DHI PRESSURE STANDARDS

USERS MANUAL 5306

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CHAPTER 1

PURPOSE AND OPERATING PRINCIPLE

I - 1 - PURPOSE

DH Model 5306 Pressure Standards are oil operated deadweight testers used to calibrate and test gauges, transducers and transmitters at pressures up to 75,000psi.

I - 2 - OPERATING PRINCIPAL

The key component is the mounting post which combines the primary metrological elements:

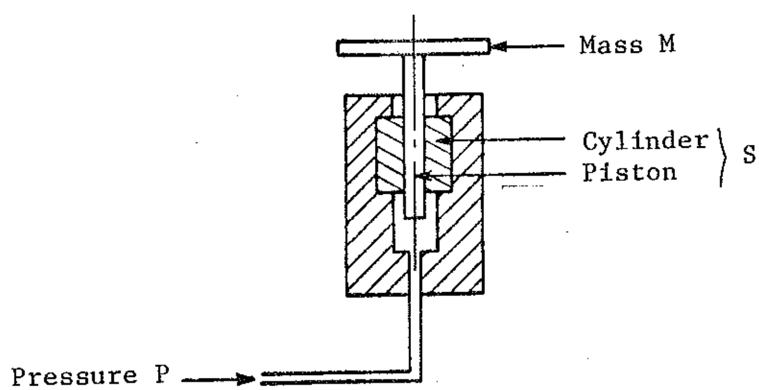
1 - The piston-cylinder which defines an effective area, S.

2 - The masses, of global value M, which act upon the piston.

The value of the pressure, P, which puts the piston into equilibrium is given by the formula:

$$P = \frac{Mg}{S}$$

g = Acceleration due to gravity



MEASURING PRINCIPAL

(Figure I - 1)

CHAPTER II

DESCRIPTION OF THE MODEL 5306

II - 1 - COMPONENT CHECK LIST

- Housing : Light alloy casting, housing all the components necessary for operation. Delivered in a wooden cabinet.

- Mass set : Total value is generally 100kg or 50kg. The masses are supplied in a series of wooden storage cases.

- Piston-cylinder : Supplied in a carrying case with a special mounting key.

- Standard accessories :

  - 1 Instruction manual
  - 1 Calibration certificate and technical data
  - 1 Quart sebacate
  - 1 Drive belt No. 650
  - 2 Piston travel limit pins No. 30199
  - 4 Foot rest No. 37613
  - 1 Plastic cover No. 31113
  - 1 O-ring assembly mounting key No. 40957
  - 1 O-ring assembly for the measuring post No. 41096
  - 1 O-ring assembly for the quick connecting head No. 41087
  - 1 Priming pump maintenance kit No. 41377
  - 1 Gland for standard DH 20,000psi fitting No. 40966
  - 1 Plug for standard DH 20,000psi fitting No. 41009
  - 1 Gland for standard DH 75,000psi fitting No. 40961
  - 1 Plug for standard DH 75,000psi fitting No. 41086
  - 1 DH quick connector with DH standard 75,000psi fitting No. 41102
  - 1 Mass carrying bell
  - 1 Oil run-off cup No. 39509
  - 1 250 mA delayed fuse
  - 1 Power supply cord
  - 1 RTD output cable (S and S^2 accuracy only)

II - 2 - SUB-ASSEMBLY LOCATION WITH MANUFACTURES REFERENCE NUMBERS

The Model 5306 is made up of a housing into which the following sub-assemblies are integrated:

Center
(1) The mounting post into which the piston-cylinder is installed No. 40933 (No. 40959 for S and S^2)

Upper Front Face
(2) Power on/off switch No. 527
(3) On/off indicator light No. 380627-2
(4) Reference level line

Lower Front Face
(5) Low pressure shut off valve No. 40912
(6) High pressure shut off valve No. 40908
(7) Piston displacement indicator No. 38576
(8) Variable volume screw press No. 40985

Top
(9) Oil reservoir cap No. 37369
(10) Quick connecting head No. 40896
(11) Bubble level No. 41468

Right Side
(12) Priming pump handle No. 41315
(13) Carrying handle No. 5000
(14) Reservoir shut off valve No. 40912

Left Side
(13) Carrying handle No. 5000
(15) Sump purge drain-cock No. 35376

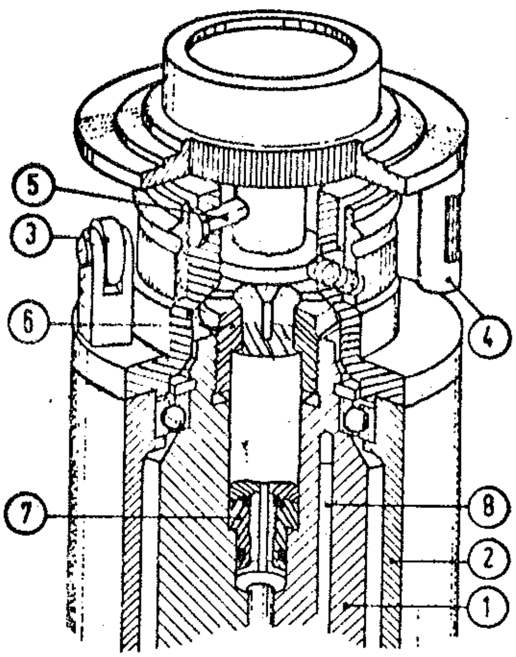
Rear
(16) Receptacle for motor power supply cable No. SLEM-23C
(17) Fuse No. 19201
(18) RTD output receptacle No. SLEM-25S (S and S^2 only)
(19) Oil run-off cup No. 39509 (delivered with the accessories)

Inside
(20) Intensifier No. 40924
(14) Reservoir shut off valve No. 40912
(8) Variable volume screw press No. 40985
(21) Oil reservoir No. 40999
(22) Priming pump No. 40992
(23) Sump No. 40918
(5) Low pressure shut off valve
(6) High pressure shut off valve
(24) Motor for piston rotation No. 39149 (110V AC)

The housing is closed in the rear by an anodized panel held by a quick disconnect pin.

II - 3 - DESCRIPTION OF THE SUB-ASSEMBLIES

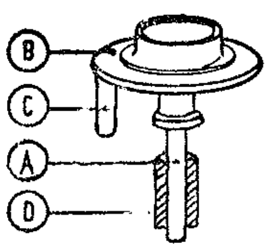
Mounting post



Function : Piston-cylinder mounting post.

Description: Stainless steel body (1) over which a pulley (2) is mounted on bearings. The pulley is rotated by the motor using a drive belt. The pulley assures piston rotation using the drive pin (3) which pushes the pin (4) on the piston plate.
(5) Piston travel limit pin
(6) Cylinder retaining nut
(7) O-ring assembly
(8) Platinum RTD (S and S^2 accuracy only)

Piston-cylinder



Function : Fundamental metrological element which transforms the pressure into a measurable proportional force.

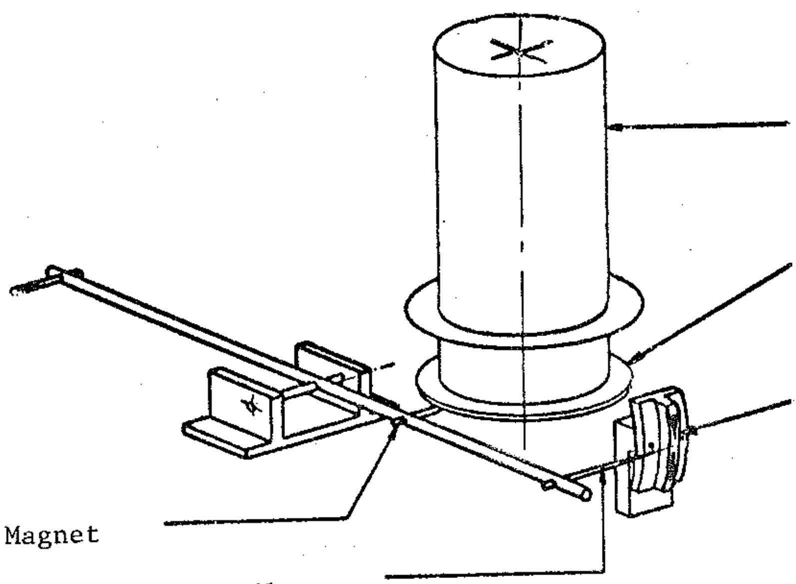
Description: The piston (A) is equipped with a plate (B) on which is mounted a pin (C). The cylinder (D) is always made of tungsten carbide and the piston is made of tungsten carbide or steel.

Piston-cylinders of different effective areas are interchangeable. All pistons have the same mass (0.2kg) and all cylinders have the same external dimensions.

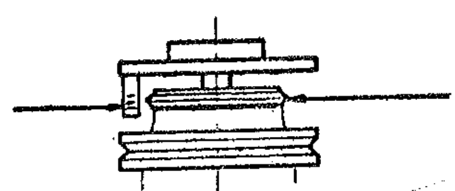
Piston displacement indicator

Function : To give a precise indication of piston position and of its movement.

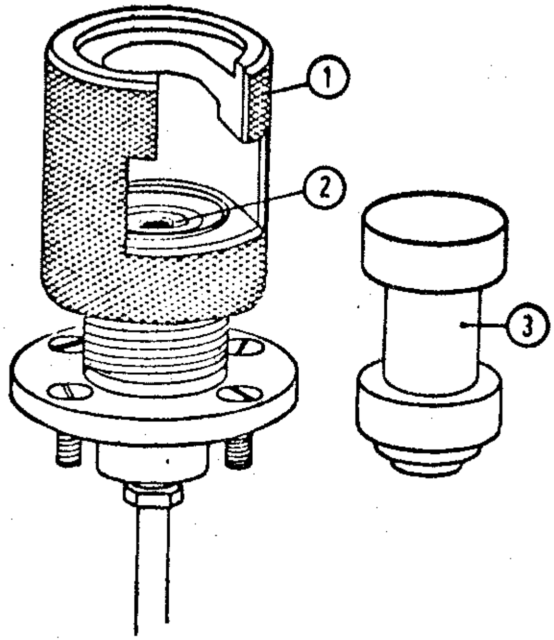
Description: It is a lever that moves in the same direction as the piston. On the lever is a needle which is visible on a scale on the front of the standard. The scale indicates upper and lower end of stroke position as well as the mid-stroke equilibrium point. The lever moves via a magnet which tracks a nickel plated iron ring on the mass carrying bell without interferring with its movement. The indication given by the needle is a 4X amplification of actual piston movement.



NOTE: When working without the mass carrying bell, the mid-stroke equilibrium point is identified by the middle marking on the piston drive pin when it is in line with the index ring.



Quick-Connecting Head

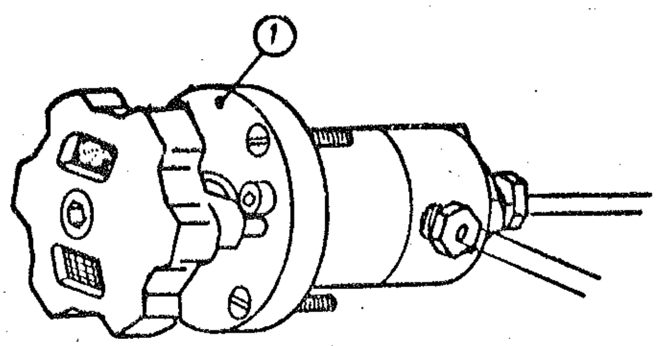


Function : Connection point to the system under test.

Description: A convenient connection which will not be damaged or wear despite many make and break operations. The knurled nut (1) tightens onto a connector (3). An O-ring assembly (2) makes the seal. The knurled nut is tightened by hand even at the highest pressures. The quick connecting head is an interchangeable sub-assembly but general maintenance requires only the replacement of the O-ring assembly.

Note: Many different connectors for the quick-connecting head are available. Please consult CTS Division.

Valve



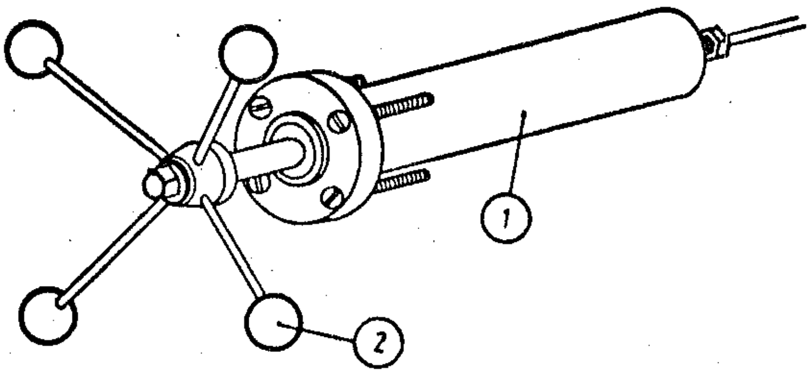
Function : To isolate one part of the hydraulic circuit from another.

Description: In the closed position, the red label on the handle is across from the white reference dot (1). A belleville spring pushes the needle onto its seat. The handle feels loose when valve is closed. The opening of the valve is progressive and made by turning the handle clock wise to compress the spring. Rotation of the handle is limited to a half turn by stops. The valves are interchangeable sub-assemblies.

Variable volume screw press

Function : Pressure generation and regulation up to 20,000psi.

Description: A cylinder (1) in which a plunger moves by turning a handle (2). Variation of volume for the entire plunger stroke is 8 cm^3 (.49 in^3).
Variation for one handle turn is 0.17 cm^3 (.0104 in^3).

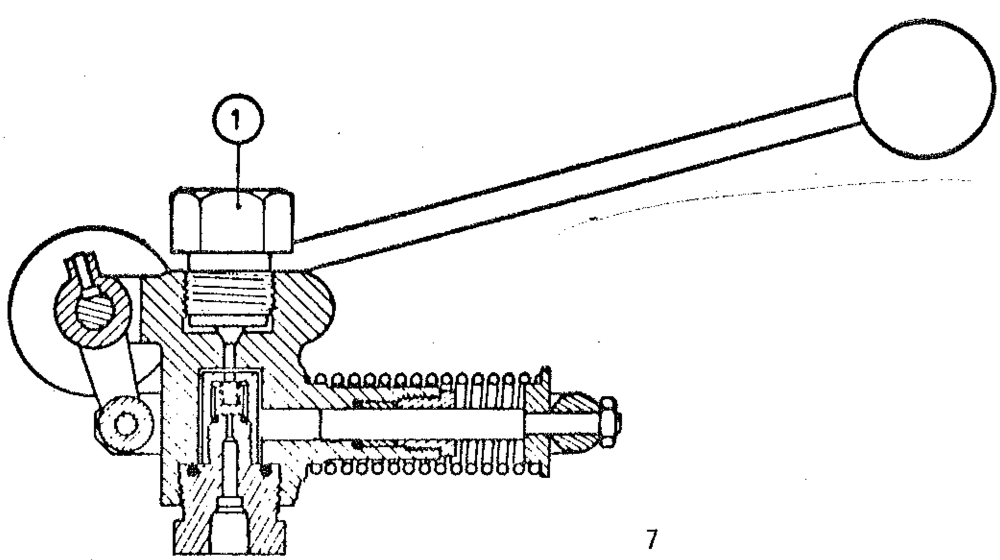


The variable volume screw press is an interchangeable sub-assembly.

Priming pump

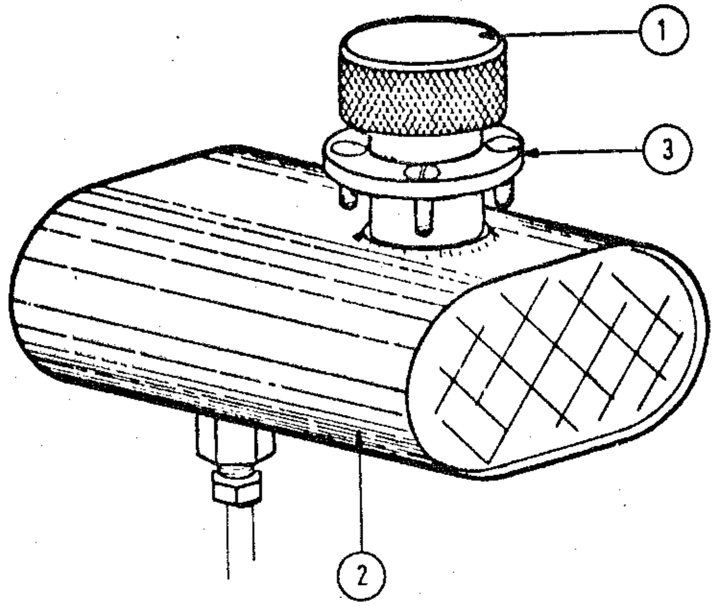
Function : To fill and prime the internal and external hydraulic circuits.

Description: Single piston pump consisting of an inlet (1) and outlet check valve. Flow for one stroke is 3.5 cm^3 (.214 in^3). The priming pump is an interchangeable sub-assembly.



Oil Reservoir

Function : Hold the pressure medium.

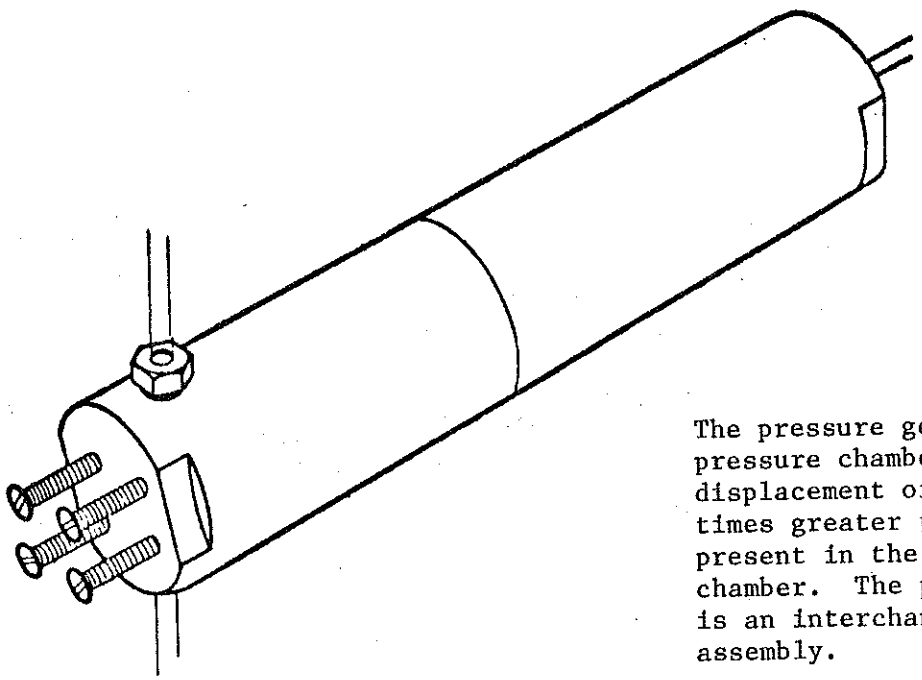


Description: Tank (2) fabricated in stainless steel. The cap (1) is equipped with an O-ring for hermetic sealing during travel and storage. The oil reservoir is an interchangeable sub-assembly.

Pressure Intensifier

Function : High pressure generation.

Description: A cylinder incorporating two moving pistons with an effective area ratio of 5 to 1.

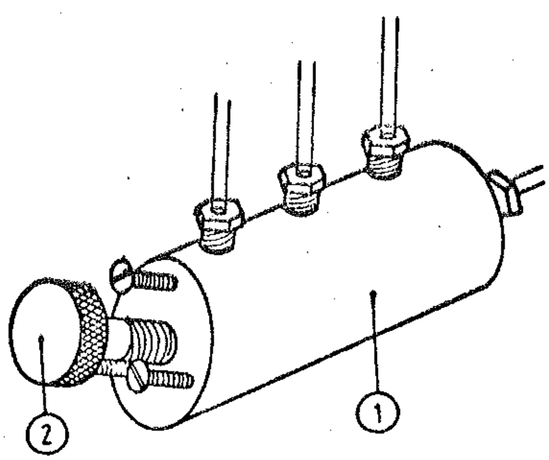


The pressure generated in the high pressure chamber by the displacement of the pistons is five times greater than the pressure present in the low pressure chamber. The pressure intensifier is an interchangeable sub-assembly.

Sump

Function : Located at the low point of the hydraulic circuit to serve as a purge point for impurities coming from the system under test. Serves as the manifold for all the tubing of the high pressure circuit.

Description: A cylinder (1) with the fittings needed for the connection of the various hydraulic lines. A drain-cock (2) allows partial or complete purge of the system. The sump is an interchangeable sub-assembly.

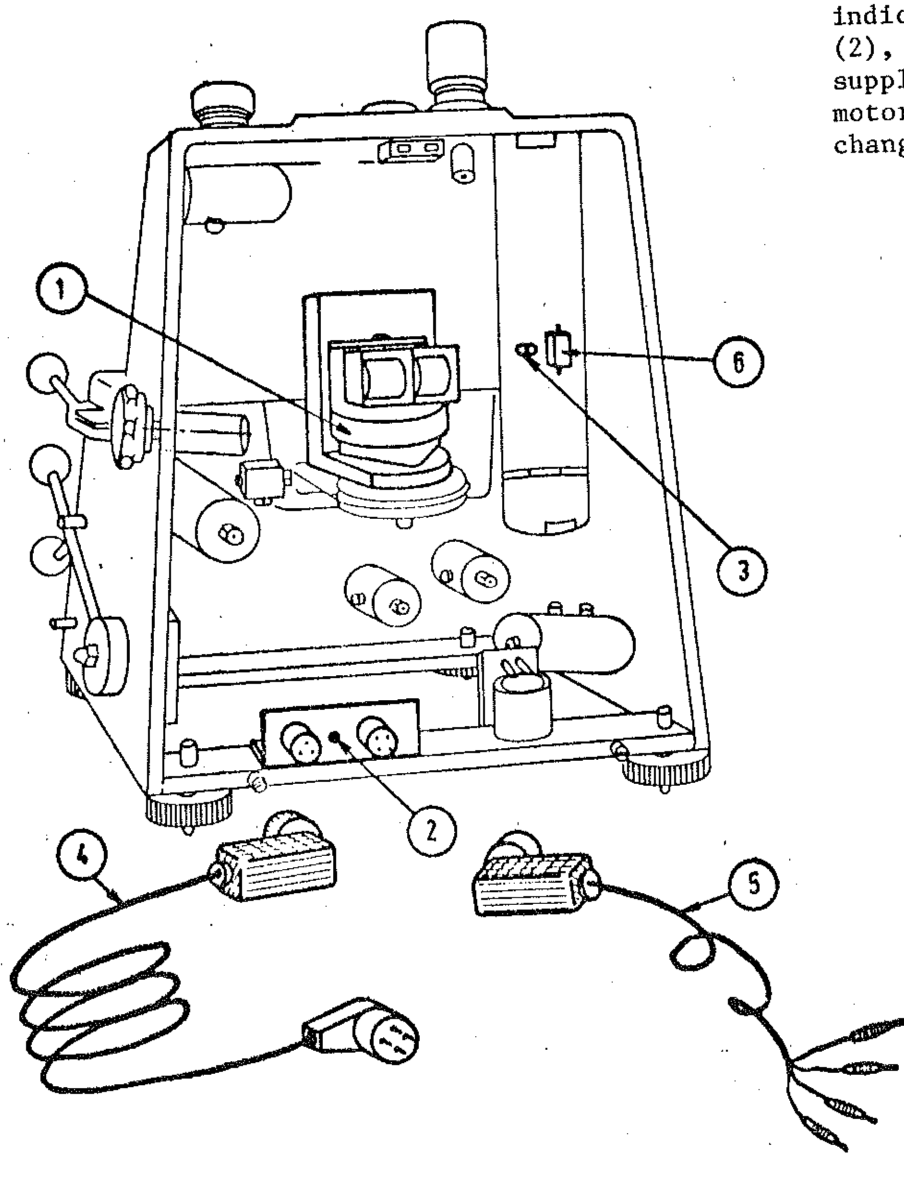


Electrical System

A) Motor

Function : For piston rotation using a drive belt and the mounting post pulley.

Description: Made up of a 30RPM squirrel cage motor (1), an on/off switch (6), an on/off indicator light (3), a fuse (2), and a 2.5 meter power supply cable (4). The motor is an interchangeable sub-assembly.

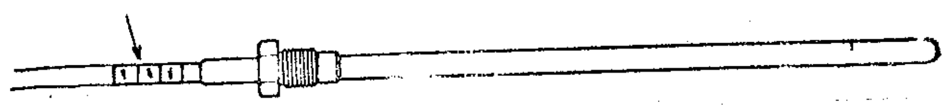


B) Temperature probe (S and S^2 accuracy only)

Function : Measure as well as possible the temperature of the piston-cylinder assembly.

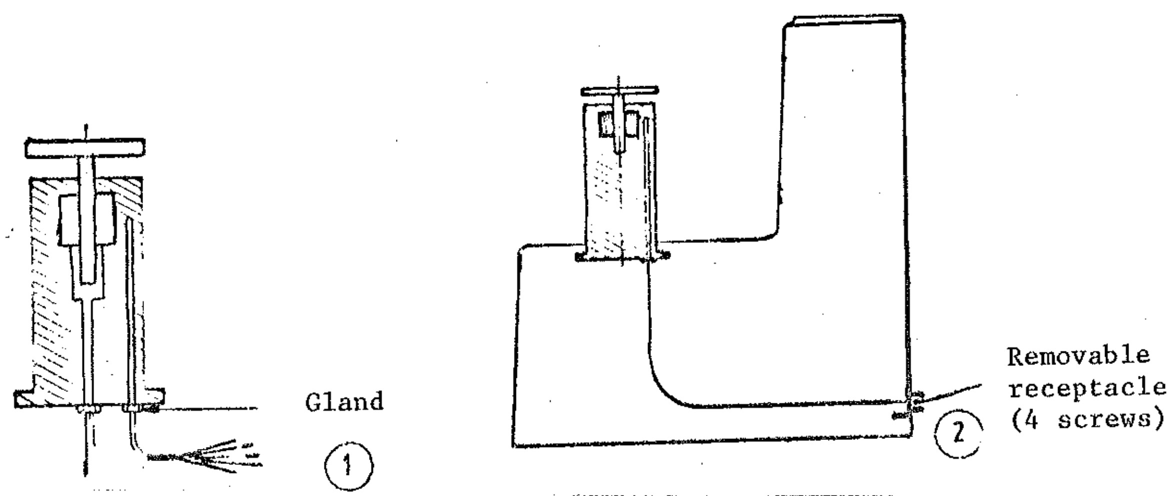
Description: Platinum RTD with 100 ohm nominal resistance at 0°C following DIN standard 43760. The 100 ohm value is given with an uncertainty of ± 0.1 ohm which corresponds in temperature to ± 0.25°C. The DH Laboratory determines the value of the resistance at 0°C inside the tolerance of the standard with an uncertainty of ± 0.02 ohm.

Serial number of the RTD



Installation of the temperature probe

The temperature probe is mounted in the mounting post as close as possible to the piston-cylinder. It makes possible valid and accurate temperature corrections. The probe is connected to a removable receptacle so that it can be removed and periodically recalibrated.



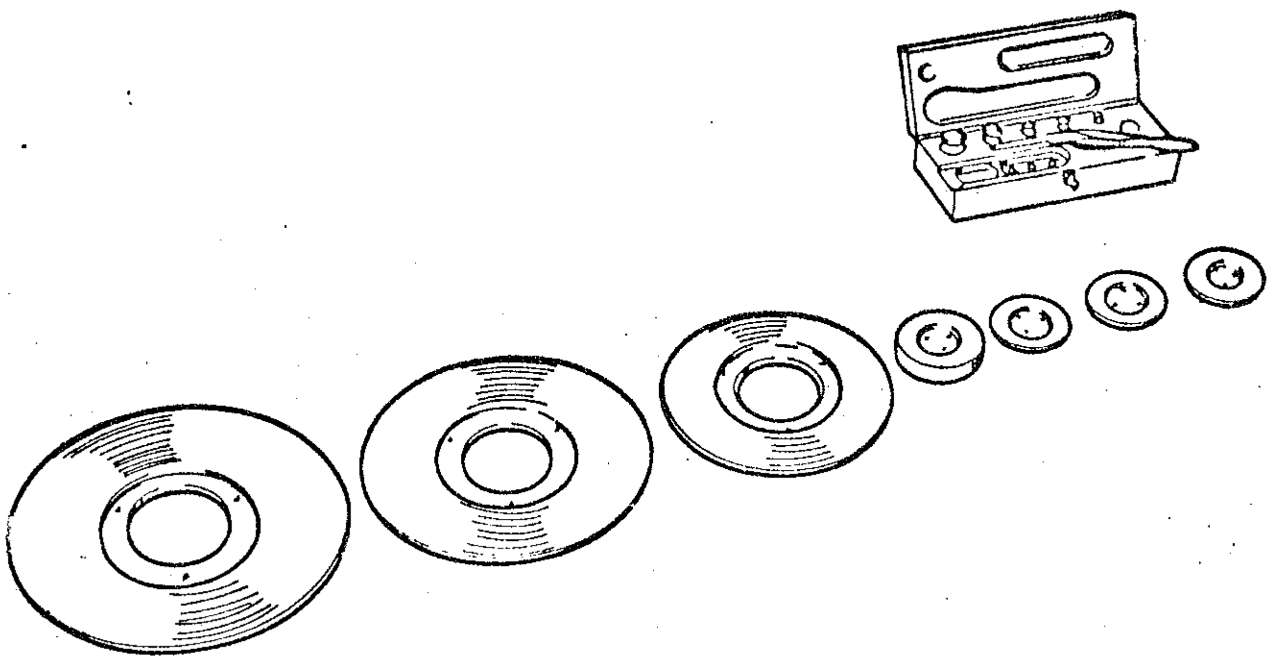
Removing the probe:

- Unscrew the gland (1) under the mounting post.
- Unscrew the 4 screws of the receptacle (2).
- Run the wire through the hole in the receptacle mount.
- Carefully remove the probe from the mounting post.

Mass set

Function : Define the value M which is subjected to acceleration due to gravity giving the force, F.

Description: Made of non-magnetic stainless steel. Masses of 1kg and above are discs with a central hole to be slipped onto the mass carrying bell.



Note: Masses are engraved in kilograms which makes it possible to interchange piston-cylinders while using the same mass set.

CHAPTER III

INSTALLATION AND START-UP

III - 1 - THE STANDARD AS DELIVERED

- The standard and its accessories are in a wooden cabinet.
- The four adjustable feet are retracted (screwed in).
- The reservoir is 3/4 full.
- The reservoir cap is tightened.
- The mounting post has installed a stainless steel piston-cylinder plug, instead of the piston-cylinder.
- The masses are in their carrying cases.
- The piston-cylinder is in its carrying case with the piston-cylinder key.

III - 2 - INSTALLING THE PISTON-CYLINDER

The overall piston-cylinder installation procedure includes the following:

1) Setting the standard on a rigid table at a convenient height.
2) Cleaning the piston-cylinder.
3) Removing the piston-cylinder plug.
4) Installing the piston-cylinder.
5) Purging air from the system.

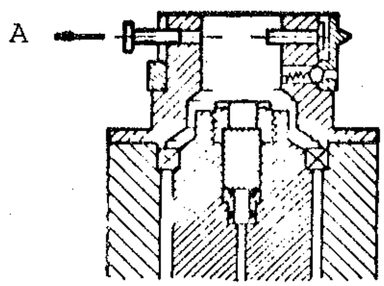
III - 2 - 1 - Cleaning the piston-cylinder

Before installing the piston-cylinder, it must be cleaned with a liquid solvent (for recommendation consult CTS Division).

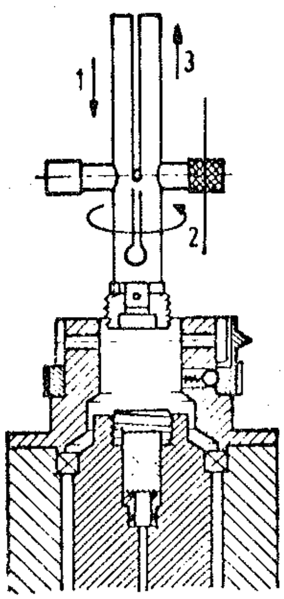
- Submerge the cylinder in the fluid and wipe the exterior and interior with a clean lint free cloth or tissue.
- Soak the piston in the fluid and wipe it off.
  NOTE: Care should be taken not to submerge the piston plate in the fluid.
- Put the piston in the cylinder. If both elements are properly cleaned, the piston moves freely without resistance in the cylinder.
- Once the elements are clean, lubricate the piston in the oil used in the standard and put the piston into the cylinder so that both pieces are lubricated.

III - 2 - 2 - Removing the piston-cylinder plug

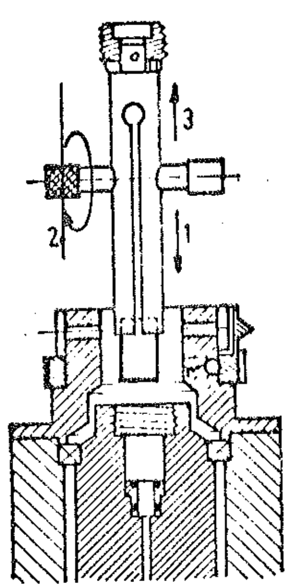
Complete the following first:
- Loosen the oil reservoir cap.
- Open the reservoir isolation valve.
- Unscrew the variable volume to mid stroke.
- Close the reservoir isolation valve.



1 - Rotate ring (A) to expose the head of the piston travel limit pins. Remove each pin as it appears.



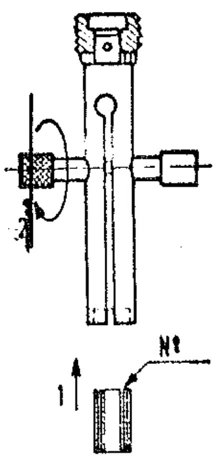
2 - Insert the pin end of the piston-cylinder key into the cylinder retaining nut. Unscrew and remove the nut. (A lock ball keeps the nut on the key).



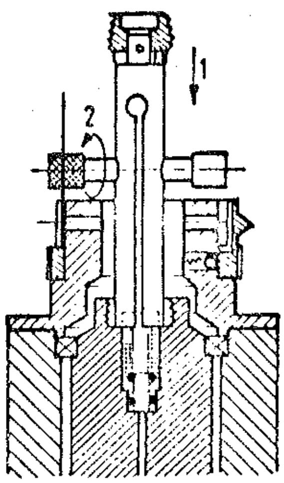
3 - Invert the key and set the notched end over the plug and tighten the T handle as indicated. Remove the key and plug.

III - 2 - 3 - Installing the piston-cylinder

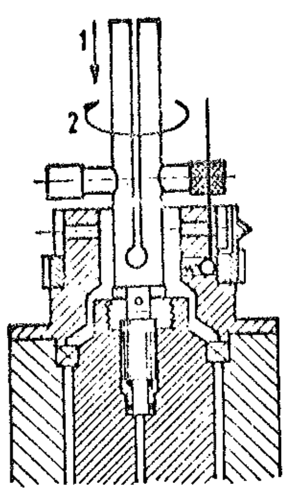
A) Installing the cylinder



1 - Put the cylinder into the notched end of the piston-cylinder key. Tighten T handle.
NOTE: The cylinder serial number and/or X notation must face upwards after installation. To do so, put this end of the cylinder into the key.

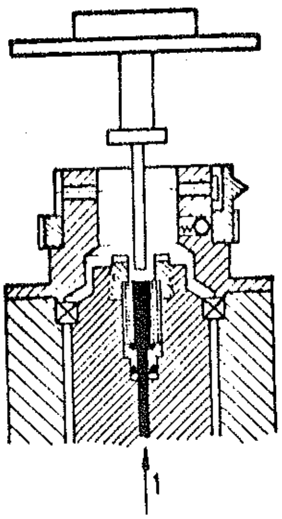


2 - Insert the cylinder in the mounting post and loosen the T handle. Remove the key.

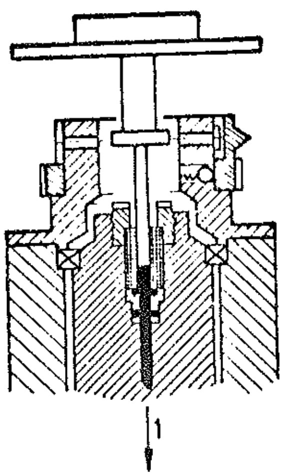


3 - Invert tool.
Reinstall the piston-cylinder retaining nut. Tighten until it bottoms out against the cylinder.
NOTE: A lot of torque is not required here.

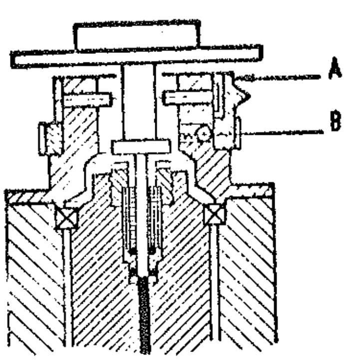
B) Installing the piston



1 - Pump oil to the top of the cylinder using the priming pump.



2 - Insert the piston into the cylinder.



3 - Replace the three piston travel limit pins and rotate ring (A) to engage locking ball (B).

III - 2 - 4 - Purging the system of air

After installing the piston-cylinder, the system should be purged of any air which may be present.

1 - Check that:
- The quick-connecting head is plugged.
- The oil reservoir cap is loosened.
- The piston travel limit pins are installed.
- The mass carrying bell is not on the piston.

2 - Close the reservoir isolation valve.

3 - Increase the pressure in the system using the priming pump until the handle becomes hard to move.

4 - Open rapidly and completely the reservoir isolation valve.

5 - Close the reservoir isolation valve and repeat operation 3 and 4 two or three times.

III - 3 - START-UP

The description below pertains to start-ups with the piston-cylinder already installed.

1 - Level the standard using the 4 leveling feet and the bubble level:
- Unscrew all four feet a few turns.
- Screw in completely the front right foot.
- Push down the left rear of the standard to stabilize it on the three feet that are screwed out.
- Put the bubble into proper position on the right/left axis using the front left foot.
- Put the bubble into the reference circle using the right rear foot.
- Unscrew the front right foot to stabilize the standard.

2 - If you have a standard with a switchable voltage motor, select the appropriate voltage (110V or 220V) with the switch on the inside of the standard.

3 - Connect the power supply cable to the receptacle on the rear of the standard. Plug the cable into the power supply.

4 - Connect the temperature probe cable to the receptacle on the rear of the standard and to a digital ohmmeter (S and S^2 standards only) (see Chapter IV - 4).

5 - Proceed as follows:
- Plug the quick-connecting head.
- Open the reservoir shut-off valve.
- Put the variable volume at mid-stroke.
- Close the reservoir shut-off valve. Close the low pressure shut-off valve.
- Open the high pressure shut-off valve.

6 - Switch the motor on to rotate the piston.

7 - Check that the intensifier is in start position. Return to start position if necessary. (see Chapter III - 7)

8 - Place the mass carrying bell on the piston plate and load 10kgs on the bell.

9 - Increase the pressure using the priming pump. Pump the handle until it becomes hard (do not force the handle). Then, if necessary, screw in the variable volume until the piston reaches its fully up position.

10 - Wait approximately two minutes. The purpose of this step is to form the pressurized components and to check the system for leaks.

11 - Decrease the pressure by unscrewing the variable volume until the piston reaches its fully down position.

12 - Open the reservoir shut-off valve to bring the pressure inside the standard back to ambient.

III - 4 - CALIBRATIONS WITHOUT USING THE INTENSIFIER

Note: The low pressure circuit of the 5306 has a maximum operating pressure of 20,000psi. Therefore, for pressures above 20,000psi it is mandatory to use the intensifier.

1) Connect the system under test to the appropriate quick-connector.
2) Remove the plug from the quick-connecting head.
3) Close the reservoir shut-off valve.
4) Using the variable volume, bring oil to the top of the connecting head O-ring assembly.
5) Connect the system under test to the connecting head.
6) Unscrew the variable volume leaving about one inch of travel.

7) Load the mass carrying bell with the quantity of mass corresponding to the first pressure increment.
8) Check that the low pressure shut-off valve is closed.
9) Check that the high pressure shut-off valve is open.
10) Prime the standard and the system under test using the priming pump until pumping becomes difficult. (do not force the handle)
11) Screw in the variable volume until the piston moves up to mid-float position as defined by the piston displacement indicator.
12) Take readings of the system under test.
13) Add the masses necessary to define the next pressure increment.
14) Repeat 11, 12, and 13 for subsequent ascending pressure increments.
15) For descending pressure increments, remove the appropriate masses and unscrew the variable volume.
16) After the last increment, unscrew the variable volume until the piston is in its full down position. Open the reservoir shut-off valve and return to ambient pressure.

III - 5 - CALIBRATIONS USING THE INTENSIFIER

(see the hydraulic circuit schematic on page 37)

To calibrate an instrument using the intensifier, proceed as above. When the variable volume handle becomes stiff (8,000 to 12,000psi not to exceed 20,000psi), the intensifier should be used following the procedure below.
NOTE: In no case, during valve operation, should the piston be floating or fully up. Unscrew the variable volume until piston is fully down.

1) Close the high pressure isolation valve.
2) Open the low pressure isolation valve.
3) Float piston using the variable volume.
4) Add the masses necessary to define the next pressure increment.
5) Use the variable volume to bring the piston into equilibrium.
6) Take readings of the system under test.
7) Repeat 4, 5, and 6 for ascending increments.
8) Descending pressures must be made through the intensifier until the intensifier is returned to start position. (the same increment at which the change onto the intensifier was made).
9) To come off the intensifier:
   - Put the piston in its fully down position.
   - Ensure the high pressure shut-off valve is closed.
   - Open the reservoir shut-off valve.
   - Close the low pressure shut-off valve.
   - Close the reservoir shut-off valve.
   - Put the variable volume in a 3/4 position.
   - Using the priming pump and the variable volume, increase the pressure which was present when the reservoir shut-off valve was opened to roughly the same pressure.
   - Open the high pressure shut-off valve.

III - 6 - REFILLING THE VARIABLE VOLUME DURING A CALIBRATION

If the plunger of the variable volume is completely screwed in and further ascending pressure increments are required perform the following operations:

1) Close the low pressure shut-off valve.
2) Unscrew the variable volume completely.
3) Prime the low pressure system using the priming pump.
4) Use the variable volume to bring the pressure in the low pressure circuit to roughly the same point at which it was when the operation was begun.
5) Open the low pressure shut-off valve and continue with the calibration.

III - 7 - RETURNING THE INTENSIFIER TO THE START POSITION

NOTE: This procedure can be followed using piston-cylinder plug, piston only (without bell), or mass loaded to define 8000psi.

CAUTION: Do not float piston during this operation unless only the piston is installed.

1 - Close the reservoir shut-off valve. Close the low pressure shut-off valve. Open the high pressure shut-off valve.
2 - Prime the system with the priming pump until the handle becomes stiff.
3 - Close the high pressure shut-off valve. Open the reservoir shut-off valve.
4 - Open the low pressure shut-off valve.
NOTE: If pressure in the high pressure circuit returns to ambient, repeat steps 1-4. If pressure holds, intensifier is in start position. To verify pressure in high pressure circuit, repeat step 1. If priming pump is stiff, intensifier is in start position.

III - 8 - PRECAUTIONS TO BE TAKEN TO ASSURE GOOD MEASUREMENTS

1) Clean the piston-cylinder thoroughly before installation.
2) Install the cylinder in the correct direction: serial number and/or X upwards.
3) Verify that the piston travel limit pins are installed.
4) Check that the oil reservoir is full.
5) Loosen the oil reservoir cap.
6) Purge air from the standard and the system under test.
7) Level the standard and check the level when different mass values are loaded.
8) Rotate the piston.
9) Always put the piston in fully down position before opening any valve.
10) Calibrate instruments in their operating position.
11) Begin calibrations with the intensifier in start position.

III - 9 - SHUT-DOWN PROCEDURE

1) Return the intensifier to the start position.
2) Open the reservoir shut-off valve.
3) Screw the variable volume all the way in.
4) Close the reservoir shut-off valve.
5) Tighten the oil reservoir cap.
6) Turn off the motor.
7) Cover the standard with its plastic cover.
8) Put the masses in their storage cases.

III - 10 - PERIODIC MAINTENANCE

1) Empty the oil from the oil run off cup (never reuse this oil).
2) Open the sump drain-cock and drain off oil until it runs clear.
3) Clean piston plate and masses.

III - 11 - PERIODIC OPERATIONAL CHECK

For regular use, it is recommended to return the standard to DH every three years for a system overhaul. Production and high volume applications may require more frequent maintenance.

III - 12 - RECALIBRATION OF PISTON-CYLINDER AND MASSES

Periodic recalibration of the piston-cylinder and masses assure the long term reliability and optional metrological performance of the system. Though other organizations can perform these calibrations, it is recommended that the DH Calibration, Test and Service Division be used in order to receive data which allows the exploitation of piston K_N factors and whole number masses. The DH calibration chain also documents long term repeatability of the system well inside of accuracy tolerances.

- N Class Standards
  Two years after delivery, a complete recalibration by the CTS Division is advised. If no significant change from original data has occured, adoption of a three year calibration cycle is recommended.
- S^1, S and S^2 Class Standards
  The first and second year after delivery, a complete recalibration by the CTS Division is advised. If no significant change from original data has occurred, adoption of a two year calibration cycle is recommended.

III - 13 - MOVING THE STANDARD

When moving the standard, complete the following:

1) Remove the piston-cylinder.
2) Store the piston and cylinder in their case.
3) Install the piston-cylinder plug into the mounting post.
4) Tighten the oil reservoir cap.
5) Plug the quick-connecting head.

III - 14 - SHIPPING THE STANDARD

When shipping the standard, the special shipping crates provided should be used.

1 - Follow moving the standard instructions 1-5 on previous page.
2 - Completely screw in the four adjustable feet.
3 - Put the standard, the piston-cylinder, and the masses in their carrying cases.
4 - Store the standard's accessories in the top of the standard's case.
5 - Pack all the cases in their shipping crates.

IV - 15 - STORING THE STANDARD

Follow shipping the standard instructions 1-5 above. Storage temperature: -15°C +65°C (+5 to +150°F).

CHAPTER IV

METROLOGICAL THEORY OF THE PRESSURE STANDARD

IV - 1 - FUNDAMENTAL THEORY

IV - 1 - 1 - General

The formula which gives the pressure at the reference level of the standard is:

$$P = \frac{Mg\left(1 - \frac{\rho a}{\rho m}\right)}{S_{(\theta,P)}}$$

Where:
- P: pressure
- M: total mass on the piston
- g: acceleration due to gravity
- ρa: air density
- ρm: mass density
- $S_{(\theta,P)}$: effective area of the piston cylinder at temperature θ and pressure P.

The expression $1 - \frac{\rho a}{\rho m}$ is the correction due to the effect of air buoyancy on the masses. Under standard gravity and air density conditions, pressure is defined as:

$$P = \frac{M\ gn\left(1 - \frac{\rho a}{\rho m}\right)}{S_{(\theta,P)}}$$

Where:
- gn: $9.80665 m/s^2$ (standard gravity)
- ρa: air density at 20°C and atmospheric pressure of 1013.25mbar: $1.2 kg/m^3$
- ρm: density of stainless steel: $7920 kg/m^3$.
- $S_{(\theta,P)}$: effective area of the piston-cylinder at temperature θ and pressure P.

In writing:

$$K_{N(\theta,P)} = \frac{gn\left(1 - \frac{\rho a}{\rho m}\right)}{S_{(\theta,P)}} \qquad (1)$$

One obtains:

$$P = K_{N(\theta,P)} \times M \qquad (2)$$

The effective areas of DH piston-cylinders is such that K_N is a whole number when θ = 20°C and P = 0 psig.

$K_{N(20,0)}$ is called the normal conversion coefficient. It is a whole number for each piston-cylinder such that under standard conditions a mass of 1kg is put into equilibrium by a pressure of $K_{N(20,0)}$ psi or $K_{N(20,0)}$ bar.

Piston-cylinders, for this model, are available with the following $K_{N(20,0)}$:

Measurements in psi

$K_{N(20,0)}$ = 100psi/kg
$K_{N(20,0)}$ = 200psi/kg
$K_{N(20,0)}$ = 300psi/kg
$K_{N(20,0)}$ = 500psi/kg

Measurements in bar

$K_{N(20,0)}$ = 5bar/kg
$K_{N(20,0)}$ = 10bar/kg
$K_{N(20,0)}$ = 20bar/kg
$K_{N(20,0)}$ = 50bar/kg

IV - 1 - 2 - Correction for acceleration due to gravity

At the location where the standard is used, the local gravity gl is usually different from standard gravity gn.

This gives:

$$P = \frac{M\, gl \left(1 - \frac{\rho a}{\rho m}\right)}{S_{(\theta,P)}}$$

By writing:

$$K_{1(\theta,P)} = \frac{gl \left(1 - \frac{\rho a}{\rho m}\right)}{S_{(\theta,P)}} \qquad (3)$$

From which:

$$K_1(20,0) = \frac{gl \left(1 - \frac{\rho a}{\rho m}\right)}{S_{(20,0)}}$$

One can write:

$$K_{1(20,0)} = \frac{gl\left(1 - \frac{\rho a}{\rho m}\right)}{S_{(20,0)}} = \frac{gn\left(1 - \frac{\rho a}{\rho m}\right)}{S_{(20,0)}} \times \frac{gl}{gn} = K_{N(20,0)} \frac{gl}{gn} \qquad (3')$$

With:

$$Cg = \frac{gl}{gn}$$

Cg is the gravity correction. This value can be found in the Cg annex.

$K_{1(20,0)}$ is called the local conversion coefficient, which is defined by the piston-cylinder used and the location of use.

For a given location K_1 is a constant:

$$K_{1(20,0)} = K_{N(20,0)} \times Cg \qquad (4)$$

IV - 1 - 3 - Correction of effective areas as a function of temperature and pressure

When the temperature is other than 20°C and the guage pressure other than zero, the change in effective area is defined by the following formula:

$$S_{(\theta,P)} = S_{(20,0)} [1+ (\alpha C + \alpha P)\ (\theta - 20)]\ (1 + \lambda P) \qquad (5)$$

Where:

$S_{(\theta,P)}$:	effective area at temperature θ and pressure P.
$S_{(20,0)}$:	effective area at temperature 20°C and pressure 0 psi.
αC:	thermal expansivity of the cylinder.
αP:	thermal expansivity of the piston.
θ:	temperature.
λ:	distortion coefficient of the effective area with pressure.
P:	pressure.

IV - 1 - 4 - General formula

From the formulas (3), (3') and (5) we obtain:

$$K_{1(\theta,P)} = K_{1(20,0)} [1 - (\alpha P + \alpha C)\ (\theta - 20)]\ (1 - \lambda P)$$

If $C_\theta = 1 - (\alpha P - \alpha C)\ (\theta - 20)$ one obtains $K_{1(\theta,P)} =$

$$K_{1(20,0)}\ C_\theta\ (1 - \lambda P) \qquad (6)$$

C_θ is the correction coefficient for temperature. This value can be found in the annex. Using formulas (6) and (4), it is possible to calculate P.

$$K_{1(20,0)} = K_{n(20,0)} \times Cg$$

$$P = K_{N(20,0)} \times Cg \times C_\theta \times (1 - \lambda P) \times M$$

IV - 1 - 5 - Fluid head correction

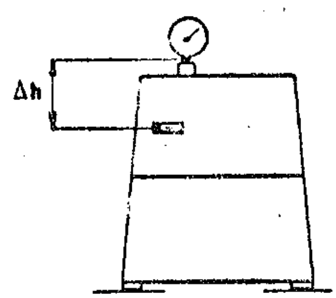
The calculations on the previous page define the pressure at the bottom of the piston. The position of the bottom of the piston, when the piston is in mid-float position, is identified by a label "reference level" on the standard's housing.

Generally, the instrument under test is not at the same height as the standard's reference level. Therefore, a correction defined by the following formula must be made:

$$P = \rho \times g \times h$$

Where:

	P:	fluid head correction.
	ρ:	density of the fluid at operating pressure P.
	Δ:	difference in height between the reference levels of the standard and the instrument under test.
	g:	acceleration due to gravity



The ΔP correction is negative if the instrument under test is above the standard's reference level:

P instrument under test = P standard $-\Delta P$.

The P correction is positive if the instrument under test is beneath the standard's reference level.

P instrument under test = P standard + ΔP.

IV - 2 - PRESSURE CALCULATION

The following parameters are given with the standard:

- $S(mes)_{(20,0)}$: Measured effective area at 20°C and 0 guage pressure.
- $K_{N(20,0)}$: Normal conversion coefficient at 20°C and 0 guage pressure.
- αP: Thermal expansivity of the piston.
- αC: Thermal expansivity of the cylinder.
- λ: Distortion coefficient of the piston-cylinder.
- Ro: Resistance value of the RTD at 0°C.

Pressure is calculated as follows:

IV - 2 - 1 - Calculation of the local conversion coefficient at 20°C and 0 guage pressure

$$K_{1(20,0)} = K_{N(20,0)} \times Cg$$

- Cg: correction coefficient for gravity for a given location.
- $K_{1(20,0)}$ is a constant for one location.

IV - 2 - 2 - Calculation of the pressure at the reference level of the standard

$$P = K_{1(\theta,P)} \times M$$

Where: $K_{1(\theta,P)} = K_{1(20,0)} \times C_\theta \times (1-\lambda P)$

- M: total mass on the piston.
- P: the value of P used to calculate $K_{1(\theta,P)}$. This value can be calculated using nominal values as follows:

$$P = K_{1(20,0)} \times M$$

With: $\theta = \frac{R\theta - Ro}{0.389}$

IV - 2 - 3 - Calculation of the pressure at the height of the instrument under test

P instrument under test = P standard $+\Delta P$. ΔP is the fluid head correction which can be positive or negative.

IV - 2 - 4 - Simplified calculation of the pressure

For calculations where maximum accuracy is not imperative, since the value of the distortion coefficient is very small, a median conversion coefficient can be used.

$$K_{1(\theta, \frac{Pmax}{2})} = K_{1(20,0)} - C_\theta \left(1 - \frac{\lambda Pmax}{2}\right)$$

The maximum additional uncertainty on a pressure measurement is $\pm \frac{Pmax}{2}$

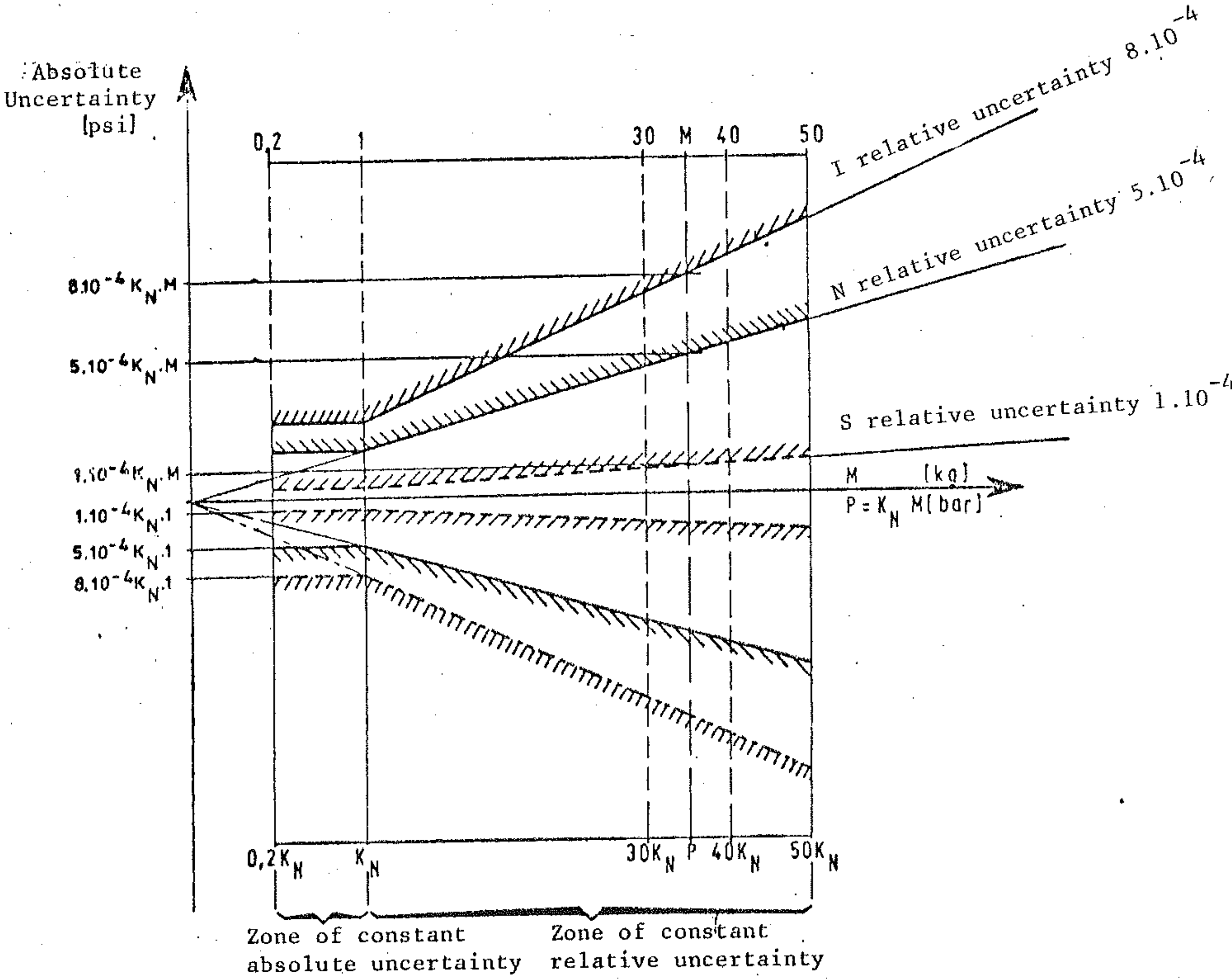
IV - 3 - ACCURACY OF THE PRESSURE STANDARDS

The accuracy class of a pressure standard defines the relative uncertainty on a measured pressure.

The lower limit is the pressure which puts into equilibrium 1kg of mass, which is a value equal to the K_N of the piston-cylinder used. 1kg is defined by the mass of the piston + the mass of the mass carrying bell.

At 1kg and above, there is enough rotation inertia to assure good mobility of the piston. In addition, the piston displacement indicator can be used.

Reference pressures between 0.2kg (the piston alone) and 1kg (piston + bell) can be defined. In this range however, there is a constant absolute error equal to the relative error on the pressure defined by 1kg.



IV - 4 - TEMPERATURE PROBE (S and S^2 accuracy only)

IV - 4 - 1 - Measuring principal

In the range of 0 - 40°C, the temperature is proportional to the change in resistance of the platinum RTD following the formula:

$$\theta = \frac{Re-Ro}{0.389}$$

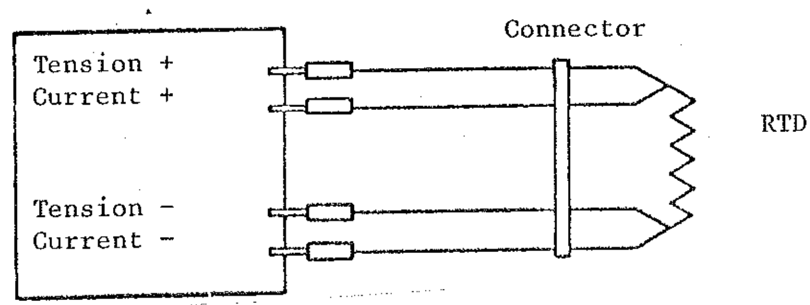
Where:
- θ: temperature in degrees C.
- Re: read resistance of the platinum RTD at temperature θ.
- Ro: resistance of the platinum RTD at 0°C (supplied by DH).
- 0.389: conversion coefficient of ohms to degrees C following DIN norm 43760.

The resistance used must be the resistance of the platinum RTD only excluding the resistance of the read-out cable. This is why a four wire cable is used.
- Two wires are used to give a constant power supply to the RTD (5mA max).
- Two wires are used to measure the resistance of the RTD.

IV - 4 - 2 - Measurements

A) Using an ohmmeter allowing 4 wire measurement. In this case, there is a direct read-out of the R value.

- Connecting the temperature probe
  1) Connect the read-out cable to the receptacle on the back of the standard.
  2) Connect the 4 plugs of the cable to a digital ohmmeter (supply current must not exceed 5mA).



  3) The ohmmeter should be calibrated to read a value of about 100 ohm with an accuracy of ± 0.01ohm.

- Example of a calculation
  Value read on the ohmmeter: 107.32 Ω.
  Ohmic resistance at 0°C: 99.98 Ω.

$$\theta = \frac{107.32 - 99.98}{0.389} = 18.87°C$$

B) Using an ohmmeter allowing only 2 wire measurements. The resistance measured is the resistance of the RTD plus the resistance of the connecting leads. To diminish the effect of the resistance of the connecting leads, leads R_1 and R_2 and leads R_3 and R_4 should be connected in parallel.

R_1 red plug
R_2 red plug -- same end of the RTD

R_3 blue plug
R_4 blue plug -- same end of the RTD

Since the length of the leads is approximately equal, we can say:

$$R_1 = R_2 = R_3 = R_4$$

When the leads are in parallel, the effect of the resistance of the leads in the measurement is:

$\frac{R_1 + R_2}{4}$ for leads R_1 and R_2

$\frac{R_3 + R_4}{4}$ for leads R_3 and R_4

given: $$\frac{R_1 + R_2}{4} + \frac{R_3 + R_4}{4}$$

Therefore, from the value measured in 2 leads, the value: $$\frac{R_1 + R_2 + R_3 + R_4}{4}$$

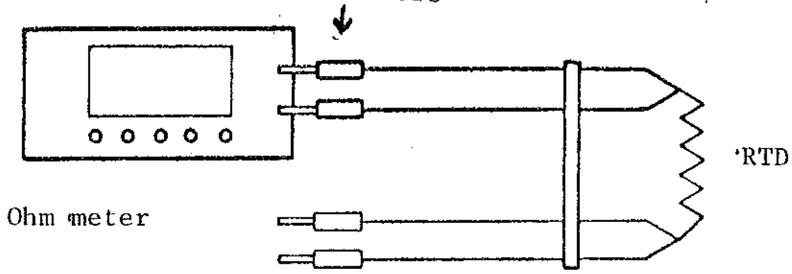
must be subtracted to obtain the value of the resistance of the RTD.

1) Determination of the $R_1 + R_2$ resistance value (red plugs)

- Put the ohmmeter in measuring mode.
- Connect the temperature probe cable to the receptacle on the standard.
- Measure the resistance between the two red leads.
- Read the value (about 0.3Ω).

2) Determination of the $R_3 + R_4$ resistance value (blue plugs)

Proceed as for $R_1 + R_2$ on previous page using the blue plugs rather than the red plugs. Resistance should be about 0.3 Ω.



3) Measuring the resistance of the RTD to determine the temperature.

- Put into parallel the two red plugs by plugging one into the other.
- Put into parallel the two blue plugs by plugging one into the other.
- Connect the red plugs and blue plugs to the ohm-meter (take care that there is no contact between the red and blue plugs).
- Read the resistance value (about 107 Ω)

$$R = R_\theta - \left(\frac{R_1 + R_2}{4} + \frac{R_3 + R_4}{4} \right)$$

4) Temperature calculation.

$$Re = R - \left(\frac{R_1 + R_2}{4} + \frac{R_3 + R_4}{4}\right)$$

$$\theta = \frac{Re - Ro}{0.389}$$

5) Example of temperature calculation.

Measure: $R_1 + R_2 = 0.3\,\Omega$ (following B1)
$R_3 + R_4 = 0.4\,\Omega$ (following B2)

$$R_\theta - \frac{(R_1 + R_2)}{4} + \frac{(R_3 + R_4)}{4} = 107.5\,\Omega \text{(following B3)}$$

from which: $$Re = 107.5 - \left(\frac{R_1 + R_2}{4} + \frac{R_3 + R_4}{4}\right)$$

$$Re = 107.5 - \left(\frac{0.3}{4} + \frac{0.4}{4}\right)$$

$$Re = 107.5 - (0.08 + 0.1)$$

$$Re = 107.5 - 0.18$$

$$Re = 107.32\,\Omega$$

For ohmic resistance of the RTD at 0°C of 99.98 (value furnished by DH given on a stamped label on the back of the standard and in the Standard's Technical Data) the temperature is:

$$\theta = \frac{Re - Ro}{0.389} = \frac{107.32 - 99.98}{0.389} = 18.87°C$$

Remark:

- For a given RTD cable used with a given standard, the values $R_1 + R_2$ and $R_3 + R_4$ are constants.
- Using a different cable on the same standard or vice-versa, changes the values of $R_1 + R_2$ and $R_3 + R_4$.
- The temperature value obtained using this method is accurate to ± 1°C which corresponds to ± 0.001% on the effective area of the piston.

CHAPTER V

Trouble-Shooting

V - 1 - POOR PISTON MOBILITY

- Dirty piston-cylinder
  Remove and clean the piston-cylinder (see Chapter III, 2-2)

V - 2 - PISTON DOES NOT ROTATE

1) Bad connection of the motor power supply cable.
2) Blown fuse (see Chapter II, 3).
3) Slip or deterioration of the drive belt - reinstall or replace drive belt (see Chapter VI, 3).
4) Burned out motor - replace the electrical assembly (see Chapter II, 3).

V - 3 - ABERRANT MEASUREMENTS

- Purge air from the hydraulic circuits (see Chapter III, 2-5).

V - 4 - IMPURITIES PRESENT IN THE SYSTEM

1) Purge oil through the sump (see Chapter II, 3).
2) If the system is too polluted, completely purge of the standard and refill using new oil (see Chapter II, 3).

V - 5 - POOR PRESSURE STABILITY

There is a leak in the hydraulic circuit.

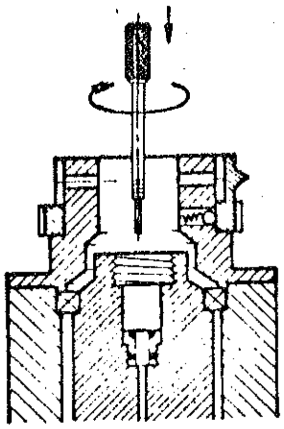
A) The leak can be located by observation.
   1) Sump drain cock: tighten the sump drain cock (see Chapter II, 3).
   2) Quick-connecting head: replace the connecting head O-ring assembly (see Chapter VI, 2).
   3) Measuring post: the oil run off cup fills rapidly. Change the measuring post O-ring assembly (see Chapter VI, 1).
   4) Loose gland nut in the hydraulic circuit: tighten the nut (No. 12 metric wrench).
      NOTE: Do not tighten nut with pressure applied.

B) The leak cannot be located by observation.
   1) Priming pump: replace the outlet check valve (see Chapter II, 3)
   2) Reservoir shut-off valve: isolate the reservoir shut-off valve by putting a plug on T No. 2 (see Chapter VII). Increase the pressure using the priming pump. If the leak in the system is no longer present, change the valve (see Chapter II, 3).

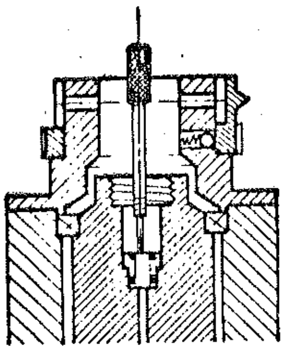
NOTE: Manufacturer's reference numbers of the sub-assemblies are given in Chapter II, 2.

CHAPTER VI - MAINTENANCE

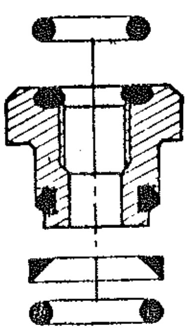
VI - 1 - CHANGING THE MOUNTING POST O-RING ASSEMBLY NO. 41096



1 - Remove the cylinder and screw the special tool into the O-ring assembly.



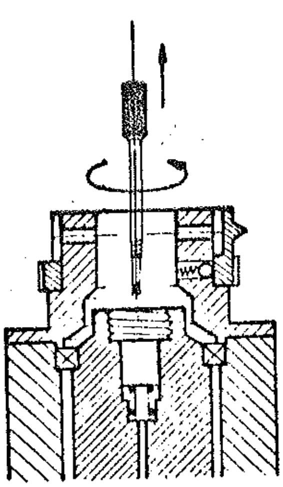
2 - Pull the tool upwards to extract the O-ring assembly.



The upper O-ring is an "R 5a".

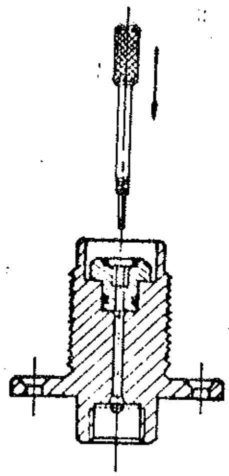
The anti-extrusion ring is ref. no. 36871.

The lower O-ring is an "R 6".

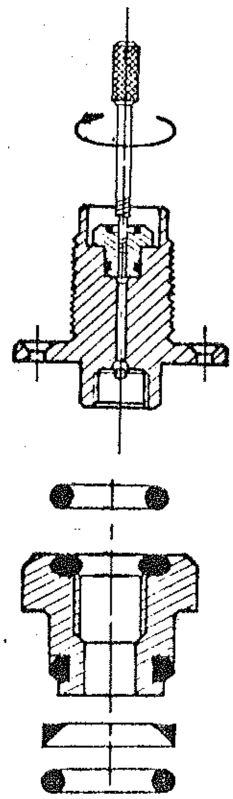


3 - Screw a new O-ring assembly onto the special tool, push it into place in the mounting post and unscrew and remove the special tool.

VI - 2 - CHANGING THE QUICK-CONNECTING HEAD O-RING ASSEMBLY NO. 41087



1 - Remove the knurled nut from the quick-connecting head.



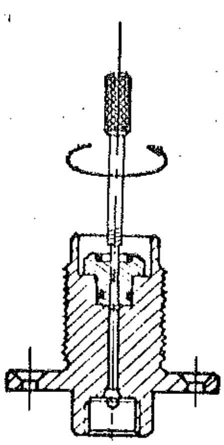
2 - Screw the special tool into the O-ring assembly and pull upwards to remove the O-ring assembly.

The upper O-ring is an "R 4".

The O-ring assembly is ref. no. 41087.

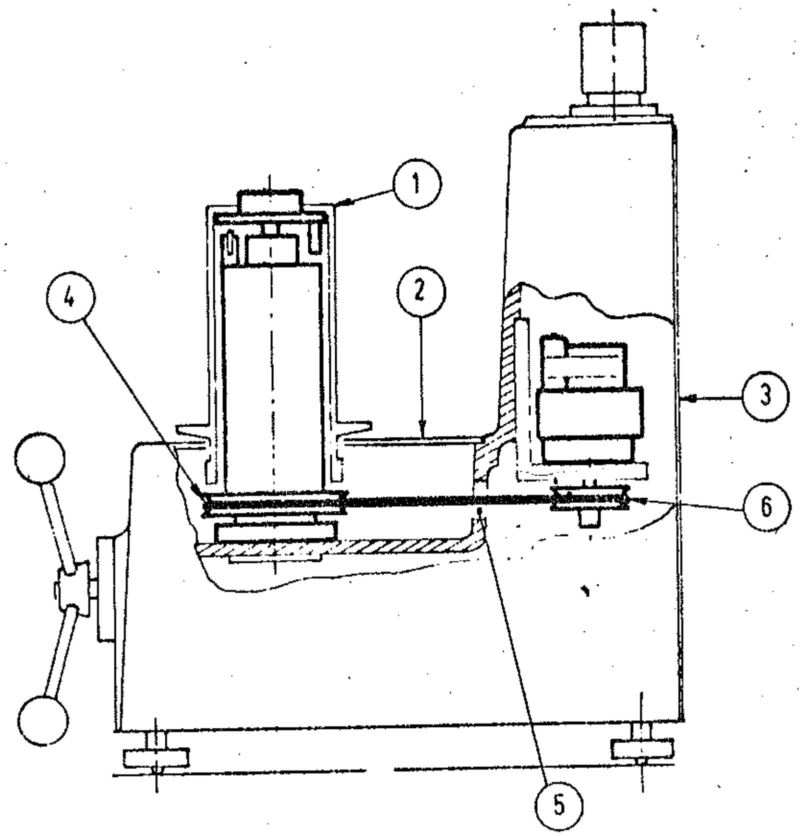
The anti-extrusion ring is ref. no. 40900.

The lower O-ring is an "R 5".



3 - Screw a new O-ring assembly onto the special tool and push it into the quick-connecting head. Unscrew the special tool.

VI - 3 - REPLACING THE DRIVE BELT



1) Remove the mass carrying bell (1), the upper cover (2) and the rear cover (3).

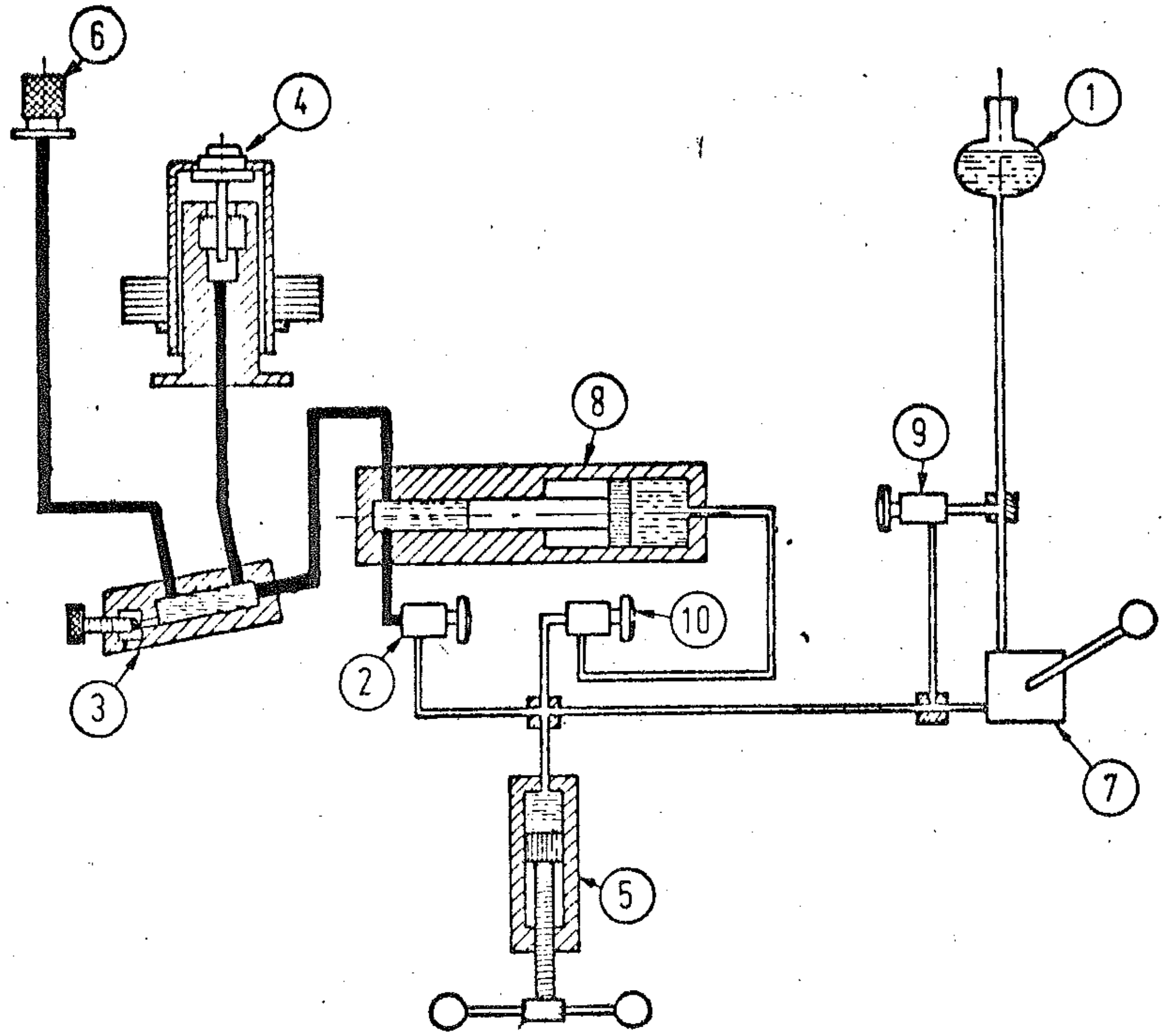
2) Remove the used belt.

3) Slip the new belt over the pulley (4) and position it in the groove. Pass the belt through the opening (5) and position it in the groove of the motor pulley (6).

4) Reinstall the protective covers, (2) and (3).

CHAPTER VII

HYDRAULIC CIRCUIT SCHEMATIC



1 - Oil Reservoir
2 - High pressure shut-off valve
3 - Sump
4 - Mounting post
5 - Variable volume screw press
6 - Quick-connecting head
7 - Priming pump
8 - Intensifier
9 - Reservoir shut-off valve
10 - Low pressure shut-off valve

High pressure circuit
(maximum pressure 75,000psi)

Low pressure circuit
(maximum pressure 20,000psi)