figure7 Half-sectional view of XP-221 equipped with thermal insulation

4-4) Malfunction due to insufficient information on current condition of installed equipment

There has been a case where, due to long-term use of the equipment, earthquakes, and aging, there were deviations between the information in the documentation when the equipment was first installed and the current situation, leading to mounting defects and damage after operation. In addition, sometimes the distance between the surfaces becomes longer, or the bolt positions are shifted by several degrees. Since such deviations are not taken into account in the design, there are high chances that the equipment will be damaged after operation even if it can be installed, and thus it is crucial to verify the current conditions.

5. Precautions for usage

As mentioned above, it is possible to design the product if the pink sections in Figure4 are provided. However, since troubles such as those mentioned above may occur due to insufficient information, it is important that we proactively confirm and obtain detailed information from our customers. Even so, installation problems are more common than other products, and since the installation is done by the customer, particular attention should be paid to the following:

1) Set bolts are to be removed after the product is installed.
2) If the product is equipped with an inner cylinder, consider the flow direction, and do not reverse the installation.
3) Do not wrap with thermal insulation.

6. Conclusion

The Flector™ introduced in this report is a product directly related to the safe and secure operation of a plant, so it is necessary to design the product carefully. In order to do so, sufficient information is indispensable, and we intend to make use of our long years of knowledge to proactively conduct extensive hearings and propose solutions.

※"Flector" is a trademark of VALQUA, LTD.

Takanori Sakamoto
H&S Sales Div.
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Technical Paper

Launch of the BLISTANCE™ blister resistant material series

1. Introduction

O-rings and other elastomer seal materials (hereinafter referred to as "seal materials") are considered to have existed since the second half of the 19th century to the first half of the 20th century. They are one of the components that have supported the development of mankind over the past 100 years by preventing liquids and gases from leaking from joints and other connections of pipes used in a wide range of industries such as automobile, aircraft, chemical and steel.

The development of the aforementioned industries has been extremely rapid, and the environments to which seal materials are exposed are also becoming more severe and complex in the process.

When the elements of environmental complexification that was previously mentioned are broken down, they can be broken down into two, energetic factors and environmental factors[1]. Energetic factors include heat, stress, light, and radiation, while environmental factors include air, water, acids, alkalis, oils, and fluids such as organic solvents.

When seals are used in an environment where such factors are intertwined, their characteristics gradually change and their mechanical strength and chemical properties deteriorate compared to the initial state, or there is a change in appearance. Such phenomena are generally referred to as degradation, and as degradation progresses, seals no longer prevent fluids from leaking and eventually reach the end of their service life.

As mentioned above, degradation is caused by a combination of various factors, and there are many types of degradation. In this paper, we will focus on a type of degradation called blisters, explain its formation mechanism, and introduce our new product line, "BLISTANCE™" series, which is resistant to blisters.

2. Blisters[2]

This section describes the mechanism leading to the occurrence of blisters, a type of degradation in seal materials.

Blisters occur under certain conditions, when seal material such as O-rings in equipment and devices are exposed to sudden pressure fluctuations while in contact with gases and fluids such as volatile liquids under high temperature and high pressure.

Firstly, from a microscopic point of view, elastomers are composed of intertwined molecular chains and are relatively porous materials. Therefore, in high-temperature and high-pressure environments, gases and volatile liquids can easily penetrate the interior of the seal material through the gaps in the molecular chains, and some of which remain inside.

Furthermore, when the pressure is rapidly reduced from the state where the fluid is retained inside the seal material, the gas or volatile liquid expands in volume inside the seal material and tries to escape outside from the surface of the seal material.

When the above phenomenon occurs or reoccurs multiple times, the force of the fluid trying to escape overcomes the mechanical strength of the seal material, causing foaming and cracking inside and on the surface (Figure1).

In industries dealing with elastomers, this type of degradation, where fluids trapped inside physically damage the seal material upon depressurization, is called "blister" (Figure2).

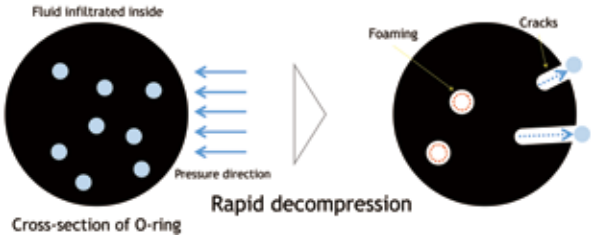

Figure1 Schematic diagram of blister formation mechanism

Figure2 Example of an O-ring where blisters have occurred

When blisters occur, the corresponding area may become a leak path, or fracture due to pressure applied to the fissure, making the seal material unable to perform its function of preventing fluid leakage.

For instance, high-pressure hydrogen gas environments are an area where damage can be caused due to blisters. If a leak occurs due to blister generation of the seal material, the static electricity generated in the surroundings may cause an explosion, which may lead to a severe accident involving human lives.

Moreover, a prime example of volatile fluids are refrigerants (CFC or CFC substitutes), which are also a kind of fluid where the occurrence of blisters is sometimes seen. In recent years, R134a and other CFC alternatives have become the most common refrigerants, and unlike the specified CFCs used in the past, they do not deplete the ozone layer. However, their global warming potential is not significantly different, and their impact on global warming is considered to be significant in case of leakage.

In order to prevent the leakage caused by these blisters, it is important to select the most suitable seal material for that environment. Some of the criteria are described below:

① Select a seal material with high hardness and mechanical strength.

② Select a seal material that has low compatibility with fluids.

③ Decrease the cross-sectional diameter of the seal material to reduce the amount of fluid retention inside.

In addition, adjustments to the operating environment, such as lowering the operating temperature and slowing down the decompression rate, are considered to be effective in preventing blister formation.

3. Product overview of the "BLISTANCE™" series

Using ① and ② in the previous section 2 as criteria, we have launched a new series of products called "BLISTANCE™", including both newly developed products as well as previously available blister-resistant seals, to make it easier for customers concerned about or troubled by blisters forming in high-pressure hydrogen gas, high-temperature steam, refrigerant + refrigerant oil, and other environments, to select seal materials.

In this section, we will introduce the features of each of the following four products:

1. "BLISTANCE™- H Series", suitable for use in hydrogen gas environments.
2. "BLISTANCE™- St Series", suitable for use in high-temperature steam environments.
3. "BLISTANCE™- Rf Series", for use in refrigerant + refrigerant oil environments.
4. "BLISTANCE™- Mu Series", for use in a wide range of other environments.

3-1) BLISTANCE™-H series

The BLISTANCE™-H series is a seal material suitable for use in hydrogen gas environments. Currently, BLISTANCE™-HST for low pressure (under 2MPa), BLISTANCE™-HMP for medium pressure (under 35MPa), and BLISTANCE™-HLT series for high pressure (under 95MPa) are available, all three of which are made of EPDM seal material.

The maximum pressure of hydrogen gas used at current hydrogen stations is 82MPa, and its mechanism

is as follows: from a container called a "curdle," through a compressor and a pressure accumulator, cooled by a pre-cooler, and then filled into a vehicle through a dispenser. Since the filling of hydrogen gas from the dispenser into the vehicle is done by using differential pressure, the compression by the compressor affects the filling speed. The higher the pressure to increase the filling speed, the greater the heat generated by adiabatic compression during filling.

Therefore, when hydrogen gas is filled at room temperature, there is a risk of exceeding the heat resistance temperature of the hydrogen tank inside the vehicle (said to be 85℃ for Type IV hydrogen tanks made of CFRP), so it is necessary to cool the hydrogen gas to -40℃ using a pre-cooler (Figure3).

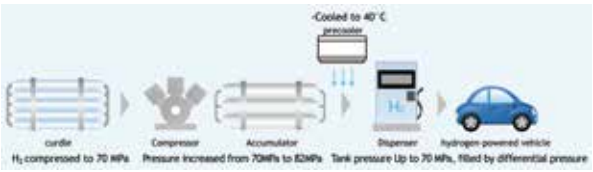

Figure3 Mechanism of a hydrogen station, schematic diagram

In this case, the situation where blisters are most likely to form is when a sudden decompression from 82 MPa to atmospheric pressure occurs while the temperature has risen to around 85℃ and the chances are particularly high with general-purpose seal materials. In addition, the same seal material must be able to seal at a pressure of 82 MPa and temperature of -40℃.

Also, hydrogen gas is handled at pressures of 35 MPa in small hydrogen stations and 2 MPa in hydrogen gas detection sensors, and since these facilities are not equipped with pre-coolers, the presence or absence of low temperature characteristics is not questioned here.

In introducing the BLISTANCE™-H series, we will first introduce the features of BLISTANCE™-HLT, which is most suitable for seals used in areas exposed to high pressure and low temperature[3].

The most remarkable feature of BLISTANCE™-HLT is that even after 11,250 cycles of rapid pressurization and depressurization of hydrogen gas at a pressure of 90 MPa at 90℃, no leakage of hydrogen gas was detected during the cycle test and no trace of blisters was found on the seal material after the test. (The pressure cycle test was conducted at the Hydrogen Energy Products Research and Testing Center (HyTReC)).

We have run a similar test on general-purpose seals and the difference in appearance after the test is apparent (Figure4).

Figure4 Surface condition of O-ring after high-pressure hydrogen cycle test

BLISTANCE™-HLT also has excellent low-temperature properties. The following is a comparison of low-temperature properties between BLISTANCE™-HLT and a general-purpose seal material also made of EPDM. The low-temperature properties were evaluated by conducting a low temperature elastic recovery test (hereinafter referred to as TR test) in accordance with JIS K6261-4. The results are shown below (Figure5, Table1).

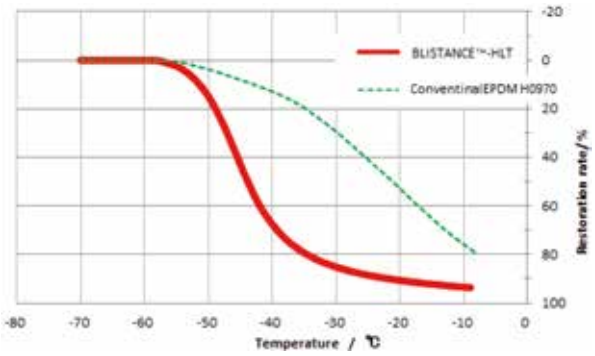

Figure5 Measurement results of BLISTANCE™-HLT TR test (Comparison: General-purpose EPDM)

Table1 Comparison of BLISTANCE™-HLT and H0970 TR values

	BLISTANCE™-HLT	Conventianal EPDM H0970
TR10 (℃)	-51	-43
TR30 (℃)	-47	-30
TR50 (℃)	-44	-21
TR70 (℃)	-39	-13
Shrinkage at minus 40℃ (%)	67.4	12.8

The above graph shows that the temperature moves toward room temperature as the horizontal axis moves to the right, and the seal material regains its elasticity as the vertical axis moves downward. From this result, it can be confirmed that general-purpose EPDM regains 10% of its elasticity at around -43℃, whereas BLISTANCE™-HLT regains the same level of elasticity at around -51℃, showing that it has excellent low-temperature properties.

The fact that no leakage of hydrogen gas was detected after 1,000 cycles of 90 MPa pressurization at -40℃ and another 20 cycles of 90 MPa pressurization at -50℃ at HyTReC, indicates that BLISTANCE™-HLT is suitable as a seal material for use in low-temperature and high-pressure hydrogen gas environments.

As mentioned above, BLISTANCE™-HLT is a product that displays its performance in a high-pressure hydrogen gas environment that can be exposed to low temperatures, but it is over-specified for use in a medium-pressure hydrogen gas environment where the temperature is not as low and the pressure is less than 35 MPa or in a low-pressure hydrogen gas environment where the pressure is less than 2 MPa. For these applications, we recommend BLISTANCE™-HMP for medium-pressure hydrogen gas or BLISTANCE™-HST for low-pressure hydrogen gas.

Finally, please refer to VALQUA Technology News No.39 (2020) for the details of BLISTANCE™-HLT characteristics and tests.

3-2) BLISTANCE™-St series

BLISTANCE™-St series is a blister-resistant seal material for high-temperature and high-pressure steam environments, and there is only one type of BLISTANCE™-StHT in the current range.

In general, seal materials made of binary fluororubber (FKM) are used in high temperature environments under air, but it is known that when the environment becomes steam, hydrolysis occurs and the mechanical strength decreases.

In addition, there have been cases where, when used under high pressure, steam penetrated and stayed inside the seal material, which expanded upon depressurization, resulting in blister formation.

Seal materials that are used in food and beverage manufacturing facilities are actually exposed to such conditions, and blister formation can become a problem.

The product that we would like to recommend for customers who are facing the above problems is BLISTANCE™-StHT[4]. This product is based on tetrafluoroethylene-propylene rubber (FEPM), and has a different molecular structure from conventional binary FKMs consisting of vinylidene fluoride (VDF) and hexafluoropropylene (HFP) (Table2).

Table2 Molecular structures of FEPM and binary FKM

Type	Molecular Structures
FEPM	$-(CF_2\text{-}CF_2)_p\text{-}(CH(CH_3)\text{-}CH_2)_q-$ TFE Pr
FKM (Bipolymer)	$-(CF_2\text{-}CH_2)_p\text{-}(CF(CF_3)\text{-}CF_2)_q-$ VDF HFP

The most significant feature of BLISTANCE™-StHT, which was developed with our compounding technology using FEPM as base material, is that the value of the compression set rate is lower than that of the conventional FEPM-based seal materials even in a steam environment of 230℃, and that blisters do not occur during decompression due to its improved mechanical strength.

Although EPDM and HNBR-based seal materials have been widely used in the past in steam environments of less than 150℃, BLISTANCE™-StHT seals demonstrate significantly higher capabilities than conventional materials at temperatures above 150℃, where sealing used to be difficult.

The following is a photograph of a compression set test specimen that was actually exposed to a steam environment at 230℃ for 72 hours in a compressed state and then rapidly decompressed, as well as the measured compression set strain rate after exposure to a steam environment at 200℃ for 72 hours (Figure6, Table3).

Figure6 Cross-section of test specimen after 72h of compression in 230℃ steam

Table3 Comparison of compression set rate between BLISTANCE™-StHT and conventional FEPM

	BLISTANCE™-StHT	conventional FEPM
compression set rate (%) 200℃×72h Under steam	18	36

From the above results, it can be seen that BLISTANCE™-StHT does not show blister formation even in environments where it has occurred in conventional FEPM, and furthermore, the compression set rate in steam environment is small and thus favorable.

In addition, as shown in the beginning of this section, FEPM has good acid and alkali resistance. Therefore, BLISTANCE™-StHT can be expected to have a long service life not only in steam but also in acidic and alkaline vapor environments. Thus, customers who have concerns or difficulties about blisters in steam environments or leakage of acidic and alkaline fluids in high-temperature environments are recommended to consider using BLISTANCE™-StHT.

3-3) BLISTANCE™-Rf series

BLISTANCE™-Rf series is a blister-resistant seal material for use in environments where a refrigerant is mixed with refrigerant oil, and there is only one produce, BLISTANCE™RfST, in the current series.

In general, refrigerants (fluorocarbons including CFC alternatives) are used as fluids in areas where heat exchange takes place. Heat exchange is achieved through the process of removing heat from the surrounding environment by vaporization heat as well as its release during liquefaction. The refrigerant changes to a liquid when pressurized, and becomes a gas when the pressure is lowered. Therefore, during heat exchange, the pressure is frequently changed, requiring the refrigerant to change its state each time from liquid to gas and vice versa. Hence, the occurrence of blisters is also seen regarding seal materials in applications where refrigerants are used.

The most important condition for selecting a seal material in a refrigerant environment is that it should have high mechanical strength to withstand blister formation caused by pressure changes, but it is also important that it has low affinity for refrigerants and refrigerant oils used as lubricants, in order to reduce the amount of fluid penetration into the seal material.

BLISTANCE™-RfST, introduced in this section, is a HNBR-based seal material with high mechanical strength and low affinity for refrigerants and refrigerant oils (mineral and synthetic oils).

The following photographs show samples removed from a pressure vessel after depressurization when our conventional HNBR and BLISTANCE™-RfST were placed into a pressure vessel filled with refrigerant and refrigerant oil, and kept at elevated temperature and internal pressure for 72h. (Figure7).

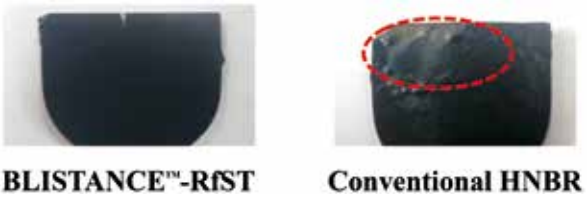

Figure7 Comparison of test specimen surfaces after refrigerant immersion test

Blisters occurred on our conventional HNBR, but were not observed on BLISTANCE™-RfST exposed to a refrigerant environment under the same conditions.

From this example, it can be said that BLISTANCE™-RfST is suitable for use in a refrigerant environment.

In case the main component of the refrigerant oil is a synthetic oil such as polyalkylene glycol, we would also like to recommend the BLISTANCE™-H series, in particular, BLISTANCE™-HMP, as described in 3-1).

3-4) BLISTANCE™-Mu Series

BLISTANCE™-Mu series is not a blister-resistant seal material for specific environments such as high-pressure hydrogen gas, high-temperature steam, and refrigerant environments introduced so far, but all possess high

mechanical strength, and therefore, if there is no compatibility problem with the used fluid, they can be considered as products that prevent blister formation.
Currently, we offer three types of products: BLISTANCE™-MuST, a HNBR-based product with hardness 70, BLISTANCE™-MuHP, a HNBR-based product with hardness 95, and BLISTANCE™-MuHT, a FKM-based product with hardness 90.
In order to use the most suitable seal material in any given environment, when blister formation is a concern, please consider the BLISTANCE™-H, St, and Rf series as well.

4. Environmental compatibility and basic physical properties of the BLISTANCE™ series

As a summary, Table4 and 5 show the environmental compatibility and basic physical properties of the BLISTANCE™ series introduced in this paper.

Table4 List of BLISTANCE™ Series Environmental Compatibility

Main Applications			High-pressure hydrogen gas environment			High-pressure steam environment	Refrigerant environment	Other Environments		
Series name			BLISTANCE™ H Series			BLISTANCE™ St Series	BLISTANCE™ Rf Series	BLISTANCE™ Mu Series		
Product name			BLISTANCE™-HST	BLISTANCE™-HMP	BLISTANCE™-HLT	BLISTANCE™-StHT	BLISTANCE™-RfST	BLISTANCE™-MuST	BLISTANCE™-MuHP	BLISTANCE™-MuHT
Material			EPDM	EPDM	EPDM	FEPM	HNBR	HNBR	HNBR	FKM
Nominal Hardness (HA)			70	80	90	90	80/85	70	95	90
Service temperature (℃) *Highest and lowest℃)			-40～120	-40～130	-50～100	0～200	-20～120	-20～120	-15～120	-30～200
Application Suitability	hydrogen	High pressure (～95MPa)	×	×	◎	×	×	×	×	×
		Medium pressure (～35MPa)	○	◎	◎	◎	○	○	◎	◎
		Low pressure (～2MPa)	◎	◎	◎	◎	○	◎	◎	◎
	Steam		○	◎	△	◎	○	○	○	△
	Natural gas		×	×	×	○	◎	○	◎	◎
	Refrigerant※	Mineral oil as refrigeration machine oil	×	×	×	×	◎	○	◎	×
		Synthetic oil as refrigeration machine oil	◎	◎	◎	×	○	△	○	×

※R134a, R245fa, R32, R400 series, R1234 series and other refrigerants are applicable

Table5 List of BLISTANCE™ Series Basic Physical Properties

Main Applications			High-pressure hydrogen gas environment			High-pressure steam environment	Refrigerant environment	Other Environments		
Series name			BLISTANCE™ H Series			BLISTANCE™ St Series	BLISTANCE™ Rf Series	BLISTANCE™ Mu Series		
Product name			BLISTANCE™-HST	BLISTANCE™-HMP	BLISTANCE™-HLT	BLISTANCE™-StHT	BLISTANCE™-RfST	BLISTANCE™-MuST	BLISTANCE™-MuHP	BLISTANCE™-MuHT
Material			EPDM	EPDM	EPDM	FEPM	HNBR	HNBR	HNBR	FKM
Normal physical properties JIS K6251 (JIS No.3 dumbbell)	Hardness	–	75	80	93	90	80	73	94	92
	Tensile strength	MPa	17.1	22.4	14.3	26.9	21.9	30.6	28.8	22.7
	Elongation	%	200	180	110	120	185	240	90	110
	100% Tensile Stress	MPa	6.4	9.4	10.4	23.0	10.1	7.9	–	20.0
Heat aging test JIS K 6257 (JIS No.3 dumbbell)	Hardness change	–	±0※4	+1※4	+2※4	±0※6	+3※5	+3※5	+1※5	±0※4
	Tensile strength change	%	+5※4	-4※4	+4※4	-1※6	+8※5	+8※5	+4※5	-3※4
	Elongation change	%	+15※4	-4※4	-9※4	±0※6	-4※5	-11※5	-14※5	-3※4
Compression set test JIS K 6262 (φ29.5 × 12.5t)	Compression Set Rate	%	12※5	7※5	16※4	20※6	14※	-13※5	19※5	9※4

※Both environmental compatibility and basic physical properties are for reference only and are not guaranteed data.

5. Acknowledgments

We would like to express our sincere gratitude to the people at the Development Office of Ihara Science Corporation for their cooperation since the very beginning in the development and evaluation of BLISTANCE™-HLT, in particular, among the BLISTANCE™ series.

6. Conclusion

In this article, we have introduced the BLISTANCE™ series as blister-resistant seal materials, and there is a background that they were seal material with high mechanical strength. Therefore, we hope that the BLISTANCE™ series will be widely used even in environments where blister formation is not expected.
In addition to the expansion of the BLISTANCE™ series, we will continue to work hard on the development of new elastomer materials and the improvement of existing materials so that we can quickly respond to the needs of our customers.

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Report on Predictive Maintenance Technology for Equipment by Vibration Measurement

Introduction of Network-based Predictive Maintenance System

1. Introduction

The maintenance of facilities and equipment in manufacturing plants is shifting from preventive maintenance and breakdown maintenance to "predictive maintenance." Preventive maintenance is performed at regular intervals and timings, and corrective maintenance is done by maintenance and repairs after a failure, loss of production capacity or defective products. In contrast, predictive maintenance is maintenance, where signs of failure are detected in advance and repairs and maintenance are performed at the appropriate timing. We have also been developing a tablet-type abnormal vibration detection system[1]. At sites where maintenance activities are performed by patrolling, this system measures and analyzes on the spot the vibration state of the maintenance target using sensors to confirm the chronological changes in the state using charts and numerical values. In this way, the system allows us to systematically implement predictive maintenance, when an abnormality occurs, by displaying according to the degree of abnormality. This is a so-called portable predictive maintenance system, but with the advancement of sensing and IoT technologies, the market has begun to see a wide range of services based on models that store and analyze data on servers and clouds via networks. The system enables remote status confirmation and predictive maintenance from the network. However, the reality is that at actual sites that our customers are facing, there are many cases where it is not possible or not allowed to upload sensing data to an external network or the cloud server for various reasons. We have developed a system that allows them to proceed even at such sites by predictive maintenance using a local network. This report introduces the network-based predictive maintenance system and the predictive maintenance technology it incorporates.

2. Overview of Predictive Maintenance System

2-1) System configuration

A schematic diagram of the network-based predictive maintenance system in operation is shown in Figure1. The basic configuration consists of a "vibration sensor," "sensor unit," and "predictive maintenance analysis program" (to be installed on a PC for use). The sensor

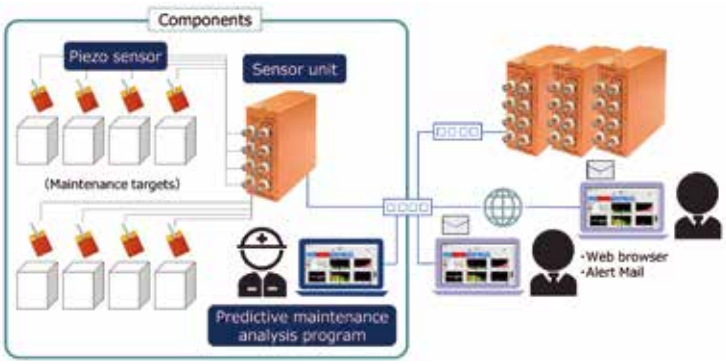


Figure1 Schematic diagram of the maintenance system

and the sensor unit are connected with the supplied low noise cable. The sensor unit and the program (PC) are connected using a LAN network. The LAN can also use an existing network. It is operational even with this basic configuration, making it easy to handle. Moreover, by increasing the number of sensor units with a switching hub, it will also be possible to increase the number of maintenance targets and sensing points, check their status from a networked location via a web screen on another PC and receive alerts by e-mail according to the degree of abnormality of the maintenance target (a mail server to be separately required).

2-2) Components

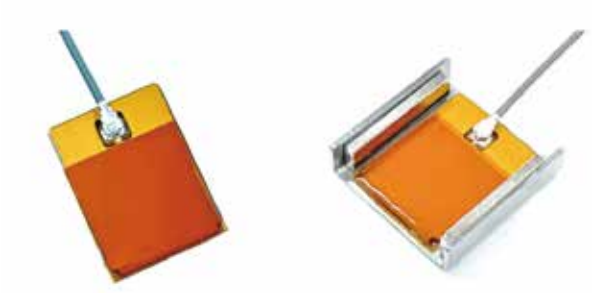
The following are the three components.

2-2-1) Organic piezoelectric vibration sensor

We have developed a thin, compact, and lightweight vibration sensor that uses an organic piezoelectric element[2] that can be easily retrofitted. It is fixed by attaching it to the mating surface, but due to its flexibility, it can be fixed to a slightly curved surface. Using a special magnetic bracket will also make it possible to fix it with magnetic force (Figure2).

2-2-2) Sensor units

Since each sensor unit is equipped with eight input channels, all of which have built-in charge amplifiers, charge output type sensors can be connected as they are. Therefore, in addition to the organic piezoelectric vibration sensor mentioned above, commercially available vibration and acceleration sensors can also be used. In the sensor unit, the sensor signal is digitally converted and transmitted from the LAN terminal to the PC on the analysis side through the network. The LAN connection also allows for distributed placement of sensor units, making it possible to build a multi-point sensing environment flexibly and cost-effectively (Figure3).



(Pilot model) Magnetic bracket

Figure2 Organic piezoelectric vibration sensors

(Pilot model)

Figure3 Sensor unit

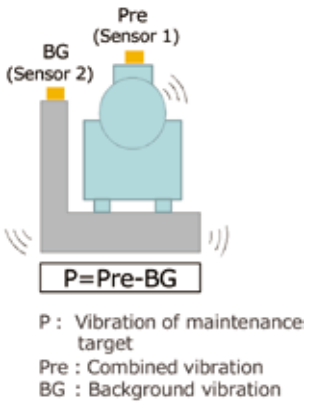


Figure5 Elimination of background vibration

2-2-3) Predictive maintenance analysis programs

Octave analysis is conducted on vibration sensing data, based on which predictive maintenance is performed by conducting "MT method (degree of abnormality analysis)" and "trend analysis (state analysis)" from the data. For each measurement point, the "time waveform," "FFT analysis," "octave analysis," "MT method," and "trend analysis" can be checked on the screen dashboard (Figure4).

It also has a function to differentiate data (Figure5) to eliminate background vibration from the environment as a disturbance signal. To check the current status of the maintenance target, the screen displays the status and alert level corresponding to the threshold value. In case of an abnormality (every time the status changes to Caution, Maintenance, or Danger), an alert e-mail can be sent to the maintenance staff.

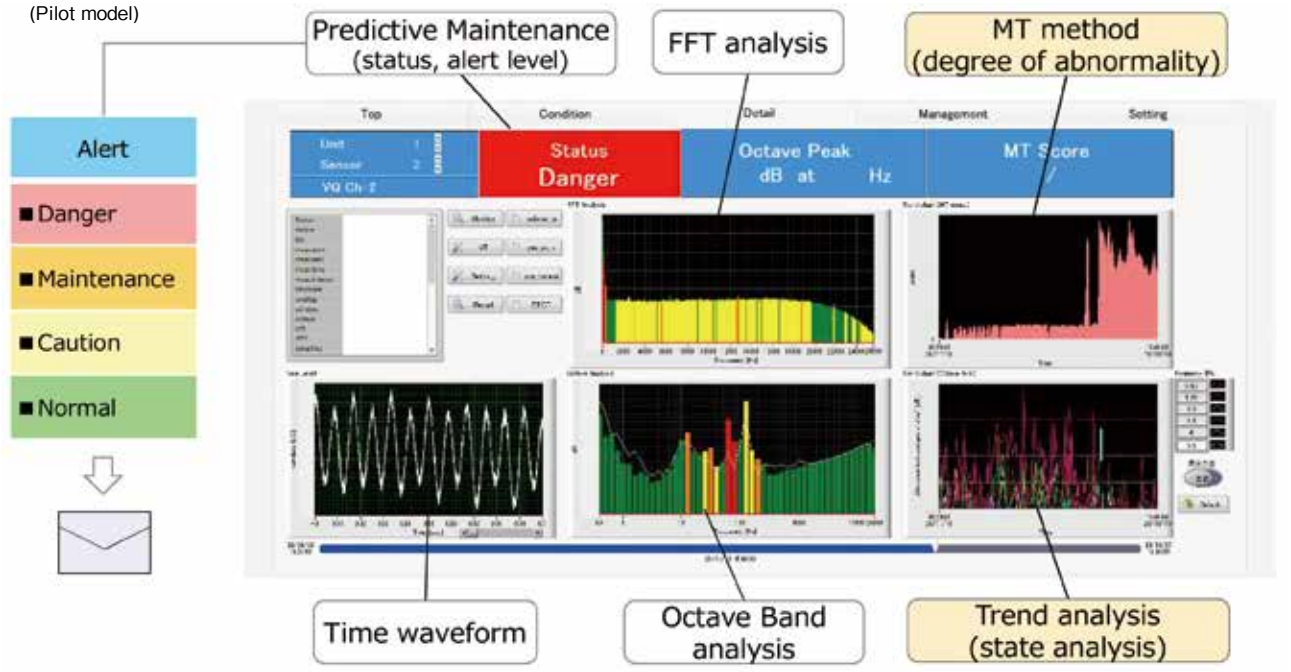


Figure4　Predictive maintenance analysis programs

3. Predictive Maintenance Methods

To perform predictive maintenance based on changes in the vibration state of the maintenance target, it is necessary to capture the changes in the vibration state of the maintenance target from sensing data. This system uses the vibration data on which octave analysis has been conducted. We have adopted this method because it is very compact compared to the amount of data in FFT analysis, which is widely used in vibration analysis, and it is suitable for analysis using the trend analysis and MT method described below.

3-1) Trend analysis (state analysis)

This method uses the vibration data of the maintenance target in normal (regular) operation as a reference to conduct the initial measurement. By using the difference value between the vibration data and the subsequent vibration measurement data to draw a trend chart of how much the vibration intensity has changed/differed, it will be compared with the threshold value to capture signs of abnormality. It is a trend analysis characteristic to focus on relative changes rather than absolute changes, and signs of abnormality will be captured through this kind of analysis of the state of vibration. For the frequencies to be used in the analysis, the top five frequencies with the maximum change in vibration intensity from the octave analysis data and another one (one can be selected arbitrarily) are automatically selected. Alternatively, all of them can also be selected manually (Figure6).

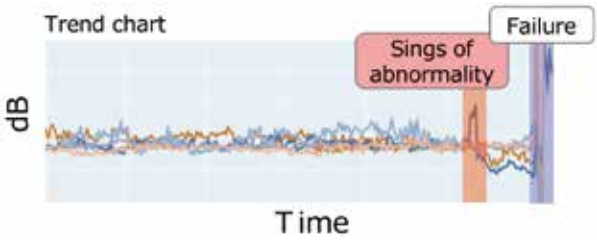


Figure6　Overview of trend analysis

3-2) MT method (degree of abnormality analysis)

The MT (Mahalanobis-Taguchi) method[3] is a pattern recognition method that aims to determine normality and abnormality based on the Mahalanobis distance. It is widely used for various types of judgment, and since it is simple and can easily detect the degree of abnormality, it is incorporated into the predictive maintenance analysis program together with the trend

analysis described above (Figure7).

This method captures the degree of abnormality by creating a unit space from the vibration data obtained when the maintenance target is operating normally (steady-state) and then calculating the Mahalanobis distance (MT score) with the subsequent vibration as data space. However, by preprocessing the data to adjust the number of analysis dimensions, we have found that the time of appearance of the MT score indicates the degree of abnormality. The predictive maintenance analysis program is equipped with this function to adjust the number of dimensions, making it possible to detect signs of abnormality based on the MT score right before the failure of the maintenance target or with enough time to spare before such an incident. Thus, the function can be used effectively by the style of the customer's maintenance activities (Figure8).

The abovementioned methods of "trend analysis" and "MT method" are installed and conducted simultaneously in this system. Capturing changes in the vibration state and the degree of abnormality numerically has improved the accuracy of its predictive maintenance.

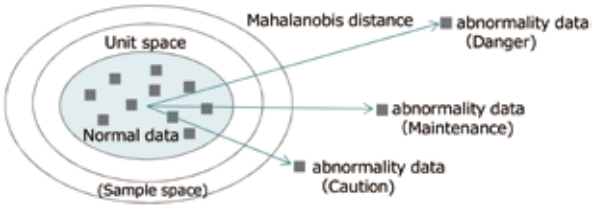


Figure7 Overview of MT method

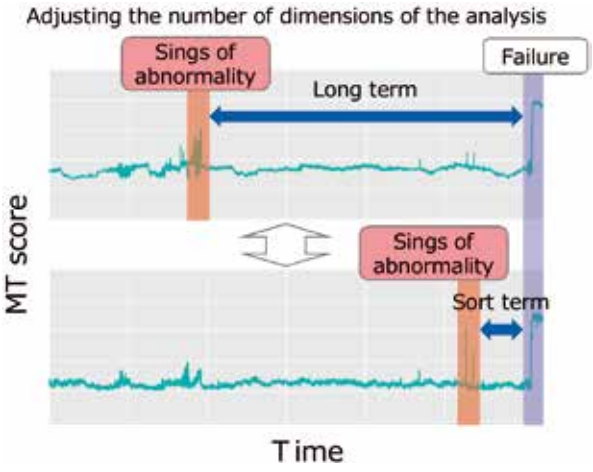


Figure8 Overview of adjustment of analysis dimensions and predictive timing

4. Opportunities for Use and Pre-verification Activities

The maintenance targets assumed for this predictive maintenance system are pumps, motors, engines and other machinery whose status can be sensed with vibration. However, it is essential to verify in advance at the customer's site whether or not predictive maintenance is possible for the maintenance target. Therefore, obtaining cooperation from the customers considering the introduction of the system, we ask them to allow us to make trial measurements in advance. We also ask them to consider the possibility of predictive maintenance and its cost-effectiveness after installation.

5. Specifications

The specifications of the organic piezoelectric vibration sensor are shown in Table1, those of the sensor unit in Table2, and those of the predictive maintenance analysis program in Table3. In actual use, the number of units and the number of sensing units will determine practical measurement settings and the number of PCs in the predictive maintenance analysis program. Thus, the frequency of data collection and the scale of sensing will need to be confirmed and planned with each customer.

＊The specification values are from the pilot model data and may differ from the product.

Table1 Specification summary of Organic piezoelectric vibration sensors

Element	Organic piezoelectric element (Thickness 1mm)	(Reference value)
Sensitivity	0.1pc/m/s^2	(Reference value)
Frequency range	0.4～10,000 Hz	(Reference value)
Dimensions	24×20×0.5mm	(Reference value)
Cable	Low noize (3m standard)	(Reference value)
Weight	approx. 1g (Cable not included)	(Reference value)

Table2　Specification summary of Sensor unit

Input Ch number	8ch (Built-in charge amplifier)
A/D Conversion	24bit (8ch at the same time)
Sampling frequency	51.2kHz
Input frequency range	0.16Hz～20kHz
Protocol	UDP/IP
Ethernet	1ch, 10/100/1000Mbps, RJ45
Trigger	Photocoupler (Requires external power supply DC24V)
Power supply	DC24V
Dimensions, Weight	W52×H126×D128mm, approx. 450g
Operating Environment	0-55℃, 95% relative humidity, non-condensing

Table3　Specification summary of Predictive maintenance analysis programs

Analysis function	FFT analysis, Octave analysis (1/1, 1/3, 1/6, 1/12, 1/24)
Predictive maintenance function	Trend analysis (state analysis), MT method (degree of abnormality analysis), Alert display and email delivery by threshold
Other functions	Background signal removal, Measurement by trigger, Remote panel connection using a web browser
Storage capacity of analysis data	[Example] approx. 160GB / year ※1 (Settings: 8ch, 1/3 octave analysis, 10-minute interval measurement ※1 When not saving the time waveform data)
Operating environment	OS: Windows10, Processor: Intel Core i5 equivalent or higher
Connectable unit	VALQUA Sensor Unit ※2 (NI9234 [National Instruments] , connectable)
	※2 The number of connected sensor units depends on the measurement settings and network environment, so advance planning is required.

6. Conclusion

This "network-based predictive maintenance system" has been developed based on the concept of a system that can be used immediately at the manufacturing site, and we hope that it will be considered as a benchmark for installation. This system will be a part of our VALQUA Predictive Maintenance System product range, and we hope that it will contribute to the maintenance of production sites in various industries.

7. References

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Mat Sensor Using Piezoelectric Sheet

1. Introduction

VALQUA has been developing organic piezoelectric sheets using fluorine materials[1] and abnormal vibration detection systems as its application[2].

The characteristics of the fluorine material and the carefully designed sheet structure enable piezoelectric properties. As a result, our fluorine-based organic piezoelectric sheet can be used even at high temperatures of 100℃ or higher, which was not possible with conventional organic (polymer-based) piezoelectric materials. Other characteristic of these sheets is that they do not lose their piezoelectric properties even in high temperature and high humidity environments (85℃ and 85% RH). In addition, it is easy to make them large in area, which is a common feature of organic piezoelectric materials. This report introduced the mat sensor we have developed as an item that makes the most of these features.

2. Detection Mechanism

2-1) Function of piezoelectric sheet

First, the functions of piezoelectric sheet will be explained. Piezoelectric sheets are a form of piezoelectric material. There are many inorganic and organic piezoelectric materials. Also, there are several types of detection mechanisms, but for simplicity, the detection mechanism of our organic piezoelectric sheet will be explained as an example.

As shown in Figure1, piezoelectric materials have two effects. The piezoelectric effect, in which a voltage is generated when force is applied, and the inverse piezoelectric effect, in which the material deforms when a voltage is applied. In this mat sensor application, the piezoelectric effect is used, and the voltage generated by applying force to the piezoelectric sheet is used as a signal.

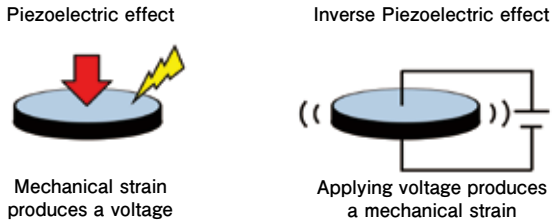

Figure1 Functional expression mechanism of piezoelectric sheet

2-2) Detection mechanism of conventional mat sensors

Many mat sensors use a method called contact-type method, as shown in Figure2. In the contact-type method, the contact points inside the sensor make contact with each other due to the applied pressure, which leads to conduction and detection of the pressure. It is a very simple detection mechanism, and the mechanism is easily understandable. On the other hand, this method requires a structure (e.g., a spacer) to separate the contact points, and thus the system is anticipated to become complicated for large-area sensors. In addition, it is expected that the effect of the deterioration of the structure over time must be considered as well.

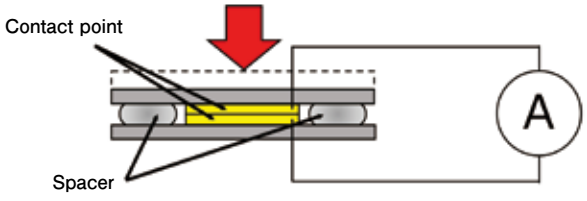

Figure2 Detection mechanism of sensor using contact-type method

2-3) Detection mechanism of piezoelectric sheet

Figure3 shows the detection mechanism of a piezoelectric sheet. The sensor has a simple structure consisting of a piezoelectric sheet and electrodes placed on both sides of the sheet. It detects the voltage generated when the sheet itself is distorted in the thickness direction by the applied pressure. This system does not require a spacer, and it is relatively easy to fabricate a thin, large-area sensor.

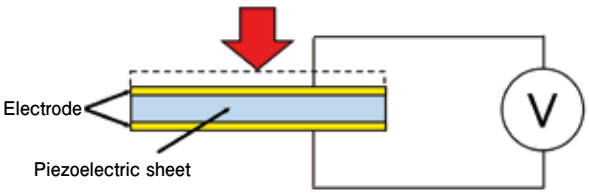

Figure3　Detection mechanism of piezoelectric sheet

Our piezoelectric sheet detects force in the direction perpendicular to the sheet surface. On the other hand, other piezoelectric materials can detect force in the direction of the surface (tension, compression, and torsion). When used as a mat sensor, detecting only vertical force like our type is assumed to be an advantage in some applications.

Next, we are going to explain how piezoelectric sheets detect force. In general, piezoelectric materials, whether inorganic or organic, generate a voltage at the moment when force is applied and thus can detect the force. In contrast, they do not generate voltage when force is continuously applied and thus cannot detect static force.

On the other hand, as a mat sensor, there is also a need to continuously detect force, not only at the moment when force is applied but also in the state when force is being applied (i.e., when a person or object is on it).

Figure4 illustrates the difference between the responsiveness of piezoelectric materials and the responsiveness required for use as a mat sensor. As shown in the figure, to detect continuous force, the output voltage waveform from the piezoelectric material needs to be converted to a form suitable for a mat sensor. In this project, we dealt with it by designing a dedicated control circuit to perform the waveform conversion.

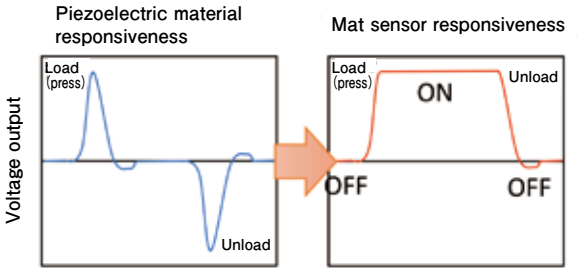

Figure4　Responsiveness of piezoelectric material and mat sensor

3. Development Details

3-1) Setting target performance

As a performance indicator for our mat sensor, we referred to JIS B 9717-1:2001 (Safety of machinery-Pressure-sensitive protective devices - Part 1: General principles for design and testing of pressure-sensitive mats and pressure-sensitive floors). This JIS summarizes the required properties for mat sensors to be installed in factories and other facilities. In this project, we used this JIS as a reference to proceed with our development of a mat sensor that would satisfy the properties shown in Table1.

Table1　Test items and conditions

Test item	Test conditions
Mechanical properties	
Durability test	2 million cycles vertical / diagonal room temperature
	1 million cycles diagonally 14.5 degrees -20℃, 50℃
Vibration test	1⇔30Hz/ up / down / left / right/ front/ back / 5 minutes each
Static load test	Φ11/750N/8h, φ80/2000N/8h
Impact resistance test	R:10mm/1kg/ Dropped from:1000mm
Weather resistance properties	
Waterproof test	IP6X
Cycle test	−20℃ (12h)⇔50℃ (12h)×10
Heat aging test	66℃ /90 days room temperature 8 years equivalent to exposure
High temperature and high humidity test	40℃ /90-95%RH/56 days
High temperature test	50℃ /72 hours
Low temperature test	−30℃ /72 hours
Electrical properties	
Dielectric strength test	AC0.72kV/1mA、DC1kV/ >100MΩ

3-2) Examining mat sensor structure

We examined the structure of a mat sensor that would satisfy the required properties described above. The pressure-sensing itself could be realized with a simple structure of a sensor consisting of a piezoelectric sheet and electrodes as described above.

However, this sensor is very thin (several hundred microns) and does not have sufficient mechanical strength. The optimal structure was determined by examining a variety of structures to satisfy the mechanical properties, weather resistance (water resistance), and electrical properties.

3-3) Performance evaluation method and results

The performance test was conducted according to the JIS standard (JIS B 9717-1:2001). We measured the voltage output when force was applied to the mat sensor before and during each test, evaluating the pressure detection performance of the mat sensor.

For the durability test, we fabricated JIS-compliant test equipment and conducted the test. Figure5 shows an example of the equipment, a durability test machine for the vertical load. Two million cycles of force were applied for the durability test.

The developed mat sensor satisfied the properties shown in Table1.

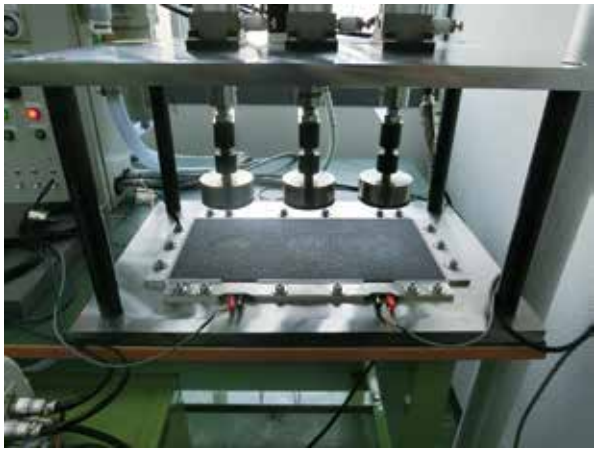

Figure5　Durability test machine (example)

4. Characteristics of developed product

Figure6 shows the appearance of the developed mat sensor system. The system consists of a mat sensor (right) and a control circuit (left). The latter is used for output waveform conversion.

In this system, the LED lamp of the control circuit lights up when pressure is applied to the mat sensor. The control circuit can be further downsized and expanded functionally.

As for the functional expansion of the control circuit, for example, it will be possible to detect only the force of arbitrary magnitude by adding a threshold setting function. Also, patterning the electrodes on both sides of the piezoelectric sheet will make it possible to detect the force distribution. Furthermore, if a wireless communication function is built-in, it can be used as an IoT device and monitored remotely.

Figure6　Developed mat sensor system

5. Conclusion

Our fluorine-based organic piezoelectric sheet was introduced. This time, we were able to develop a mat sensor that complies with the required properties of JIS B 9717-1:2001. The piezoelectric sheet has no mechanical mechanism and can be used for a long time. It is thus expected to have a long time stable performance as a mat sensor.

The size, shape, and detection sensitivity can be designed according to the application. Also, since the

piezoelectric sensor is extremely thin (several hundred microns) and flexible, it can be applied as a thin mat sensor. Taking advantage of these features, the sensor could be used in the security and health care, which are related to safety and security. We would also like to respond from our readers.

6. Acknowledgments

I would like to express our gratitude to Dr. Yoshiro Tajitsu of Kansai University (Professor of the Faculty of Engineering Science Department of Electrical and Electronic Engineering, Trustee of Kansai University) for his great cooperation in the design and development of the conversion circuit for the output voltage waveform. I sincerely appreciate his contribution to the project.

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Heat Resistant Acrylic Rubber L6070

1. Introduction

For automobiles, many rubber products are used as important functional parts, such as oil seals, belts, hoses, packing, O-rings, and diaphragms. This is because of the unique properties of rubber materials that cannot be replaced by other materials, such as ①large deformation capability, ②flexibility and ③good damping characteristics[1].

In recent years, the demand for sealing materials has been increasingly growing for applications used in the engine periphery of automobiles as they are used in ever harsher environments. Such environments include not only oil and fluid resistance but also maintenance-free long-life characteristics, space saving in the engine compartment, heat resistance required by higher performance and higher output, and others. Table1 shows the seal parts and materials used in various types of oil.

Table1 Oil and fluid resistant rubber parts for automobiles[2]

Oil classification	Part name	Material used
Engine oil	Crank oil seal	VMQ、FKM
	Cam oil seal	VMQ
	Valve stem seal	FKM
	Oil pan packing	NBR、ACM
	Head cover packing	NBR、ACM
	Oil cooler hose	NBR、ACM
	O-rings	NBR、ACM
ATF mission Oil	Transmission oil seal	ACM、VMQ
	Oil cooler hose	NBR、ACM
	O-ring and packing	NBR、ACM
PSF	Power stay hose	NBR
	Rack end seal	U、NBR
	Oil pump oil seal	NBR
	O-ring and packing	NBR
Fuel	Fuel hose	NBR
	Evapo hose	NBR
	Fuel pump diaphragm	NBR
	Check valves	NBR、FKM
	High pressure fuel hose	NBR、FKM
	Regulator diaphragm	NBR、FKM
	Injector seal	FKM
	O-ring and packing	NBR、FKM
Coolant	Radiator hose	EPDM
Brake fluid	Heater hose	EPDM
Etc.	Brake hose	NR、SBR、CR
	Master cylinder cup	SBR
	Wheel cylinder cup	SBR
	Caliper seal	EPDM

Acrylic rubber is positioned as the third rubber material following fluororubber and silicone rubber for applications that require both oil resistance and heat resistance. Figure1 shows the positioning of oil resistance and heat resistance of various rubber materials.

Acrylonitrile butadiene rubber, which has been widely used as an oil-resistant rubber, lacks heat resistance for automotive applications which are becoming increasingly sophisticated in performance. Also, fluororubber has been increasingly replaced by acrylic rubber due to price issues balancing performance and costs.

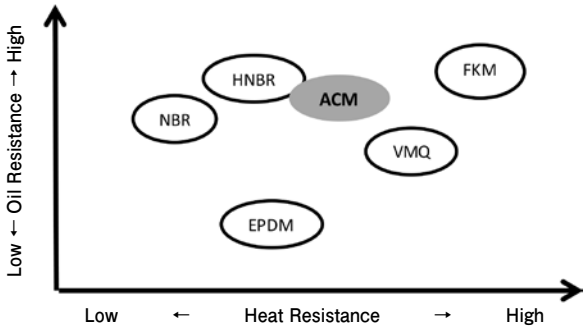


Figure1 Oil resistance and heat resistance of various rubber materials

2. Characteristics of L6070

Acrylic rubber is a copolymer composed mainly of acrylic acid ester, and its ASTM abbreviation is ACM. The chemical structure of acrylic rubber is shown in Figure2.

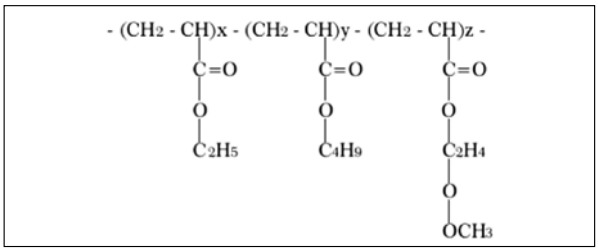
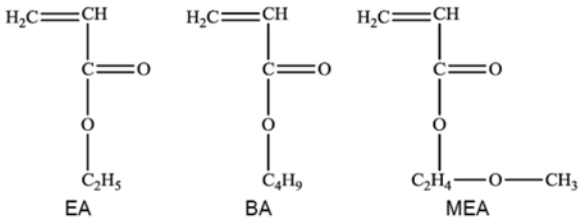


Figure2 Chemical structure of acrylic rubber

The characteristics of acrylic rubber differs depending on the combination of three types of monomers with different side chains (ethyl acrylate: EA, butyl acrylate: BA, and 2-methoxyethyl acrylate: MEA). The chemical structures of the main component monomer species and their characteristics are shown in Figure3[3].



	Heat resistance	Oil resistance	Cold resistance
EA	◎	○	△
BA	○	△	◎
MEA	△	◎	○

◎ : Excellent ○ : Good △ : Inferior

Figure3 Chemical structures and characteristics of acrylic rubber monomers

Since the main chain of acrylic rubber consists only of saturated bonds, it is necessary to introduce functional groups with crosslinking points. Table2 summarizes the characteristics of acrylic rubber according to the differences in cure sites.

Table2 Types and characteristics of functional groups at various cure sites[3]

Cure site	Cure rate	Processability	Storage stability	Compression set	Heat resistance
active chlorine group	○	×	△	○	○
Epoxy group	×	○	○	○	○
Carboxyl group	○	○	○	○	○

Due to its characteristics, acrylic rubber has been used for oil seals and hoses in the engine periphery of automobiles. Our existing acrylic rubber L1270 has also been used as oil seals and gaskets in many engine periphery applications, but it is becoming more difficult for it to meet specifications under the high temperature environment near the engine in recent years.

By utilizing our unique compound design technology that we have cultivated over the years, we have developed L6070 acrylic rubber, which has improved heat resistance while maintaining the oil resistance of acrylic rubber. The various characteristics of the developed material L6070 and the conventional material L1270 are described below.

2-1) Compression set properties

As an index of the heat resistance of sealing materials, the compression set is used. Under the same environment, the lower the compression set is, the longer the use you can expect as a quality sealing material.

The method of measuring and calculating the compression set is shown in Figure4[4].

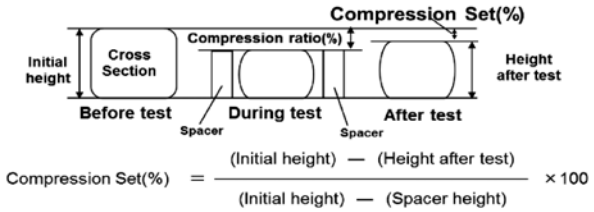


Figure4 Method of measuring and calculating compression set

In general, the compression set of 80% is used as the life expectancy of materials used for sealing materials [5].

In this report, in order to calculate the seal life and the time to reach the compression set of 80% under the environment of 150 ℃ which is required for seals used in the engine periphery, the compression sets of L6070 and L1270 are plotted to calculate the time to reach the compression set of 80% from the approximate equation.

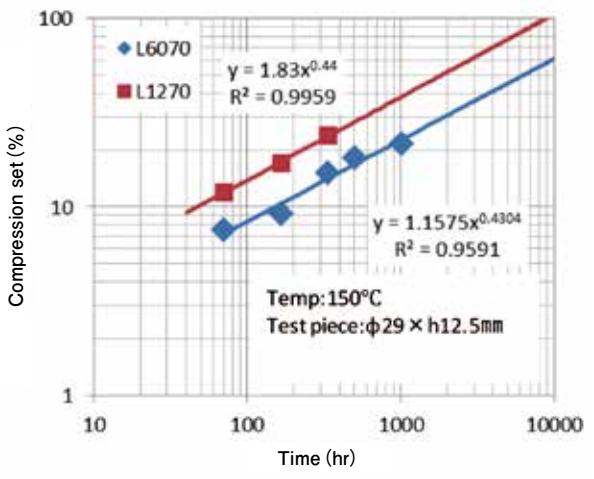


Figure5 Compression set at 150℃ in Air

Table3 Time at compression set of 80% at 150℃

Rubber Code	Approximate expression	Time at compression set of 80%
L6070	$y=1.1575x^{0.4304}$	1.88×10^{4}
L1270	$y=1.83x^{0.44}$	5.35×10^{3}

Calculated from an approximate equation, the time to reach the compression set of 80% in air at 150 ℃ is 1.88×10^{4} hours for L6070 and 5.35×10^{3} hours for L1270. This indicates that the life of L6070 is expected to be more than 3.5 times longer.

L6070 has good compression set properties even in a high temperature environment of 150 ℃ or higher. When evaluated under the same test time, the compression set of L6070 and that of L1270 are equivalent, respectively 170 ℃ and 150 ℃, which means that an increase in service temperature can be expected. The results of the compression set test under high temperature environments are shown in Figure6.

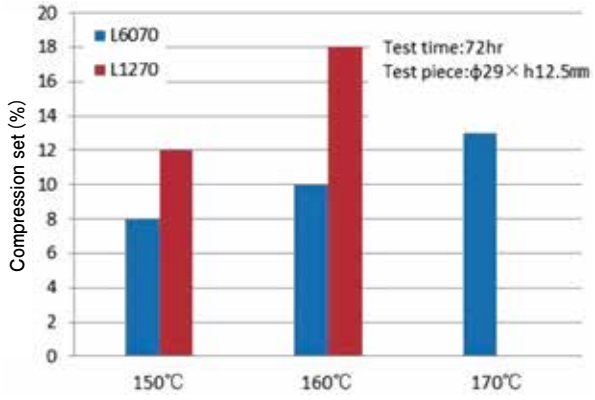


Figure6 Temperature dependency of compression set

2-2) Engine oil resistance properties

Automotive engine oil is classified by standards each for its quality and viscosity. Each standard is shown in Table4.

Table4 Classification of engine oil

Type of standard	Standard name	Description
Quality standard	API : American Petroleum Institute	Performance classification standards for internationally used engine oils
	ILSAC : International Lubricant Standardization and Approval Committee	Standards that require more fuel-efficient performance than API
Viscosity standard	SAE:Society of Automotive Engineers	Standards for classifying oil viscosity

The API standard is a standard to classify quality, setting the fuel efficiency, heat resistance, and wear resistance of engine oil. It had classifications from SA to SP, but some of them have been abolished by 2020. ILSAC is a standard that requires additional fuel efficiency and classifies the SH to SP classifications of API into GF-1 to GF-6. Table5 shows the quality classification of automotive engine oil [6), 7)].

Table5 API standard and ILSAC standard

API standard	ILSAC standard	Performance
SA		Low ↑ Performance ↓ High
SB		
SC		
SD		
SE		
SF		
SG		
SH	GF-1	
SJ	GF-2	
SL	GF-3	
SM	GF-4	
SN	GF-5	
SNPlus		
SP	GF-6	

As for the SAE standard for classifying viscosity, the SAE J300 standard established by SAE is used. For example, in the case that it is noted as 5W-30, the notation on the left side indicates viscosity at low temperatures while the notation on the right side indicates viscosity at high temperatures. Both indicate that the higher the number is, the harder the engine oil becomes. Table6 shows the viscosity classification of automotive engine oil[8)].

For the evaluation of engine oil resistance properties, the following standards were used from the viewpoint of availability: API: SN/CF (for simultaneous use of both gasoline and diesel vehicles), ILSAC: GF-5 (fuel efficiency, exhaust gas purification, oil degradation prevention, heat resistance and wear resistance) and SAE: 5W-30 (usable even at −30℃ outside temperature + medium viscosity at high temperature).

The change of volume of both L6070 and L1270 after the immersion test at 150℃ for 70 hours was small (less than 10%), confirming that both materials were resistant. Figure7 shows the change of volume of both materials after the immersion test.

Table6 SAE J300

SAE viscosity grade	Low temperature viscosity		High temperature viscosity		
	CCS viscosity (cP) / temperature (℃)	Pumping viscosity (cP) /temperature (℃)	Kinematic viscosity (cSt) (100℃)		Viscosity at high shear (cP) (150℃、106S-1min.)
			Minimum	Maximun	
0W	6,200/−35	60,000/−40	3.8	—	—
5W	6,600/−30	60,000/−35	3.8	—	—
10W	7,000/−25	60,000/−30	4.1	—	—
15W	7,000/−20	60,000/−25	5.6	—	—
20W	9,500/−15	60,000/−20	5.6	—	—
25W	13,000/−10	60,000/−15	9.3	—	—
8	—	—	4	<6.1	1.7
12	—	—	5	<7.1	2.0
16	—	—	6.1	<8.2	2.3
20	—	—	6.9	<9.3	2.6
30	—	—	9.3	<12.5	2.9
40	—	—	12.5	<16.3	3.5 (0W-40, 5W-40, 10W-40)
40	—	—	12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40monograde)
50	—	—	16.3	<21.9	3.7
60	—	—	21.9	<26.1	3.7

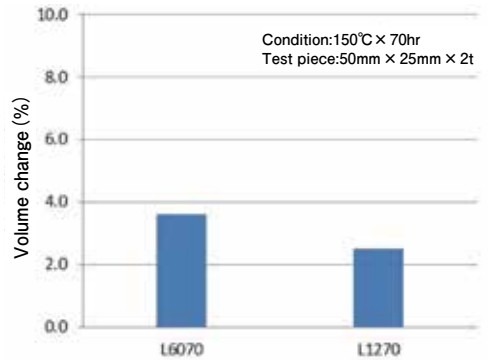


Figure7 Change of volume after gasoline oil immersion test

2-3) Low temperature properties

The low-temperature properties were confirmed by the temperature restraction test (TR test). L6070 showed the same TR10 value as L1270, and it was confirmed to have the low-temperature properties that can be used as a sealing material in the engine periphery. Table7 shows the TR values for L6070 and L1270.

Table7 Comparison of TR values

	L6070	L1270
TR10 (℃)	−21.5	−20.7
TR30 (℃)	−16.5	−16.1
TR50 (℃)	−12.9	−12.9
TR70 (℃)	−8.7	−9.3

2-4) Product shape

Since acrylic rubber L6070 has the same level of processability as that of general synthetic rubber, it can be used to manufacture various cross-sectional shapes and large-diameter products such as O-ring (VALQUA No. 640), V-packing (VALQUA No. 2631), and X-ring (VALQUA No. 641).

2-5) Mechanical properties

The results of physical properties and various durability tests of L6070 and L1270 are shown in Table8.

Table8 Comparison of physical properties

Characteristic		Test method	Unit	L6070	L1270
Hardness		JIS K 6253	SHORE A	71	72
Tensile strength		JIS K 6251	MPa	11.8	11.0
Elongation			%	250	190
Heat resistance	Compression set factor 25% compression φ29×h12.5	JIS K 6262 150℃ x70h	%	7	12
	Change of hardness	JIS K 6257 150℃ x70h	POINT	+1	+2
	Change of tensile strength		%	−3	+3
	Change of elongation		%	−6	−3
Oil resistance	Change of hardness	JIS K 6258 SN/CF, GF−5 5W−30 oil 150℃ x70h	POINT	−4	±0
	Change of tensile strength		%	+1	−6
	Change of elongation		%	−6	−12
	Change of volume		%	+3.6	+2.5
Low-temperature properties	TR10 value	JIS K 6261	℃	−21.5	−20.7

※These are measured values, not standard values

3. Applications

The newly developed acrylic rubber L6070 is expected to be applied to the automotive market (especially engine periphery).

※Oil filter gaskets (automobiles, construction machinery, agricultural machinery, etc.) head cover gaskets, oil seals, oil pump gaskets, etc.

4. Conclusion

The acrylic rubber L6070 introduced here is a material with upgraded heat resistance properties while maintaining the same level of oil resistance as that of conventional materials. In automotive applications, there is a trend where the operating environment is becoming hotter and hotter and thus seal materials are required to have high heat resistance. We believe that this new material can handle the environment adequately. In addition, the quality standard for engine oil was revised in October 2020. Since this revision has introduced stricter standards for the environment and oil performance has been improved, it is expected that the requirements for sealing products are also going to change. We, as a seal manufacturer, will continue to strive to develop new materials and improve existing materials by quickly capturing the latest trends in the market in order to meet the demands of our users.

5. References

1) Koda Tadashi, *Journal of the Society of Rubber Science and Technology, Japan*, 55, 689-697, 1982
2) Hiroshi Yoshida, *Journal of the Society of Rubber Science and Technology, Japan*, 58, 141-147, 1985
3) Mamoru Sugiyama, *Journal of the Society of Rubber Science and Technology, Japan*, 89, 22-27, 2016
4) Hirofumi Zushi, *Valqua Technology News*, No.36, 25-28, 2019
5) Toshio Kawamura, *Valqua Review*, Vol.26, No.6, 1982
6) American Petroleum Institute, 2020
7) International Lubricant Standardization and Approval Committee, 2020
8) SAE International, SURFACE VEHICLE STANDARD, SAE J300, 2015

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Elastomer Team,
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Elastomer for High Concentration Chemicals and Ozone ARCURY™ Series

1. Introduction

In the manufacturing process of various products, all materials used are required to be highly functional and clean. Particularly in the manufacture of high-performance parts, the cleaning chemicals and ozone used are required to be of increasingly higher purity. At the same time, the control of particulates, metal contamination and organic matter generated from cleaning wetted parts is becoming more stringent.

In response to these increasing demands, we have developed a lineup of sealing materials with excellent chemical resistance and ozone resistance as well as excellent purity. In this report, the outline and features of each product are introduced.

2. Product Overview

Table1 Basic properties of ARCURY™

Product name	ARCURY-AD (arcley AD)	ARCURY-AL (arcurea AL)	ARCURY-OZT (arcurea OZT)	ARCURY-OZW (arcley OZW)
Features	It is excellent in purity because of its excellent resistance to acidic solutions and reduced amount of elution of metals and organics.	Resistance to alkaline solutions such as ammonia, which has been difficult to use with conventional fluororubber, is excellent.	It is excellent in purity because of its excellent resistance to ozone gas and ozone water and its reduced amount of elution of metals and organic substances.	Resistance to ozone gas and ozone water is excellent. Compared with OZT, the heat resistance is improved.
Appearance color	Dark amber transparent	Black	Transparent	White
Hardness (Shore A)	67	75	60	68
Tensile strength (MPa)	12.0	23.8	17.0	13.0
Elongation (%)	190	220	580	230
100% stress (MPa)	3.3	7.5	1.7	3.4
Compressive Set (%)	25 *1)	31 *2)	48 *2)	37 *1)

All values in the table are measured values, not standard values.

*1)Compression set: 200℃ for 72hrs, Compression of25%, AS568-214 Using O-rings *2)Compression set: 150℃ for 72hrs, Compression of25%, AS568-214 Using O-rings

ARCURY－AD ARCURY－AL ARCURY－OZT ARCURY－OZW

Figure1 Photographs of ARCURY™ products

3. Product Features

3-1) Purity

Table2 Amount of eluted metal elements in fluoric acid and ultrapure water

Fluoric acid (25 ℃×30 days) (ng/ml)

Metallic element	ARCURY-AD	FFKM of Company A	FFKM of Company B
Na	0.6	1.6	1.3
K	0.6	2.8	0.4
Ca	0.9	＜0.5	0.7
Mg	0.9	0.6	0.5
Al	6.7	13	21
Fe	2.0	5.8	3.5
Cu	＜0.5	＜0.5	＜0.5
Pb	＜0.5	＜0.5	＜0.5
Meter	＜12.7	＜25.3	＜28.4

Ultrapure water (80℃ ×30days) (ng/ml)

Metallic element	ARCURY-AD	FFKM of Company A	FFKM of Company B
Na	0.6	2.1	0.5
K	0.6	1.8	＜0.5
Ca	0.6	0.6	＜0.5
Mg	＜0.5	0.9	＜0.5
Al	＜0.5	9.8	18
Fe	＜0.5	3.4	0.6
Cu	＜0.5	＜0.5	＜0.5
Pb	＜0.5	＜0.5	＜0.5
Meter	＜4.3	＜19.6	＜21.6

3-2) Chemical resistance

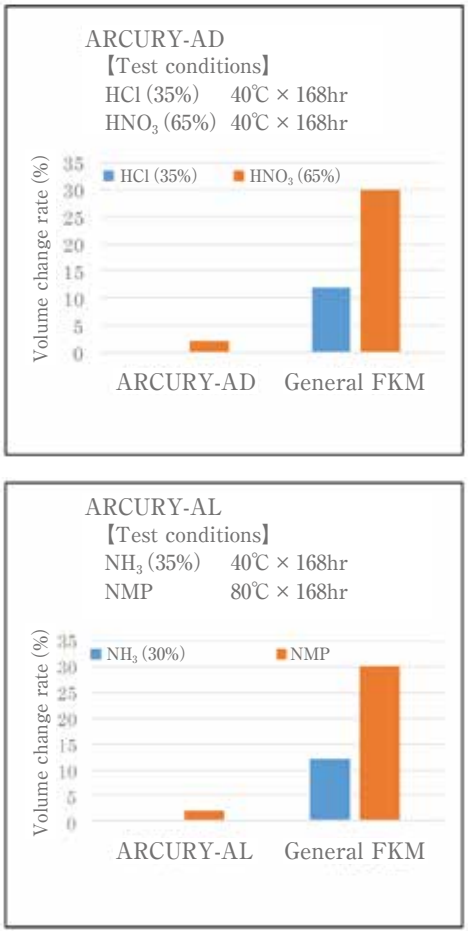
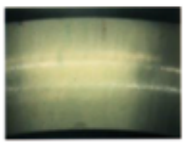
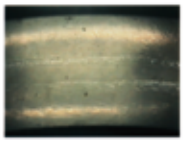
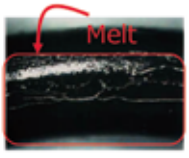


Figure2 Rates of change in volume after immersion in each solution

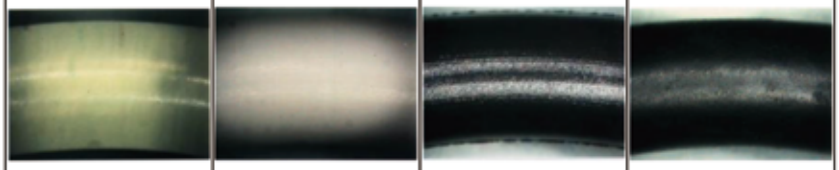
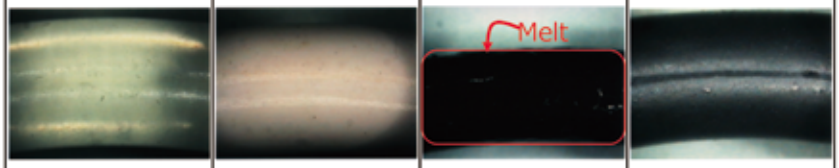
3-3) Surface condition after ozone gas exposure test

Table3 Photographs of the surface before and after exposure to ozone gas

	ARCURY-OZT	ARCURY-OZW	Black FKM A	Black FFKM A
Before the test				
After the test Exposure time : 2000 hours Concentration : 160g/Nm^3 Temperature : 20℃				

3-4) Surface condition after ozone water immersion test

Table4 Photographs of the surface before and after exposure to ozone water

	ARCURY-OZT	ARCURY-OZW	Black FKM A	Black FFKM A
Before the test				
After the test Immersion time : 2000 hours Concentration : 40mg/ℓ Temperature : 20℃				

3-5) Change in hardness

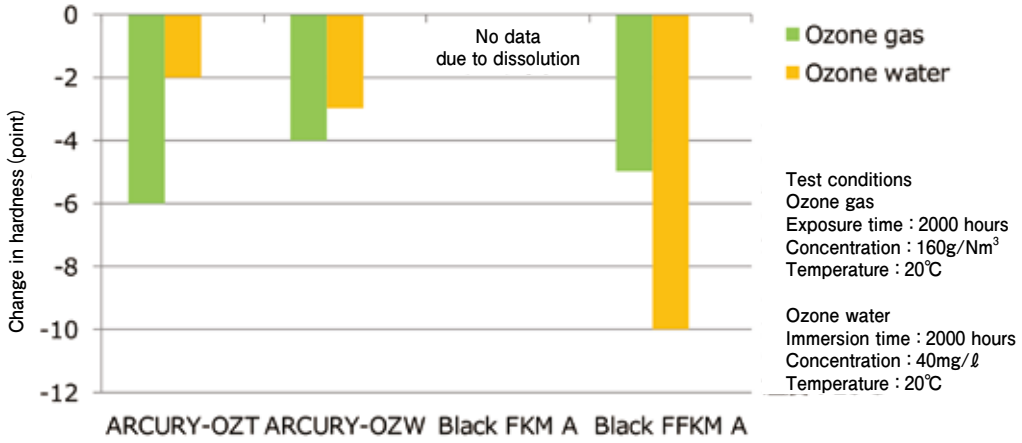


Figure3 Change in hardness after exposure to ozone gas and immersion in ozone water

4. Product Applications

The ARCURY™ Series is expected to be used for the following applications:

1) Seals for flange pipes, chemical containers and pipe joints of cleaning lines in chemical plants.
2) Seals for equipment such as ozone generators and ozone cleaning equipment.

5. Conclusion

It is anticipated that sealing materials will be required to meet ever higher requirements. The ARCURY™ series, introduced here, has excellent chemical and ozone resistance, and we hope that it will be used in the future to solve the problems which existing products have.

6. References

1) Tatsuhiro Oshita: *Valqua Technology News*, No.4, 15-16 (2002)
2) VALQUA: *Elastomer Product Catalogue*, No.MA06, 9 (2020)

※"ARCURY" is a trademark of VALQUA, Ltd.

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No.38 Winter 2020

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- **Introduction to Valqua Technology News No.38 Winter 2020**
  Director, Managing Executive Officer CTO & CQO Mutsuo Aoki
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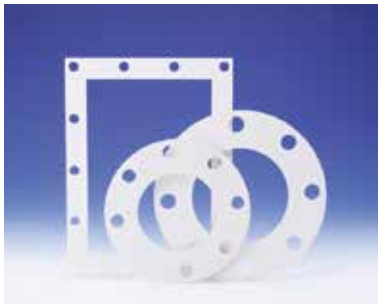
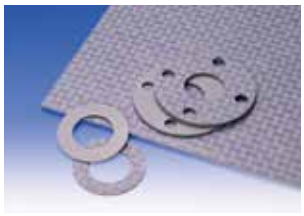


VALQUA HEAT RESIST SHEET™(HRS)

Sheet gasket that can be used at high temperatures of 1000℃ or higher. It does not contain RCF (Refractory Ceramic Fiber) and is exempt from the Regulation of Industrial Safety and Health Law.

● Operating temperature range: -200 to 1200℃ ● Maximum pressure: 1.0MPa
*Please refer to our catalog for details.



UNIVERSAL HYPER™(UF300)

Sheet gasket that can be integrated in chemical lines.
In addition to stability at high temperatures and long-term use, chemical resistance has been improved, greatly expanding the range of applicable fluids.
It can be used for both strong acid and strong alkali lines.

● Operating temperature range: -200 to 300℃ ● Maximum pressure: 3.5MPa
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