H

TECHNICAL DATA

1. JIS STANDARDS FOR LEAKAGE AMOUNT (Old JIS B 8354 : 1992)

PISTON PACKING (INTERNAL OIL LEAKAGE)

Old JIS B 8354: 1992 states that, when the maximum pressure is applied to one side of an immobilized piston, the amount of oil leakage to the other side of the piston must be less than those listed in the **Table H-1**, under the test condition shown in the right. With combined seals (SPG, SPGW), the amount of the internal oil leakage must be less than twice the figures in **Table H-1**.

Testing Conditions

Oil used : Hydraulic oil, unless specified, shall be equivalent to JIS K 2213 class 2 (additive turbine oil) withviscosity grade VG32 or VG46.

Oil temperature : 50 ± 5℃ unless specified otherwise.

Piston speed : 0

〈Table H-1〉 Acceptable amount of internal oil leakage for piston packings

Unit : ml/10min

I.D. (mm)	Amount of oil leakage	I.D. (mm)	Amount of oil leakage	I.D. (mm)	Amount of oil leakage
32 (31.5)	0.2	100	2.0	200	7.8
40	0.3	125	2.8	220 (224)	10.0
50	0.5	140	3.0	250	11.0
63	0.8	160	5.0		
80	1.3	180	6.3		

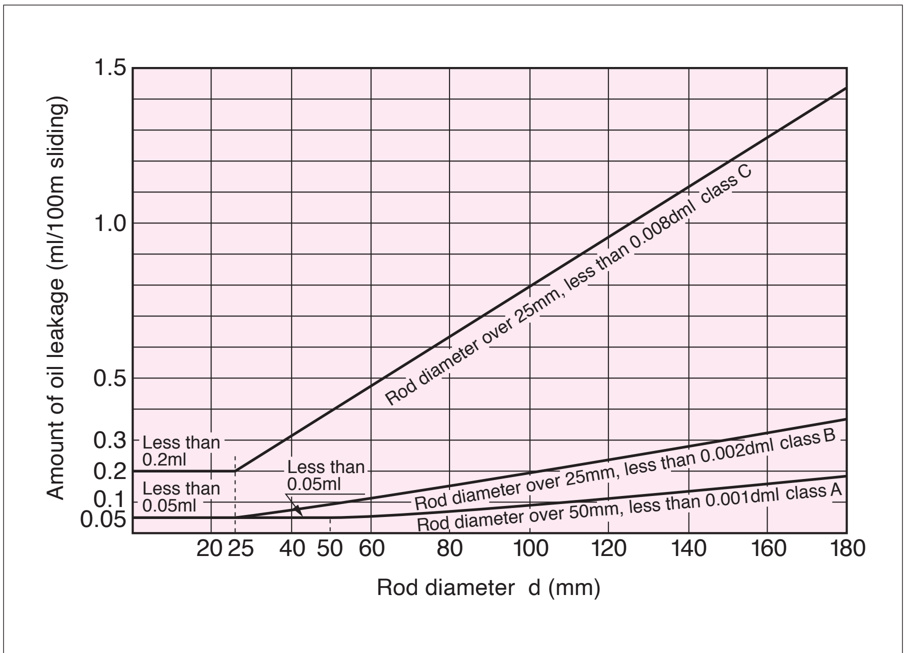
＊Acceptable leakage amount for combined seal is double of the listed value.

ROD PACKING (EXTERNAL OIL LEAKAGE)

Old JIS B 8354:1992 states "that there should be no leakage, except from the rod, under any operating condition, when piston makes reciprocating motion under the test condition as described below with regard to external oil leakage of hydraulic cylinder." Oil leakage from rod is classified into Type A, Type B and Type C as given in **Fig. H-1**.

〈Table H-2〉 PISTON SPEED

Cylinder tube I.D. (mm)	Piston speed (mm/s)
32 40 50 63	8 ～ 400
80 100 125	8 ～ 300
140 160 180 200 220 250	8 ～ 200



〈Fig. H-1〉 Acceptable external oil leakage

Test conditions

Oil used : Hydraulic oil, unless specified, shall be equivalent to JIS K 2213 class 2 (additive turbine oil) withviscosity grade VG32 or VG46.

Temperature of oil : 50 ± 5℃ unless otherwise specified

Piston speed : To be decided according to the inside diameter of the cylinder tube. (Table H-2)

Internal pressure : internal pressure generated in the cylinder shall not exceed, at any moment during the test, the maximum operating pressure except hydraulic pressure test.

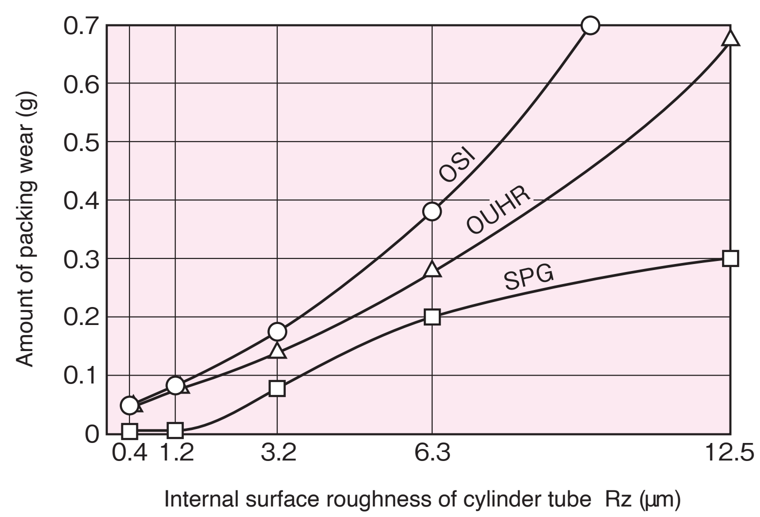
2. AMOUNT OF WEAR AND OIL LEAKAGE OF PISTON PACKINGS

■ Relationship between internal surface roughness of the cylinder tube and amount of wear

Fig. H-2 shows the relationship between internal surface roughness of the cylinder tube and the amount of wear for piston packings (SPG, OSI, and OUHR).

Test conditions

Pressure : 17.7MPa {180kgf/cm²} (Constant)
Stroke : 100mm
Piston speed : 100mm/s
Oil used for test : Turbine oil grade 2
Temperature of oil : 60 ~ 70°C (In the tank)
Tube inside diameter : φ100
Sliding distance : After sliding 80 km



〈Fig. H-2〉 Acce

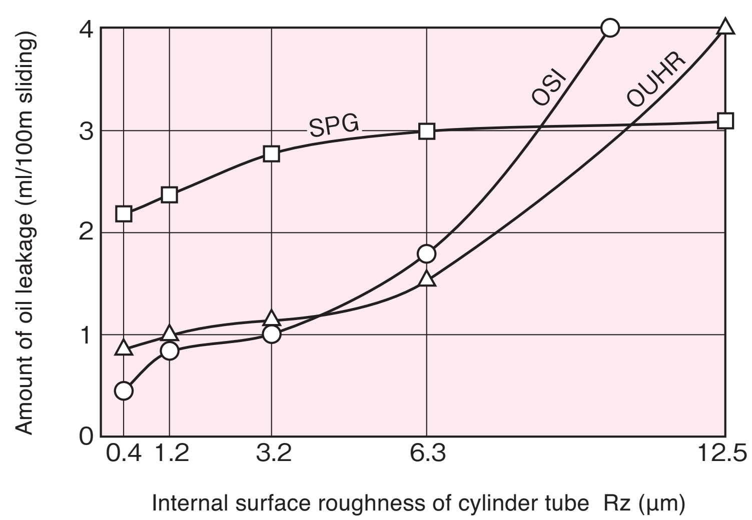
- Packings for high wear resistance such as SPG are suitable for use with the types of hydraulic cylinders which can allow some internal oil leakage.
- It is recommended to finish the internal surface of cylinder tube at 0.4 - 3.2 μm Rmax.

■ Relationship between internal surface roughness of the cylinder tube and amount of wear

Fig. H-3 shows the relationship between internal surface roughness of the cylinder tube and the amount of oil leakage for piston packings (SPG, OSI, and OUHR).

Test conditions

Pressure : 17.7MPa {180kgf/cm²} (Constant)
Stroke : 100mm
Piston speed : 100mm/s
Oil used for test : Turbine oil grade 2
Temperature of oil : 60 ~ 70°C (In the tank)
Tube inside diameter : φ100
Sliding distance : After sliding 80 km



〈Fig. H-3〉 Acce

- Old JIS B 8354:1992 allows the internal oil leakage at static condition as shown in the **Table H-1**, but no internal oil leakage has been found on any packings with this test.

H
TECHNICAL DATA

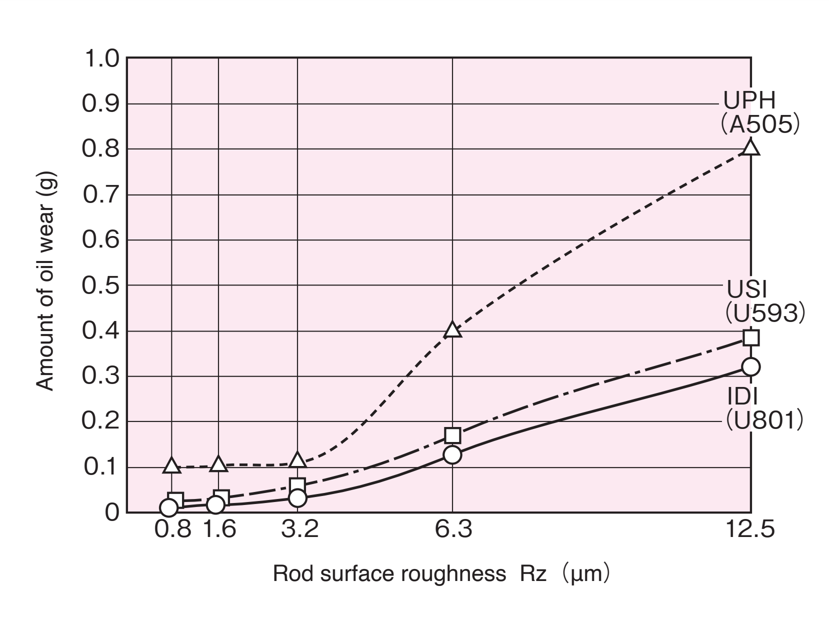
3. AMOUNT OF WEAR AND OIL LEAKAGE OF ROD PACKINGS

Relation between rod surface roughness and amount of wear

Fig. H-4 shows the relationship between rod surface roughness and amount of wear of U packings (UPH, USI and IDI).

Test conditions

Pressure	: 0 ～ 13.7MPa {0 ～ 140kgf/cm²}
Stroke	: 200mm
Rod speed	: 500mm/s
Oil used for test	: Turbine oil grade 2
Temperature of oil	: 100°C
Rod diameter	: φ50
Sliding distance	: After sliding 1000 km



〈Fig. H-4〉 Rod Surface Roughness and Amount of Wear

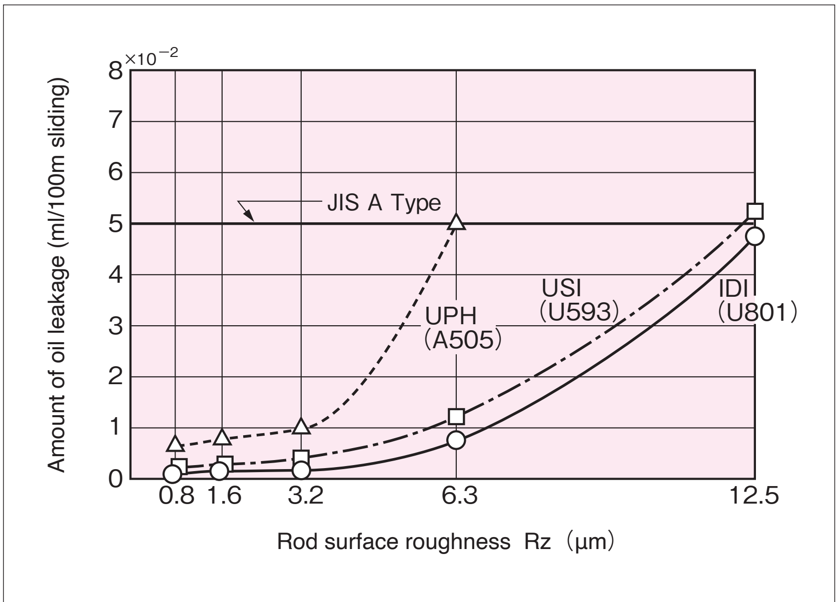
● When the rod surface is too rough, the amount of wear of rod packing will increase. Therefore, it is suggested to finish it to 0.8 ～ 1.6 μm Rz

Relationship between rod surface roughness and amount of oil leakage

Fig. H-5 shows the relationship between rod surface roughness and the amount of oil leakage for U packings (UPH, USI, and IDI).

Test conditions

Pressure	: 0 ～ 13.7MPa {0 ～ 140kgf/cm²}
Stroke	: 200mm
Rod speed	: 500mm/s
Oil used for test	: Turbine oil grade 2
Temperature of oil	: 100°C
Rod diameter	: φ50
Sliding distance	: After sliding 1000 km



〈Fig. H-5〉 Rod surface roughness and amount of oil leakage

● As the rod surface roughness affects the oil leakage, it is suggested to finish to 0.8 ～ 1.6 μm Rz

H TECHNICAL DATA

4. MINIMUM OPERATING PRESSURE

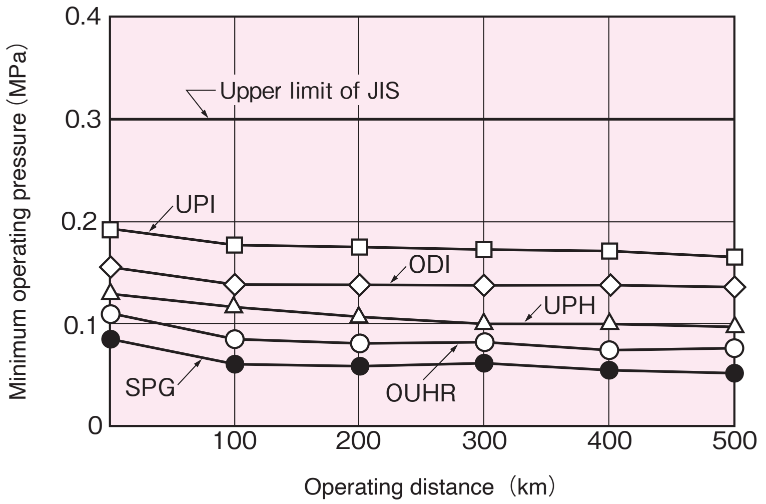
Fig. H-6 shows an example of actual measurement of the minimum operating pressure of piston packings (ODI, UPI, UPH, OUHR and SPG).

Test conditions

Cylinder tube I.D. : φ100
Rod diameter : φ70
Rod packing : UPH 70×90×15
Dust seal : DKB 70×84×8×11
Pressurizing board : Cylinder head side

Cylinder operating conditions

Pressure : 0 ~ 16.7MPa {0 ~ 170kgf/cm²}
Stroke : 650mm
Speed : 650mm/s (Average)
Oil used : Turbine oil grade 2
Oil temperature : 80°C (Maximum)

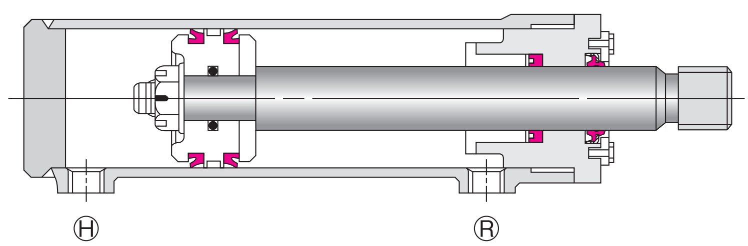


〈Fig. H-6〉 Example of actual measurement of the minimum operating pressure

● As NOK Rareflon is used for sliding material of SPG packing, and self-lubrication property of OUHR packing is improved, the operating pressure for the both shows low values.

WHAT IS MINIMUM OPERATING PRESSURE

The minimum pressure is required to ensure the operation of the cylinder. When the pressure is applied from the head side Ⓗ or the rod side Ⓡ of the cylinder without any load as shown in the **Fig. H-7**, the minimum pressure required to allow a smooth operation of the piston at the minimum speed (8mm/sec) shown in the **Table H-2** is called the minimum operating pressure. Old JIS B 8354:1992 (Hydraulic cylinder) prescribes this minimum operating pressure. **Table H-3** shows the minimum operating pressure in the case when the pressure is applied from the cylinder head side. According to Old JIS B 8354:1992, "When the minimum operating pressure is required lower than specified below, the said value can be modified under an agreement between the parties concerned for delivery" .



〈Fig. H-7〉 Example of cylinder used for measuring the minimum operating pressure.

〈Table H-3〉 Example of JIS Minimum Operating Pressure (when the pressure is applied from the cylinder head side). Unit : MPa

Shape of piston packing	Nominal pressure	Shape of rod packing		Remark
		Other than V packing	V packing	
V packing	3.5 , 7	0.5	0.75	The minimum operating pressure when the pressure, is applied from the rod side, is defined by the classification of rod diameter.
	14 , 21	Nominal pressure×6%	Nominal pressure×9%	
U,L Packing, X ring, O ring, combination seal	3.5 , 7	0.3	0.45	
	14 , 21	Nominal pressure×4%	Nominal pressure×6%	
Piston ring	3.5 , 7	0.1	0.15	
	14 , 21	Nominal pressure×1.5%	Nominal pressure×2.5%	

H TECHNICAL DATA

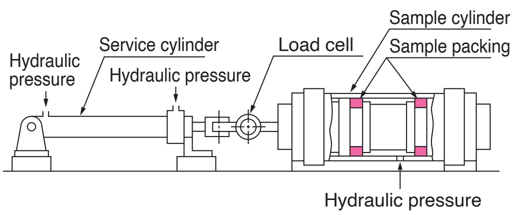
5. FRICTIONAL RESISTANCE

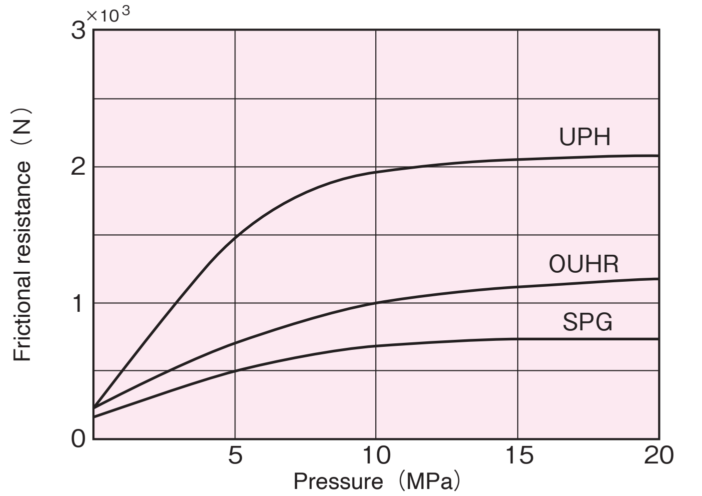
Fig. H-8 shows an example of actual measurement of frictional resistance of piston packings (SPG, UPH, and OUHR).

Test conditions

I.D. of cylinder tube : Φ100
Piston speed : 300mm/s
Oil used : Turbine oil grade 2 (ISO VG46)
Oil temperature : 60°C

Test equipment



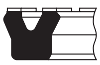


〈Fig. H-8〉 Frictional resistance and Pressure

● Use SPG or SPGW for piston packing for low friction.

Shape of lip edge with U packing that affects frictional resistance and sealing performance.

Frictional resistance and sealing performance vary with the lip shape of U packings as shown in **Fig. H-9** and **Fig. H-10**.

	OUHR (Φ120) packing	USH (Φ120) packing
Sample packing		

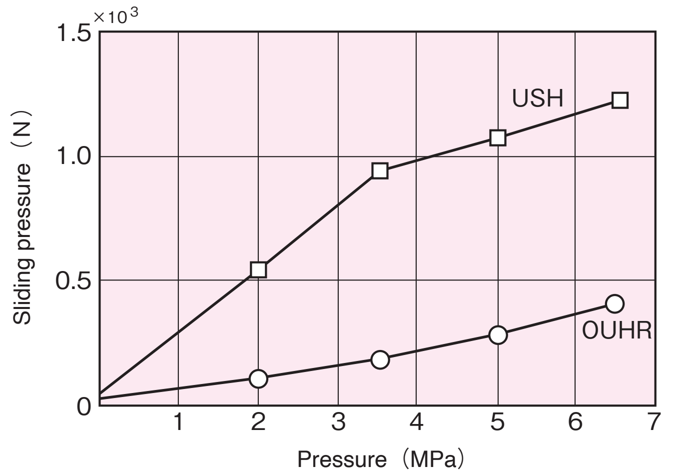
Measuring conditions of frictional resistance

Temperature : 80°C constant
Pressure : 0、2、3.4、4.9、6.4MPa
{0、20、35、50、65kgf/cm²}
Speed : 75mm/s
Stroke : 20mm
Oil used : Turbine oil grade 2
(ISO VG46)

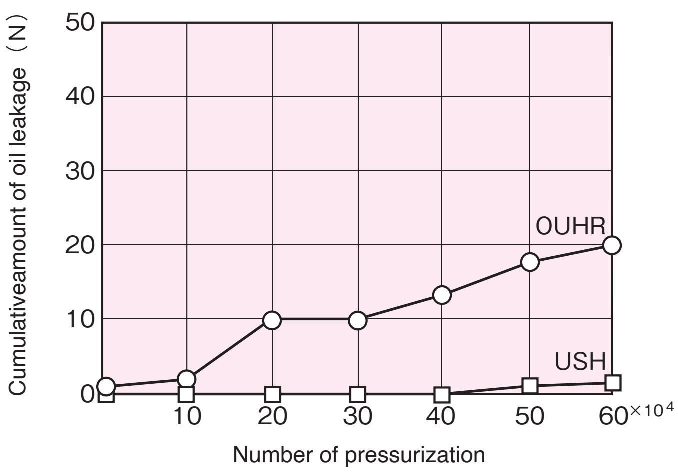
Impulse endurance test conditions

Temperature : 100°C
Pressure : 0 ~ 24.5 ~ 36.8MPa
{0 ~ 250 ~ 375kgf/cm²}
Frequency of pressurization : 70c.p.m
Number of pressurization : 600,000 times
Speed : 150mm/s
Stroke : 150mm
Oil used : Turbine oil grade 2
(ISO VG46)

● Recommend to use OUHR packing with improved self-lubrication property as the piston U packing for low friction.



〈Fig. H-9〉 Frictional resistance and pressure



〈Fig. H-10〉 Number of pressurization and amount of oil leakage

H TECHNICAL DATA

HOW TO CALCULATE FRICTIONAL RESISTANCE OF PACKINGS

Frictional resistance can be calculated from the following formula.

$$\boxed{F = f \times Pr} \quad \cdots\cdots\cdots\cdots (5)$$

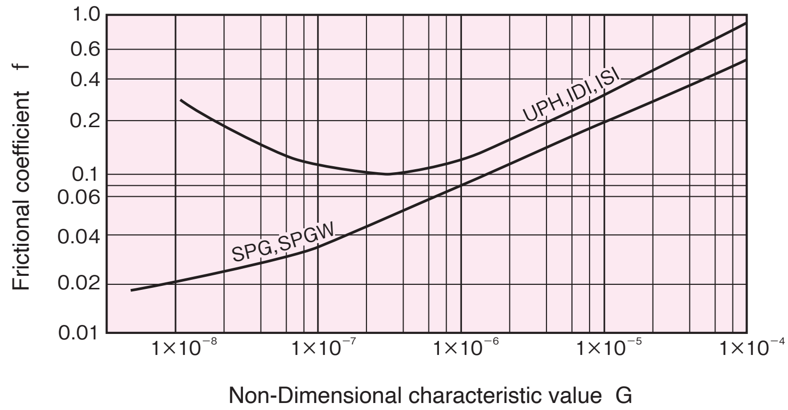
Where,

F : Frictional resistance (N)

f : Frictional coefficient

Pr : Packing radial force (N)

Therefore, in order to find the frictional resistance, it is necessary to know the values of frictional coefficient and packing radial force. To obtain the friction coefficient f, use the non-dimensional characteristic diagram in **Fig. H-11**, G in accordance with operating condition and read the value f.



〈Fig. H-11〉 Dimensionless characteristic diagram

● Please refer to Page 12 for calculating method of the dimensionless characteristic number G.

Use Formula (6) to find out the radial force of a packing when pressure is applied.

$$\boxed{Pr = \pi dbp + Pro} \quad \cdots\cdots\cdots (6)$$

Where,

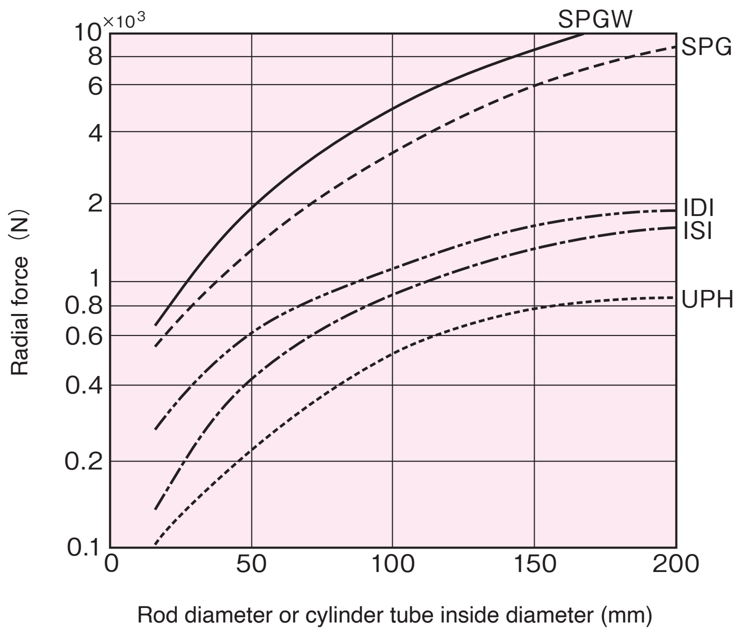
d : Rod diameter (cm)

b : Contact width (cm)

p : Applied pressure (Pa)

Pro : Radial force of packing under ambient pressure (N)

(The value Pro varies with the shape and material of packings. **Fig. H-12** shows, for your reference, an example of actual measurement of radial force of representative packings. As the applied pressure becomes higher, Pro becomes a negligible value in function to π dbp in the formula (6).)



〈Fig. H-12〉 Radial force of packing (Under ambient pressure)

H
TECHNICAL DATA

6. LOW TEMPERATURE RESISTANCE PACKINGS

The standard rubber material for NOK packings (material code A505, U801) aims at about -30℃ as limit temperature for low temperature usage. In low temperature areas, the rubber packing material' s elasticity decreases and its sealing performance becomes unstable. As the packing lip' s ability to follow the eccentricity of the rod decreases, it becomes important to reduce the amount of eccentricity of the rod. When using packings in a low temperature area, minimize rod eccentricity, and apply a low temperature resistance packing.

Test conditions
Sample : U packing for rod diameter Φ75
(Dipped in oil at100°C for 70H prior to the test)
Pressure : 2MPa {20kgf/cm²} (constant pressure)
Stroke : 20mm
Cycle : 1c.p.s
Oil used for test : Hydraulic oil for extra low temperature
Test duration : After leaving the test piece for 15 hours at each temperature, stroke for 15 minutes.

EFFECT OF ECCENTRICITY ON SEALING PERFORMANCE AT A LOW TEMPERATURE

Table H-4 and **Table H-5** show an example of test results with low temperature resistant U packings and standard U packings.

As the eccentricity affects sealing performance at low temperature, use H9/f8 fit for bush or bearing.

〈Table H-4〉 Cold resistant U packings

Sample packing	IUH 75 85 6 (A567) Low temperature resistant nitrile rubber					UNI 75 88 10 (① U801 ② S813)				
Amount of eccentricity (TIR) \ (°C)	−40	−45	−50	−55	−60	−40	−45	−50	−55	−60
0.15mm	○	○	○	○	△	○	○	○	○	△
0.30mm	○	○	○	○	△	○	○	△	△	●
0.45mm	○	○	△	△	●	△	△	△	●	●

〈Table H-5〉 Standard U packings

Sample packing	IUH 75 85 6 (A505)		ISI 75 85 6 (U801)		
Amount of eccentricity (TIR) \ (°C)	−15	−20	−25	−30	−35
0.15mm	○	○	○	○	△
0.30mm	○	○	○	○	△
0.45mm	○	○	△	△	●

○…No oil leakage　△…Oil leakage while sliding　●…Oil leakage at static

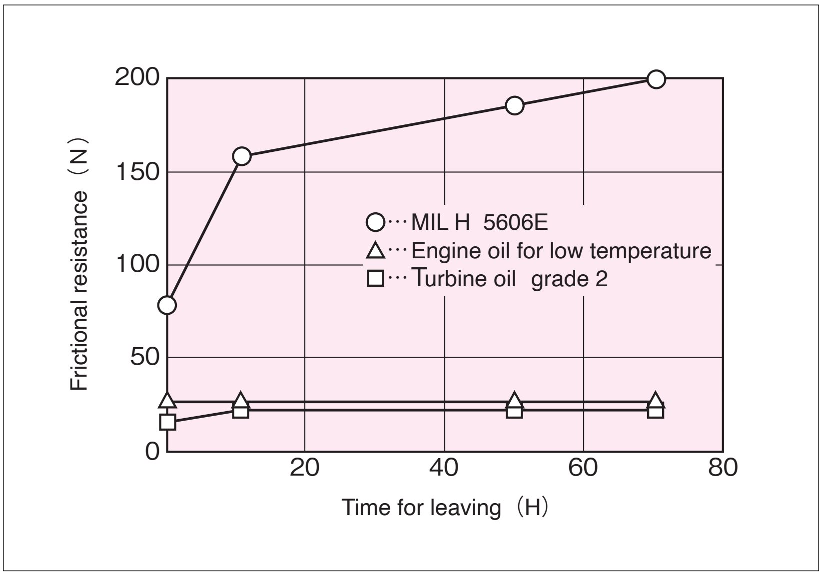
EFFECT OF LOW TEMPERATURE HYDRAULIC OIL FOR INITIAL FRICTIONAL RESISTANCE

Some low temperature hydraulic oil increase the frictional resistance of packings. This is caused by remaining dried additives in oil. **Fig. H-13** shows an example of measuring the initial frictional resistance with low temperature oil.

Test conditions
Temperature : 25°C
Pressure : Ambient pressure
Speed : 250mm/s
Stroke : 50mm
Oil used : ① MIL H 5606E
② Engine oil for low temperature
③ Turbine oil grade 2 (ISO VG32)
Time for leaving sample : 0、12、48、72 (H)

Leaving conditions
By making rod to perform several stroke, let the oil film deposited on the rod surface and leave the packing as it is at room temperature.

Sample packing	IUH type packing (Material : A567)



〈Fig. H-13〉 Result of measurement of initial frictional resistance

H TECHNICAL DATA

7. BUFFER RINGS

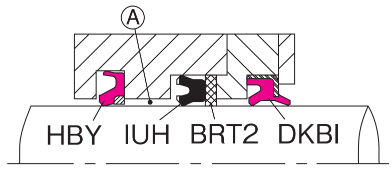
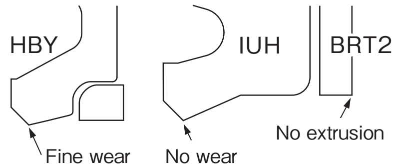
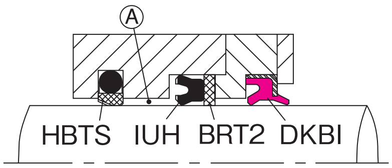
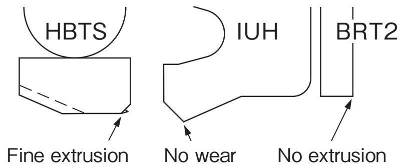
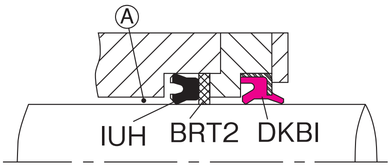
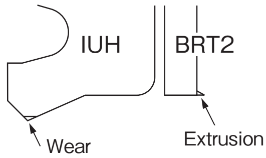
Buffer rings (HBY and HBTS) are inserted in the pressure side of rod packings to protect and improve packing durability. Also, under extremely short stroke conditions, they help prevent abnormal wear of rod packings.

3 effects of buffer rings

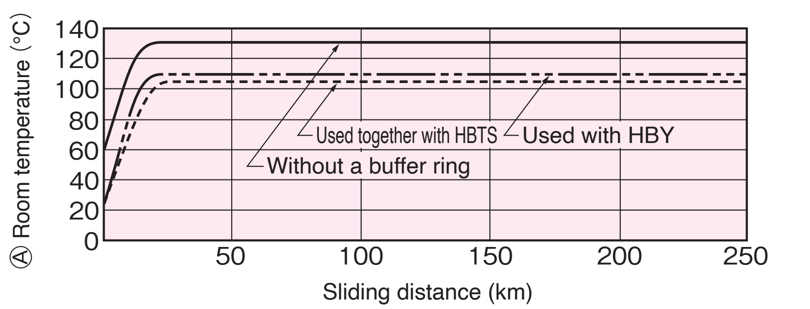
(1) To buffer the impact pressure generated on the rod side of a hydraulic cylinder.
(2) To inhibit transmission of oil temperature to rod packings.
(3) To reduce frictional resistance and generation of sliding heat of rod packings.

Buffer ring does not generate accumulated pressure between rod packings, because of back pressure relief property.

EXAMPLE OF BUFFERING EFFECT ON IMPACT PRESSURE

Test conditions		Construction (rod sealing system)	Conditions after test
Rod diameter : Φ70 Pressure : 0 ～ 41.2MPa {0 ～ 420kgf/cm²} Speed : 530mm/s Stroke : 900mm Oil used : Turbine oil grade 2 (ISO VG46) Oil temperature : 90±5°C (in the tank) Sliding distance : After sliding 250 km	With a buffer ring		
	With a buffer ring		
	Without a buffer ring		

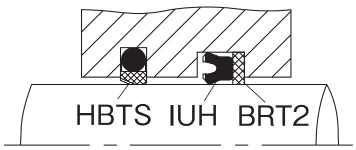
EXAMPLE OF REDUCTION OF TEMPERATURE AT SLIDING AREA



〈Fig. H-14〉 An example of measurement of temperature at sliding area
(For test conditions and temperature at Ⓐ, refer to the test condition.)

- When the impact pressure and the oil temperature are high, reduction of pressure and temperature of sliding part can be obtained by using a buffer ring.
- It is recommended to use packing and buffer ring together.

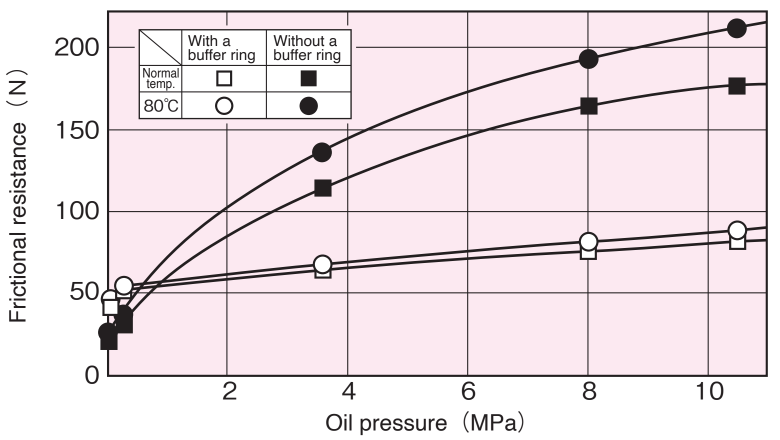
EXAMPLE OF REDUCTION OF FRICTIONAL RESISTANCE



Construction (Rod sealing system)

Test conditions

Pressure : 0 ～ 9.8MPa
{0 ～ 100kgf/cm²}
Speed : 30mm/s
Stroke : 100mm
Oil used : General purpose hydraulic oil
Temperature : Constant temperature at 80°C



〈Fig. H-15〉 Relation between hydraulic pressure and frictional resistance

H TECHNICAL DATA

8. PACKINGS FOR EXTREMELY SHORT STROKE

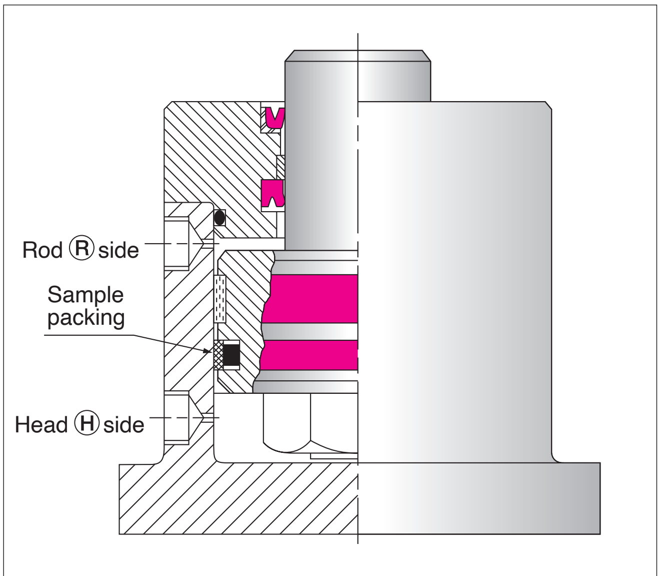
When packings are used with extremely short strokes, breaking of oil film (out of lubricant) occurs, and abnormal wear of the packing may occur. To prevent this, the packing must be designed to allow an easy formation of the lubricant film and to use material with better wear resistance.

Extremely short stroke roughly means a stroke below “the minimum stroke of 25 mm” defined in the old JIS B 8354 : 1992.

PISTON PACKINGS

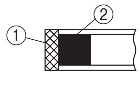
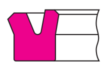
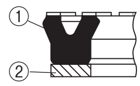
Test method

In order to investigate the internal oil leakage amount, test was conducted with the condition below. The oil leakage was measured at 250,000, 500,000, 750,000 and 1,000,000 cycles. The amount of oil leakage inside the test sample packing is measured by measuring the amount of oil leakage from the head-side Ⓗ port when a given pressure of 34.3 MPa {350kgf/cm²} is applied from the rod-side Ⓡ port for 10 minutes as shown in **Fig. H-16**.



〈Fig. H-16〉 Test equipment

Sample packing

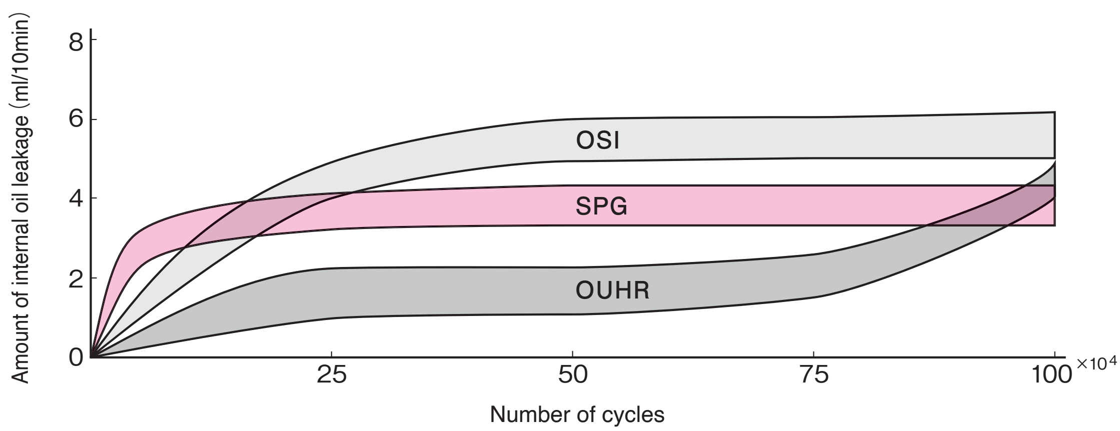
Cross section of seal	Type and size	Material
	SPG 94 110 7.3	① 19YF ② A980
	OSI 110 95 9	U801
	OUHR 110 95 9 BRT2 95 110 3	① A567 ② 19YF

Test condition

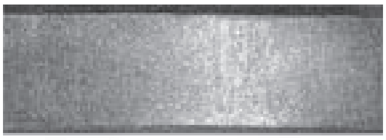
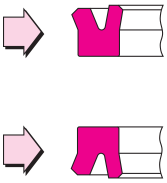
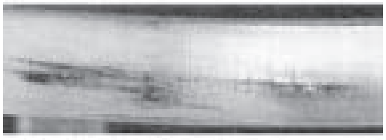
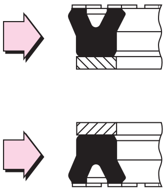
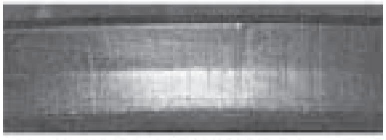
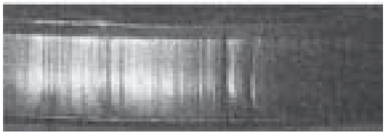
Oil used : General purpose hydraulic oil
Pressure : Rod Ⓡ side
0 ～ 34.3MPa {0 ～ 350kgf/cm²}
Head Ⓗ side
0 ～ 2MPa {0 ～ 20kgf/cm²}
Stroke : 2 mm
Cycle : 16 c.p.m (Average speed 4mm/s)
Sliding cycle : 100×10⁴ times
Temperature : 95±5°C (at cylinder internal surface)
Roughness of cylinder internal surface : 3.2μm Rmax

Test results

※ The amount of internal oil leakage for SPGW is almost the same as SPG.



〈Fig. H-17〉 Change in amount of internal oil leakage

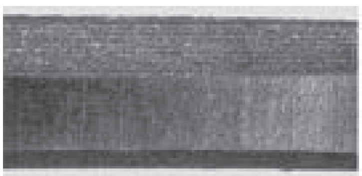
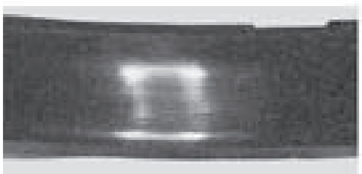
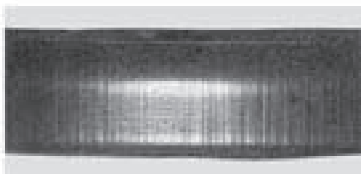
Type & size	Direction of photo	Surface condition	Remarks
SPG 94 110 7.3	Head side  Rod side		No abnormalities are observed on the sliding face.
OSI 110 95 9	Head side  Rod side	 	Wear and"sliding trace"are observed on the sliding face.
OUHR 110 95 9	Head side  Rod side	 	Wear and"heavy sliding trace"are observed on the sliding face.

〈Fig. H-18〉 Sliding surface condition after test

●For extremely short stroke, it is recommended to use combination seal (SPG or SPGW), using NOK Rareflon as the sliding material.

■ ROD PACKINGS

Fig. H-19 shows the condition of sliding surface after the extremely short stroke test.

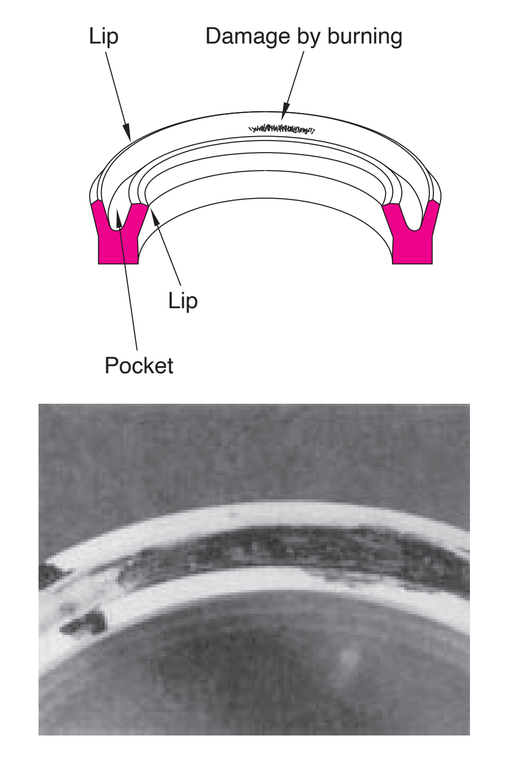
Type & size (Material)	Direction of photo	Surface condition: When buffer ring is used together.	Surface condition: When buffer ring is not used together.
〈Buffer ring〉 HBTS 75 90.5 5.9 (19YF, A626)			————
〈Rod packing〉 IUH 75 85 6 (A505)			

〈Fig. H-19〉 Condition of sliding surface after test

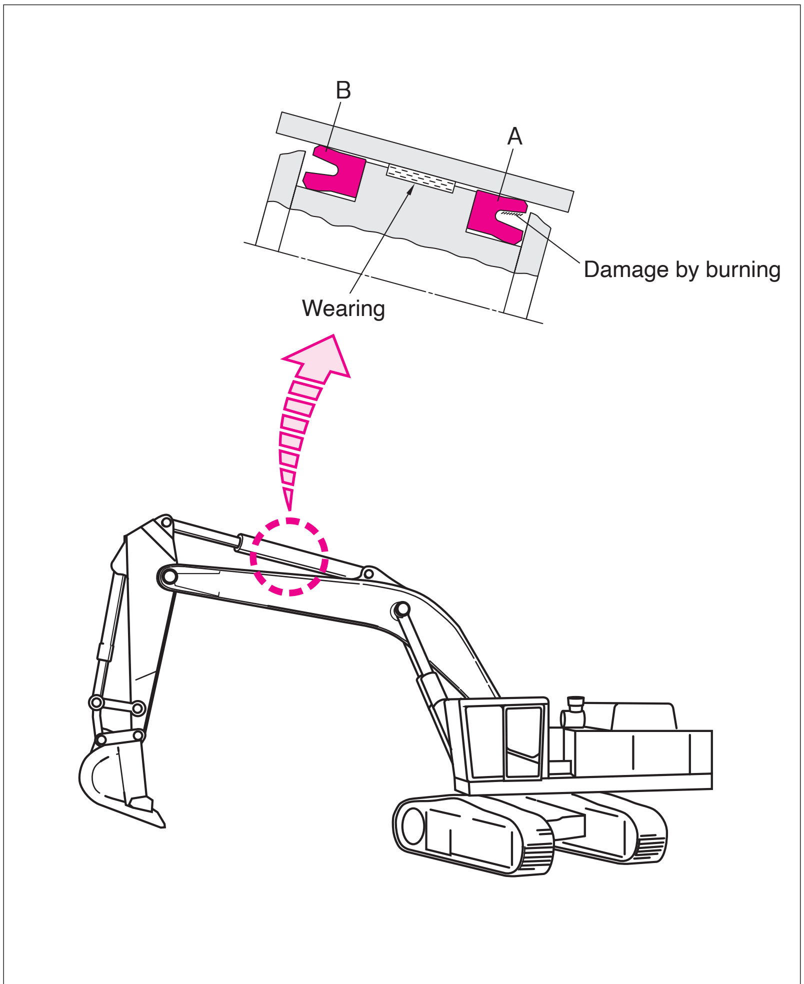
●It is recommended to use the buffer ring (HBTS or HBY) as a part of the sealing system along with the packings, when extremely short stroke condition is expected.
Abnormal wear of rod packing may occur due to breakage of oil film without the buffer ring.

9. PHENOMENON OF BURNING

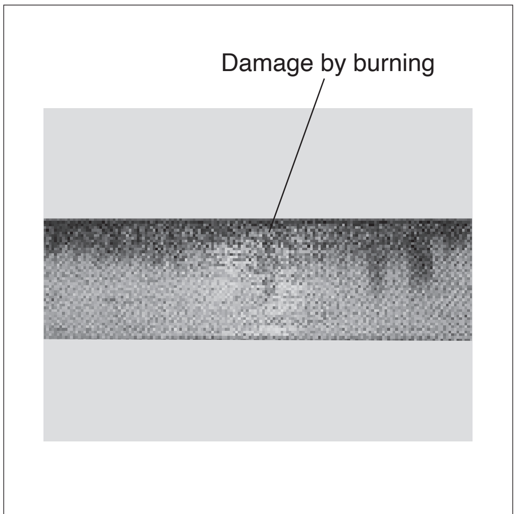
In some cases, piston packings or wear rings are burned and carbonized or melted. This is due to the high temperature resulting from sudden compression when air inside the hydraulic cylinder has not been completely exhausted.
For example, when a U packing is used as a piston packing, air tends to be accumulated in the pocket part of the U packing. When this air is not replaced by oil at starting movement, the air will be compressed quickly, resulting in high heat generation, at the U packing' s pocket, as shown in **Fig. H-20**.
The packing may result in partially burned and carbonized. Some material may actually melt.
When the rod is directed upward, air is accumulated at the pocket part of U packing A on the head side, and "damage by burning" can be seen in **Fig. H-21**. Also, the wear ring may be burnt, as shown in **Fig. H-22**.
The phenomenon of burning tends to occur when starting a hydraulic cylinder, but seldom occurs during operation.
The heat generation due to adiabatic compression may reach 600 to 800℃ for a short period of time and instantaneously exceeds the heat resistant limit of packing material.



〈Fig. H-20〉 Example of damage by burning of U packing



〈Fig. H-21〉 Example of locations of damage by burning



〈Fig. H-22〉 Example of damage by burning of wearing

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■ FORMULA FOR CALCULATING RISE OF TEMPERATURE BY ADIABATIC COMPRESSION

Although, in the case of an actual hydraulic cylinder, it cannot be said to be a perfect adiabatic compression due to the existence of heat conduction and dispersion, etc. from the rod surface or tube wall face, the rise of temperature can be calculated from the formula (7).

$$T_2 = T_1 \times \frac{P_2 \cdot V_2}{P_1 \cdot V_1} = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{\kappa - 1}{\kappa}} \quad \cdots\cdots\cdots\cdots \quad (7)$$

T_1 : Absolute temperature before compression (°K)
T_2 : Absolute temperature after compression (°K)
P_1 : Pressure before compression (MPa)
P_2 : Pressure after compression (MPa)
V_1 : Volume of air before compression (cm^3)
V_2 : Volume of air after compression (cm^3)
κ : Adiabatic index (In case of air, $\kappa = 1.4$)

Now, let' s calculate the heat generation by adiabatic compression by using this formula. Suppose the pressure in the hydraulic cylinder varies between 1 and 42MPa. For example, suppose the oil temperature is 80℃ when the pressure is 1MPa, then the absolute temperature T2 by the adiabatic compression is

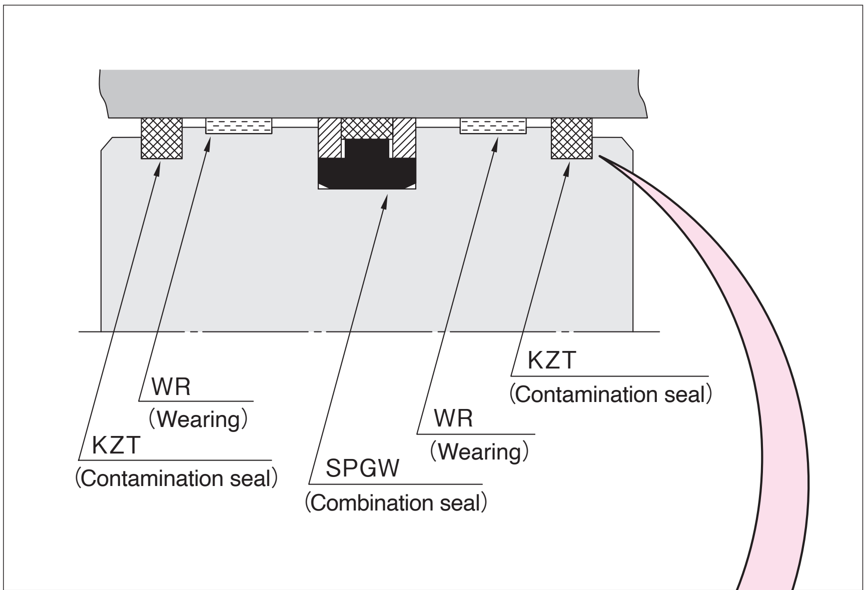
$$T_2 = (273 + 80) \times \left(\frac{42}{1}\right)^{\frac{1.4-1}{1.4}} \doteqdot 1027\,(°K)$$

This temperature is equivalent to 754℃. The value neglects the adiabatic efficiency and other loss in its calculation. Even if this were taken into consideration, the packing is instantaneously exposed to a high temperature.

■ PREVENTION OF DAMAGE BY BURNING

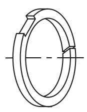
Remark the following points to prevent the damage of burning due to such adiabatic compression.

(1) Bleed air from the hydraulic cylinder sufficiently before starting the hydraulic cylinder.
(2) When starting the hydraulic cylinder, do not operate it quickly to its full stroke.
(3) When using U packings, fill the pocket with grease to minimize the accumulation of air.
(4) Design the construction of piston as shown in the **Fig. H-23** and use Rareflon seal (Type KZT, contamination seal) having a good heat resistance at the outside of the wearing (WR).



〈Fig. H-23〉 Example of countermeasure against damage by burning

● **Fig. H-23** shows the most effective piston sealing system as a countermeasure against the damage by burning.



We recommend to use KZT (Contamination seal) to prevent entry of foreign materials in the oil and to prevent the damage by burning.

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10. STICK-SLIP

PHENOMENON

Stick-slip is a phenomenon that a sliding surface has sticking and slipping condition periodically. In the case of packings, the stick-slip occurs at a contact face between a packing, an elastic body, and metal mating face, sometimes resulting in vibration and generating sound.

The stick-slip phenomenon in hydraulic cylinders is caused by complex factors including types of bearings, types of packings, fixing method of cylinder, amount of load, etc. Also, the sound generated by stick-slip varies from low to high frequency tones.

CONDITIONS CAUSE THE PHENOMENON

Vibrations and sound generation due to the stick-slip of a hydraulic cylinder have not been quantitatively clarified yet. It is qualitatively known, however, that they occur under the following conditions.

(1) When a static friction coefficient of a packing or bearing material is high.

(2) When the roughness of metallic surface is not appropriate.

(3) When the quality of oil used is poor (when the additive to oil is not appropriate).

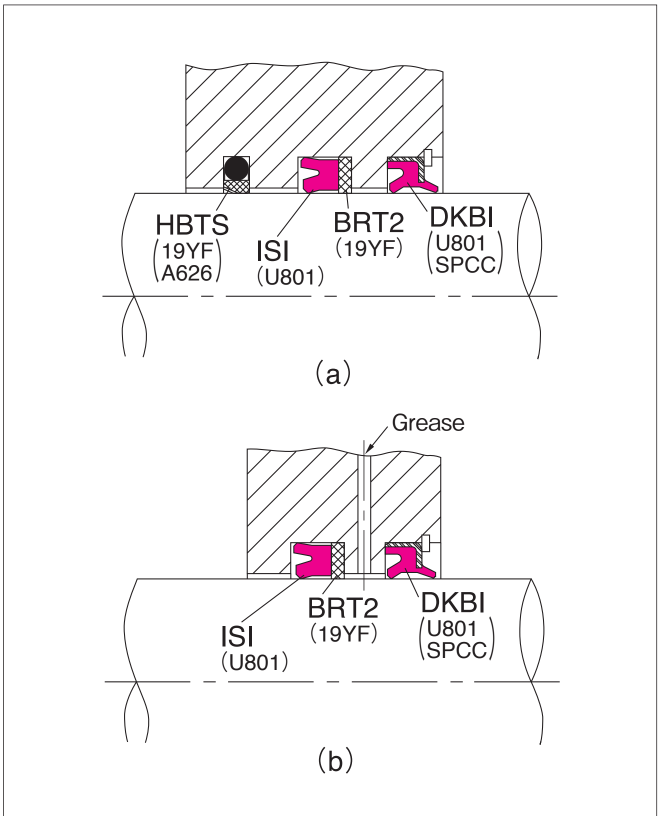
(4) When the lubricant film on the sliding face is liable to be broken due to a high pressure, high temperature or operation in a low speed.

(5) When using a cylinder tube or a hollow rod which thickness is extremely thin or when using a hydraulic hose with a low rigidity.

COUNTERMEASURES

As previously mentioned, it is not possible to make perfect countermeasures for stick-slip solely by a packing itself. However, use of a combination seal (SPG or SPGW) made from low-friction material such as Rareflon or use of the U packing(OUHR) improved self lubrication.

Also, additional use of a buffer ring with good lubricating characteristic (HBTS) as shown in **Fig. H-24**(a) and/or filling grease between a rod packing and a dust seal will be effective in preventing oil film breakage, due to high pressure.



〈Fig. H-24〉 Example of countermeasure against stick-slip

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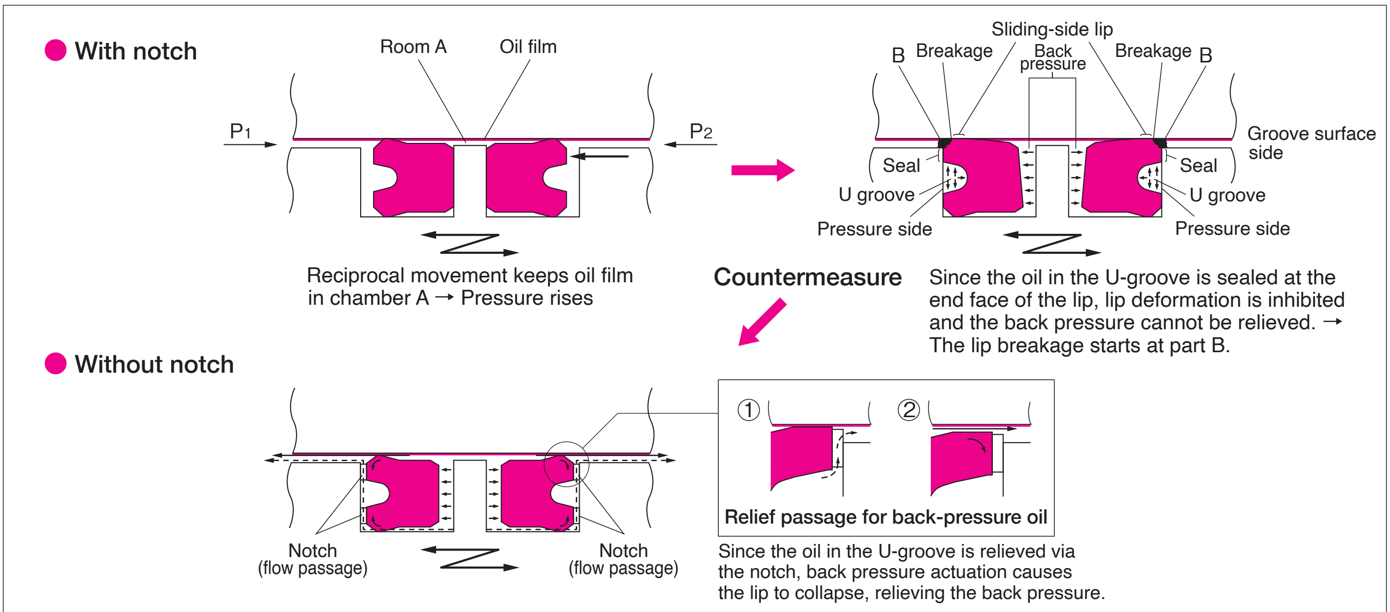
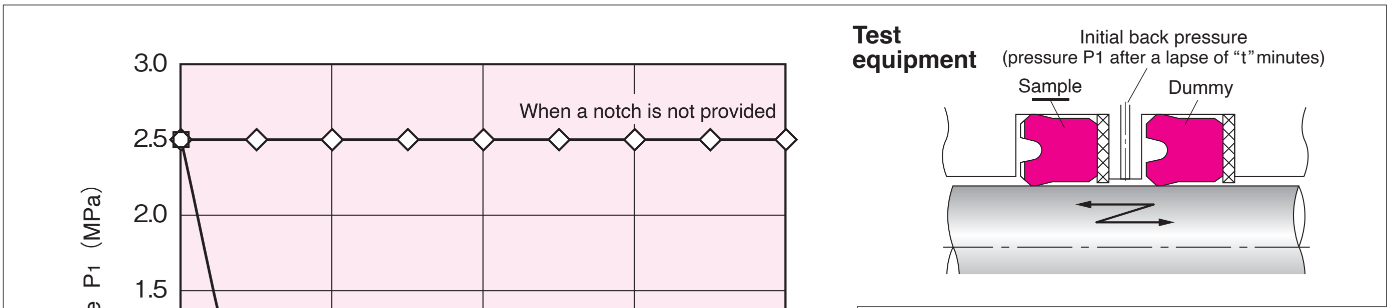
11. BREAKAGE DUE TO PRESSURE BUILD-UP

When two lip packings are used back-to-back for the piston, the packings fail due to pressure build-up between them. The failure occurs because the oil film passing through the packings remains between the packings due to reciprocal movement, gradually increasing the pressure (**Fig. H-25**). Also, when using multiple packings, it is necessary to consider the possibility of pressure build-up. Using a packing with a notch (relief passage) at the tip of the lip is an effective countermeasure to pressure build-up. If there is no notch, the lip end surface and installed groove surface side touch each other due to back pressure, so pressure in the U-groove is not released, forcing the sliding-side lip into close contact with the sliding surface. As a result, because back pressure is not released, the packing is pressed to the pressure-side groove surface side, breaking the lip starting from the point touching the corner of the groove. However, when a notch is provided, since the pressure in the U-groove is released via the notch, the sliding-side lip easily collapses at back-pressure actuation, relieving the back pressure. For reference, **Fig. H-26** shows the difference in back-pressure relief performance when a notch is and is not provided.

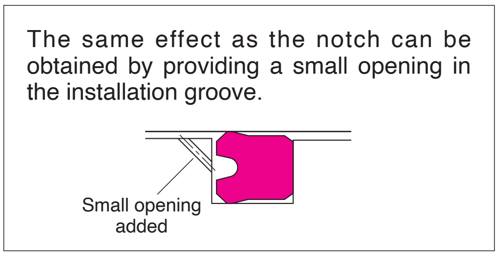
※ For rod packings, it is also necessary to consider pressure build-up when using multiple packings. For example, pressure build-up may occur when using a double-lip dust seal and a rod seal together. The most reliable countermeasure to pressure build-up is a drain between the packings (returning oil to oil tank). Using a DKBI3 dust seal with small holes on the oil lip allows pressure build-up oil to escape



〈Fig. H-25〉 Mechanism of package failure due to pressure build-up and countermeasures



〈Fig. H-26〉 Back pressure leakage performance is different with and without a notch.



〈Fig. H-27〉 Example of countermeasures for pressure build-up without packing

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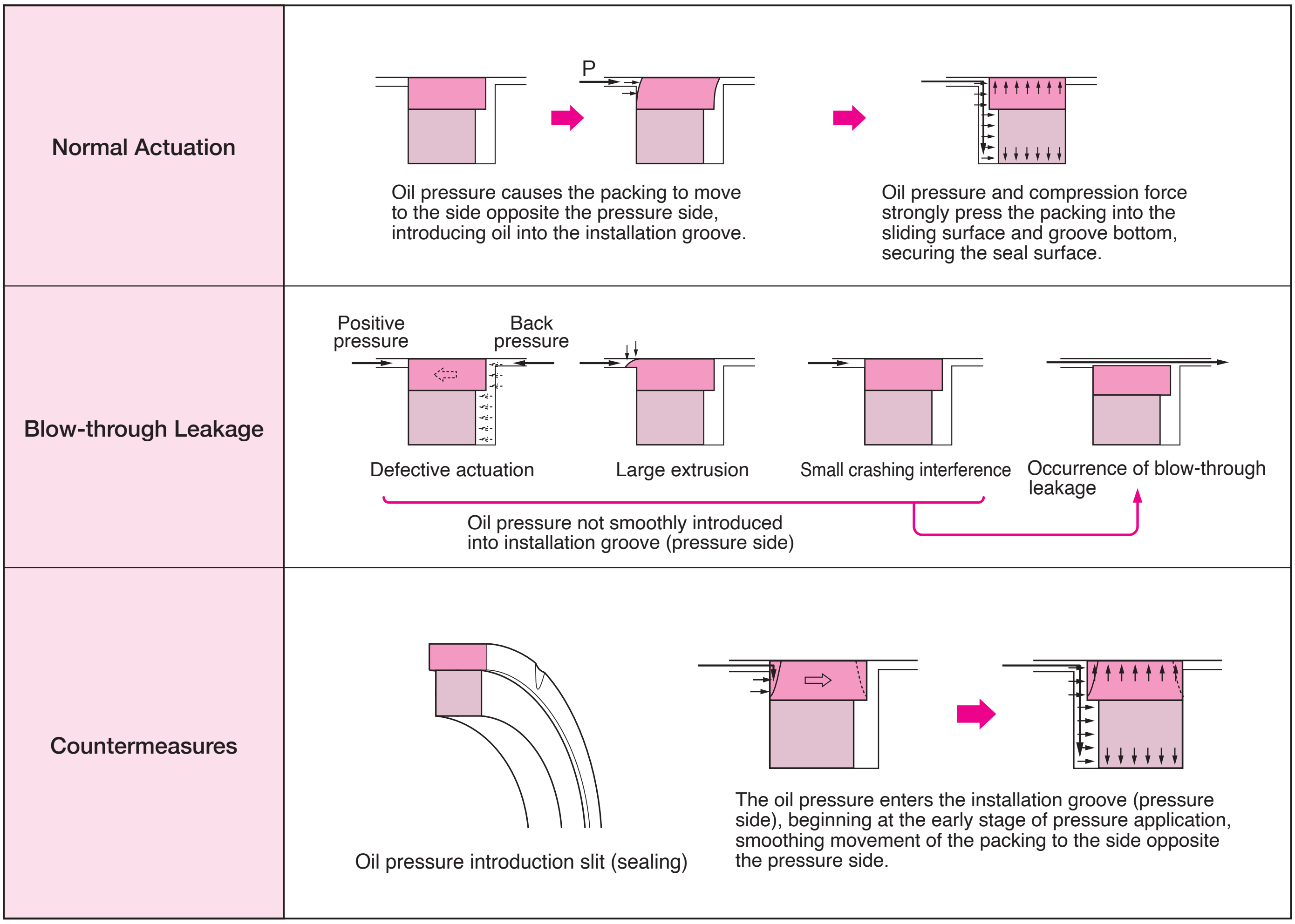
12. BLOW-THROUGH LEAKAGE (PASSING)

A packing initially seals oil under its own compression force. After application of pressure, it also seals high oil pressure by further extension due to oil pressure. Therefore, for the packing to maintain its sealing performance, it is important to introduce the oil pressure into the installation groove and to obtain the extension force due to oil pressure. Blow-through leakage (passing) occurs infrequently when the oil pressure is not introduced smoothly into the installation groove in the above state.
Once blow-through leakage has occurred, a great amount of leakage may continue for a long time, yet at the same time, blow-through leakage does not always reoccur when investigating the cause. This makes blow-through leakage a very troublesome phenomenon. Such leakage typically occurs when pressure acts in both directions of the combination seal for a piston packing on a power steering cylinder. For example, as shown in **Fig. H-28**, blow-through leakage occurs when the positive pressure acts from the left and back pressure acts from the right. Since the packing is pressed into the left-hand groove side by the back pressure, it is difficult for positive pressure from the left to enter the groove. As a result, extension force due to oil pressure is not obtained, causing blow-through leakage. A countermeasure for blow-through leakage is to smooth the introduction of oil pressure into the installation groove by installing "an oil pressure introduction slit" in the side of the seal ring.
Also, blow-through leakage tends to occur when the pressure causes extrusion of the seal ring or lowers the interference.
A slit is effective in these cases and the packing becomes more reliable and has prolonged life.

※ A combination seal with a slit is a special product and is not described in this catalog; consult NOK for details.



〈Fig. H-28〉 Blow-through leakage in combination seals and countermeasures for blow-through leakage

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13. SWELLING MECHANISM

Swelling is the state in which equilibrium is attained between the force of oil molecules entering the polymer molecules and spreading the spacing between polymer molecules and the elasticity of the cross-linked meshes.
Whether the swelling is large or small depends directly on the affinity between the oil and polymer, the larger the affinity, the larger the swelling.
The SP (Solubility Parameter) value is often used as an index of affinity. Two materials with similar molecular structures have larger affinity (the closer the polarity, the larger the affinity).

〈Example 1〉 EPDM and mineral oil (high affinity) → Large swelling

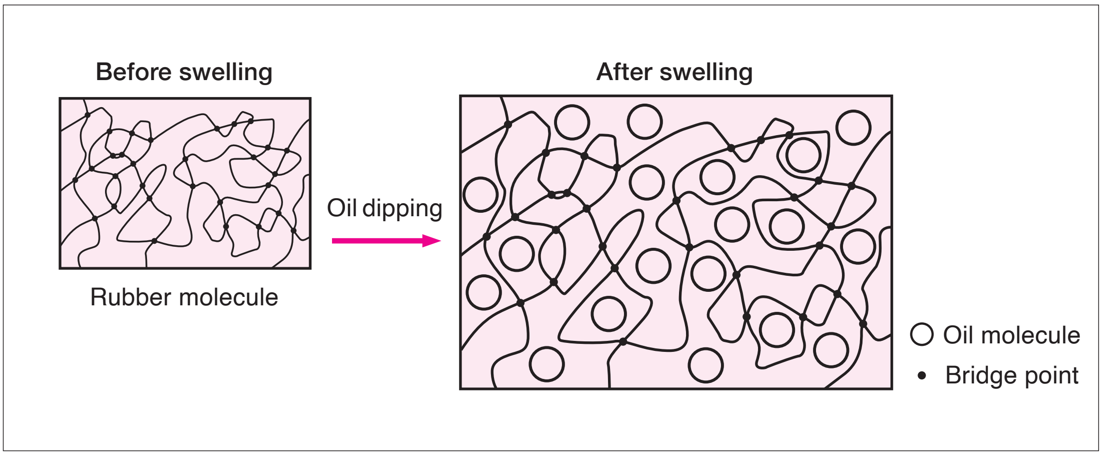
EPDM SP value: 8 (small polarity)	Mineral oil SP value: 6 to 8 (small polarity)
$[CH_2-CH_2]_n[CH+CH_2]_m$ $\vert$ CH_3	C_nH_{2n+2}

→ EPDM and mineral oil are similar in structure (only C and H have no polar group) and their affinity is high, so the swelling is large.

〈Example 2〉 NBR and mineral oil (poor affinity) → Small swelling

NBR SP value: 9 to 10 (large polarity)	Mineral oil SP value: 6 to 8 (large polarity)
$[CH_2-CH=CH-CH_2]_n[CH-CH_2]_m$ $\vert$ $C\equiv N$ ← Polar group	C_nH_{2n+2}

→ NBR and mineral oil are dissimilar (NBR has a polar group) and their affinity is poor, so the swelling is small.



〈Fig. H-29〉 Swelling advancement

Oil tries to get between rubber molecules, spreading the clearance between the rubber molecules (swelling phenomenon).
The clearance between the rubber molecules is spread by oil swelling, but because of bridges, clearance swelling does not occur beyond a point (called equilibrium swelling).

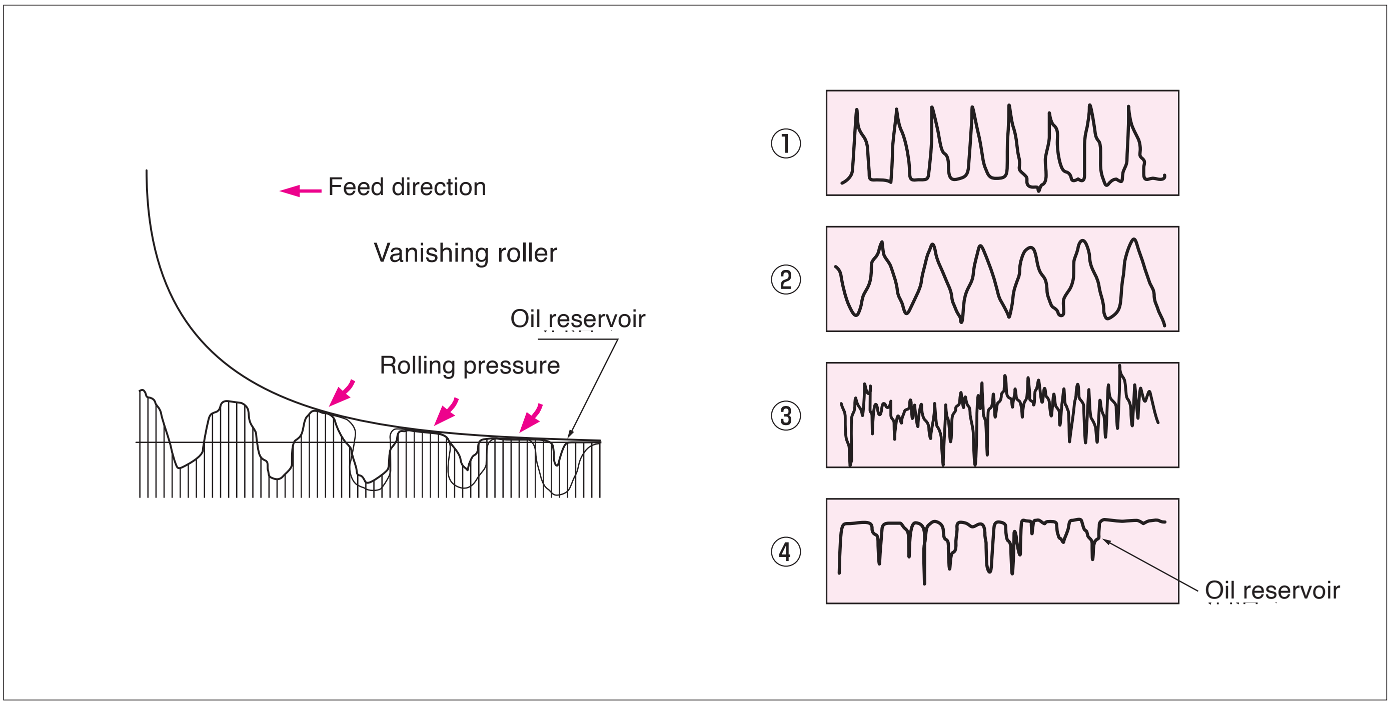
< Reference: With non-bridged rubbers, swelling becomes bigger and bigger until dissolution finally occurs (such as rubber adhesive material and spray glue). >

14. ROUGHNESS OF CONTACTING OBJECT

Roughness of Sliding Surface

Surface roughness greatly affects seal performance, efficiency and life, and both the size and form of the roughness are very important. When a surface has convexities, the seal wears quickly. Conversely, seal durability is improved when a surface has concavities that form oil reservoirs, reducing seal abrasion.

For this reason, we recommend using a roller vanishing finish (RLB) for the inside surface of the cylinder tube and a buff finish (SPBF) for the rod surface to flatten convexities.



〈Fig. H-30〉 Roughness example

①～④ are examples of surface roughness.
④ is the figure of roughness when the roller vanishing finish is used.
Using the roller vanishing finish, convexities are flattened by plastic deformation, and an oil reservoir is formed in concavities, reducing the seal's abrasion and improving its durability.

Roughness of Groove Bottom

Generally, the packing installation groove is machined by a lathe, so it has a spiral continuous machining track (roughness), but since the packing material has flexibility, the machining track does not become an oil relief passage due to filling-in of concavities in the rough area. However, when the roughness is large, concavities in the rough area cannot be filled in, forming an oil relief passage and causing oil leakage. The sliding surface of the packing is often managed because of packing friction problems. When the roughness of the bottom of the installation groove cannot be reduced sufficiently due to high machining difficulties, oil leakage may occur. The permissible roughness of the bottom of the groove is 6.3 mmRz or smaller for rubbers, such as nitrile rubber, with high flexibility, and 3.2 mmRz or smaller for iron rubber with relatively high rigidity. However, since the ability to match the roughness of the contact object is affected by both the rubber material and the pressing force (compression force), the ability may differ due to the shape of the packing even when the material is the same.

※ The roughness index is based on JIS B 0601: 2001.

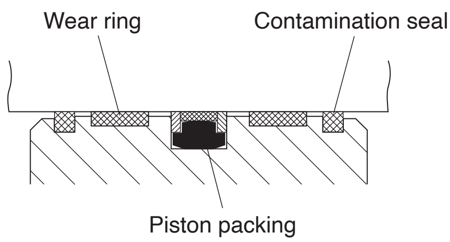
15. SEALING SYSTEM (COMBINATION EFFECT)

Example of Long-life System for Construction Machines

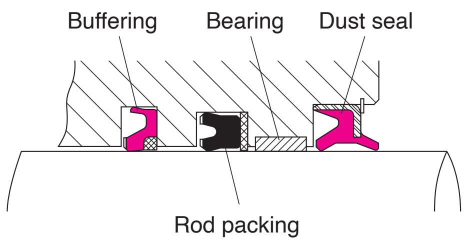
Among hydraulic cylinders, the cylinders of construction machines are subject to harsh usage conditions, such as high pressure and temperature.
Since the sealing system is used outdoors, external contamination is severe and the sealing system must cope with harsh use. The traditional mainstream rod sealing system used a combination of buffer rings, rod seals and dust seals made of high-strength iron rubber.
However, recently, nitrile rubber is increasingly being used as the rod packing material to improve performance and prolong life.

Compared to iron rubber, nitrile rubber has excellent ability to follow low-temperature eccentricity, so increasing use of nitrile rubber for rod seals improves low-temperature sealing performance and low-temperature durability.
However, use of nitrile rubber assumes use of a buffer ring with the rod packing, because the strength of nitrile rubber is lower than iron rubber (**Fig. H-31**, **Fig. H-32**).
As shown in this example, to achieve excellent long-term seal performance, it is necessary to examine not only the selection of each packing, but also the system configuration.

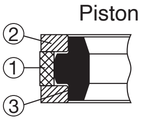
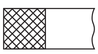
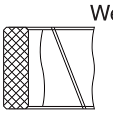
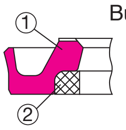
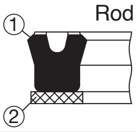
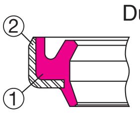
Piston Area



Rod Area



〈Fig. H-31〉 Example of sealing system for hydraulic cylinder of a construction machine

	Shape	Material	Main function	Feature
Piston Area	Piston packing 	①PTFE : Rareflon ②PA : Polyamide ③ NBR : nitrile rubber	Retention of oil pressure	A PTFE seal ring ① with excellent friction and abrasion characteristics is used. Also, to augment PTFE's creep characteristics and pressure resistance, a combination of a buffer ring ③ made of NBR and a backup ring ② made of PA is used.
Piston Area	Contamination seal 	PTFE : Rareflon	Elimination of foreign objects in oil	Intrusion of foreign objects into the piston packing is inhibited by burying and capturing the foreign objects not only by scraping off foreign objects in the oil but also using PTFE's plastic deformability.
Piston Area	Wear ring 	PTFE : Rareflon	Bearing	Stick-slip is prevented by using PTFE's excellent friction characteristics. Fabric phenol resin with high elasticity is used for applications requiring large lateral load.
Rod Area	Buffering 	①PUR : Iron rubber ②PA : Polyamide	Buffering of impact pressure applied to rod packing	Since there are high pressures, a PTFE seal ring ① is used in combination with a PA backup ring ②, to use PUR with a combination of strength and flexibility so that the pressure resistance is supplemented.
Rod Area	Rod packing 	①NBR : nitrile rubber ②PTFE : Rareflon	Prevention of external oil leaks	Long life is achieved by using NBR with excellent creep characteristics. Supplementing pressure resistance using a PTFE backup ring ② with (② made of PA is inappropriate due to the large strength difference between ② and ① causing extrusion breakage in ①).
Rod Area	Dust seal 	①PUR : Iron rubber ②SPCC	Prevention of intrusion of foreign objects	To cope with the harsh external contaminant conditions, high-strength PUR is used to resist plastic deformation.

〈Fig. H-32〉 Features of each packing material

16. BLISTERS

Phenomenon

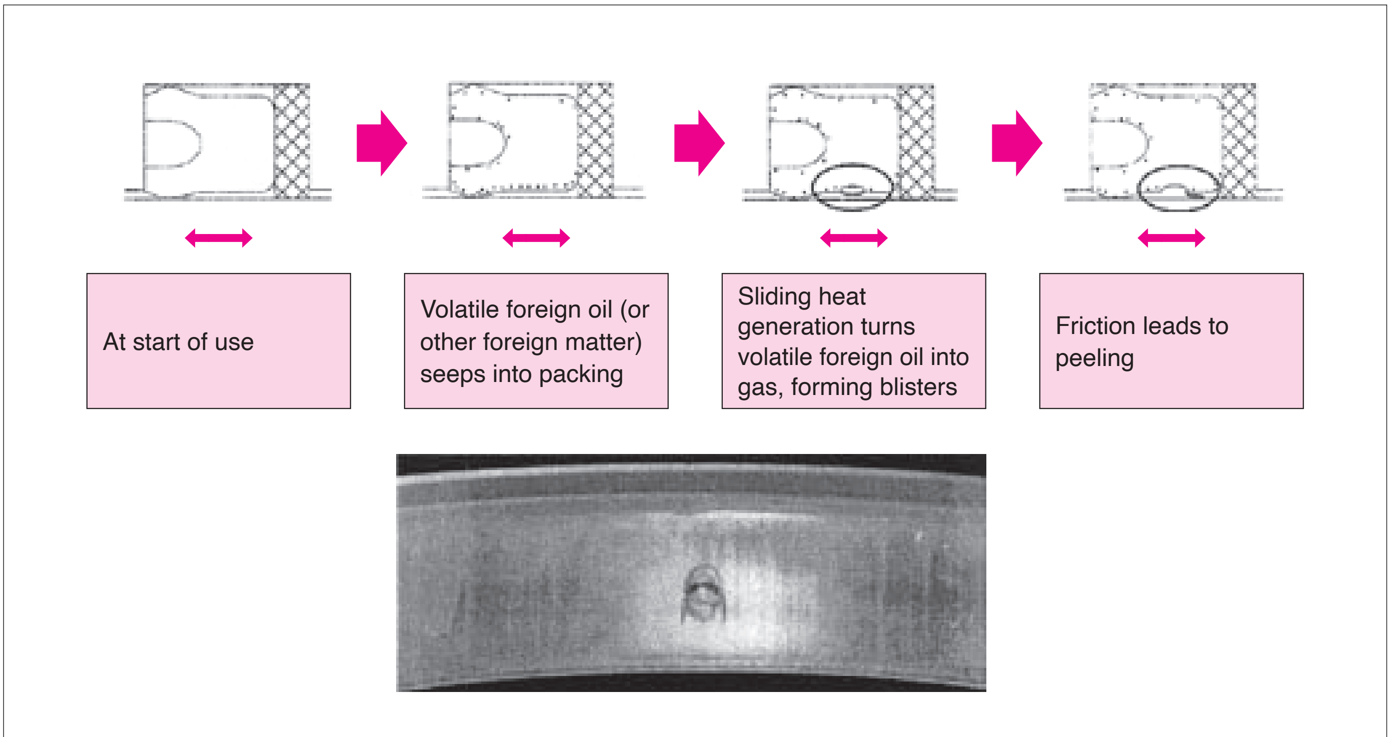
Blisters refers to foam or bubbles formed in the vicinity of sliding sections of the seal when liquid absorbed into the seal is converted to gas form by sliding heat generation.
Since packing is used at high pressures, blisters in the vicinity of the sliding face of the seal can cause peeling due to friction caused by sliding movement in the vicinity **(Fig. H-33)**.

Conditions conducive to blisters

Where volatile oils are used, blisters may form in a high-temperature operating environment (high temperature, high speed, high pressure). In some cases this is caused by the presence of a volatile foreign oil in the oil being used.

Response

Blisters are caused by certain combinations of oils and operating conditions. Although the problem cannot be solved by packing alone, it is possible to reduce sliding heat generation through the use of low-friction materials such as combined seals made from Rareflon and self-lubricating U-packing such as OUHR.



〈Fig. H-33〉 Packing example (blister formation ⇒ peeling)