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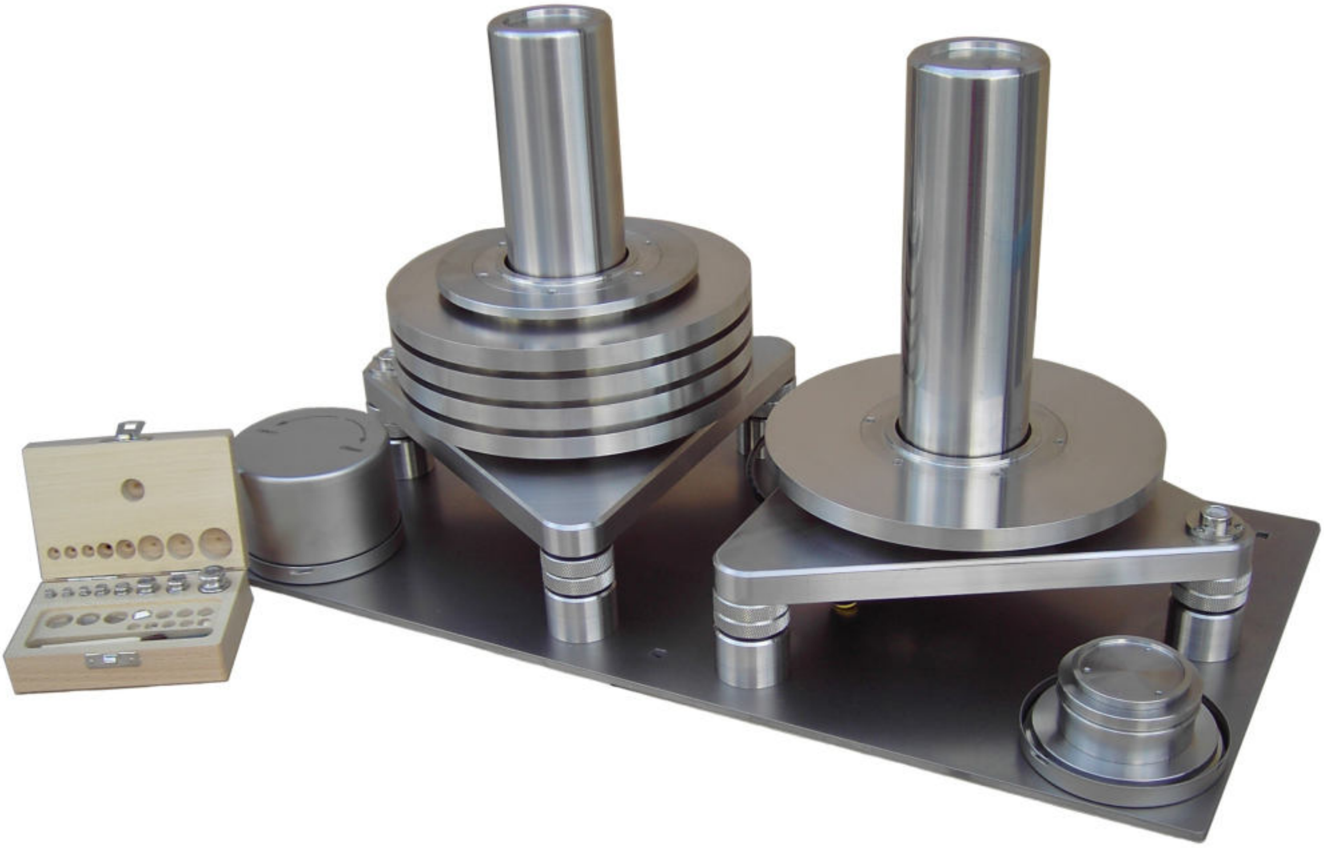
DGDP-001



pressure standard for high line differential pressure

STIKO
MEETAPPARATENFABRIEK BV

Table of Contents

1 introduction

1.1 general product description

The Stiko DGDP-001 Pressure Standard is a pneumatically operated twin deadweight tester used to calibrate test gauges, transducers and transmitters at line pressures up to 20 MPa. The system consists of the following main components :

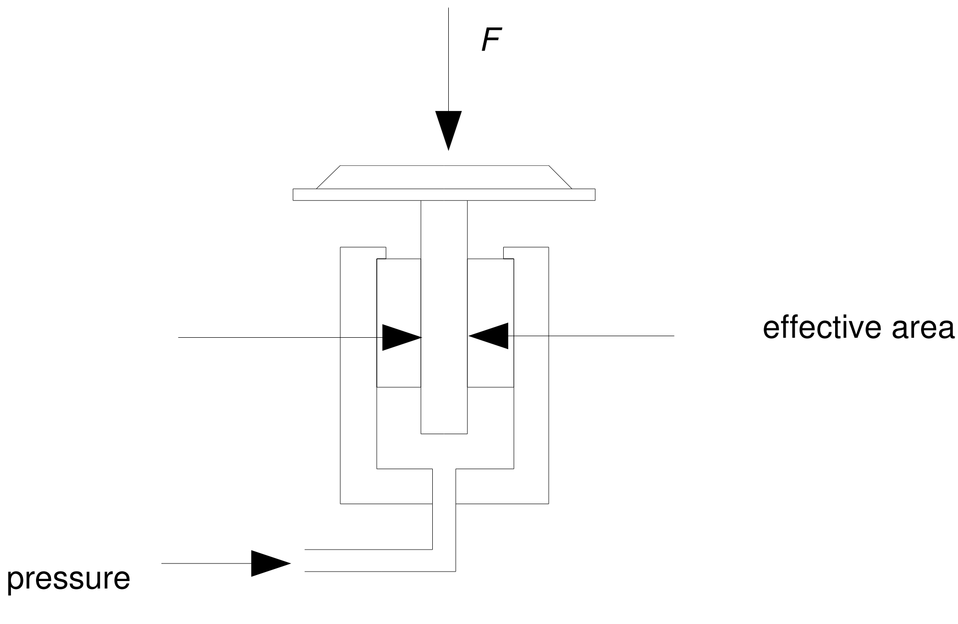
	master	slave
deadweight tester platform	x	x
piston cylinder assembly	x	x
mass set	x	x

To complete the system a dedicated pressure controller for differential pressure like the GPR200D plus interconnection hardware is necessary.

1.2 operating principle

The key components of the system are the master & slave mounting posts which combines the primary metrological elements :

1. the piston-cylinder which defines an effective area, *A*.
2. the masses, of global value *m*, which act upon the piston.



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

$$p_e = \frac{m_c \cdot (1-\rho_a / \rho_m) \cdot g_l}{A_{20} \cdot (1+(\alpha_p+\alpha_c) \cdot (t-20)} \cdot 10^{-3} \quad \text{[kPa]}$$

where

p_e	:	gauge pressure at reference level		[kPa]
m_c	:	conventional mass		[kg]
$1-\rho_a / \rho_m$	:	air buoyance correction	(= 0,99985)	[-]
g_l	:	local gravity		[N/kg]
A_{20}	:	effective area at 20 °C / mid pressure		[m²]
$\alpha_p+\alpha_c$	:	thermal expansion coëfficiënt piston + cylinder	(= 9.10^{-6})	[°C⁻¹]
t	:	piston cylinder temperature		[°C]

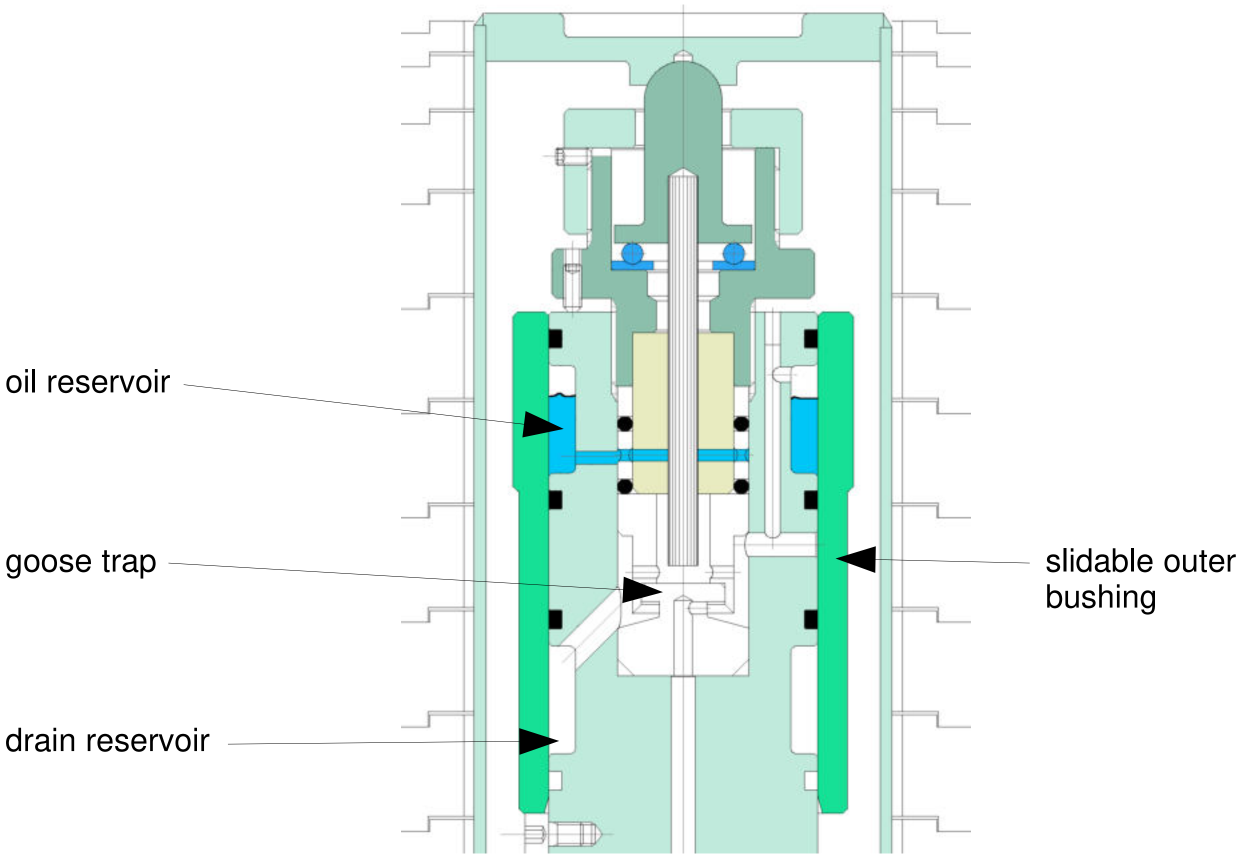
The oil lubricated / gas operated pistons of the DGDP series are specially designed to have superior performance at higher gas pressures without the problems of other types of pistons :

- gas lubricated / gas operated pistons cylinders

  These piston cylinders have better sensitivity then oil lubricated pistons, however the natural drop rate at higher line pressure make them difficult to operate. Oil lubricated pistons have no significant drop rate as the oil acts as a seal.

- oil lubricated /oil operated pistons with oil gas interface

  There are a lot of deadweight tester manufacturers who claim oil lubrication / gas operation, but they use a traditional oil / oil piston and an oil gas interface. The biggest and obvious disadvantage of this solution is that the surface level of the oil gas interface precisely has to be known. The added uncertainty especially in high line differential applications make this solution not the most obvious one. The piston cylinders of the DGDP series are really different. The oil is fed to the gap between piston and cylinder by means of an oil reservoir around the cylinder. As the oil surface is slightly higher than the entrance bore in the cylinder the oil pressure is also slightly higher than the gas pressure ensuring enough lubrication between piston and cylinder.

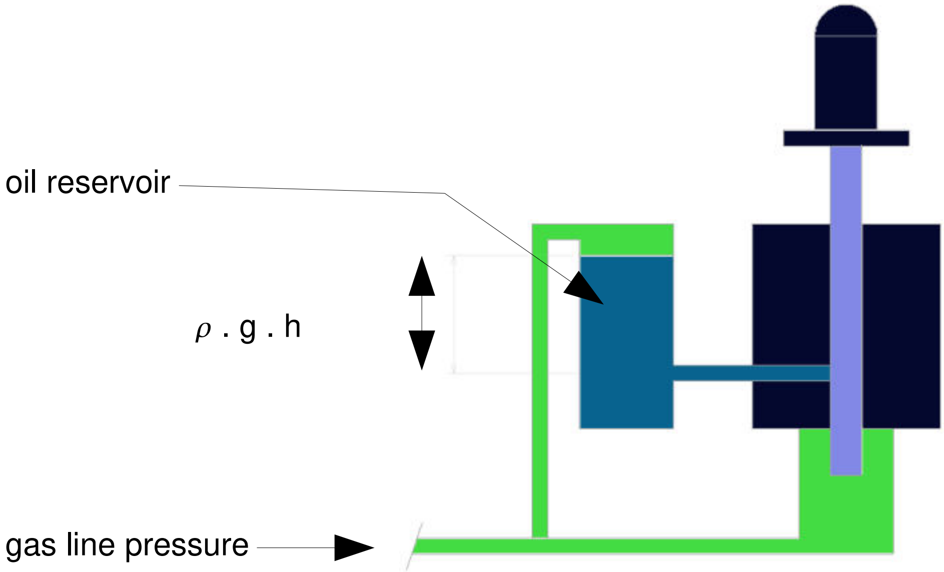


The main challenge of defining Δp at high line pressures comes from the very high ratio of line pressure to differential pressure. Relatively small errors and instabilities in the line pressure are very large relative to the differential pressure.

The principal of high line differential measurement with 2 pistons is to crossfloat the two pistons so that the force F defined by the masses divided by A_{eff} are in equilibrium with the line pressure. After the crossfloat is completed, a bypass valve is closed isolating the master piston from the slave piston. The slave piston maintains the line pressure. Mass is added to the master piston to define differential pressures “on top of” the line pressure. The intrinsic performance of the oil lubricated / gas operated piston cylinders allows to set and maintain a line pressure with uncertainty much lower than the overall measurement uncertainty on either piston. The master and slave piston are crossfloated at the line pressure prior to making differential measurement to minimize the contribution of line pressure errors to differential pressure.

The piston that is used only to maintain the line pressure on the low side of the device under test (DUT) is designated the slave. The slave is a standard DGDP-001 deadweight tester but it is normally used with a slave piston cylinder and a slave mass set. A slave piston cylinder has the same nominal effective area and performance as the master piston cylinder but is not calibrated. In fact during every crossfloat it is calibrated at one point. A slave mass set has the same configuration as a standard mass set but the exact values of the masses are not calibrated and all masses are adjusted slightly under the nominal value. This assures that the tare side always is the light side when crossfloated with the reference side.

! High line differential mode relies upon the very high sensitivity of oil lubricated / gas operated piston cylinders to set and stabilize low differential pressures relative to very high line pressures. To meet the full performance potential of high line differential mode operation, external influences on the piston gauges must be minimized. Oil contamination in tubing, air currents and vibrations are the most significant possible influences. Do not operate near an active air conditioning or heating duct, avoid opening and closing doors or any movement of personnel around the system. Consider putting the instrument in an electrostatic free enclosure if the environment cannot be adequately controlled.



2 general specifications

pressure range	0 .. 20	MPa g
differential pressure range	0 .. 20	MPa d
measurement uncertainty *p*	$1.10^{-4}.p_e$ + 10 Pa	
certification	standard delivered with ***EA***[1] certificate	
max. supply pressure	25	MPa g
pressure connections	¼" BSP female[2]	
platform	stainless steel triangle shape	
footprint base plate	600 x 320	mm
overall height	315	mm
lubricating oil	DWT oil 812	

2.1 piston cylinders

2.1.1 master piston cylinder

material piston + cylinder	tungsten carbide	
nominal piston diameter	5	mm
nominal Kn	500	kPa/kg
thermal expansion	9.10^{-6}	$^{o}C^{-1}$
type	re-entrant	
medium	gas operated / oil lubricated	
certification	***EA*** calibrated on effective area	

2.1.2 slave piston cylinder

material piston + cylinder	tungsten carbide	
nominal piston diameter	5	mm
nominal Kn	500	kPa/kg
type	re-entrant	
medium	gas operated / oil lubricated	
certification	none, selected on equal performance as master piston cylinder	

1 European Accreditation, see http://www.european-accreditation.org
2 on request MM quick connectors can be supplied

2.2 mass set

2.2.1 master mass set

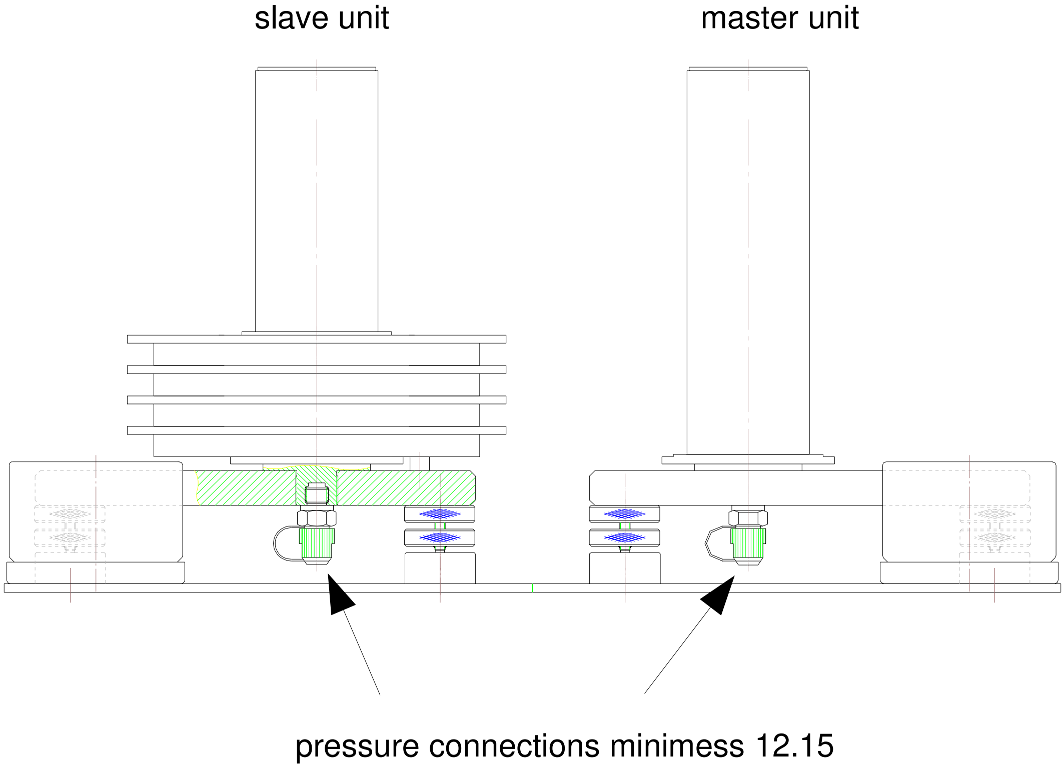
description		nominal mass	
mass carrier (piston mass included)		1	kg
	6 x	4	kg
	1 x	2	kg
	1 x	1	kg
	1 x	500	g
	2 x	200	g
	1 x	100	g
	1 x	50	g
	2 x	20	g
	1 x	10	g
	1 x	5	g
	2 x	2	g
	1 x	1	g
certification		***EA*** certification on conventional mass	

2.2.2 slave mass set

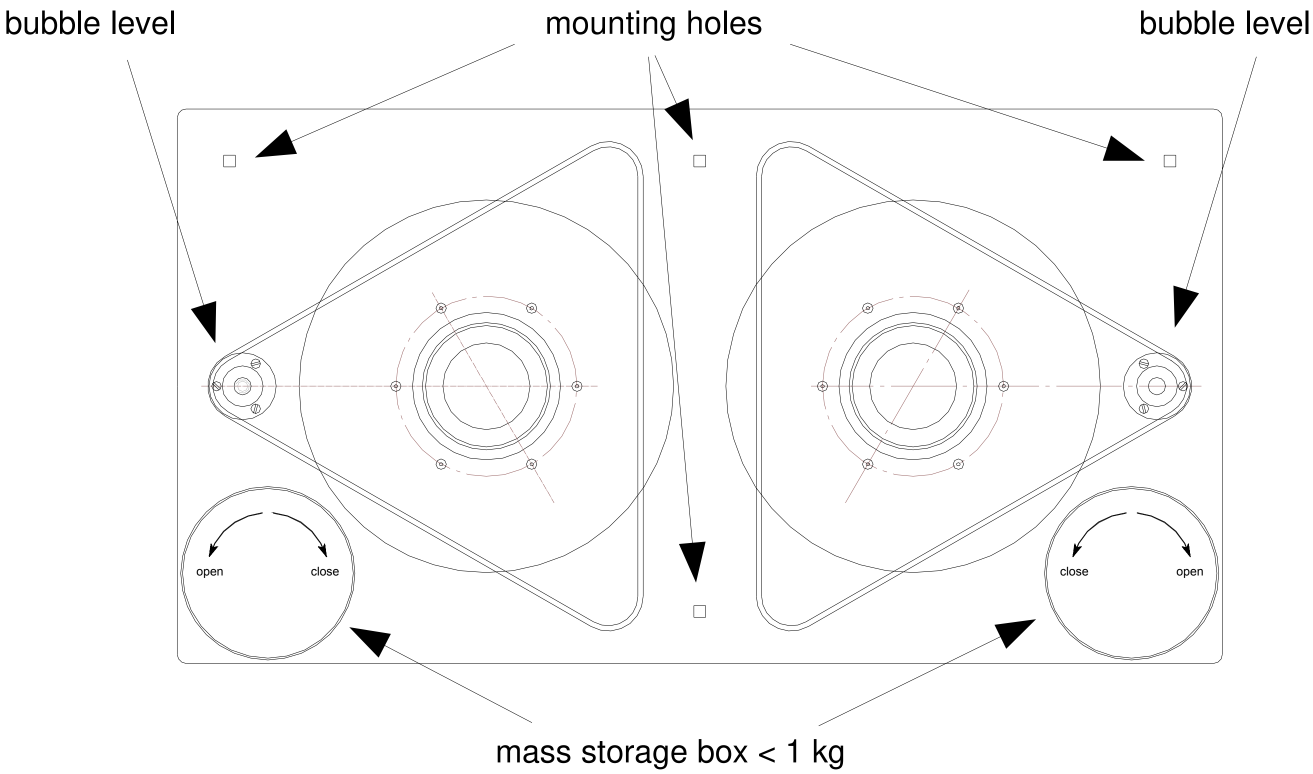
description		nominal mass	
mass carrier (piston mass included)		< 1	kg
	6 x	< 4	kg
	1 x	< 2	kg
	1 x	< 1	kg
	1 x	< 500	g
	2 x	< 200	g
	1 x	< 100	g
	1 x	50	g
	2 x	20	g
	1 x	10	g
	1 x	5	g
	2 x	2	g
	1 x	1	g
	1 x	500	mg
	2 x	200	mg
	1 x	100	mg
	1 x	50	mg
	2 x	20	mg
	1 x	10	mg
certification		none, masses tared below nominal mass	

2.3 instrument outline

2.3.1 front view



2.3.2 top view



3 installation

3.1 as received

The DGDP-001 is sealed in plastic and packed in an export quality carton box. When opening the box, check the contents against the scope of delivery.

! As the piston cylinder mounting system is specially designed to protect the piston, they are normally mounted into the mounting post with a plastic transport cap. This protection is sufficient for transport and long term storage.

! The DGDP-001 is transported without lubricating oil, do not operate the instrument before topping off the oil reservoir.

3.2 site requirements

The DGDP-001 should be placed as close as possible to the pressure controller (like the GPR200D) and the DUT[3]. A separate interconnection hardware kit for connecting the controller to the rest of the world is available.

- Although the DGDP-001 can operate with not perfectly clean gasses (like natural gas), optimal long term performance is achieved with Nitrogen class 5.0.
- The room in which the instrument is placed should have proper founding, no vibrations are allowed during operation of the DGDP-001 as this results in unpredictable errors
- The DGDP-001 should be placed on a rugged table which is rated for at least 100 kg without deforming. The table should be horizontally leveled.
- The DGDP-001 base plate can be fixated on the table with stainless steel locking bolts (in the scope of delivery).
- Air movement in the neighborhood of the DGDP-001 should be avoided.
- Room temperature needs to be stable during the time the DGDP-001 is used to avoid uncertainties due to the thermal expansion coefficients of the piston cylinder and adiabatic effects in the measuring system.

3.3 setup

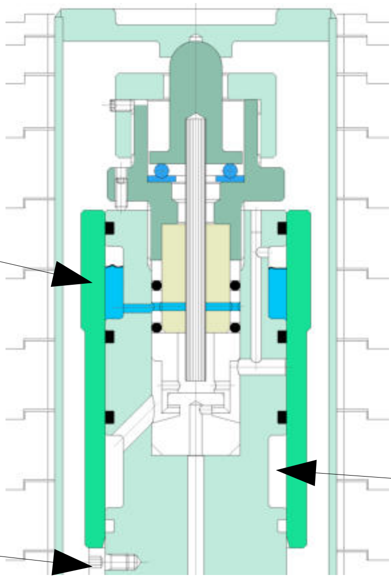
If the DGDP-001 was purchased with the GPR200D, make the connections to pressure controller. For more details a reference to the GPR200D manual is made.
All DGDP-001 pressure connections are 1/4” BSP female. Therefore, a 1/4” BSP male adapter is needed to make each of the connections. BSP connections can either be sealed with a metal ring or elastomer manchette ring.

- Connect the master and slave pressure connections to the REF HI and REF LO ports on the pressure controller.
- Connect the pressure controller test ports to the DUT.

! Make sure not to overpressurize the DUT

3 Device Under Test

3.4 topping off the lubricating oil



- remove the bushing retaining screw with the delivered allen key
- slide the slidable outer bushing down till the end of its stroke
- fill the the delivered syringe with 812 lubricating fluid
- fill the oil reservoir until the hollow meniscus levels the upper surface of the outer bushing in bottom position

! Make sure not to overfill the oil reservoir as this may result in oil entering the gas system ergo introducing unpredictable oil columns.

- carefully raise the slidable outer bushing until the drain reservoir opens to atmosphere
- operate the pressure controller to flow gas through the tubing towards the deadweight tester thus purging any trapped oil out of the drain reservoir.
- vent the system
- remount the bushing retaining screw
- carefully slide the slidable outer bushing down until it hits the retaining screw

! In time the O-rings encountering the slidable outer bushing may age resulting in needing excessive force to manipulate the bushing. Either use lubricating oil to grease the O-rings or replace the O-rings by new ones.

After repeating the above procedure for both platforms the DGDP-001 is ready for use.

! It is good practice to check both the oil and the drain reservoir every time before operating the DGDP-001 to ensure its performance, see also chapter 4.2

4 operating DGDP-001

The operation of the DGDP-001 is dependent on the used pressure controller. In case of the GPR200D a reference is made to its operating manual.

4.1 setting a line pressure

The DGDP-001 piston diameter is designed to have a nominal mass to pressure factor of 5 bar/kg, e.g. 1 kg represents approximately 5 bar. To calculate the mass needed to approach a desired pressure, just divide the pressure by 5 to get the nominal mass load. When using an DGDP-001 in normal conditions a mass loading resolution of 100 gram is good enough as you compare the calculated deadweight tester pressure with the actual readout of the DUT.

example :

nominal pressure point	94 bar g
nominal mass to pressure constant	5 bar/kg
calculated nominal mass	18,8 kg

pressure calclulation from certificate data

local gravity	9,812703 N/kg
summarized conventional mass	18,8001 kg
effective area	0,196255 .10-4 m2

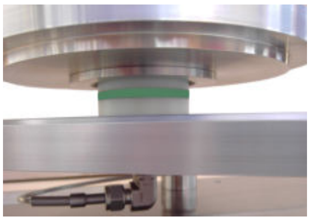
So in the above example, we loaded :

piston+mass carrier	: 1	kg
4 kg nr. 1..4	: 16	kg
1 kg	: 1	kg
500 gr	: 0,5	kg
200 gr	: 0,2	kg
100 gr	: 0,1	kg

- close vent valve
- close bypass valve between master- and slave deadweight tester
- carefully open inlet valve until the master piston starts to raise

! the readout of the DUT can be used to monitor change in line pressure

- fine tune the line pressure with the variable volume connected to the master deadweight tester
- the piston mid stroke position is reached when the bottom of the mass carrying bell is levelled with the green colored band on the mounting post



4.2 setting a differential pressure on elevated line pressure

- disconnect the pressure controller from external volumes (to DUT's) which might affect stability

! When disconnecting external tubing, make sure the external tubing is vented

- calculate the nominal mass load as described in 3.1
- load masses both on master and slave deadweight tester

! do not mix up calibrated master - and uncalibrated slave masses

- open bypass valve between master- and slave deadweight tester platform
- close vent valve
- carefully open inlet valve until the slave piston raises and engages its upper stop
- manipulate the line pressure with the variable volume of the pressure controller until the slave piston just starts to drop.
- rotate both master and slave piston clockwise
- start putting tare (uncalibrated) fractional masses on the slave mass carrying bell until the master and slave piston are in equilibrium

! When the master and slave pistons are almost in equilibrium, it is good practice to close the bypass valve and carefully manipulate both pistons into mid-stroke position, wait for 5 .. 10 seconds to be sure there is no vertical piston movement and open the bypass valve again to see if the pistons stay stable.

When the operator is confident that equilibrium has been reached a second stage verification of the quality of equilibrium is possible with the differential DUT attached.

- open bypass valve and vent both deadweight testers
- connect differential pressure DUT to pressure controller

! make sure the DUT high pressure connection is connected to the master deadweight tester / the DUT low pressure connection should be connected to the slave deadweight teser

- close vent valve
- carefully pressurize the system until both pistons are floating
- rotate the pistons clockwise

With the bypass valve still open, record the readout of the DUT which should be almost zero. After that close the bypass valve and record the readout of the DUT in this state. Both readings should be almost the same. There can be a slight difference, but the difference should be within the uncertainty of the deadweight tester differential pressure uncertainty. If necessary the result can be trimmed with fractional masses.

! Putting extra mass on the slave piston results in lowering the DUT readout, removing mass results in raising the DUT readout. Remember that the influence is approximately 5 mbar per gram.

5 maintenance

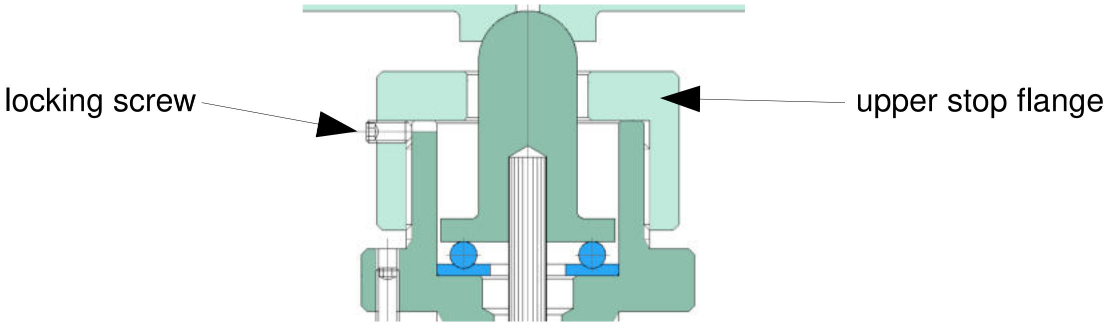
5.1 changing lubricating fluid / cleaning piston cylinder

It is good practice to change lubricating fluid at least once every year.

- make sure the deadweight tester is vented

! MM connectors have internal valves which close when flex tubes are removed and may result in trapped pressure. To be sure the deadweight tester is vented, connect a flex tube to the MM connector (if present) to vent.

- remove the piston upper stop flange, do not forget to loosen the locking screw



- place a towel around the base of the mounting post
- raise the slidable outer bushing until the drain reservoir opens to atmosphere
- carefully lift up the piston out of the cylinder

When the piston is removed, the oil will flow from the oil reservoir to the drain reservoir and downwards to the mounting post base.

- remove the outer bushing completely and remove the remaining fluid with lint free cloth.
- clean all surfaces with alcohol or cleaning solvent like Loctite 7061, also poor some solvent into the cylinder bore
- clean the piston with lint free cloth wetted with alcohol or cleaning solvent like Loctite 7061

! before assembly, make sure all solvent has vapoured

! the piston should be wetted with lubricating fluid before assembly

5.2 overhaul

The DGDP-001 is designed to be allmost maintenance free. The in 4.1 described cleaning is expected to be the only regular maintenance performed by the end-user. On the longer term it might be necessary to exchange the cylinder o-rings, for this a separate overhaul kit is available, including :

- overhaul manual
- cylinder removing tool
- bullet proof storage container for piston & cylinder
- spare o-ring kit

5.3 recalibration

Although the DGDP-001 is designed to have a very good long term stability, the manufacturer recommends a first recalibration at 2 years after purchase is recommended both for piston cylinder and mass set. The results of the recalibration can be used as a guideline for future recalibration. Dependant on the environment and frequency of use a recalibration interval of 2 to 5 years is normal.

! It is not necessary to send the whole deadweight tester for recalibration, when the overhaul kit is purchased, the cylinder can be removed from the platform and shipped in the storage container.

6 parts list

Product	Part	Code	Qty.	Remark
Dead weight tester DGDP-001	Mounting plate	600 x 320 mm	1	
	Weight column		2	gas operating, oil lubricated
	Adapter	2101-01-18.00	2	for minimess 1215 tubes
	O-ring	Ø17,13x2,62 90° NBR	3	for cilinder
	O-ring	Ø40x2,5 70° NBR	3	for oil reservoir
Weight set	Weight carrier		1	tared & certified
	4 kg	1; 2; 3; 4; 5; 6	6	
	2 kg		1	
	1 kg		1	
	500 g		1	
	200 g	1; 2	2	
	100 g		1	
	50 - 1 g	in wooden box	1	
	Weight carrier		1	tared under nominal weight
	4 kg		6	
	2 kg		1	
	1 kg		1	
	500 g		1	
	200 g		2	
	100 g		1	
	50 g - 50mg	in wooden box	1	
Other	*EA* certificate (RVA)		1	Minerva Meettechniek B.V.
	Weight box	for weight set	2	
	Dust cover	for weight column	2	
	Allen key	3 mm (M4)	1	for bushing retaining screw
	Bushing retaining screw	M4x8	1	
	Bolt and nut	M6 x 50 A2	4	fixing mounting plate
	Plastic tubing	S-100-AA-AJ-0100 DN2-400	2	Minimess 1215, angle connection for weight column
	Plastic tubing	S-100-AA-AA-0100 DN2-400	4	minimess 1215
	Dead weight tester oil	812	½ ltr.	

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