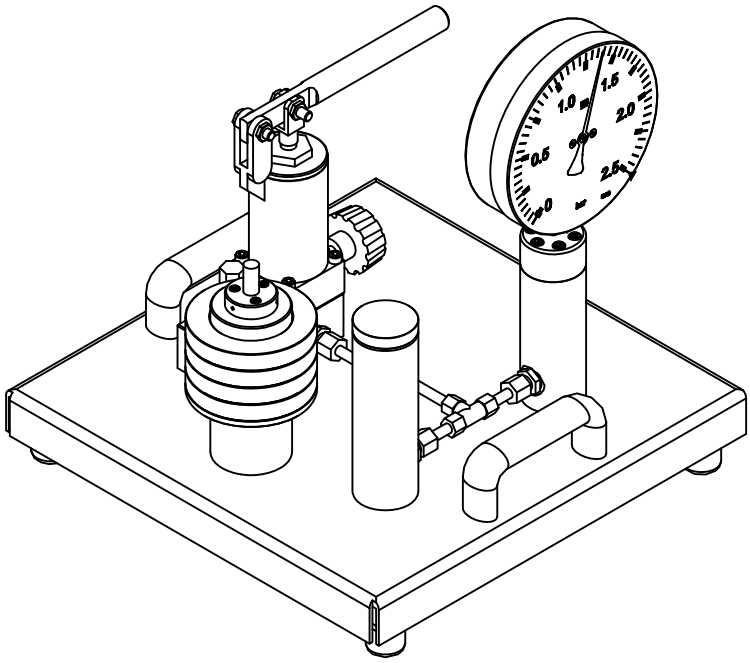
Experiment Instructions

HM 150.02 Dead-Weight Piston Gauge



Experiment Instructions

This manual must be kept by the unit.

Before operating the unit:
- Read this manual.
- All participants must be instructed on handling of the unit and, where appropriate, on the necessary safety precautions.

Table of Contents

1 Introduction

The G.U.N.T. Dead-Weight Piston Gauge is used to introduce to students the principles of checking and adjusting of manometers - (calibrating principles).

The pressure is applied via weights which are placed on a weight support. The latter has a piston which acts on hydraulic oil in a pipe system, so that a manometer which is also connected to the system should indicate certain pressures.

The device contains a Bourdon spring manometer with a transparent dial. The display mechanism and the various adjustment opportunities are therefore clearly identifiable.

Hydraulic oil is used to transfer pressure.

2 Safety

2.1 Intended Use

The unit is to be used only for teaching purposes.

2.2 Structure of the Safety Instructions

The signal words DANGER, WARNING or CAUTION indicate the probability and potential severity of injury.

An additional symbol indicates the nature of the hazard or a required action.

Signal word	Explanation
⚠ DANGER	Indicates a situation which, if not avoided, **will** result in **death or serious injury**.
⚠ WARNING	Indicates a situation which, if not avoided, **may** result in **death or serious injury**.
⚠ CAUTION	Indicates a situation which, if not avoided, may result in **minor or moderately serious injury**.
NOTICE	Indicates a situation which may result in **damage to equipment**, or provides instructions on **operation of the equipment**.

Symbol	Explanation
	Notice

2.3 Safety Instructions

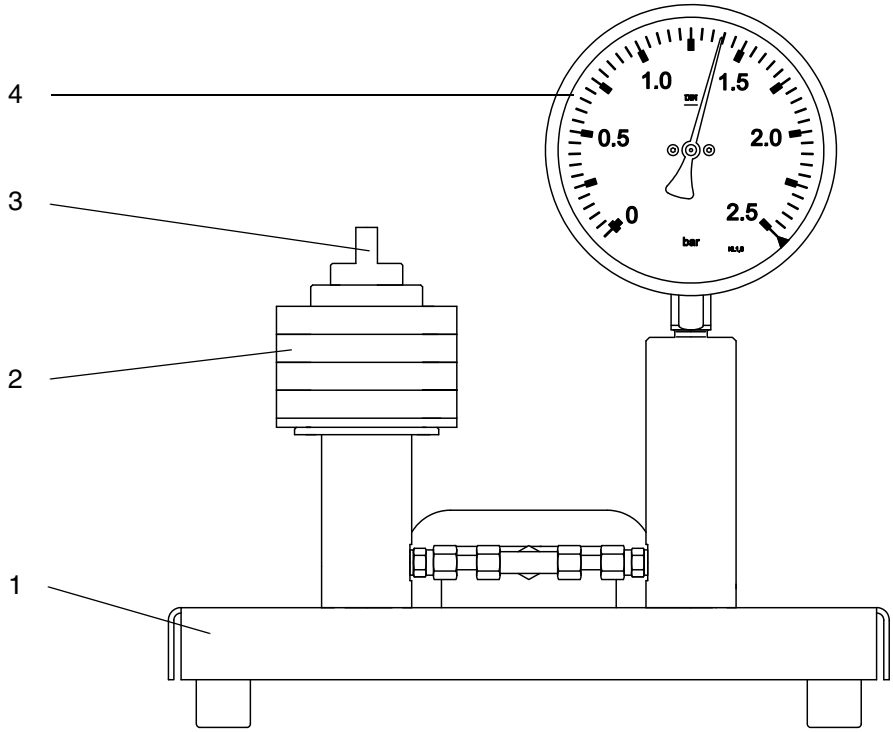
NOTICE

Please note for transport:

- For transport, take the ram out of the load unit. When doing this, take care not to scratch the cylinder or even score it. Such damage would lead to loss of the metal-to-metal seal.
- During transportation, the load unit should be closed off with the cap provided, so that no oil escapes. When fitting and removing the cap it may be necessary to operate the compensation cylinder hand lever.
- Pressurised oil could spray out of the opening.
- The transparent dial and the front glass of the spring-tube pressure gauge are made of glass and can break.

3 Unit Descriptiont

3.1 Unit Layout



1 Base plate
2 Weights
3 Weight support
4 Manometer

Fig. 3.1 Layout HM 150.02

The device for calibrating pressure gauges essentially consists of two units:

1. The pressure gauge unit
   This is where the manometer to be calibrated is screwed in.

2. The load unit
   The load unit consists of several weights and a cylinder with a piston. An increase in the load results in an increase in pressure. The load unit is connected to the pressure gauge unit via an oil-filled line, enabling the manometer to display the increase in pressure.

The following sectional drawing shows how the load unit and pressure gauge unit are connected:

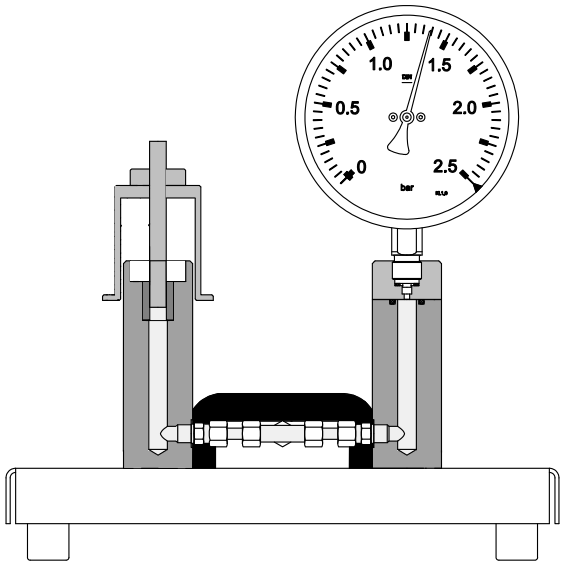


Fig. 3.2 Hydraulic connections

As you can see, both units are connected by means of a pipeline. When the support is loaded with weights, the oil pressure in the system increases. The seal between the piston and the cylinder is metallic, with no other sealing elements. The fit has been very carefully designed to

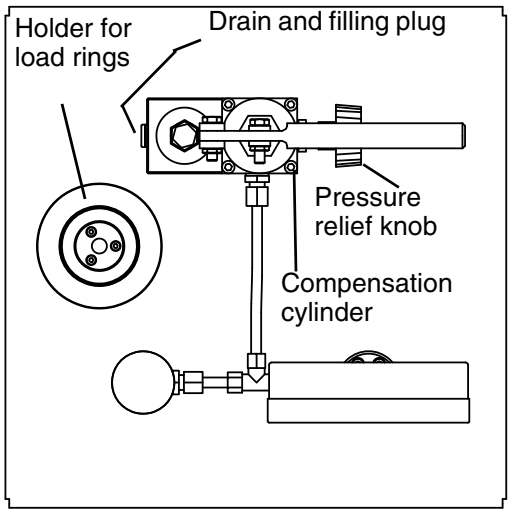


Fig. 3.3 Top view

ensure that the piston operates almost entirely without friction, and with minimal oil leakage.

The weights are designed in such a way that pressure increments of 0,5 bar are possible.

Place the small weight on the weight support first. A guide pin is provided for this purpose.

The other weights would lie askew on the plunger, and would corrupt the measurements due to different levels of friction.

The unit is also equipped with a drain and filling plug in order to drain or fill the oil.

The compensation cylinder can be used to raise and lower the weight load on the oil cushion of the hydraulic oil. For the measurements, the load must be kept on the oil cushion so that the pressure is applied in the hydraulic system.

After unscrewing the pressure relief knob, the weight load can be brought down until it is supported.

The hydraulic is then relieved of the load.

In addition, the compensation cylinder can be used to easily check the oil level and top it up if required.

NOTICE

Do not replace the pressure gauge. Oil can only be refilled using a vacuum.

3.2 Removing the transport protection

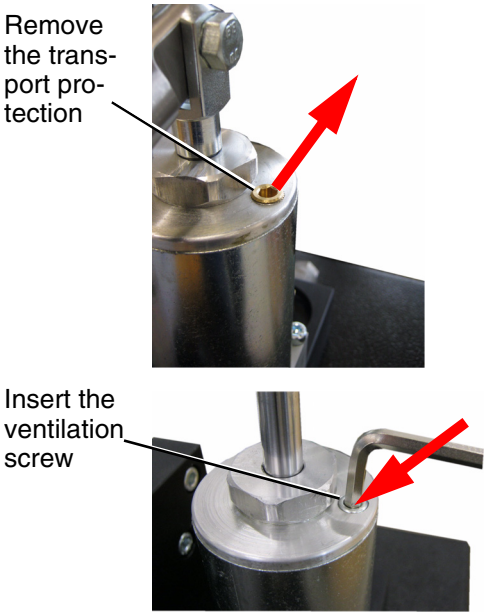


Abb. 3.4 Replace the transport protection with the ventilation screw

Before the compensation cylinder can be used, the transport protection must be replaced with the ventilation screw provided.

1. To do so, loosen the transport protection using the hexagon socket wrench provided and unscrew completely. Keep the transport protection in a safe place in case of subsequent transportation.

2. Place the ventilation screw provided in the now empty tapped hole and tighten using the hexagon socket wrench provided.

In the event of subsequent transportation, reinstall the transport protection in place of the ventilation screw. To do so, follow this procedure in the reverse order.

3.3 Remove and Insert Transport Cap

The transport cap is held in the cylinder by an O-ring, not by a thread.

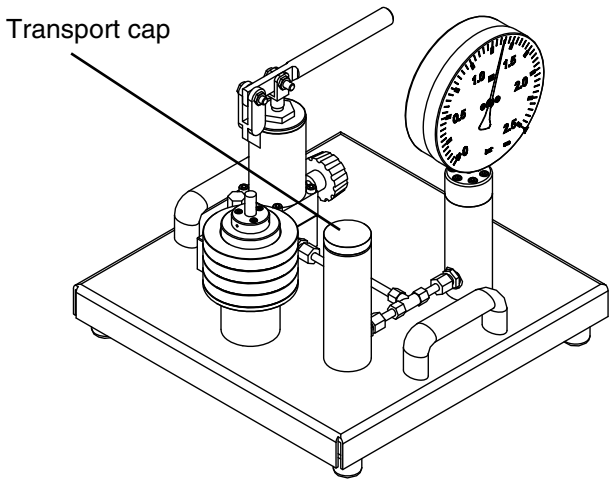


Fig. 3.5

Remove transport cap:

- Push the compensation cylinder hand lever until the pressure increases.
- Hold the transport cap securely and push the hand lever further until the transport cap is loose and can be removed.

NOTICE

Pressurized oil may squirt out of the opening.

Insert transpor cap:

- Place transport cap in place.
- Unscrew the pressure relief knob then press on the transport cap.
  Screw the pressure relief knob back in.

3.4 Starting

- If necessary, top up oil (Chapter 3.6) and check zero balance (Chapter 3.5).
- Push the hand lever down until the cylinder is filled up to the brim (Fig. 3.8).
- Insert the piston.

3.5 Zero Balance

To check the zero point of the manometer, proceed as follows:

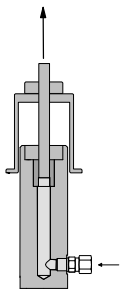


Fig. 3.6 Cylinder with piston

- Push the hand lever down so that the piston is pushed out of the cylinder.

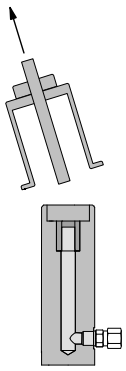


Fig. 3.7 Cylinder with piston and weight carrier

- Remove the piston and weight support.

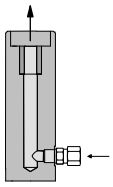


Fig. 3.8 Adjusting the oil level

- Adjust the oil level in the open cylinder until the cylinder is filled up to the edge.

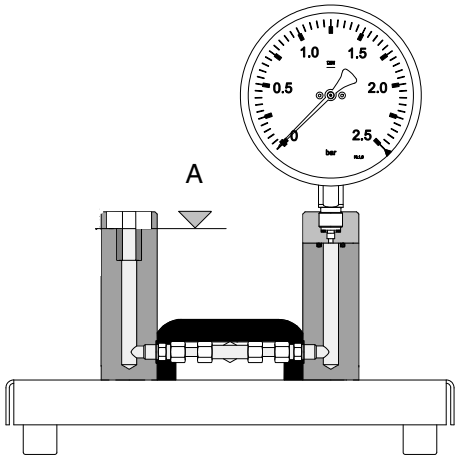


Fig. 3.9 Oil level (A)

- The manometer being tested should now indicate zero, as it is only subject to ambient pressure.
  If this is not the case, the pointer on the pressure gauge can be adjusted with a small screwdriver. For this, remove the front glass by turning the front ring.

NOTICE

The transparent dial of the spring-tube pressure gauge are made of glass and can break.

3.6 Topping up the Hydraulic Oil

If despite repeatedly operating the hand lever the oil does not reach the brim of the cylinder, the oil must be topped up.

For this purpose, proceed as follows:

1. If you have not already done so, remove the piston with a weight support as described in Chapter 3.5, Page 9

2. Pull hand lever to its highest position
3. Unscrew pressure relief knob
4. Top up oil to the first ledge
5. Fit piston with weight support
6. Push down piston with weight support
7. Screw in pressure relief knob
8. Perform zero balance in accordance with Chapter 3.5, Page 9

3.7 Chaniging the Oil

- Remove the drain and filling plug (see Fig. 3.3)
- Drain the old oil, bleed if necessary.
- Make an additional screwed connection between the three-way valve and vacuum pump.

NOTICE

A vacuum pump and a three-way valve are not included in the content of supply.

- Open the three-way valve so that the vacuum pump generates a vacuum.
- Reverse the three-way valve to allow oil into the system.
- Then shut off the hydraulic system.

NOTICE

Do not replace the pressure gauge. Oil can only be refilled using a vacuum.

4 Basic Principles

The basic principles set out in the following make no claim to completeness. For further theoretical explanations, refer to the specialist literature.

4.1 Calibrating Pressure Gauges

Once the zero point of a manometer has been checked, the weight support is re-inserted into the cylinder of the pressure gauge unit.

To do this:

1. Unscrew pressure relief knob
2. Press down weight support
3. Screw in pressure relief knob

Press down the hand lever, thereby slowly lifting the piston with weight support until it just floats on the oil with sufficient guidance. In order to avoid static friction, set the weight support in gentle rotation. The mass of the support is 385 g. Taking into account the piston diameter of 12 mm, it is now possible to determine the increase in pressure according to the following basic formulae.

$$p = \frac{F}{A} \tag{4.1}$$

and

$$F = m \cdot g \tag{4.2}$$

A : Cross-sectional area of piston

d : Piston diameter

F : Force

p : Pressure

m : Mass of load unit

g : Gravity constant

This produces the following results:

e.g. $m = 0{,}385\,\text{kg}$

$$F = m \cdot g = 0{,}385\,\text{kg} \cdot 9{,}81\,\frac{\text{m}}{\text{s}^2} = 3{,}78\,\text{N}$$

$$A = \frac{\pi}{4} \cdot d^2 = \frac{\pi}{4} \cdot (12\,\text{mm})^2 = 113{,}1\,\text{mm}^2$$

$$p = \frac{F}{A} = \frac{3{,}78\,\text{N}}{113{,}1\,\text{mm}^2} = 0{,}0334\,\frac{\text{N}}{\text{mm}^2}$$

Other pressures occurring when the weight on the support is increased can be calculated in exactly the same way.

The display of 0,5bar is achieved by placing a weight with a mass of 193g on the support. The other weights weigh 578g, which is equivalent to a pressure increase of 0,5bar each time.

The following table shows the ratio of pressure to weights:

Mass *m* in kg	0	0,385	0,578	1,156	1,734	2,312	2,890
Pressure *p* in bar	0	0,334	0,5	1,0	1,5	2,0	2,5

Tab. 4.1

4.2 Accuracy Class Rating

The accuracy class rating describes the maximal percentage difference allowed between real and measured pressure, in relation of the end scale value. For an instrument of quality class 1,0 the max. allowed difference is +/- 1% from the end scale value. With a display range of 0...2,5bar and an accuracy class of 1,0, this gives a maximum permissible error of 0,025bar over the entire range of the scale.

5 Experiments

The selection of experiments makes no claims of completeness but is intended to be used as a stimulus for your own experiments.
The results shown are intended as a guide only. Depending on the construction of the individual components, experimental skills and environmental conditions, deviations may occur in the experiments. Nevertheless, the laws can be clearly demonstrated.

5.1 Preparation of Experiment

- Remove the transport cap.
- Top up with oil if necessary and check the zero signal.

5.2 Performing the Experiment

- Read off the zero signal on the pressure gauge, check it and make a note of it. See Chapter 3.4.
- Set the weight carrier to 0,334 bar by inserting the piston in the load unit cylinder.

To do this:

1. Unscrew pressure relief knob
2. Press down weight support
3. Screw in pressure relief knob

- Press down the hand lever, thereby slowly lifting the piston with weight support until it just floats on the oil with sufficient guidance. To avoid sticking due to static friction, gently twist

the weight carrier as it sinks. Note the pressure signal on the pressure gauge.

- Place the load ring for 0,166bar on the weight carrier. When so doing, make sure that the weight carrier floats freely on the oil. To minimise sticking due to static friction whilst performing this measurement, gently twist the weight carrier. Note the pressure signal on the pressure gauge.
- Add each of the other four load rings for 0,5bar in turn, repeating the action described above and noting the pressure values.

5.3 Evaluation

Weight of loads with pressure value	Measured pressure *p* in bar	Theoretical pressure p_{theo} in bar
0		0
0,385		0,334
0,578		0,5
1,156		1,0
1,734		1,5
2,312		2,0
2,890		2,5

Tab. 5.1

Pressure gauge characteristic curve:

The ideal result would be a linear characteristic curve in which the pressures printed on the weights (0...2,5bar) are displayed on the pressure gauge.

$$p = \frac{m \cdot g}{A} \qquad (5.1)$$

$$p = \frac{0{,}385\text{kg} \cdot 9{,}81 \frac{\text{m}}{\text{s}^2}}{113{,}1\text{mm}^2} = 0{,}0334 \frac{\text{N}}{\text{mm}^2}$$

$$p = 0{,}334 \cdot 10^5 \frac{\text{N}}{\text{m}^2} = 0{,}334\text{bar}$$

Load (with imprint) in kg	Measured pressure p in bar	Lower limit -1% in bar	Theoretical pressure p_{theo} in bar	Upper limit +1% in bar
0		-0,025	0	+0,025
0,385		+0,309	0,334	+0,359
0,578		0,475	0,5	0,525
1,156		0,975	1,0	1,025
1,734		1,475	1,5	1,525
2,312		1,975	2,0	2,025
2,890		2,475	2,5	2,525

Tab. 5.2

For graphical evaluation, the measured pressures and limit values are plotted in an x,y diagram (load against pressure).

6 Appendix

6.1 Technical Data

Dimensions

Length x width x height	400 mm x 400 mm x 400	mm
Weight	approx. 7	kg

Pressure gauge

Measuring range	0...2,5	bar
Accuary	Class 1,0	

Hydraulic oil

Type	HLP ISO 32	
Filling volume	approx. 500	ml
Top-up bottle	500	ml

Piston

Diameter	12	mm

Weights

1 weight carrier	385 g	→	0,334±0,002	bar
1 load ring	193 g	→	0,166±0,002	bar
4 load rings	578 g	→	0,5±0,002	bar

6.2 List of Symbols of Formulae and Units

Symbols of formulae	Mathematical / physical quantity	Unit
A	Piston area	mm^2
d	Piston diameter	mm
F	Force	N
g	Acceleration due to gravity	m/s^2
m	Mass (weight)	kg
p	Pressure	bar
p_{actual}	Actual pressure due to load	bar
p_{theo}	Theoretical pressure	bar

Unit	Pa	N/mm^2	bar
1 Pa = 1 N/m^2	1	10^{-6}	10^{-5}
1 N/mm^2	10^6	1	10
1 bar	10^5	0,1	1

Tab. 6.1 Conversion table for pressure units

6.3 Work Sheet

No.		Weight *m* in kg	Pressure *p* in bar
1	Open hydraulics		
2	+ carrier		
3	+ small load ring		
4	+ load ring		
5	+ load ring		
6	+ load ring		
7	+ load ring		