INSTRUCTION MANUAL
FOR
MODEL PD82 PNEUMATIC DEAD-WEIGHT PRESSURE TESTER
MODEL PD89 CONTROL PACK

NAGANO KEIKI CO., LTD.

CONTENTS

1. INTRODUCTION

Pressure is defined as the force acting perpendicularly per unit area.
The combination of a piston and a cylinder fits this definition. A dead-weight pressure tester employs a piston, cylinder, pressure pump, valve, etc. and is designed to produce a pressure suitable for calibrating aneroid pressure gauges and producing standard pressures.
The dead-weight pressure tester generally uses oil as pressure medium. Hydraulic pressure acts on the bottom on the piston within the cylinder, and accurate pressure is obtained from the sectional area and mass of the piston under balanced conditions. Due to the viscosity and density of oil as medium, it is difficult to improve accuracy. Measurement is difficult especially for the low pressure below 0.05 MPa. The PD82 uses dry, clean gas as medium, which is made to act on the precision-finished piston and cylinder. Use of gas lubrication ensures pressure measurement of the extremely high accuracy, which can not possible be obtained from oil medium.
The dead-weight pressure tester is therefore a primary instrument that is used as a standard instrument for calibrating secondary instruments and producing standard pressures for other instruments. It has a wide variety of applications and is an important instrument for measurement control.
This manual describes how to use the PD82 pneumatic dead-weight pressure tester and PD89 control pack. Read it carefully and fully understand the functions and operations of the PD82 or the PD89 to ensure trouble-free operations.
In this manual, WARNING marks indicate matters where there is a risk of serious damage or injury to personnel or property. Be sure to observe such marks.

(1) Warranty

If the delivered products within the warranty period (within one year from the delivered date) are determined to be non-conforming products according to "Defects due to the design or manufacturing by NKS", they are repaired or replaced with conforming products free of charge.

However, please note that the following cases are excluded.

① Where the delivered products are disassembled, altered or where their parts are replaced or where any new function is added by the customer or any third party.
② Where directions described in the instruction manual or catalog are not observed.
③ Where the non-conformance is caused by deterioration due to use, natural disaster, fire or other force majeure events.
④ The secondary damage caused by the non-conformance of the products including the above.

Regardless of recognition of miss handling by the customer, where any apparent evidence of deformation, abrasion, burnout, etc. are seen in parts, they shall be excluded from the warranty scope and the cost shall be paid.

(2) Exemption from Responsibility

We shall not be held responsible for any troubles caused by not following the instructions in this manual.

(3) Definition of Safety Terms

The safety term used in this manual is defined as follows:

① ⚠ WARNING

WARNING indicates a potentially hazardous situation, which, if not avoided, could result in death or serious injury.

(4) Precautions

①The PD82 uses weight units that are stacked.
Take great care not to drop them, as doing so could be dangerous.

- Install the PD82 on a stable base that can withstand the weight of the PD82 itself and the weight unit as well as loads applied to it during operation.
- Do not open the release valve quickly with the weight unit apart from the cylinder. Otherwise, the weight unit will immediately fall and apply impact to the PD82, causing not only damage to the PD82 but also dropping of the weight unit itself.
- When using two or more weight units, put the heavier weights below the lighter weights. Make sure that the weight units are fully engaged, and rotate them clockwise slightly. If the weight units are rotated without being completely engaged (i.e., the entire weight units are floating or tilting), they may drop, causing a dangerous accident.
- Do not move or transport the PD82 with a weight unit placed on the piston and cylinder. Otherwise, the weight unit may drop, causing a dangerous accident.

⚠ WARNING

Dropping a weight unit onto your foot is dangerous.
Wear safety boots and take great care not to drop a weight unit onto your foot.

②When testing an instrument that could explode when pressure is applied to it, take appropriate protective measures such as protection nets and so forth.

⚠ WARNING

Explosion of a vessel while applying pressure could cause a dangerous accident.
Appropriate protective measures shall be taken.

③Do not apply a pressure over the maximum pressure indicated on the PD82 body or the PD89 body.
Doing so is not only dangerous but could cause failure or breakage of the PD82 or the PD89.

④Do not change the direction of the calibration pressure gauge installed on the instrument mount or loosen it while pressure is being applied.
Otherwise, gas may spout out, causing a dangerous accident.

⑤Be sure to use an O-ring of the specified size for sealing the instrument mount.
If an O-ring of an improper size is used, gas may spout out, causing a dangerous accident.

⑥Do not modify the PD82 and the PD89 itself or add new functions to it.
If repair service is required, please contact us.

⑦If the PD82 and the PD89 will be used in a condition where a failure or malfunctioning could cause death or serious injury, please consult us in advance

2. APPLICATIONS

The PD82 pneumatic dead-weight pressure tester is traceable to the National Standard and can be used as the pressure standards that produces stable and precision pressures.
And also the PD82 pneumatic dead-weight pressure tester is designed to produce pressure, and so could be used for accuracy inspections and pressure tests of pressure gauges, confirmation of set values of pressure switches and so forth.

3. FEATURES

①The PD82 pneumatic dead-weight pressure testers has high accuracy, and indirectly are traceable to the National Standard.

②The dead-weight is made of austenite stainless steel. It is free from weight variations due to rust and is not influenced by magnetism.

③The dead-weight and produced pressures are compensated for buoyancy.
The gravitation are determined according to the specified gravitational acceleration (or the standard gravitational acceleration 9.80665 m/s^2 unless otherwise specified).

④The PD82 is supplied with an indicator that indicates the temperature and height of the piston.
The user may measure the piston temperature and height, which serve as compensation data.

4. SPECIFICATIONS

(1) Standard Specifications

①Model No. : PD82-M01

・Measuring Range

Table 4-1

Measuring Range (MPa)			Piston		Marking on weight units (MPa)															Approx mass of weight units
Maximum pressure	Minimum pressure	Minimum increment	Sectional area (cm^2)	Diameter (mm)	Piston		Hat		Position censor of weight units		Number of weight units								Total	
					0.004	0.02	0.016	0.08	0.01	0.05	0.001	0.002	0.005	0.01	0.02	0.05	0.1	0.2		(kg)
0.3	0.004	0.001	5	25.231	1	—	1	—	1	—	1	2	1	1	1	5	—	—	0.32	16
0.5					1	—	1	—	1	—	1	2	1	1	1	1	4	—	0.52	26
1	0.02	0.005	1	11.284	—	1	—	1	—	1	—	—	1	1	2	1	8	—	1.055	11
2					—	1	—	1	—	1	—	—	1	1	2	1	2	8	2.055	21

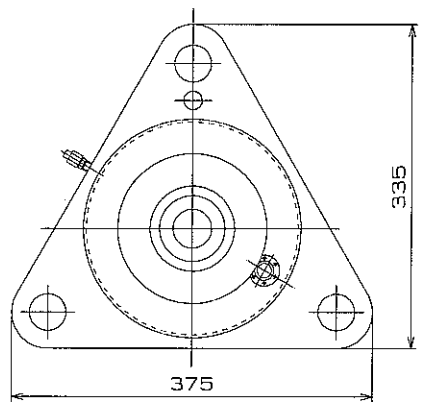
・Accuracy: The main measuring range ... ±0.02% O.R.
(From 10% to 100% of the maximum pressure)
The supplementary measuring range ... ±0.02% (0.1Pmax)
(From the minimum pressure to not more than10% of the maximum pressure)

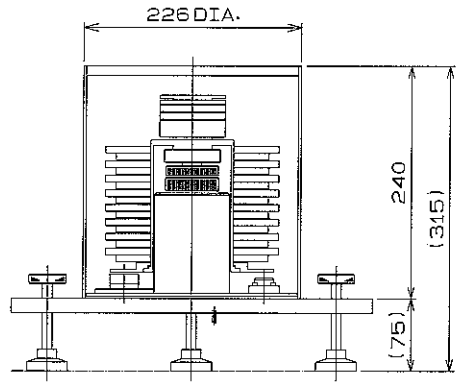
・Operation conditions: Temperature / 15 to 30 ℃
Relative humidity / 30 to 80% R.H.
・Reference pressure: Atmospheric pressure
・Pressure medium: Dry, clean nitrogen gas
・Instrument mounting screws: Conversion adapters G1/2, G3/8 & G1/4
・Mass: Approx. 15 kg
・Coating color: Pearl light green
・Indicator: Piston Temperature / 0 to 100 ℃
Piston position / 0 to 10 mm

②Model No. : PD89-M01

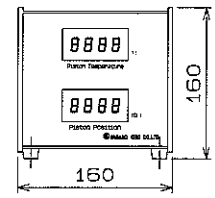
・Measuring Range
0 to 0.3, 0.5, 1, 2, 5 MPa
・Mass: Approx. 8 kg

（2） Appearance



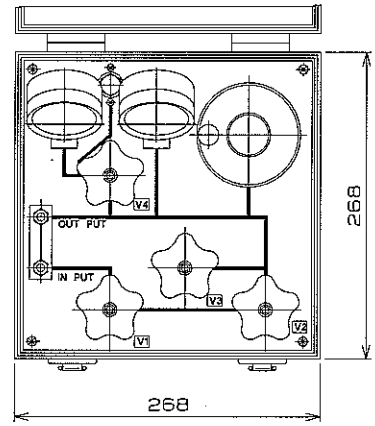


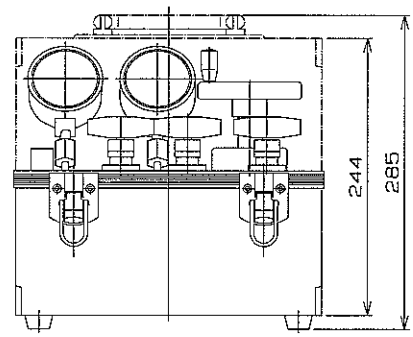
Weight part



Indicator

PD82

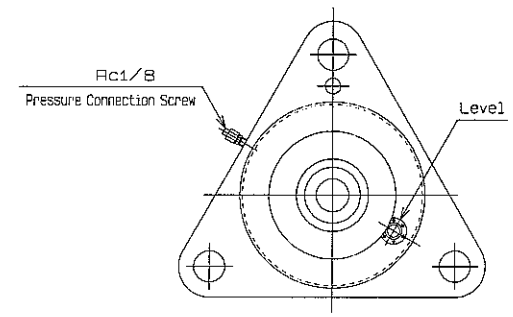


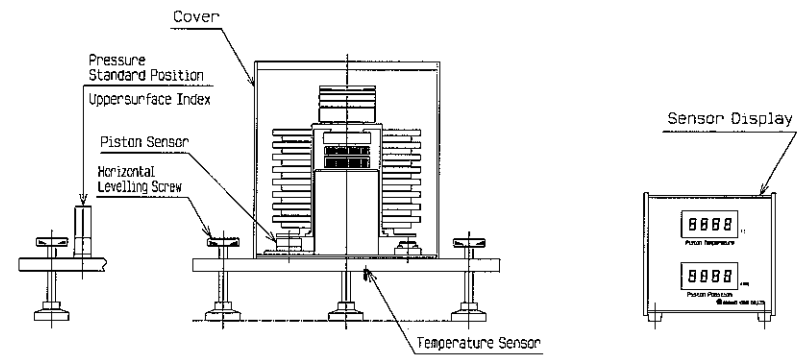


PD89

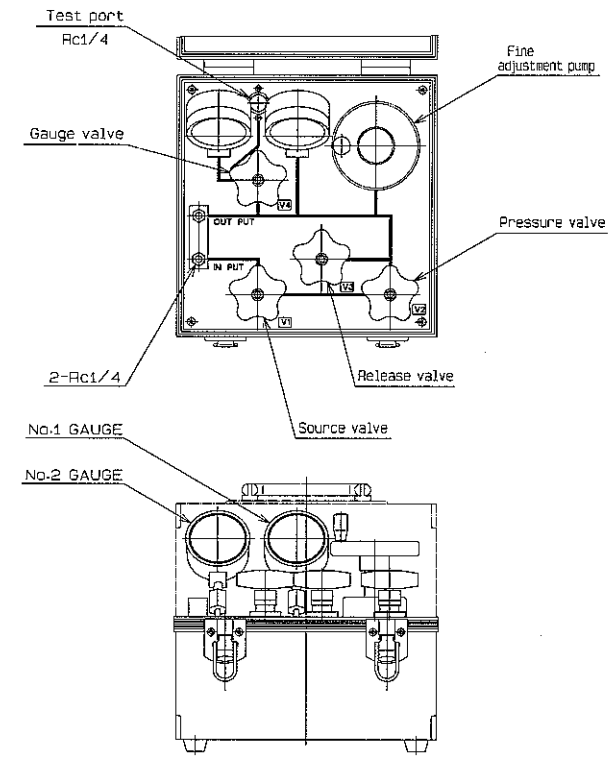
Figure 4-1

（3） Name





PD82



PD89

Figure 4-2

（4） Piping diagram

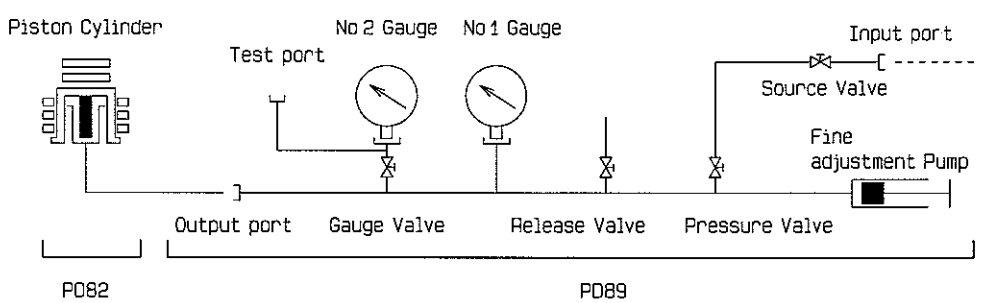


Figure 4-3

5. PRINCIPLE OF OPERATION

Figure 5-1 shows the structure of the piston and cylinder block, which produces pressures in the dead-weight pressure tester.
The piston and cylinder are precision machined so that the piston can be inserted into the closely fitting cylinder. A weight corresponding to the pressure to be produced is placed on the piston.
Fluid pressure is applied to the bottom of the piston, and the piston with the weight unit moves up. When the weight is rotated to reduce the friction error of the piston-cylinder and establish the balanced condition, the specified pressure is produced.

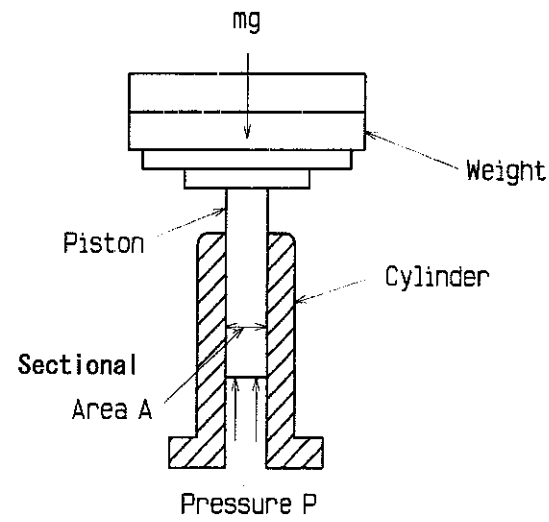


Figure 5-1

The produced pressure P is determined as shown below, where the mass of the piston and weight unit is m, the cross-sectional area of the piston is A, and the gravitational acceleration is g:

$$P = \frac{m \cdot g}{A}$$

P: Pressure (Pascal)
m: Mass of the weight unit (kg)
g: Gravitational acceleration (m/sec^2)
A: Sectional area of the piston (m^2)

The above expression is simply the definition of pressure, i.e., "pressure is defined as the force acting perpendicularly per unit area." In other words, the dead-weight pressure tester faithfully implements this definition using a combination of a cylinder and a piston that is closely engaged with the cylinder and sliding freely inside it, thus serving as a pressure-force converter.

6. INSTALLMENT

(1) Precautions for Unpacking

Unpack the product carefully. Do not handle the package roughly.
Unpack the product in a wide space to avoid dropping the product after taking it out of the package.

(2) Installed Placement

Table 6-1

Temperature	15 to 30 ℃
Relative humidity	30 to 80% R.H

Do not install the PD82 and the PD89 in a hot and humid place, a place with a corrosive atmosphere or dust, a place subject to vibration or impact, or a place that could adversely affect the PD82 and the PD89.
A place exposed to direct sunlight is subject to quick temperature changes. Do not use the PD82 and the PD89 in such a place. The PD82 is a precision standard, it is recommended that it should be installed in a thermostatic chamber.
Install the PD82 and the PD89 on a stable foundation that withstands the masses of the gauge and dead-weight and loads applied during operation.

⚠ WARNING

Install the PD82 and the PD89 on a stable foundation that withstands the masses of the gauge and dead-weight an loads applied during operation.
If the foundation tilts during measurement, the piston becomes non-vertical and the gauge fails to produce correct pressures.

(3) Installation Procedure

①Connect the PD82, the PD89, pressure source and the test gauge with the pipe supplied with the gauge as shown in Figure 6-1.

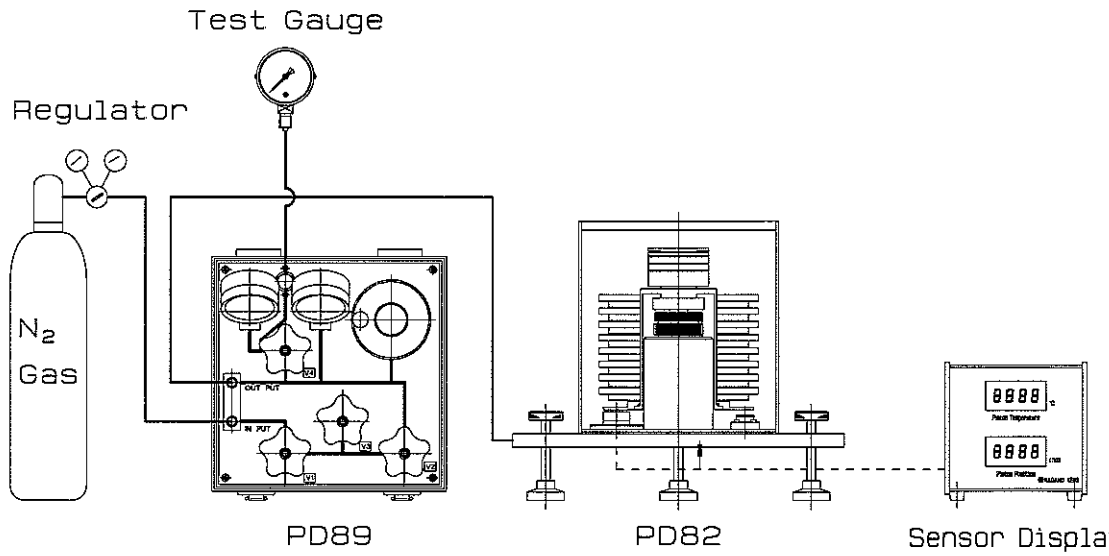


Figure 6-1

②The piston temperature and position indicator close to the dead-weight part, and connect the cables of the temperature sensor and position sensor coming from the dead-weight part as shown in Figure 6-2. Also connect the power cord.

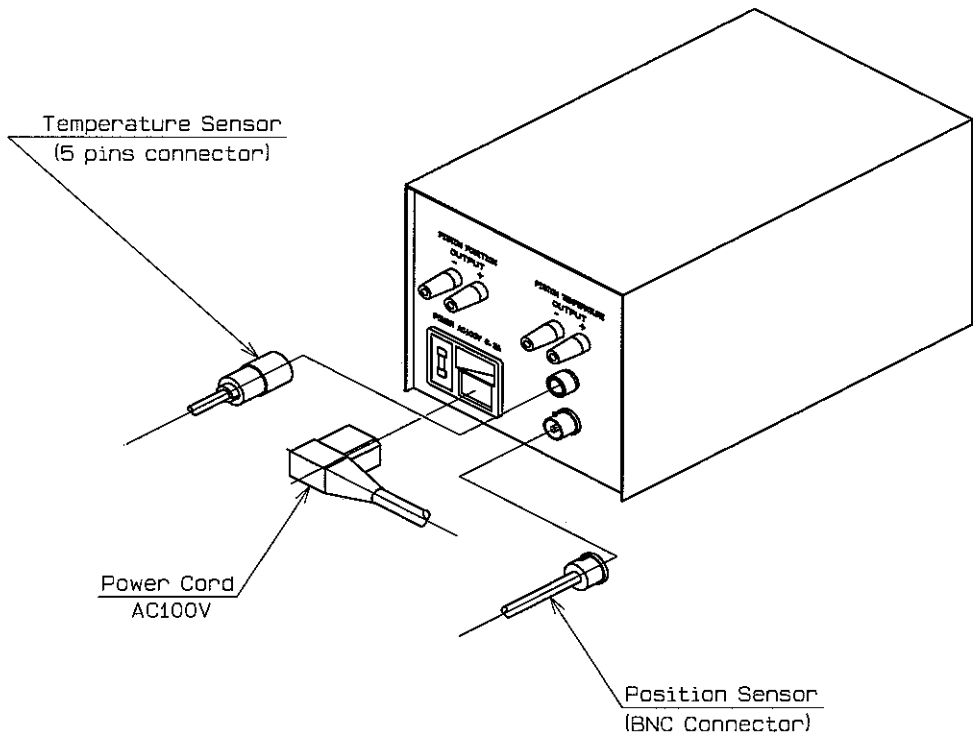


Figure 6-2

(4) Piston and Cylinder Assembly Procedure

①Use clean nylon glove to prevent grease or sweat from attaching from your fingers.

②Remove the retainer, stopper and cap in that order. The housing incorporates the filter, O-ring, seat, O-ring, and bearing as illustrated in Figure 6-3. Remove the fine dust particle from the housing, using a blower brush.

③The piston and cylinder are packed in clean conditions. Before installing them in position, be sure to clean them according to the procedure given below, and make sure that inner side of the cylinder and outer side of the piston are free from dust.
Never touch the outer face of the piston and inner face of the cylinder, even with nylon gloves. Through the gloves, the temperature and humidity of the hands and fingers may be transmitted to these parts, causing them to be contaminated. This will result in operation failure and seizure. It should be strictly forbidden to below fine dust particles from the surface through your mouth.

④The side marked " ↑ " on the outer circumference of the cylinder should be placed to face upward. Under this condition, gently insert it into the housing; then push it in the cap to tighten the cylinder firmly.

⑤Lightly hold the piston head (piston nose) by fingers. Holding the piston vertical, insert it into the cylinder from the top, making sure that the piston is correctly aligned with the cylinder.
If they are correctly aligned, put the piston into the cylinder only several millimeters; then the piston goes down into position by its weight
If you are not used to this procedure, it will be difficult to support the piston vertical, and the piston may not be inserted into the cylinder.
Every time this occurs, raise the piston upward and repeat the procedure unit it enters the cylinder.

⑥After inserting the stopper into the neck portion of the piston, insert the retainer into position and tighten it firmly be screwing.

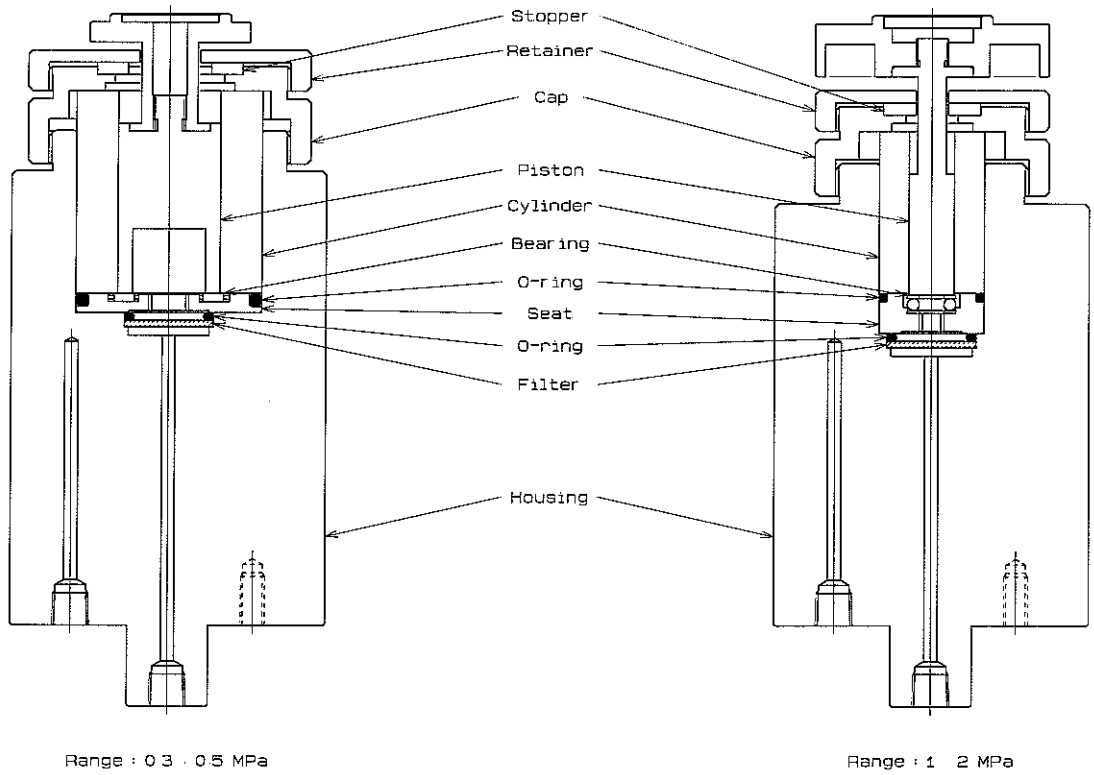


Figure 6-3

(5) Running

Leave the gauge unused for twelve hours or more before starting measurement first after installation. Turn on the piston temperature and position indicator and wait until the difference between the gauge temperature and ambient temperature becomes below 1°C and stable.

7. OPERATION

(1) Preparative

①Make sure that the piston, cylinder and weight units are free from corrosion, flaws or other defects that could influence the measurement performance.

②Be sure to use the piston, cylinder and weight units of the same serial number.

③While checking the level on the PD82, adjust the levelness by rotating the leveling screw below the PD82.

If the piston is tilted, the piston is in contact unevenly with the cylinder and the gauge may fail to produce correct pressures. The cylinder may also wear unevenly.

> ⚠ WARNING
> The gauge may fail to produce correct pressures unless the piston is vertical.

④Fully return the handle of the pressure regulator attached to the nitrogen gas container. Then open the valve of the nitrogen gas container.

Tighten the handle of the pressure regulator, and make adjustment so that the secondary pressure gauge will indicate the pressure slightly higher than the value measured by the PD82.

(2) Calibration Pressure

①Close all valves of the PD89.

②Place the dead-weight corresponding to the calibration pressure on the PD82.

(The pressure value is marked on the weight.)

The dead-weights may be combined in the range between the minimum and maximum values at the minimum division.

Handle the dead-weight with hands with clean gloves. Do not touch it with bare hands.

> ⚠ WARNING
> The gauge may fail to produce the correct pressure if the mass of the weight changes.

③Open the gauge valve (V4) of the PD89.

④Open the source valve (V1) of the PD89.

⑤Observing the pressure gauges of the PD89, gradually open pressure valve (V2), and then checking the piston position indicated by the piston temperature and position indicator to apply pressure until the piston moves up slightly. Then close pressure valve (V2).

At this time, the piston may jump up if pressure over the calibration pressure is applied Be careful not to apply excessive pressure.

> ⚠ WARNING
> If the piston jumps up, it may become defective or broken.

The approximate pressure can be read on the pressure gauge, so operate pressure valve (V2) for control.

⑥The piston stroke is from 0.0 mm to 10.0 mm.

If the gauge pressure is too high and the piston hits the stopper, operate the fine adjustment pump handle of the PD89 to decrease the pressure, so that the piston will be lifted slightly. If this is still unsatisfactory, gradually open release valve (V3) to decrease the pressure.

Adequate pressure control is achieved by proper operation of the valve and fine adjustment pump.

⑦Turn*1 the dead-weight slightly clockwise. The piston rotates when the dead-weight is turned.

*1: The rotation speed keep 30 rpm or less.

⑧Operate the fine adjustment pump handle slowly while checking the piston position indicated by the piston temperature and position indicator in the condition where the dead-weight is rotating in order to adjust the pressure so that the piston is located between 2.0 mm and 8.0 mm.

⑨Put the acrylic cover supplied with the gauge to the PD82.

The gauge produces the correct pressure in this condition. Calibrate the tested gauge (instrument to be calibrated).

There is a slight clearance between the piston and cylinder for smooth rotation. Nitrogen gas leaks through this clearance little by little during pressurization. As gas leaks, the raised piston moves down little by little.

Always keep the piston raised during calibration. Adjust the piston position with the pressure adjust handle if the piston moves down.

⚠ WARNING

The gauge will not produce the correct pressure unless the piston is raised.

The dead-weight must be rotating during calibration. If the weight is not rotating, friction is produced between the piston and cylinder and the gauge fails to produce the correct pressure. If the dead-weight is rotating even slightly, the gauge produces the correct pressure. Make the dead-weight rotate at the revolution of 3 rpm or more. If it is going to stop rotating during calibration, lower the piston to the 0.0 mm position once with the fine adjustment pump handle and rotate the dead-weight. Then, adjust the piston position with the fine adjustment pump handle.

⚠ WARNING

The gauge will not produce the correct pressure unless the dead-weight rotates.

⑩Move down the piston to the 0.0 mm position, detach the acrylic cover and stop the dead-weight, if the pressure should be increased step by step. Then, place a dead-weight corresponding to the calibration pressure.

⑪Carry out the operations shown in items ⑤ to ⑨. Repeat these operations in sequence to increase the pressure step by step.

Turn the fine adjustment pump handle fully counterclockwise once and carry out the operations shown in items ⑤ to ⑥ if pressurization using the fine adjustment pump handle is disabled.

⑫Turn the fine adjustment pump handle counterclockwise slowly to reduce the pressure.

⑬Reduce the pressure close to the calibration pressure with the fine adjustment pump handle, detach the acrylic cover, and stop the dead-weight if calibration should be done by reducing the pressure. Then, put dead-weight (s) corresponding to the calibration pressure. Remove weight (s) slowly if the dead-weight mass should be reduced. If the piston moves up, return the dead-weight (s), reduce the pressure further with the fine adjustment pump handle, and remove dead-weight (s).

⑭Carry out the operations shown in items ⑫ to ⑬ to reduce the pressure step by step. Repeat these operations in sequence to reduce the pressure step by step.

⑮Lower the piston to the 0.0 mm position with the fine adjustment pump handle and open the release valve (V3) gradually if the pressure should be reduced to zero
If the release valve is opened in the condition where the piston is raised, the piston moves down instantaneously, resulting in breakage of the piston or disengagement of dead-weights. It is very dangerous. Never open the discharge valve with the piston raised.

・Addition
Gravity compensation, head compensation, temperature compensation, atmospheric buoyancy compensation, etc. are needed to make the dead-weight tester produce the correct pressure.
See section 11, "Compensation" in detail.
It is possible to produce the correct pressure using the Jcss calibration certificate.

(3) Indicator of Piston Temperature and position
The piston temperature and position indicator has, on the rear panel, output terminals of analog voltages of the displayed values. The output voltage range is from 0 V to 10 V in each range.
The red terminal is the positive (+) terminal. The black terminal is the negative (-) terminal.
The panel meter has various functions. See the instruction manual of the panel meter for detailed handling procedures of the panel meter.

Specifications of this panel indicator
・Manufacturer:
WATANABE ELECTRIC INDUSTRY Co., Ltd.
・Model No.
Temperature indicator: A7118-7
Position indicator: A7111-7
・Initial setting range
Temperature indicator: 0 to 100 ℃
Position indicator: 0 to 10 mm

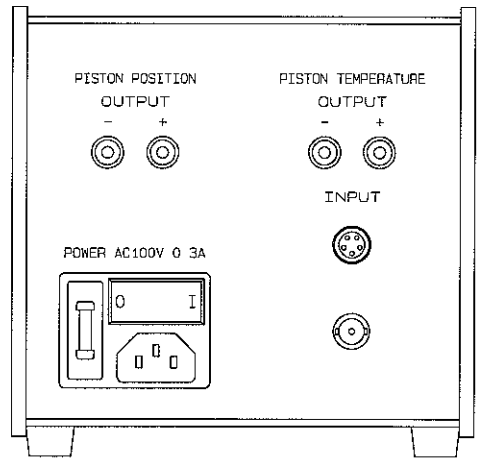


Figure 7-1

8. ACCESSORIES

Table 8-1

Name	Number of units		Remarks column
	0.3, 0.5 MPa	1, 2 MPa	
Blower	1	1	To clean the cylinder
Brush	1	1	To clean the cylinder
Wiper Holder	1	1	To clean the cylinder
Hundle	1	1	To clean the cylinder
Screw Bar	1	1	For fetch the adapter
Paper	20	20	To clean the piston and the cylinder
O-ring	1	1	For filter
O-ring	1	1	For adapter
Filter	1	1	For the piston and the cylinder
Connector	1 set	1 set	
Tube	1	1	Length:About 2m
Cover	1	1	For dead-weight part, acrylic material
Dead-weight box	2	2	For the dead-weight storage
Instruction manual	2	2	For the panel meter.

9. PRECAUTIONS

①Be sure to install the PD82 horizontally.

②The piston and the cylinder are assembled after special machining and treatment. When assembling them, take sufficient care that they are free from dust and other foreign substance.

③Do not increase or decrease pressure suddenly. When increasing the pressure, lightly touch hands on the weights, so that the piston will not hit the upper stopper forcibly.

④Do not allow the piston rotating for a long time when in contact with the upper or lower stopper.

⑤If piston rotational speed reduces suddenly when measuring, the piston and the cylinder are contaminated. Immediately stop the rotation of the weight, and remove the piston and the cylinder. Carefully wash them to remove dirts.

⑥If metal contact noise is heard between the piston and the cylinder, immediately stop rotation of the weight.

⑦Never use the piston if contaminated.

⑧If the instrument is subjected to wind during measurement, put on the acrylic cover.

⑨The performance of the weight type gas pressure gauge depends on piston operation. In the worst case, the lubrication film of gas (nitrogen gas) will be broken, resulting in seizure or burnining.
Before this stage is reached, the piston speed will suddenly reduce or metallic noise will occur between the piston and the cylinder. The trouble will be prevented if you take care of these symptoms. The following describes the possible causes for piston operation faults:
a) Contamination of piston and the cylinder
b) Presence of water, oil and dust mixed in pressure medium
c) Dust, water and oil (oil mist) in air entering between the piston and the cylinder
d) Sudden temperature change, vibration and defective level adjustment

⑩Do not touch the piston, ram plate, hat, position sensor dead-weight and dead-weights with bear hands. Put on gloves when handling them.

⑪Place the dead-weights properly and horizontally. Do not apply lateral loads to the piston.

⑫Do not open the discharge valve in the condition where the piston is raised.

10. MAINTENANCE

(1) How to clean the piston and the cylinder

①Use the following tools and items to clean them:
a) Clean nylon gloves
b) Blower brush
c) Cleaning tool and vessel
d) Cleaning solvent (ether, ethyl alcohol, acetone)
e) Tissue paper
f) Wiper

②Clean them at a place so that dust or soil will not easily stick to them. Cover the work bench with paper towel which is carefully cleaned.

③Cleaning the cylinder
a) Clean the outer cylinder face with tissue paper impregnated with solvent.
b) To clean inside the cylinder, insert the folded tissue paper into the slit of the resin-made wiper holder of the cleaning tool, and wind it around. Pour ether on the wound tissue paper, and push it into the cylinder while turning, and clean inside the cylinder.
Repeat this procedure twice or thrice.
c) Using a dry, clean tissue paper, clean inside and outside the cylinder according to the above procedure.
Repeat this procedure twice or thrice. Use special care to clean inside. After cleaning, means should be provided not to allow the cylinder to be contaminated by dust.

④Cleaning the piston
a) Carefully clean the piston with tissue paper impregnated with solvent.
Repeat this procedure twice or thrice.
b) Using a dry, clean tissue paper, clean the piston. Fold three or four sheets of tissue paper, and wind it around the piston. Hold it lightly with your right hand, and hold the top of the piston with your left hand. Clean it by turning.
Repeat this procedure twice or thrice.
After cleaning, means should be provided not to allow the cylinder to be contaminated by dust

⑤Use the blower brush to blow off the dust particles and flax from the piston and the cylinder; then insert the piston into the cylinder gently and pull it out again. After repeating this procedure twice or thrice, insert the piston into position.
Then the dust and flax are removed, and preparation is completed for assembly.

(2) Function test for cleanliness

①Prepare a rubber sheet of 2 to 3 mm in thickness, and clean the surface with such solvent as alcohol.

②Make the piston top flush with the cylinder top, and press the cylinder against the rubber seat to seal the bottom, so that much air will stay under the piston.

③Lightly tap the piston nose with your right forefinger until the piston is lifted slightly.
Never tap it forcibly. This tapping compresses the air which causes the piston to be lifted.
Compressed air will serve as a pneumatic spring to give vertical vibration to the piston.
Compressed air spreads into the corners of the piston and cylinder, holding the piston with extremely thin air film. The piston is thus made completely detached from the cylinder wall.

④If cleaning is satisfactory, the piston will slowly turn to the right or left when tapped.
Turn the piston by holding the piston nose with your fingers, and it will smoothly rotate and stop gradually. It will take three to five seconds for the final one-fourth rotation to stop.
If the above procedures are followed with success, the piston and the cylinder are perfectly clean. If the final rotation stops suddenly, they are not completely cleaned.
If used under this condition, the performance of the piston and the cylinder will deteriorate, or they will be "seized", resulting in operation failure.
Take sufficient care to prevent this.

11. COMPENSATION

(1) Factors Affecting Accuracy

①Gravitational acceleration

The gravitational acceleration differs with location on the earth due to variations of the centrifugal forces of the rotating earth and other factors.
In general, the gravitational acceleration is lower near the equator than in the polar regions.
Dead-weight pressure testers are manufactured based on the standard gravitational acceleration (9.80665 $m/sec^{2)}$ unless otherwise specified.
For details, refer to the authorized materials issued by astronomical observatories, etc. and determine the gravitational acceleration at the site of use.

②Head

In a dead-weight pressure tester, the intended pressure is produced at the bottom of the piston, in principle.
While a gaseous pressure medium has less influence.

③Buoyancy

Aerial buoyancy affects any object in the atmosphere.
The force F produced in an object of mass m by the gravitational acceleration g of the earth is given by:

$$F = m \cdot g$$

The buoyancy of the standard air density is taken into consideration and the dead-weight masses are adjusted properly. Compensation is needed if the air density is different from the standard air density The value is approximately 0.003% when the air density is 1.0 kg/m^3.

④Temperature

As the temperature changes, the effective area of the piston changes, resulting in errors of the measured pressure.

No compensation is needed if the pressure tester is used at the same temperature as the temperature during manufacturing (23℃). If it is used at a different temperature, temperature compensation is required.

The error per 10℃ is approximately 0.01%.

⑤Elastic deformation of piston and cylinder caused by the pressure

The effective cross sectional areas of the piston and cylinder change due to elastic deformation caused by the pressure. The dead-weight masses of the gauge have been adjusted properly, taking account of elastic deformation.

⑥Others

In addition to the above factors, the buoyancy and surface tension of the pressure medium acting on the piston, elastic deformation due to the pressure, etc. may affect the measurement.

However, the influences of these factors are relatively small and are omitted here.

(2) Compensation Procedures

①Compensation of influences of gravitational acceleration

If the gravitational acceleration at the site of use is greater than that assumed when the dead-weight pressure tester was manufactured, a pressure higher than that indicated on the weight unit is produced.

On the contrary, if the gravitational acceleration at the site of use is smaller than the assumed acceleration, the produced pressure is lower than the indicated pressure.

The error ΔP_{gr} caused by the gravitational acceleration is given by:

$$\Delta P_{gr} = P_{app} \frac{g_{use} - g_{man}}{g_{man}} \qquad (11\text{-}1)$$

where, P_{app} : Sum of pressures marked on the weight units

g_{use} : Gravitational acceleration at the site of use

g_{man} : Gravitational acceleration assumed when producing the dead-weight pressure tester (Standard acceleration: 9.80665 m/sec^2)

Use the following expression for simple compensation of the error caused by the gravitational acceleration only:

$$P_{act} = P_{app} \frac{g_{use}}{g_{man}} \qquad (11\text{-}2)$$

where, P_{act}: Pressure produced actually

②Compensation of head errors

The head error ΔP_{head} is given by the following formula, where the density of the pressure medium is ρ and the head is H:

$$\Delta P_{head} = -\left(\rho_{N_2} - \rho_a\right) \cdot g_{use} \cdot H \quad (11\text{-}3)$$

The head H in the condition shown in Figure 11-1 is a positive value.

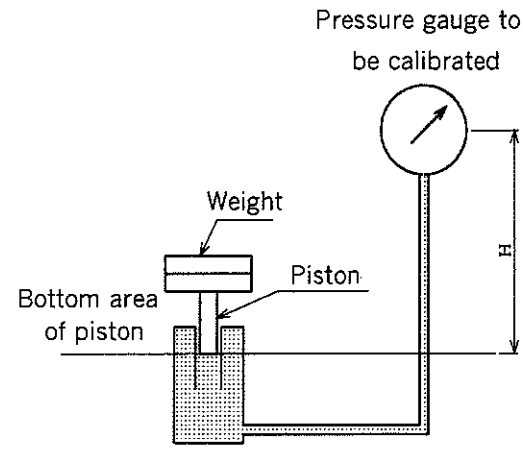


Figure 11-1

The following shows a calculation ex

$\Delta P_{head} = -0.66$ Pa

where, $\rho_{N2} = 1.875$ kg/m^3 (Nitrogen: at 50 kPa)
$\rho_a = 1.2$ kg/m^3 (Air: atmosphere)
$g_{use} = 9.80665$ m/sec^2 (Standard gravitational acceleration)
H = 0.1 m (The pressure gauge to be tested is in the higher position.)

The reference position of the gauge is the top of the column indicating the bottom of the piston in the dead-weight part plus the piston position indicated by the piston temperature and position indicator.
Regard the difference from the reference position as H and carry out compensation, if needed.

③Compensation of buoyancy

The mass of each weight unit is determined by comparing the weight unit against the standard weight using a balance; buoyancy is not taken into consideration. The mass of the weight unit is adjusted so that the force produced by the gravitational acceleration of the weight unit balances the force produced by the gravitational acceleration of the standard weight. Strictly speaking, the mass of the weight unit is different from that of the standard weight if both weights have different densities. However, this purpose is achieved by buoyancy compensation of the standard weight, since the weight unit is adjusted so that the forces produced by the gravitational accelerations of both weights are identical in air.
The ratio of the standard weight density to the air density is used for buoyancy compensation. The OIML determines these values as the conventional values. Use these values normally.
The dead-weight masses has been compensated for the buoyancy and adjusted properly. Thus, the gauge requires no compensation. However, compensation is needed if the air density is different from the standard air density.

・OIML Conventional Values
Reference temperature: 20℃
Density of the standard at 20℃: 8000 kg/m^3 (Density of standard weight)
Air density: 1.2 kg/m^3

If the air density in the place where the gauge is used is different from the standard air density, the error ΔP_{buoy} caused by the buoyancy is given by:

$$\Delta P_{buoy} = -P_{app} \frac{g_{use}}{g_{man}} \cdot \frac{\rho_{use} - \rho_a}{\rho_w} \qquad (11\text{-}4)$$

where, ρ_a : Standard air density (1.2 kg/m^3)
ρ_{use}: Air density at the site of use
ρ_w: Weight unit density (8000 kg/m^3)

④Temperature error compensation

The temperature error ΔP_{temp} is given by:

$$\Delta P_{temp} = -\alpha \left(t_{use} - t_{man}\right) \cdot P_{app} \frac{g_{use}}{g_{man}} \qquad (11\text{-}5)$$

where, α : Linear expansion coefficient of the piston (8.1 x 10^{-6} /℃)
t_{use} : Temperature when using the piston (℃)
t_{man} : Temperature when manufacturing the piston (23℃)

⑤Comprehensive compensation

Considering all of the above, the pressure P_{act} actually produced at the intended position is given by:

$$P_{act} = P_{app} + \Delta P_{gr} + \Delta P_{head} + \Delta P_{buoy} + \Delta P_{temp} \qquad (11\text{-}6)$$