DATA SHEET

Hydraulic Fluid [Part 1]
Requirements, Classification, and Properties

■ Requirements

Hydraulic pumps, control valves, and hydraulic cylinders operate at high pressure and high speed; they are also constructed of a variety of materials. Considering these facts as well as fluid temperature and ambient conditions during operation, the following requirements for hydraulic fluids must be met.

- Maintaining proper viscosity as temperature changes
- Flowable at low temperature
- Resistant to high temperature degradation
- Providing high lubricity and wear resistance
- Highly oxidation stable
- Highly shear stable
- Non-corrosive to metal
- Exhibiting good demulsibility/water separation when mixed with water
- Rust-preventive
- Non-compressible
- Providing good defoaming performance
- Fire-resistant

■ Classification

JIS standards for hydraulic fluids do not currently exist, and fluids that meet the above requirements and have a viscosity equivalent to that of petroleum based turbine oils (JIS K 2213) are used. Turbine oils are classified into two types: Type 1 (without additives) and Type 2 (with additives). Type 2 turbine oils contain antirust, antioxidant, and other additives. JIS K 2213 Type 2 turbine oils and special oils with a viscosity grade of ISO VG 32, 46, or 68 are widely used. If there is a risk of fire in the event of fluid leakage or blowout from hydraulic systems, fire-resistant synthetic or water containing fluids are employed. These fire-resistant fluids have different properties from petroleum base oils and must be handled carefully in practical applications. Chlorinated hydrocarbon fluids are rarely used for industrial purposes in Japan, since they become highly toxic and corrosive when decomposed. While other fluids are also available, fluids used for general industrial purposes are largely categorized as follows.

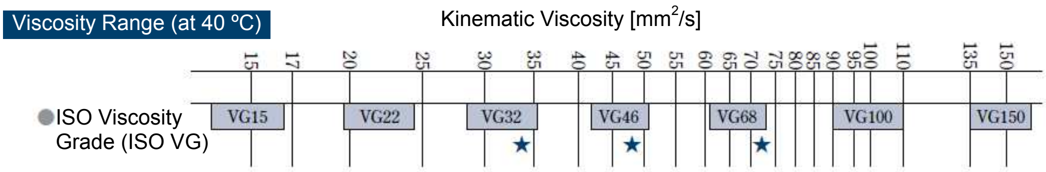
- Hydraulic Fluid
  - Petroleum Base Oil
    - R&O Type Oil
    - Additive Turbine Oil
    - Special Oil
      - Anti-Wear Type Hydraulic Oil
      - High Viscosity Index Hydraulic Oil
      - Low Temperature Hydraulic Oil
      - High Temperature Hydraulic Oil
  - Synthetic Fluid (Fire-Resistant)
    - Phosphate Ester Fluid
    - Polyol Ester Fluid
    - Chlorinated Hydrocarbon Fluid
  - Water Containing Fluid (Fire-Resistant)
    - Water-Glycol Fluid
    - Water-In-Oil (W/O) Emulsion
    - Oil-In-Water (O/W) Emulsion

■ Properties (Example)

Item \ Hydraulic Fluid		Petroleum Base Oil (Type 2 Turbine Oil Equivalent to ISO VG 32)	Phosphate Ester Fluid	Polyol Ester Fluid	Water-Glycol Fluid	W/O Emulsion	O/W Emulsion
Specific Gravity (15/4 °C)		0.87	1.13	0.93	1.04 - 1.07	0.93	1.00
Viscosity (mm^2/s)	40 °C	32.0	41.8	40.3	38.0	95.1	0.7
	100 °C	5.4	5.2	8.1	7.7	-	-
Viscosity Index (VI)		100	20	160	146	140	-
Max. Operating Temp. (°C)		70	100	100	50	50	50
Min. Operating Temp. (°C)		-10	-20	-5	-30	0	0
Strainer Resistance		1.0	1.03	1.0	1.2	0.7 - 0.8	(Same As Water)

■ Viscosity

The viscosity of industrial lubricants, including hydraulic fluids, is measured by kinematic viscosity ν [m^2/s], which is obtained by dividing absolute viscosity by density. It is typically expressed in units of square millimeters per second (mm^2/s). For viscosity measurement, a capillary viscometer is used to determine kinematic viscosity (mm^2/s) as per JIS K 2283 “Crude petroleum and petroleum products - Determination of kinematic viscosity and calculation of viscosity index from kinematic viscosity”. Hydraulic fluid viscosity critically affects the performance of hydraulic systems. System operation with a hydraulic fluid viscosity outside the specified range may result in pump suction failure, internal leakage, poor lubrication, valve malfunction, or heat generation in the circuit, shortening the life of equipment or causing a major accident.
According to JIS K 2001 “Industrial liquid lubricants - ISO viscosity classification”, 20 viscosity grades are available ranging from ISO VG 2 to 3200. The figure below shows the viscosity range associated with the operation of hydraulic systems. For details, see “Viscosity vs. Temperature” on page 862.



★ For JIS K 2213 Type 2 (with additives), three grades ISO VG 32, 46, and 68 are available.

■ Contamination control

● Cleanliness

Hydraulic fluid replacement is required in the following three cases.

(a) Deterioration or degradation of the fluid
(b) Particulate contamination of the fluid
(c) Water contamination of the fluid

While Table 3 provides guidelines for (a), the necessity of hydraulic fluid replacement is caused by (b) and (c) in most cases. Particulate contamination of hydraulic fluids may result in pump wear or valve malfunction. In particular, the performance of systems equipped with precision valves (e.g. electro-hydraulic servo valves) and actuators is adversely affected by fine particles of a few micrometers to a few tens of micrometers. Thus, it is necessary to control the level of contamination properly by measuring the size and number of particles in the fluid with a microscope or by measuring the mass of particles per unit volume of the fluid.
For the determination of the fluid cleanliness level, filter 100 ml of the fluid through a filtration device and collect particles on a millipore filter (a filter with fine pores of 1/1000 mm). Measure the number and size of the collected particles for classification as shown in Table 1. For highly contaminated fluids, determine the cleanliness level based on the mass of particles collected on the millipore filter, as shown in Table 2. Unused R&O type oils have a cleanliness level of Class 6 to 8 shown in Table 1.

Table 1 NAS Cleanliness Level Based on Particle Counting — Number of particles per 100 ml

Size (μm)	Class (NAS 1638)													
	00	0	1	2	3	4	5	6	7	8	9	10	11	12
5 - 15	125	250	500	1,000	2,000	4,000	8,000	16,000	32,000	64,000	128,000	256,000	512,000	1,024,000
15 - 25	22	44	89	178	356	712	1,425	2,850	5,700	11,400	22,800	45,600	91,000	182,400
25 - 50	4	8	16	32	63	126	253	506	1,012	2,025	4,050	8,100	16,200	32,400
50 - 100	1	2	3	6	11	22	45	90	180	360	720	1,440	2,880	5,760
More than 100	0	0	1	1	2	4	8	16	32	64	128	256	512	1,024

NAS: National Aerospace Standard ISO: International Organization for Standardization

Table 2 Classification Based on the Gravimetric Method

NAS	Class	100	101	102	103	104	105	106	107	108
	mg/100 ml	0.02	0.05	0.10	0.3	0.5	0.7	1.0	2.0	4.0
MIL	Class	A	B	C	D	E	F	G	H	I
	mg/100 ml	Less than 1.0	1.0 - 2.0	2.0 - 3.0	3.0 - 4.0	4.0 - 5.0	5.0 - 7.0	7.0 - 10.0	10.0 - 15.0	15.0 - 25.0

MIL: Military Specifications and Standards

Hydraulic Fluid [Part 3]
Service Limit and Contamination Measuring Instrument

Data Sheet

● Service limit

Unused R&O type oils contain 50 to 80 ppm (0.005 to 0.008%) of water, but the water content increases due to entry of atmospheric moisture through the actuator or air breather. Water may cause rust on the inside of hydraulic equipment, poor lubrication, or accelerated degradation of the hydraulic fluid. The water content of the fluid is measured by Karl Fischer titration (based on the quantitative reaction of the reagent with water) with a sensitivity of 10 ppm. The particulate/water contamination tolerance of hydraulic fluids varies depending on the system configuration as outlined in Tables 4 and 5.

Table 4 Recommended Control Level of Fluid Contamination

System Configuration	Class	
	JIS B 9933 (ISO 4406)	NAS
System with Servo Valve	18/16/13	7
System with Piston Pump	20/18/14	9
System with Proportional Electro-Hydraulic Control Valve	20/18/14	9
System Operating at Pressures Higher than 21 MPa	20/18/14	9
System Operating at Pressures of 14 to 21 MPa	21/19/15	10
General Low Pressure Hydraulic System	21/20/16	11

★ Comparison of JIS B 9933 (ISO 4406) and NAS for reference

Table 3 Criteria for Hydraulic Fluid Replacement (Example)

<table>
<tr><th rowspan="2">Fluid Type / Test Item</th><th colspan="3">Petroleum Base Oil</th><th rowspan="2">Water-Glycol Fluid</th></tr>
<tr><th>R&O</th><th colspan="2">Anti-Wear</th></tr>
<tr><td>Kinematic Viscosity (40 °C)★ mm²/s</td><td colspan="3">±10%</td><td>±10%</td></tr>
<tr><td rowspan="2">Total Acid Number★ mgKOH/g</td><td rowspan="2">0.25</td><td>a☆</td><td>0.25</td><td rowspan="2">-</td></tr>
<tr><td>b☆</td><td>±40%</td></tr>
</table>

★: Variation in kinematic viscosity
☆: Additive type (a: Non-zinc based, b: Zinc based)

Table 3 provides guidelines for hydraulic fluid replacement. Detailed specifications vary depending on the manufacturer, and additional control requirements may be applied. Contacting the fluid manufacturer is recommended.
For example, the total acid number (or acid number) is a measure of fluid degradation and affected by the additive type and level. For water-glycol fluids, the pH value is also controlled.

Table 5 Water Contamination Tolerance of R&O Type Oils

1 ppm = 1/1000000

System Conditions	Service Limit
The hydraulic fluid is cloudy with water.	To be immediately replaced
The system has a circuit for circulating the hydraulic fluid back to the oil tank and operates without long-term shutdown.	500 ppm
The piping length of the system is long, and the hydraulic fluid does not fully circulate in the circuit.	300 ppm
The system remains out of service for a long period (safety system), has a circuit in which the hydraulic fluid hardly moves, or is designed to provide precision control.	200 ppm

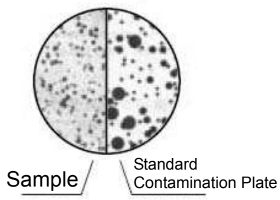
● Portable Fluid Contamination Measuring Instrument

YUKEN CONTAMI-KIT

Model Number: YC-100-22

YUKEN's CONTAMI-KIT is a fluid contamination measuring instrument that samples hydraulic fluids and microscopically measures the distribution of particles collected on a membrane filter as per JIS B 9930 or SAE ARP 598 A.

■ Specifications
1) Power supply: Both AC and DC power supplies supported (100 V AC/6 V DC)
2) Microscope magnification: 100 times (40 times: Option for KYC-100-L-20)
3) Applicable fluids: Petroleum base oil, polyol ester fluid, and water-glycol fluid (optional)
4) Case dimensions: L 600 × W 240 × H 360 mm
5) Total mass: Approximately 9 kg



■ Features of CONTAMI-KIT
1) Usable everywhere
   Portable and supports both AC and DC power supplies (switchable).
2) User-friendly
   Requires no skills and involves only comparing the results with the standard contamination plate.
3) Time-efficient
   Takes only about 10 minutes for each measurement.
4) Supporting photo taking
   Allows photo taking with a single-lens reflex camera for recording.

Hydraulic Fluid [Part 4]
YUKEN's Hydraulic Equipment and Fluid Types (1)

Hydraulic equipment is affected differently depending on the fluid type; special care should be taken when selecting the equipment. The table below shows YUKEN's hydraulic equipment available for each fluid type. For details, see the relevant pages.

Equipment \ Hydraulic Fluid		Petroleum Base Oil (Equivalent to JIS K 2213 Type 2)	Phosphate Ester Fluid	Polyol Ester Fluid
A Series Variable Displacement Piston Pump		Standard	Custom: Z6 Seal: Fluororubber	Consult us.
Fixed Displacement Vane Pump		Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Pressure Control Valve		Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Flow Control Valve		Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Directional Control Valve		Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Modular Valve		Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Logic Valve		Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Proportional Electro-Hydraulic Control valve		Standard	"F-" + Standard Model★1 Seal: Fluororubber	Standard★2
Servo Valve		Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Cylinder	CJT Series	Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Cylinder	CBY14 Series	Standard Packing Material: 6 (HNBR)	Semi-Standard Packing Material: 3 (Fluororubber)	Standard Packing Material: 6 (HNBR)
Accumulator		Standard/ Commercially Available Product	Butyl Rubber Diaphragm Type/ Piston Type (Except for Aluminum) Permitted	Butyl Rubber Diaphragm Type Prohibited
Needle Valve		Standard	"F-" + Standard Model Seal: Fluororubber	Standard
Tank Filter		Aluminum	Aluminum	Aluminum
Oil Level Gauge		Direct Reading Type	Remote Reading Type	Direct Reading Type
Rubber Tube		Nitrile Rubber	Butyl Rubber	Nitrile Rubber
Inside Coating of Oil Tank		Epoxy/Phenolic Coating Permitted	Inside Coating Prohibited (Chemical Conversion Coating Permitted)	Phenolic Coating Prohibited
Effect on Metals		None	Aluminum Sliding Parts Prohibited	None
Seal	Nitrile Rubber	Permitted	Prohibited	Permitted
Seal	Fluororubber	Permitted	Permitted	Permitted
Seal	Silicone Rubber	Prohibited	Permitted	Permitted
Seal	Butyl Rubber	Prohibited	Permitted	Prohibited
Seal	Ethylene Propylene Rubber	Prohibited	Permitted	Permitted
Seal	Urethane Rubber	Permitted	Prohibited	Permitted
Seal	Fluororesin	Permitted	Permitted	Permitted
Seal	Chloroprene	Permitted	Prohibited	Permitted
Seal	Leather	Permitted	Permitted	Permitted
Other		-	Protect electrical wiring by applying oil resistant coating or by running it in conduits.	-

★1. Contact us for details of EH Series High Response Directional and Flow Control Valves (EHDFG-04/06).
★2. Contact us for details of EH Series Directional and Flow Control Valves (EHDFG-03) and EH Series High Response Directional and Flow Control Valves (EHDFG-04/06).

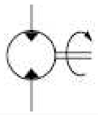
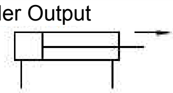
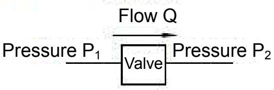
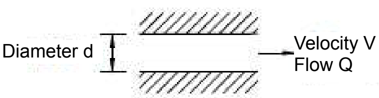
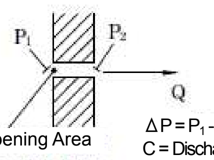
YUKEN

Hydraulic Fluid [Part 5]
YUKEN's Hydraulic Equipment and Fluid Types (2)

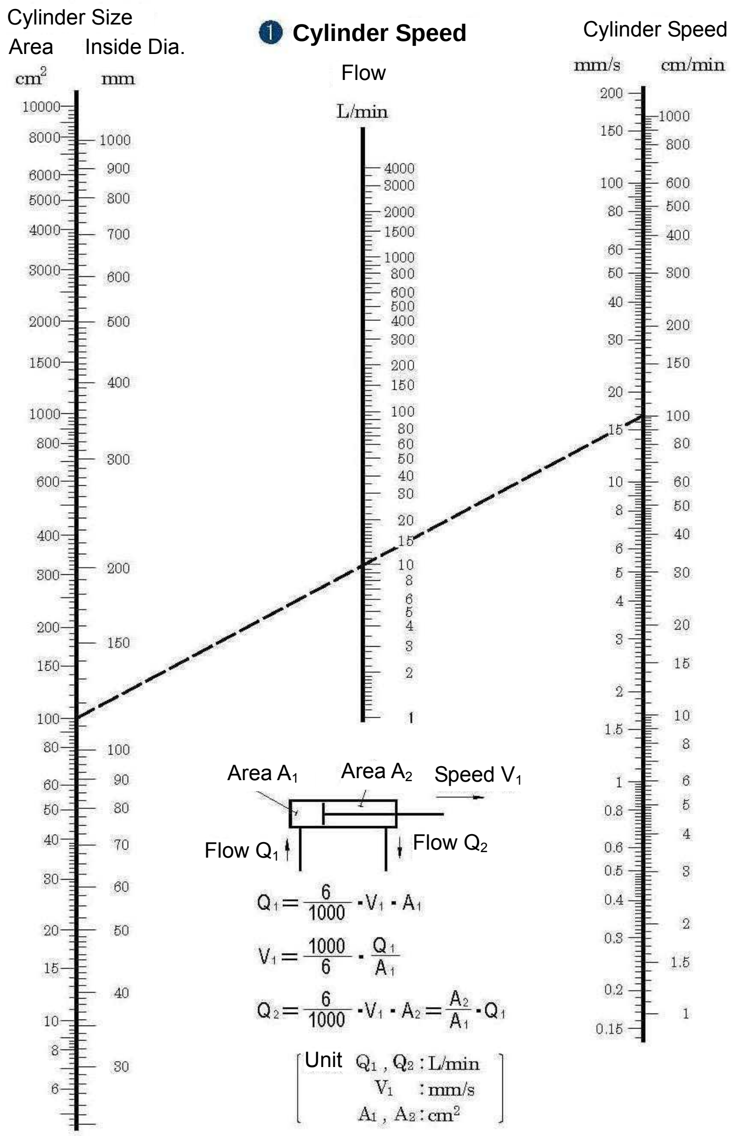
Data Sheet

Equipment \ Hydraulic Fluid		Water-Glycol Fluid	W/O Emulsion	O/W Emulsion
A Series Variable Displacement Piston Pump		Custom: Z30	Custom: Z30	Consult us.
Fixed Displacement Vane Pump		"M-" + Standard Model PV2R: Standard	Custom: Z35 ("M-" + Standard Model in some cases) PV2R: Standard	Consult us.
Pressure Control Valve		Standard	Consult us.	Consult us.
Flow Control Valve		Standard	Consult us.	Consult us.
Directional Control Valve		Standard	Standard	Consult us.
Modular Valve		Standard	Consult us.	Consult us.
Logic Valve		Standard	Consult us.	Consult us.
Proportional Electro-Hydraulic Control Valve		Standard★1	Consult us.	Consult us.
Servo Valve		Standard★2	Consult us.	Consult us.
Cylinder	CJT Series	Standard Seal: Nitrile Rubber	Standard Seal: Nitrile Rubber	Custom Seal: Nitrile Rubber
Cylinder	CBY14 Series	Standard Packing Material: 6 (HNBR)	Standard Packing Material: 6 (HNBR)	Standard Packing Material: 6 (HNBR)
Accumulator		Standard/ Commercially Available Product	Standard/ Commercially Available Product	Standard/ Commercially Available Product
Needle Valve		Standard	Standard	Standard
Tank Filter		Stainless Steel (Aluminum, Cadmium, or Galvanizing Prohibited)	Aluminum/Stainless Steel (Cadmium or Galvanizing Prohibited)	Stainless Steel (Aluminum Prohibited)
Oil Level Gauge		Direct Reading Type	Direct Reading Type	Direct Reading Type
Rubber Tube		Nitrile Rubber	Nitrile Rubber	Nitrile Rubber
Inside Coating of Oil Tank		Inside Coating Prohibited (Chemical Conversion Coating Permitted)	Inside Coating Prohibited (Chemical Conversion Coating Permitted)	Epoxy Coating Permitted
Effect on Metals		Aluminum, Cadmium, or Zinc Prohibited	Copper, Cadmium, or Zinc Prohibited	None
Seal	Nitrile Rubber	Permitted	Permitted	Permitted
Seal	Fluororubber	Permitted	Permitted	Permitted
Seal	Silicone Rubber	Prohibited	Prohibited	Prohibited
Seal	Butyl Rubber	Permitted	Prohibited	Prohibited
Seal	Ethylene Propylene Rubber	Permitted	Prohibited	Prohibited
Seal	Urethane Rubber	Prohibited	Prohibited	Prohibited
Seal	Fluororesin	Permitted	Permitted	Permitted
Seal	Chloroprene	Permitted	Permitted	Permitted
Seal	Leather	Prohibited	Prohibited	Prohibited
Other		-	Be sure to have the oil tank bottom tilted and equipped with a drain cock.	-

★1. Contact us for details of EH Series High Response Directional and Flow Control Valves (EHDFG-04/06).
★2. Contact us for details of the following products.
- On-Board Electronics Type Linear Servo Valves without DR Port (Wet Type Pilot Valve: LSVHG-*EH-*-W)

<table>
<tr><th colspan="2"></th><th>SI Unit</th><th>Engineering Unit (Reference)</th></tr>
<tr><td rowspan="4">Hydraulic Pump</td><td>● Hydraulic Power (Pump Output)</td><td>$L_O=\frac{P\cdot Q}{60}$
[L_O: Hydraulic Power kW
P: Pressure MPa
Q: Flow L/min
* 1 kW = 1 kN•m/s
= 60 kN•m/min]</td><td>$L_O=\frac{P\cdot Q}{612}$
[L_O: Hydraulic Power kW
P: Pressure kgf/cm^2
Q: Flow L/min
* 1 kW = 102 kgf•m/s
= 6120 kgf•m/min]</td></tr>
<tr><td>● Shaft Input</td><td>$L_i=\frac{2\pi TN}{60000}$
[L_i: Shaft Input kW
T: Shaft Torque N•m
N: Shaft Speed r/min]</td><td>$L_i=\frac{2\pi TN}{6120}$
[L_i: Shaft Input kW
T: Shaft Torque kgf•m
N: Shaft Speed rpm]</td></tr>
<tr><td>● Volumetric Efficiency</td><td colspan="2">$\eta_V=\frac{Q_P}{Q_O}\times 100$
[η_V: Volumetric Efficiency %
Q_P: Flow at Pressure P L/min
Q_O: Flow at No Load L/min
* Q_O - Q_P = Pump's Total Internal Leakage]</td></tr>
<tr><td>● Overall Efficiency</td><td>$\eta=\frac{L_O}{L_i}\times 100$
$=\frac{P\cdot Q}{60L_i}\times 100$
[η: Overall Efficiency %
L_O: Hydraulic Power kW
L_i: Shaft Input kW
P: Discharge Pressure MPa
Q: Flow L/min]</td><td>$\eta=\frac{L_O}{L_i}\times 100$
$=\frac{P\cdot Q}{612L_i}\times 100$
[η: Overall Efficiency %
L_O: Hydraulic Power kW
L_i: Shaft Input kW
P: Discharge Pressure kgf/cm^2]</td></tr>
<tr><td colspan="2">● Hydraulic Motor Output
</td><td>$L=\frac{2\pi T\cdot N}{60\,000}$
[L: Output kW
T: Torque Nm
N: Speed r/min]</td><td>$L=\frac{2\pi T\cdot N}{6120}$
[L: Output kW
T: Torque kgf•m
N: Speed rpm]</td></tr>
<tr><td colspan="2">● Cylinder Output
</td><td>$L=\frac{F\cdot V}{60}$
[L: Output kW
F: Force kN
V: Speed m/min]</td><td>$L=\frac{F\cdot V}{6120}$
[L: Output kW
F: Force kgf
V: Speed m/min]</td></tr>
<tr><td colspan="2">● Valve Power Loss

Pressure Loss: $\Delta P=P_1-P_2$
Power Loss between Valve Inlet and Outlet: L</td><td>$L=\frac{\Delta P\cdot Q}{60}$
[L : kW
ΔP : MPa
Q : L/min]</td><td>$L=\frac{\Delta P\cdot Q}{612}$
[L : kW
ΔP : kgf/cm^2
Q : L/min]</td></tr>
<tr><td colspan="2">● Viscosity (Absolute) and Kinematic Viscosity</td><td>$\mu=\rho\cdot\nu_1=\rho\cdot\nu_2\times 10^{-6}$
[μ : Viscosity (Absolute) Pa•s (= N•s/m^2)
ρ : Density kg/m^3
ν_1: Kinematic Viscosity m^2/s
ν_2: Kinematic Viscosity mm^2/s]</td><td>$\mu=\rho\cdot\nu_1=\frac{\gamma}{g}\cdot\nu_1=\frac{\gamma\cdot\nu_2}{100g}$
[μ : Viscosity (Absolute) kgf·s/cm^2
ρ : Density kgf·s^2/cm^4
ν_1: Kinematic Viscosity cm^2/s
ν_2: Kinematic Viscosity cSt
γ : Specific Gravity kgf/cm^3
g: Gravitational Acceleration 980 cm/s^2
* 1 cSt = 0.01 cm^2/s]</td></tr>
<tr><td colspan="2">● Reynolds Number

R: Reynolds Number
ν : Kinematic Viscosity</td><td colspan="2">$R=\frac{V\cdot d}{\nu_1}=\frac{4000Q}{60\pi d\cdot\nu_1}=\frac{2120Q}{d\cdot\nu_2}$
[R : Dimensionless Quantity
V : cm/s
d : cm
ν_1 : cm^2/s
ν_2 : mm^2/s{cSt}
Q : L/min]
* R < 2300: Laminar Flow
R > 2300: Turbulent Flow</td></tr>
<tr><td colspan="2">● Orifice Flow

A: Opening Area
$\Delta P=P_1-P_2$
C = Discharge Coefficient
γ = Specific Gravity
ρ = Density</td><td>$Q=C\cdot A\sqrt{\frac{2\Delta P}{\rho}\times 10^6}\times 6$
[Q: L/min ρ : kg/m^3
C: Dimensionless Discharge Coefficient
ΔP: MPa A: cm^2]</td><td>$Q=C\cdot A\sqrt{\frac{2g}{\gamma}\cdot\Delta P}\times\frac{60}{1000}=2.66C\cdot A\sqrt{\frac{\Delta P}{\gamma}}$
(Q: L/min g: 980 cm/s^2
C: Dimensionless Discharge Coefficient
γ: kgf/cm^3 A: cm^2
ΔP: kgf/cm^2)</td></tr>
<tr><td colspan="2"></td><td colspan="2">Note) The value of discharge coefficient depends on the flow channel geometry and the Reynolds number; it generally ranges from 0.6 to 0.9.</td></tr>
</table>

❶ Cylinder Speed



$$Q_1 = \frac{6}{1000} \cdot V_1 \cdot A_1$$

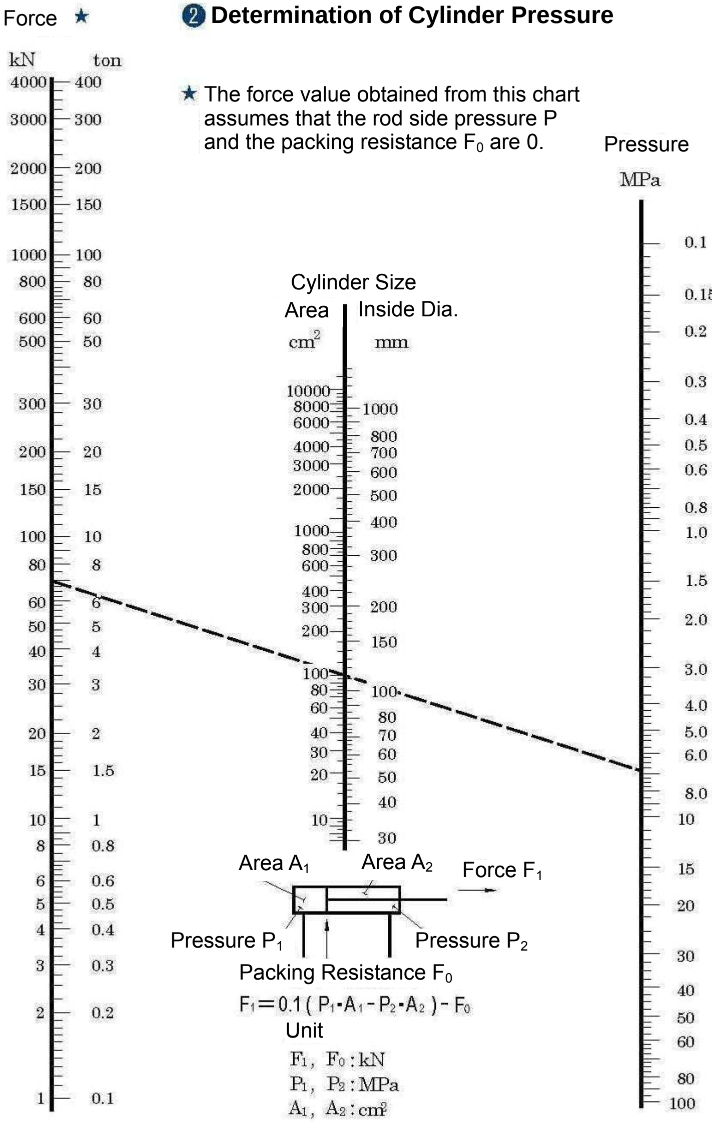
$$V_1 = \frac{1000}{6} \cdot \frac{Q_1}{A_1}$$

$$Q_2 = \frac{6}{1000} \cdot V_1 \cdot A_2 = \frac{A_2}{A_1} \cdot Q_1$$

Unit Q_1, Q_2 : L/min
V_1 : mm/s
A_1, A_2 : cm²

❷ Determination of Cylinder Pressure

★ The force value obtained from this chart assumes that the rod side pressure P and the packing resistance F_0 are 0.

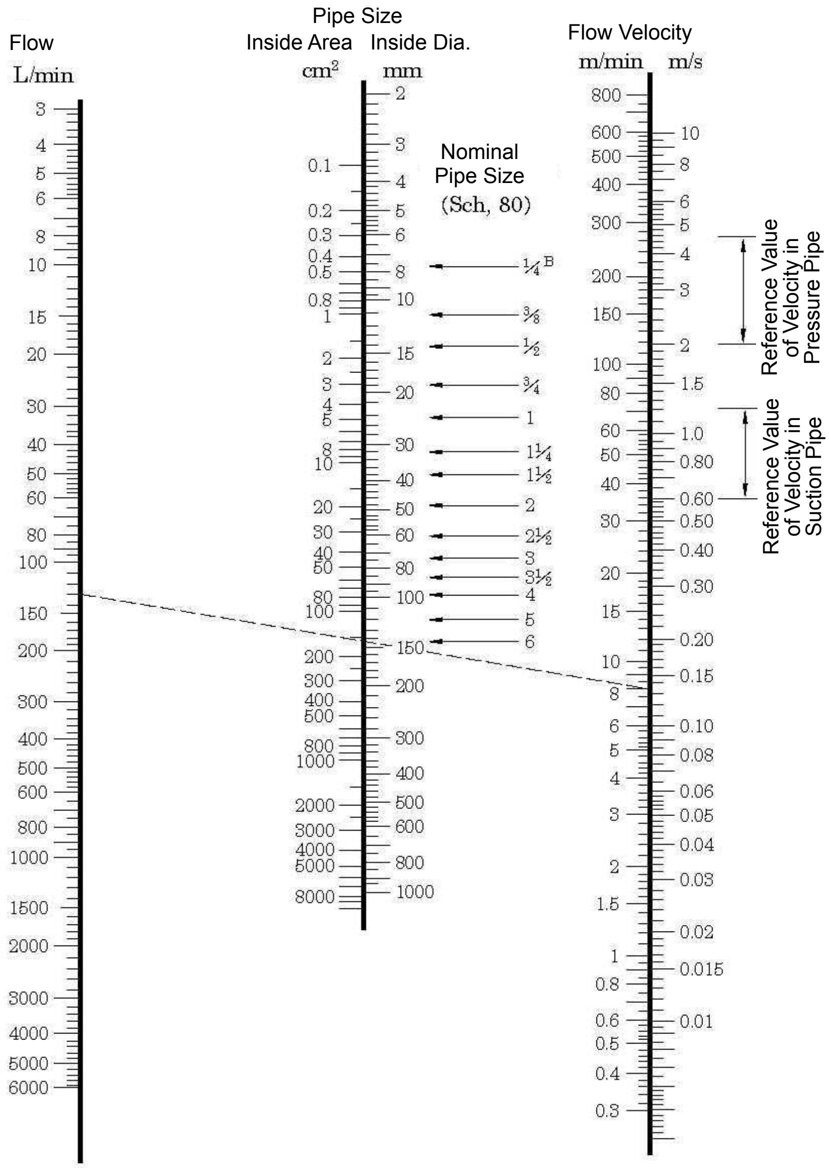


$$F_1 = 0.1\,(P_1 \cdot A_1 - P_2 \cdot A_2) - F_0$$

Unit
F_1, F_0 : kN
P_1, P_2 : MPa
A_1, A_2 : cm²

Formulas/Nomograms [Part 3]
(1) Pipe Size/Flow Velocity, (2) Steel Pipes/Tubes

1 Pipe Size/ Flow Velocity



2 Steel Tubes/Pipes SGP. STS370. STPS2

● Carbon Steel Pipes

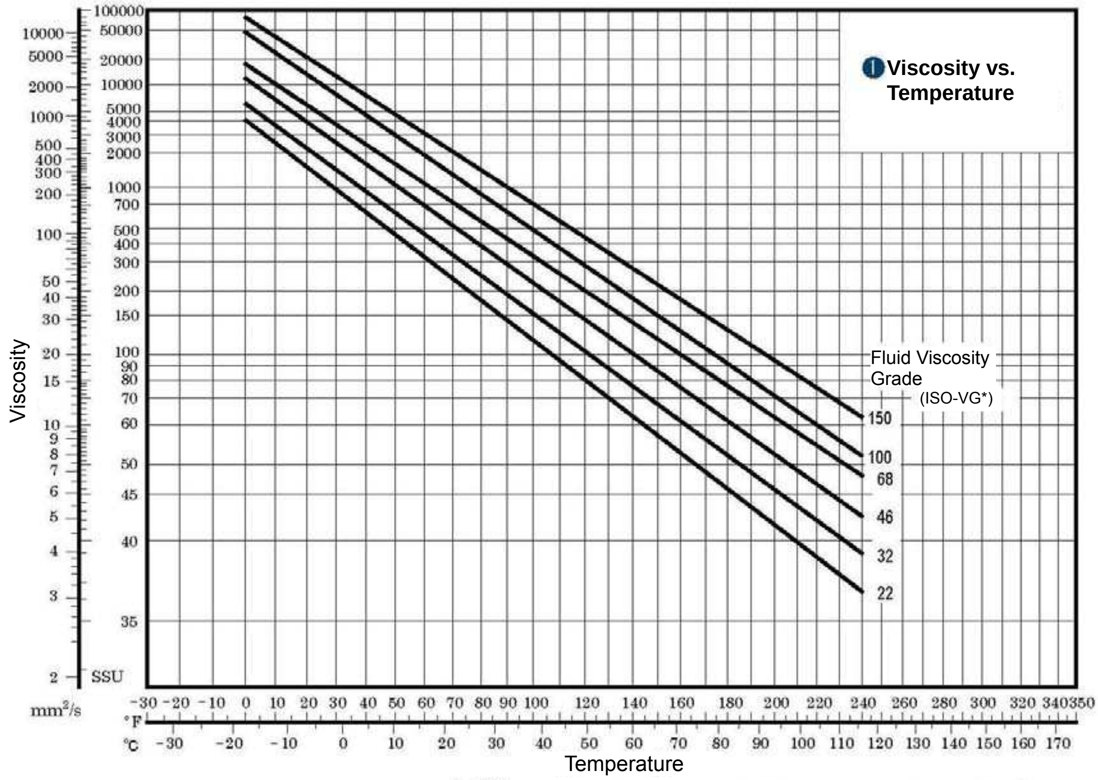
Pipe Type ->			SGP (JIS G 3452)	STS370 (JIS G 3455)											
Nominal Pres. MPa ->			2	4		6		10		16		25		35	
Safety Factor ->			8 or more					6 or more		5 or more		4 or more			
Nominal Dia. (A)	(B)	Outside mm	Thickness mm	Thick mm	Sch. No.	Thick mm	Sch. No.	Thick mm	Sch. No.	Thick mm	Sch. No.	Thick mm	Sch. No.	Thick mm	Sch. No.
8	1/4	13.8												3.0	80
10	3/8	17.3												3.2	80
15	1/2	21.7				2.8	40					3.7	80	4.7	160
20	3/4	27.2				2.9	40					3.9	80	5.5	160
25	1	34.0				3.4	40	4.5	80					6.4	160
32	1 1/4	42.7				3.6	40	4.9	80			6.4	160	8.0	★
40	1 1/2	48.6				3.7	40	5.1	80			7.1	160	9.0	★
50	2	60.5		3.9	40			5.5	80			8.7	160	11.2	★
65	2 1/2	76.3	4.2	5.2	40			7.0	80	9.5	160			14.2	★
80	3	89.1	4.2	5.2	40			7.6	80	11.1	160			16.5	★
90	3 1/2	101.6	4.2	5.7	40	8.1	80			12.7	160			20.0	★
100	4	114.3	4.5	6.0	40	8.6	80			13.5	160			20.0	★
125	5	139.8	4.5	9.5	80			15.9	160						
150	6	165.2	5.0	11.0	80			18.2	160						

Note)
1. The selection of steel pipes based on the operating pressure may be difficult, since the pressure fluctuation, pipe vibration, pipe connection type, and other factors must be considered. Refer to the nominal pressure values and their corresponding safety factors in the left table for pipe selection.
2. "Sch. No." is an abbreviation for schedule number. Note that "★" indicates special thick wall steel pipes with no schedule number.
<Reference>
JIS G 3452, 3454 to 64
Description
Schedule number = 10 × P/S
where
P: Operating pressure MPa
S: Allowable stress MPa
3. Designation (-B Series of Yuken)
(Example 1)
SGP pipe: SGP-2 1/2B
(Example 2)
STS370 with Sch. No.:
STS370-3/4B × Sch. 80
(Example 3)
STS370 special thick wall steel pipe:
STS370-1 1/4B × 8.0 t

● Precision Carbon Steel Tubes for Compression Type Tube Fittings
・Thickness (mm)

Outside mm \ Nominal Pres. MPa / Safety Factor	10	16	25	35
	6 or more		4 or more	
6				1.5
10			1.5	2.0
12			2.0	2.5
16	2.0		3.0	
20	2.0	2.5	3.0	
25	2.5		4.0	

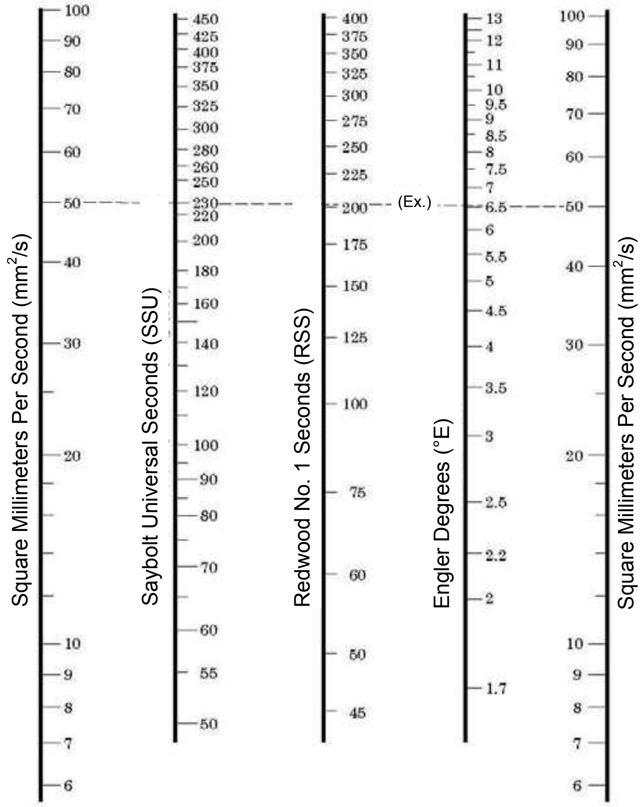
Note)
1. STPS2 defined in JIS B 2351-1 Annex 2.
2. For selection considerations, refer to Note 1 in the "Carbon Steel Pipes" section.
3. Designation
(Example) STPS2-12 × 2.5

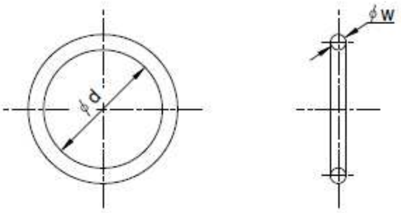


❷ Viscosity Conversion Chart

Use the following equations when the viscosity is 100 mm²/s or more.

SSU × 0.220 ＝ mm²/s
RSS × 0.2435 ＝ mm²/s
°E × 7.6 ＝ mm²/s





JIS B 2401-1$^{A}_{B}$-P※

Designation	Actual Size (mm) d	w
P 3	2.8	1.9
P 4	3.8	
P 5	4.8	
P 6	5.8	
P 7	6.8	
P 8	7.8	1.9
P 9	8.8	
P 10	9.8	
P 10A	9.8	2.4
P 11	10.8	
P 11.2	11.0	2.4
P 12	11.8	
P 12.5	12.3	
P 14	13.8	
P 15	14.8	
P 16	15.8	2.4
P 18	17.8	
P 20	19.8	
P 21	20.8	
P 22	21.8	
P 22A	21.7	3.5
P 22.4	22.1	
P 24	23.7	
P 25	24.7	
P 25.5	25.2	
P 26	25.7	3.5
P 28	27.7	
P 29	28.7	
P 29.5	29.2	
P 30	29.7	
P 31	30.7	3.5
P 31.5	31.2	
P 32	31.7	
P 34	33.7	
P 35	34.7	
P 35.5	35.2	3.5
P 36	35.7	
P 38	37.7	
P 39	38.7	
P 40	39.7	
P 41	40.7	3.5
P 42	41.7	
P 44	43.7	
P 45	44.7	
P 46	45.7	
P 48	47.7	3.5
P 49	48.7	
P 50	49.7	
P 48A	47.6	5.7
P 50A	49.6	
P 52	51.6	5.7
P 53	52.6	
P 55	54.6	
P 56	55.6	
P 58	57.6	
P 60	59.6	5.7
P 62	61.6	
P 63	62.6	
P 65	64.6	
P 67	66.6	
P 70	69.6	5.7
P 71	70.6	
P 75	74.6	
P 80	79.6	
P 85	84.6	

O-Ring Types According to JIS and YES (Yuken Engineering Standards)

JIS	YES	Remarks	
JIS B 2401-1A-P※ G※	SO-NA-P※ G※	For Use with Mineral Oils Material: Nitrile Rubber	Spring Hardness: 70
JIS B 2401-1B-P※ G※	SO-NB-P※ G※		Spring Hardness: 90
JIS B 2401-4D-P※ G※	SO-FA-P※ G※	For Use with Heat Resistant/Synthetic Oils Material: Fluororubber	Spring Hardness: 70
―――――	SO-FB-P※ G※		Spring Hardness: 90

Note) 1. "-P*" denotes dynamic O-rings; "-G*" denotes static O-rings.
2. The basic sizes for -1A, -1B, and -4D are the same.

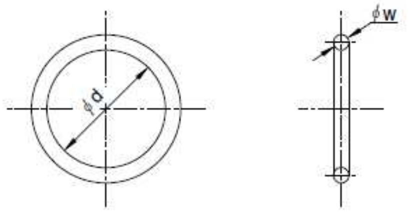
JIS B 2401-1$^{A}_{B}$-P※

Designation	Actual Size (mm) d	w
P 90	89.6	5.7
P 95	94.6	
P 100	99.6	
P 102	101.6	
P 105	104.6	
P 110	109.6	5.7
P 112	111.6	
P 115	114.6	
P 120	119.6	
P 125	124.6	
P 130	129.6	5.7
P 132	131.6	
P 135	134.6	
P 140	139.6	
P 145	144.6	
P 150	149.6	5.7
P 150A	149.5	8.4
P 155	154.5	
P 160	159.5	
P 165	164.5	
P 170	169.5	8.4
P 175	174.5	
P 180	179.5	
P 185	184.5	
P 190	189.5	
P 195	194.5	8.4
P 200	199.5	
P 205	204.5	
P 209	208.5	
P 210	209.5	
P 215	214.5	8.4
P 220	219.5	
P 225	224.5	
P 230	229.5	
P 235	234.5	
P 240	239.5	8.4
P 245	244.5	
P 250	249.5	
P 255	254.5	
P 260	259.5	
P 265	264.5	8.4
P 270	269.5	
P 275	274.5	
P 280	279.5	
P 285	284.5	
P 290	289.5	8.4
P 295	294.5	
P 300	299.5	
P 315	314.5	
P 320	319.5	
P 335	334.5	8.4
P 340	339.5	
P 355	354.5	
P 360	359.5	
P 375	374.5	
P 385	384.5	8.4
P 400	399.5	

JIS B 2401-1$^{A}_{B}$-G※

Designation	Actual Size (mm) d	w
G 25	24.4	3.1
G 30	29.4	
G 35	34.4	
G 40	39.4	
G 45	44.4	
G 50	49.4	3.1
G 55	54.4	
G 60	59.4	
G 65	64.4	
G 70	69.4	
G 75	74.4	3.1
G 80	79.4	
G 85	84.4	
G 90	89.4	
G 95	94.4	
G 100	99.4	3.1
G 105	104.4	
G 110	109.4	
G 115	114.4	
G 120	119.4	
G 125	124.4	3.1
G 130	129.4	
G 135	134.4	
G 140	139.4	
G 145	144.4	
G 150	149.3	5.7
G 155	154.3	
G 160	159.3	
G 165	164.3	
G 170	169.3	
G 175	174.3	5.7
G 180	179.3	
G 185	184.3	
G 190	189.3	
G 195	194.3	
G 200	199.3	5.7
G 210	209.3	
G 220	219.3	
G 230	229.3	
G 240	239.3	
G 250	249.3	5.7
G 260	259.3	
G 270	269.3	
G 280	279.3	
G 290	289.3	
G 300	299.3	5.7

O-Ring Size [Part 2]
AS 568 (Former ARP 568), Aerospace Size Standard for O-Rings



AS 568 Designation	Actual Size (mm)	
	w	d
001	1.02	0.74
002	1.27	1.07
003	1.52	1.42
004	1.78	1.78
005	1.78	2.57
006		2.90
007		3.68
008	1.78	4.47
009		5.28
010		6.07
011		7.65
012		9.25
013	1.78	10.82
014		12.42
015		14.00
016		15.60
017		17.17
018	1.78	18.77
019		20.35
020		21.95
021		23.52
022		25.12
023	1.78	26.70
024		28.30
025		29.87
026		31.47
027		33.05
028	1.78	34.65
029		37.82
030		41.00
031		44.17
032		47.35
033	1.78	50.52
034		53.70
035		56.87
036		60.05
037		63.22
038	1.78	66.40
039		69.57
040		72.75
041		75.92
042		82.27
043	1.78	88.62
044		94.97
045		101.32
046		107.67
047		114.02
048	1.78	120.37
049		126.72
050		133.07
106		4.42
107		5.23
108	2.62	6.02
109		7.59
110		9.19
111		10.77
112		12.37
113	2.62	13.94
114		15.54
115		17.12

AS 568 Designation	Actual Size (mm)	
	w	d
116		18.72
117		20.29
118	2.62	21.89
119		23.47
120		25.07
121		26.64
122		28.24
123	2.62	29.82
124		31.42
125		32.99
126		34.59
127		36.17
128	2.62	37.77
129		39.34
130		40.94
131		42.52
132		44.12
133	2.62	45.69
134		47.29
135		48.89
136		50.47
137		52.07
138	2.62	53.64
139		55.24
140		56.82
141		58.42
142		59.99
143	2.62	61.59
144		63.17
145		64.77
146		66.34
147		67.94
148	2.62	69.52
149		71.12
150		72.62
151		75.87
152		82.22
153	2.62	88.57
154		94.92
155		101.27
156		107.62
157		113.97
158	2.62	120.32
159		126.67
160		133.02
161		139.37
162		145.72
163	2.62	152.07
164		158.42
165		164.77
166		171.12
167		177.47
168	2.62	183.82
169		190.17
170		196.52
171		202.87
172		209.22
173	2.62	215.57
174		221.92
175		228.27

AS 568 Designation	Actual Size (mm)	
	w	d
176		234.62
177	2.62	240.97
178		247.32
210		18.64
211		20.22
212	3.53	21.82
213		23.39
214		24.99
215		26.57
216		28.17
217	3.53	29.74
218		31.34
219		32.92
220		34.52
221		36.09
222	3.53	37.69
223		40.87
224		44.04
225		47.22
226		50.39
227	3.53	53.57
228		56.74
229		59.92
230		63.09
231		66.27
232	3.53	69.44
233		72.62
234		75.79
235		78.97
236		82.14
237	3.53	85.32
238		88.49
239		91.67
240		94.84
241		98.02
242	3.53	101.19
243		104.37
244		107.54
245		110.72
246		113.89
247	3.53	117.07
248		120.24
249		123.42
250		126.59
251		129.77
252	3.53	132.94
253		136.12
254		139.29
255		142.47
256		145.64
257	3.53	148.82
258		151.99
259		158.34
260		164.69
261		171.04
262	3.53	177.39
263		183.74
264		190.09
265		196.44
266		202.79
267	3.53	209.14
268		215.49
269		221.84
270		228.19
271		234.54
272	3.53	240.89
273		247.24
274		253.59

AS 568 Designation	Actual Size (mm)	
	w	d
275		266.29
276		278.99
277	3.53	291.69
278		304.39
279		329.79
280		355.19
281		380.59
282	3.53	405.26
283		430.66
284		456.06
325		37.46
326		40.64
327	5.33	43.82
328		46.99
329		50.16
330		53.34
331		56.52
332	5.33	59.69
333		62.86
334		66.04
335		69.22
336		72.39
337	5.33	75.56
338		78.74
339		81.92
340		85.09
341		88.26
342	5.33	91.44
343		94.62
344		97.79
345		100.96
346		104.14
347	5.33	107.32
348		110.49
349		113.66
350		116.84
351		120.02
352	5.33	123.19
353		126.36
354		129.54
355		132.72
356		135.89
357	5.33	139.07
358		142.24
359		145.42
360		148.59
361		151.77
362	5.33	158.12
363		164.47
364		170.82
365		177.17
366		183.52
367	5.33	189.87
368		196.22
369		202.57
370		208.92
371		215.27
372	5.33	221.62
373		227.97
374		234.32
375		240.67
376		247.67
377	5.33	253.37
378		266.07
379		278.77
380		291.47
381		304.17
382	5.33	329.57
383		354.97
384		380.37

AS 568 Designation	Actual Size (mm)	
	w	d
385		405.26
386		430.66
387	5.33	456.07
388		481.41
389		506.81
390		532.21
391		557.61
392	5.33	582.68
393		608.08
394		633.48
395	5.33	658.88
425		113.66
426		116.84
427	6.98	120.02
428		123.19
429		126.36
430		129.54
431		132.72
432	6.98	135.89
433		139.06
434		142.24
435		145.42
436		148.59
437	6.98	151.76
438		158.12
439		164.46
440		170.82
441		177.16
442	6.98	183.52
443		189.86
444		196.22
445		202.56
446		215.27
447	6.98	227.96
448		240.67
449		253.36
450		266.07
451		278.76
452	6.98	291.47
453		304.16
454		316.87
455		329.56
456		342.27
457	6.98	354.96
458		367.67
459		380.36
460		393.07
461		405.26
462	6.98	417.96
463		430.66
464		443.36
465		456.06
466		468.76
467	6.98	481.46
468		494.16
469		506.86
470		532.26
471		557.66
472	6.98	582.68
473		608.08
474		633.48
475	6.98	658.88

International System of Units (SI) [Part 1]

(According to JIS Z 8203 "SI units and recommendations for the use of their multiples and of certain other units" and Z 8202 "Quantities and units")

■ Origin of the term SI (International System of Units)

SI stands for Système International d'Unités in French (International System of Units in English), an internationally accepted official abbreviation.

■ Purpose and historical background of the SI

The Metre Convention was signed in 1875 to oversee the keeping of metric system as a unified international system of units. Then, the metric system had more than ten variations, losing its consistency. At the 9th General Conference on Weights and Measures (Conférence Générale des Poids et Mesures: CGPM) in 1948, a resolution was adopted "to use a unified system of units in all fields". The International Committee for Weights and Measures (Comité International des Poids et Mesures: CIPM) of the treaty organization started a process to establish a unified system and determined the framework of the SI in 1960. In 1973, the International Organization for Standardization (ISO) developed the standard ISO 1000, which describes SI units and recommendations for the use of them, leading to global adoption of the system. In Japan, a policy to introduce SI units into JIS through the following three phases was determined in 1972; the introduction of SI units into JIS progressed rapidly.

First phase: Use of conventional units followed by SI units e.g. 1 kgf [9.8 N]
Second phase: Use of SI units followed by conventional units e.g. 10 N {1.02 kgf}
Third phase: Use of SI units only e.g. 10 N

The Measurement Act in Japan was fully revised in 1992 and enacted in 1993 to unify statutory measurement units into SI units. Under the new Measurement Act, a transition period of up to seven years was granted before the exclusive use of SI units for "pressure" and "moment of force" in the field of hydraulics, and the period expired on September 30, 1999. Since October 1, 1999, it has been mandatory to use SI units as statutory measurement units for transactions and certifications. Commercially available pressure gauges are in SI units. The units used in this catalogue are SI units.

All units used in this catalogue are SI units as applicable in the third phase of the SI implementation process.

■ Structure of SI units and JIS Z 8203

- JIS Z 8203
  - S I
    - SI Units
      - Base Units (7)
      - Supplementary Units (2)
      - Derived Units
        - Derived Units with Special Names (19)
        - Other Derived Units
    - Prefixes (20) and Decimal Multiples of SI units
  - Important Non-SI Units Accepted for Use with SI Units

● Base Units

Quantity	Base Unit	
	Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric Current	ampere	A
Thermodynamic Temperature	kelvin	K
Amount of Substance	mole	mol
Luminous Intensity	candela	cd

● Supplementary Units

Quantity	Supplementary Unit	
	Name	Symbol
Plane Angle	radian	rad
Solid Angle	steradian	sr

International System of Units (SI) [Part 2]

Prefixes

Prefixes are used to form decimal multiples of SI units.

Unit Multiplier	Prefix	
	Name	Symbol
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Non-SI units accepted for use with SI units

Quantity	Unit Name	Unit Symbol
Time	minute hour day	min h d
Plane Angle	degree minute second	° ′ ″
Volume	liter	l, L★
Mass	metric ton	t

★The letter "L" may be used as the symbol for liter, when the symbol "l" for liter might be confused with any other character (as a general rule, Yuken uses "L").

Units accepted for use with SI units for usefulness in special fields

Quantity	Unit Name	Unit Symbol
Energy	electronvolt	eV
Atomic Mass	atomic mass unit	u
Distance	astronomical unit	AU
	parsec	pc
Fluid Pressure	bar	bar

Derived units

Derived units are expressed algebraically in terms of base units and supplementary units (by means of the mathematical symbols of multiplication and division) in the International System of Units.

Derived units expressed in terms of SI base units

Quantity	Derived Unit	
	Name	Symbol
Area	square meter	m^2
Volume	cubic meter	m^3
Speed, Velocity	meter per second	m/s
Acceleration	meter per second squared	m/s^2
Wavenumber	reciprocal meter	m^{-1}
Density	kilogram per cubic meter	kg/m^3
Current Density	ampere per square meter	A/m^2
Magnetic Field Strength	ampere per meter	A/m
(Amount-of-substance) Concentration	mole per cubic meter	mol/m^3
Specific Volume	cubic meter per kilogram	m^3/kg
Luminance	candela per square meter	cd/m^2

Derived units with special names

Quantity	Derived Unit		
	Name	Symbol	Definition
Frequency	hertz	Hz	s^{-1}
Force	newton	N	$kg \cdot m/s^2$
Pressure, Stress	pascal	Pa	N/m^2
Energy, Work, Amount of Heat	joule	J	N·m
Amount of Work Done Per Time, Motive Power, Electrical Power	watt	W	J/s
Electric Charge, Amount of Electricity	coulomb	C	A·s
Electric Potential, Potential Difference, Voltage, Electromotive Force	volt	V	W/A
Capacitance	farad	F	C/V
Electric Resistance	ohm	Ω	V/A
(Electric) Conductance	siemens	S	A/V
Magnetic Flux	weber	Wb	V·s
Magnetic Flux Density, Magnetic Induction	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Celsius Temperature	degree celsius/degree	℃	
Luminous Flux	lumen	lm	cd·sy
Illuminance	lux	lx	lm/m^2
Activity Referred to a Radionuclide	becquerel	Bq	S^{-1}
Absorbed Dose	gray	Gy	J/kg
Dose Equivalent	sievert	Sv	Gy

International System of Units (SI) [Part 3]

■ Use of SI units

Space and Time

Quantity	SI Unit	Decimal Multiple Unit
Plane Angle	rad (radian)	mrad μrad
Solid Angle	sr (steradian)	
Length, Width, Height, Thickness, Radius, Diameter, Length of Path Traveled, Distance	m (meter)	km dm cm mm μm nm pm
Area	m^2 (square meter)	km^2 dm^2 cm^2 mm^2
Volume	m^3 (cubic meter)	dm^3 cm^3 mm^3
Time	s (second)	ks ms μs ns
Angular Velocity	rad/s (radian per second)	
Speed, Velocity	m/s (meter per second)	
Acceleration	m/s^2 (meter per second squared)	

Periodic and Related Phenomena

Quantity	SI Unit	Decimal Multiple Unit
Frequency	Hz (hertz)	THz GHz MHz kHz
Rotational Speed, Revolutions	s^{-1} (per second)	

Dynamics

Quantity	SI Unit	Decimal Multiple Unit
Mass	kg (kilogram)	Mg g mg μg
Density, Concentration	kg/m^3 (kilogram per cubic meter)	mg/m^3 or kg/dm^3 or g/cm^3
Moment of Inertia	$kg \cdot m^2$ (kilogram meter squared)	
Force	N (newton)	MN kN mN μN
Moment of Force	N·m (newton meter)	MN·m kN·m mN·m μN·m
Pressure	Pa (pascal)	GPa MPa kPa mPa μPa
Stress	(pascal or newton per square meter) Pa or N/m^2	GPa, MPa or N/mm^2, kPa
Viscosity	Pa·s (pascal second)	mPa·s
Kinematic Viscosity	m^2/s (square meter per second)	mm^2/s
Work, Energy, Amount of Heat	J (joule)	TJ GJ MJ kJ mJ
Power, Amount of Work Done Per Unit of Time	W (watt)	GW MW kW mW μW
Flow Rate	m^3/s (cubic meter per second)	

Heat

Quantity	SI Unit	Decimal Multiple Unit
Thermodynamic Temperature	K (kelvin)	
Celsius Temperature	°C (degree Celsius or degree)	
Temperature Interval, Temperature Difference	K or °C	
Amount of Heat	J (joule)	TJ GJ MJ kJ mJ
Heat Flow Rate	W (watt)	kW
Thermal Conductivity	W/(m·K)	
Coefficient of Heat Transfer	$W/(m^2 \cdot K)$	
Specific Heat Capacity	J/(kg·K)	kJ/(kg·K)

Electricity and Magnetism

Quantity	SI Unit	Decimal Multiple Unit
Electric Current	A (ampere)	kA mA μA nA pA
Electric Potential, Electric Potential Difference, Voltage, Electromotive Force	V (volt)	MV kV mV μV
(Electric) Resistance (Direct Current)	Ω (ohm)	GΩ MΩ (Remarks) MΩ is also referred to as megohm. kΩ mΩ μΩ
(Active) Electric Power	W (watt)	TW GW MW kW mW μW nW

Sound

Quantity	SI Unit	Decimal Multiple Unit
Frequency	Hz (hertz)	GHz MHz kHz
Sound Pressure Level*		

*This SI unit is not provided by ISO 1000-1973 and ISO 31 Part 7-1978, but JIS adopts and specifies dB (decibel) as a unit accepted for use with SI units.

International System of Units (SI) [Part 4]

■ SI unit conversion factors table

(Shaded columns represent SI units.)

● Force

N Newton	dyn	kgf
1	1×10^{5}	$1.019\ 72\times10^{-1}$
1×10^{-5}	1	$1.019\ 72\times10^{-6}$
9.806 65	$9.806\ 65\times10^{5}$	1

● Moment of inertia

N·m Newton meter	kgf·m
1	0.101 972
9.807	1

Note) 1 N·m = 1 kg•m²/s²

● Pressure

Pa pascal	bar	kgf/cm²	atm	mmH₂O	mmHg or Torr
1	1×10^{-5}	$1.019\ 72\times10^{-5}$	$9.869\ 23\times10^{-6}$	$1.019\ 72\times10^{-1}$	$7.500\ 62\times10^{-3}$
1×10^{5}	1	1.019 72	$9.869\ 23\times10^{-1}$	$1.019\ 72\times10^{4}$	$7.500\ 62\times10^{2}$
$9.806\ 65\times10^{4}$	$9.806\ 65\times10^{-1}$	1	$9.678\ 41\times10^{-1}$	1×10^{4}	$7.355\ 59\times10^{2}$
$1.013\ 25\times10^{5}$	1.013 25	1.033 23	1	$1.033\ 23\times10^{4}$	$7.600\ 00\times10^{2}$
9.806 65	$9.806\ 65\times10^{-5}$	1×10^{-4}	$9.678\ 41\times10^{-5}$	1	$7.355\ 59\times10^{-2}$
$1.333\ 22\times10^{2}$	$1.333\ 22\times10^{-3}$	$1.359\ 51\times10^{-3}$	$1.315\ 79\times10^{-3}$	$1.359\ 51\times10$	1

Note) 1 Pa = 1 N/m²

● Stress

Pa pascal	MPa or N/mm² Megapascal or newton per square milimeter	kgf/mm²	kgf/cm²
1	1×10^{-6}	$1.019\ 72\times10^{-7}$	$1.019\ 72\times10^{-5}$
1×10^{6}	1	$1.019\ 72\times10^{-1}$	$1.019\ 72\times10$
$9.806\ 65\times10^{6}$	9.806 65	1	1×10^{2}
$9.806\ 65\times10^{4}$	$9.806\ 65\times10^{-2}$	1×10^{-2}	1

● Viscosity

Pa•s pascal second	cP	P
1	1×10^{3}	1×10
1×10^{-3}	1	1×10^{-2}
1×10^{-1}	1×10^{2}	1

Note) 1 P = 1 dyn•s/cm² = 1 g/cm•s
1 Pa•s = 1 N•s/m², 1 cP = 1 mPa•s

● Work, energy, amount of heat

J joule	kW·h	kgf·m	kcal
1	$2.777\ 78\times10^{-7}$	$1.019\ 72\times10^{-1}$	$2.388\ 89\times10^{-4}$
$3.600\quad\times10^{6}$	1	$3.670\ 98\times10^{5}$	$8.600\ 0\quad\times10^{2}$
9.806 65	$2.724\ 07\times10^{-6}$	1	$2.342\ 70\times10^{-3}$
$4.186\ 05\times10^{3}$	$1.162\ 79\times10^{-3}$	$4.268\ 58\times10^{2}$	1

Note) 1 J = 1 W•s, 1 W•h = 3,600 W•s
1 cal = 4.186 05 J (according to the Measurement Act)

● Kinematic viscosity

m²/s square meter per second	cSt	St
1	1×10^{6}	1×10^{4}
1×10^{-6}	1	1×10^{-2}
1×10^{-4}	1×10^{2}	1

Note) 1 cSt = 1 mm²/s, 1 St = 1 cm²/s

● Power (amount of work done per unit of time or motive power)

kW kilowatt	kgf·m/s	PS	kcal/h
1	$1.019\ 72\times10^{2}$	1.359 62	$8.600\ 0\quad\times10^{2}$
$9.806\ 65\times10^{-3}$	1	$1.333\ 33\times10^{-2}$	8.433 71
$7.355\quad\times10^{-1}$	$7.5\quad\times10$	1	$6.325\ 29\times10^{2}$
$1.162\ 79\times10^{-3}$	$1.185\ 72\times10^{-1}$	$1.580\ 95\times10^{-3}$	1

Note) 1 W = 1 J/s, PS: French horsepower
1 PS = 0.735 5 kW (according to the Act for Enforcement of the Measurement Act)
1 cal = 4.186 05 J (according to the Measurement Act)

● Thermal conductivity

W/(m•K) watt per meter kelvin	kcal/(h·m·℃)
1	$8.600\ 0\times10^{-1}$
1.162 79	1

Note) 1 cal = 4.186 05 J (according to the Measurement Act)

● Temperature

$T_1 = T_2 + 273.15$
$T_3 = 1.8\,T_2 + 32$

- T_1: Thermodynamic temperature — K (kelvin)
- T_2: Celsius temperature — °C (degree)
- T_3: °F

● Specific heat capacity

J/(kg•K) joule per kilogram kelvin	kcal/(kg·℃) cal/(g·℃)
1	$2.388\ 89\times10^{-4}$
$4.186\ 05\times10^{3}$	1

Note) 1 cal = 4.186 05 J (according to the Measurement Act)

● Coefficient of heat transfer

W/(m²•K) watt per meter squared kelvin	kcal/(h·m²·℃)
1	$8.600\ 0\times10^{-1}$
1.162 79	1

Note) 1 cal = 4.186 05 J (according to the Measurement Act)