Contents

Attention. Compressed gas! The larger the volume and pressure of the gas, the greater its stored potential energy, which in the event of an accident or incorrect operator actions, can be released at the rate of the blast wave, dragging parts, fragments, etc.

This guide is intended to ensure the safety and performance of the device. Save this manual with your device. Before starting any work, the user is obliged to study and understand the manual and operating principles of the device. The basis of safe operation is compliance with the requirements of both manual and general safety regulations, local regulations, etc.

1 Intended use

1.1 Air-operated deadweight gauges of absolute and over-pressure with a simple piston directly loaded in vacuum, model MPA (hereinafter referred to as MPA), are designed to create and accurately measure absolute and over-pressure of gas

1.2 The MPA shall be used as a reference measurement tool for the verification and calibration of absolute and over-pressure measuring instruments: calibrators, measuring transducers (sensors), standard barometers. The devices shall be operated in laboratory conditions at an ambient temperature of 18 to 22°C and a relative humidity of not more than 80%.

2 Technical specifications

2.1 The MPA uses standard measuring deadweight tester systems (hereinafter referred to as IPS) (e.g. Figure 4 pos. 54) of air-operated deadweight gauges (hereinafter referred to as MGP) with special bell plates (Figure 4 pos. 52) and adapter plates (Figure 6 pos. 65).

2.2 The remaining metrological values required for the operation of the instrument are measured by additional equipment included in the MPA (See Table 1, set of delivery, additional attached Manuals).

2.3 The main technical characteristics of the device are given in the table:

Name of parameter	**MGP 0.2…0.5**	**MGP 1…4**	**MGP 10…25**	**MGP 50…100**
Nominal piston area, cm^2	25	5	1	0.2

Name of parameter	**MGP 0.2…0.5**	**MGP 1…4**	**MGP 10…25**	**MGP 50…100**
The maximum deviation of the nominal value of the effective piston area, %	±0.2%	±0.4%	±0.4%	±1.0%
Working stroke of the piston, mm, not less than	10			
IPS cylinder material	Hard alloy VK			
IPS piston material	Silicon carbide		Hard alloy VK	
Working medium	Air, nitrogen[1]			Nitrogen[1]
Deviation from the perpendicular to the bearing surface of the weight hanger to the piston axis, not more than	5'			
Upper limit of measurement MPa (kgf/cm^2)	0.02…0,05 (0.2) … (0.5)	0.1…0.4 (1) … (4)	1…2.5 (10) … (25)	5…10 (50) … (100)
Lower limit of measurement MPa (kgf/cm^2)	0.0007 (0.007)	0.004 (0.04)	0.025 (0.25)	0.06 (0.6)
Limits of permissible measurement error of overpressure, % [2]: accuracy class 0.003 accuracy class 0.005 accuracy class 0.008 accuracy class 0.01	 ± 0.003 ± 0.005 ± 0.008 ± 0.01			
Limits of permissible measurement error of absolute pressure and overpressure, % [2]: accuracy class 0.003 accuracy class 0.005 accuracy class 0.008 accuracy class 0.01	 ± 0.003 ± 0.005 ± 0.008 ± 0.01			
Piston lowering speed, mm/min, not more than accuracy class 0.003 accuracy class 0.005 accuracy class 0.008 accuracy class 0.01	 1 1 1 1			 2 2 2 2

Name of parameter	**MGP 0.2…0.5**	**MGP 1…4**	**MGP 10…25**	**MGP 50…100**
Discrimination threshold, Pa, not more than accuracy class 0.003 accuracy class 0.005 accuracy class 0.008 accuracy class 0.01	$P_{max} \cdot 0.1 \cdot 0.003/100$ $P_{max} \cdot 0.1 \cdot 0.005/100$ $P_{max} \cdot 0.1 \cdot 0.008/100$ $P_{max} \cdot 0.1 \cdot 0.01/100$			
IPS drive unit	The rotation of the IPS at a speed not lower than 30 rpm.			
Temperature measurement of the IPS	Thermometer resistance PT100 class AA, 4-wire connection diagram, (+15+35g. C.) with secondary transducer[3]. Measurement error is not more than 0.3°C.			
Measurement of residual pressure in the vacuum chamber of the IPS	Membrane-capacitive, absolute and overpressure vacuum gauge, 0-100Pa[3]. Measurement error 0.2%, of the measured value.			
The achieved value of the absolute and excess vacuum in the IPS vacuum chamber	2–10Pa (Depending on the installed IPS, pumping time, length of the vacuum line).			
Vacuum indicator in the IPS vacuum chamber	Industrial overpressure sensor, range -1… 0 bar[3]. Measurement error 0.5% of the range. The indicator is not subject to calibration.			
Indication of the IPS rising	Inductive position sensors. Indications are discrete: upper stop, above the working area, working area, below the working area, lower stop.			
Information output for the user	Video recorder[3]			
Dimensions of the main device, L×W×H, mm, not more than	690x380x650			
Weight of the main device, not more than	50 kg			
Supply voltage of the main unit	220 Volt ± 10%			
Mains frequency	50 ± 1 Hz			
Power consumption of the main device, not more than	200 W			

3 Delivery package

1	The main device	1[4]
2	MGP measuring deadweight tester systems	*on request*[5]
3	The set of loads with the actual weight, kg	*on request*
4	Pressure generating device (USD) of low measurement range (up to 10 bar)	*on request*[6]
5	Pressure generating device (USD) of high measurement range (up to 100 bar)	*on request*[7]
6	Vacuum pump for pumping out the vacuum chamber	1
7	Vacuum pump for reducing the pressure value of the measured gas	1
8	Remote control (Extension) for controlling the vacuum pumps	1
9	Connecting lines, hoses, spare rubber rings	*set*
10	Nitrogen supply system	*on request*[8]
11	Operating Manual	1
12	Verticality control device (hereinafter referred to as PKV) of IPS (level)	1
13	Soft pad (for mouse)	1[9]
14	Special templates	*set*[10]

4 Design of the device and principle of operation

4.1 The MPA is a system consisting of several devices and units. The general view of the MPA with an example of the location of other devices and units necessary for the operation of equipment is shown at Figure 1.

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[1] Recommended gaseous nitrogen of high purity grade 2 according to GOST 9293-74

[2] In the basic measurement range from 0.1·Pmax to Pmax, the error is normalized in % of the measured value; in the additional measurement range from Pmin to 0.1·Pmax, the error is normalized in % from 0.1·Pmax (where Pmax — upper limit of the measurement range; Pmin — lower limit of the measurement range).

[3] As to models of the device parts, meters, and their advanced metrological parameters refer to the attached original manufacturer's manual.

[4] The main part of the MPA (consisting of a vacuum chamber, a number of meters, indicators).

[5] IPS types and their number - depending on the required measurement ranges.

[6] Based on the required measurement ranges (If the user does not plan to work on the device above 10 bar).

[7] Based on the required measurement ranges (If the user plans to work on the device up to 100 bar).

[8] Selection of cylinder regulators, connectors, main pipe-lines.

[9] To use it as a stand for vacuum acrylic tube.

[10] To simplify the adjustment of the carriage height of the IPS position sensors (the number depends on the IPS used).

For information about related devices and units, see the individual manuals on these devices.

4.2 The principle of measurement by MPA is that the IPS is placed in a vacuum chamber with a residual pressure close to absolute zero (less than or equal to 10 Pa) which is taken into account when determining the measurement result.

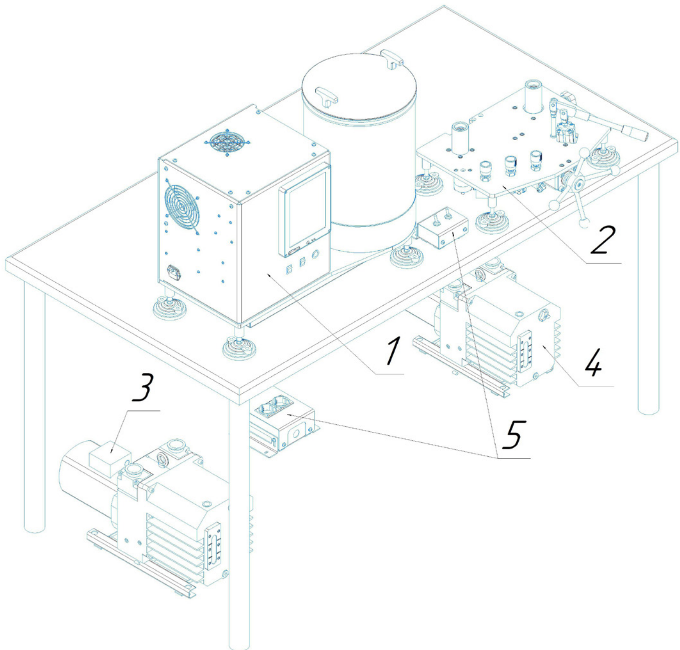

Figure 1. MPA:
1 — Main device; 2 — Pressure generating device USD (for example, USD up to 10 bar); 3 — Vacuum pump for pumping out the vacuum chamber; 4 — Vacuum pump for reducing the pressure of the measured gas value; 5 - Remote control (Extension) for controlling vacuum pumps.

The general view of the IPA with overall maximum dimensions and description of the elements is shown at the figures: 2.1 Front view, 2.2 Left view, 2.3 Rear view, 2.4 Top view.

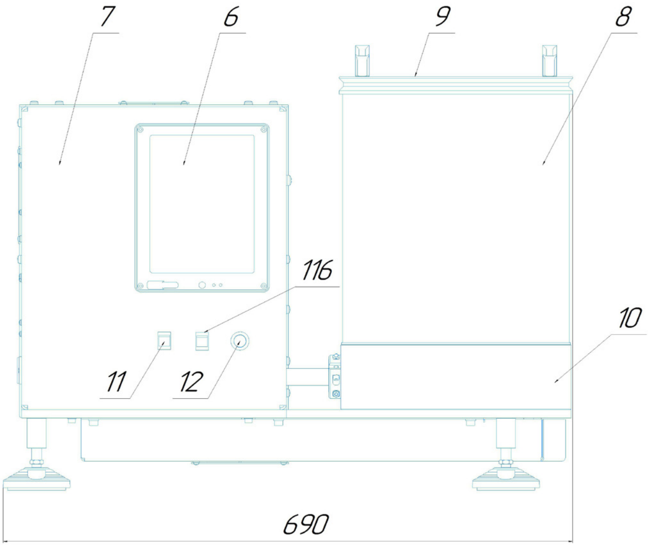

Figure 2.1:
6 — Video recorder; 7 — Body; 8 — Transparent acrylic tube of vacuum chamber;
9 — Vacuum chamber cover; 10 — Bottom part of vacuum chamber;
11 — Power switch; 12 — Button of vacuum relief of vacuum chamber;
116 — Key of forced activation of IPS rotation.

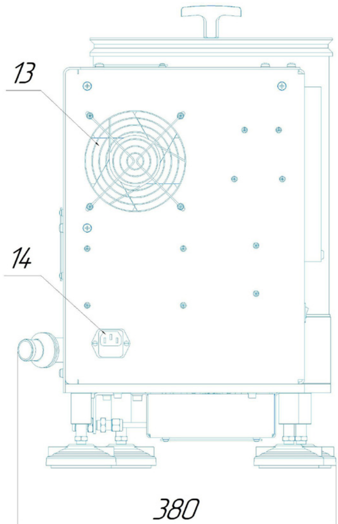

Figure 2.2:
13 — Exhaust grille of forced ventilation of the device; 14 — Connector connecting the device to the network 220 Volt, 50Hz. The connector has a fuse 250 Volt, 5A.

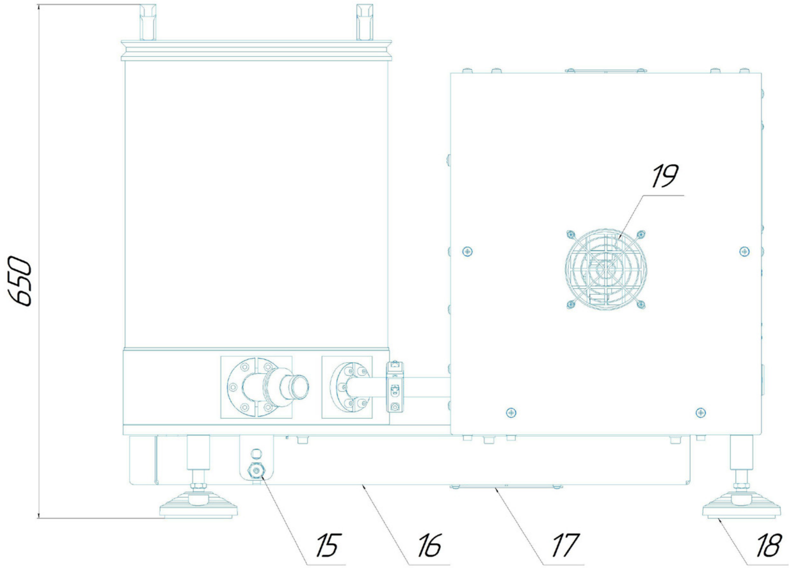

Figure 2.3:
15 — Connection fitting, measured/generated pressure; connection is made by steel tube D = 6mm; 16 — Lower protective cover; 17 — Air inlet grille; 18 — Device support; 19 — Exhaust ventilation grille.

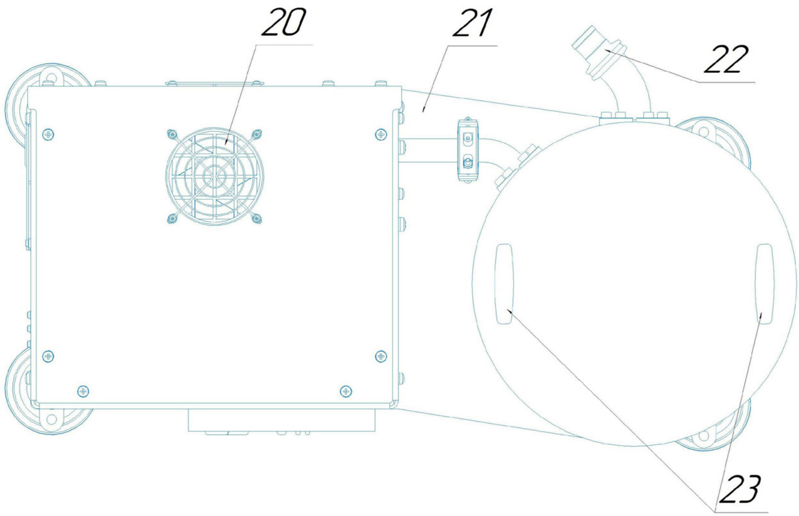

Figure 2.4:
20 — Air inlet grille of forced ventilation of the device; 21 — Plate (Base) of the device; 22 — Vacuum pump connection fitting; 23 — Handles

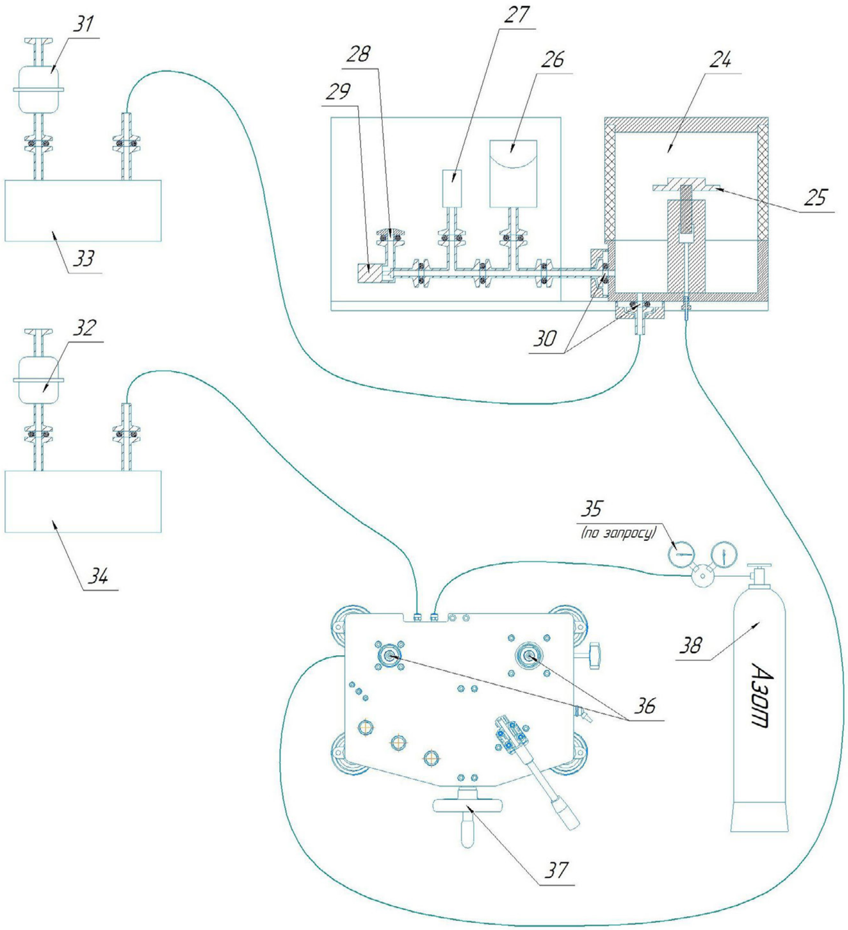

Figure 3. MPA pneumatic scheme (conditional):
24 — Vacuum chamber; 25 — IPS; 26 — Absolute diaphragm capacitive sensor; 27 — Vacuum meter indicator; 28 — Sintered filter 20micron; 29 — Relief valve; 30 — Meshed filter; 31,32 — Oil fog trap; 33 - Vacuum pump for pumping air out the vacuum chamber; 34 - Vacuum pump for reducing the pressure of the measured gas; 35 - Pressure regulator; 36 - Places of MI on test; 37 - USD MGP 10; 38 — User nitrogen source.

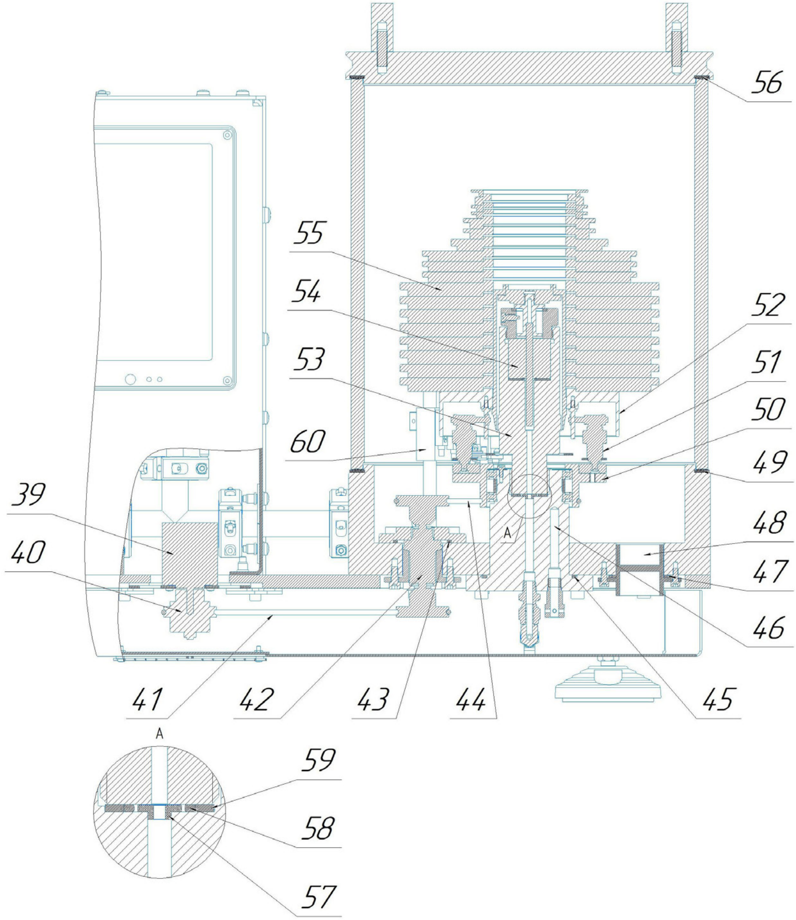

Figure 4. Sectional view of the main device:
39 — Electric motor; 40 — Safety slip clutch; (Conditionally); 41 — Round section ring (Belt) 102-108-036; 42 — Vacuum rotation inlet (Conditionally); 43 — O-ring 040-045-030; 44 — Round section ring (Belt) 140-145-036; 45 — O-ring 066-071-030; 46 — Cavity of resistance thermometer PT 100; 47 — O-ring 043-047-025; 48 — Vacuum connector (Conditionally); 49 — Vacuum chamber sealing (Special); 50 — Rotation assembly for installation of IPS pushers assemblies; 51 — Pushers assembly for IPS MGP 1-100 (Conditionally); 52 — Bell with a special plate for tracking the position of the IPS and transmitting rotation to it; 53 — Housing of IPS MGP 100; 54 — IPS MGP 100; 55 — Load of the IPS; 56 — Upper seal of the vacuum chamber (Special); 57 — Centering ring (plastic); 58 — O-ring 014-018-025; 59 — Steel snap ring; 60 — IPS position sensor carriage.

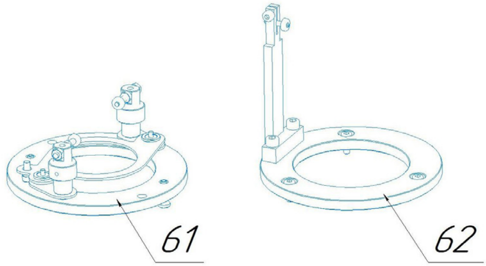

Figure 5. Pushers assemblies.
(Presence of pushers assemblies depends on configuration of the device):
61— Pushers assembly for IPS from 1 to 100 bar, used with bell (for use of IPS 1-100 with adapter plate, it is necessary to use pushers assembly with adapter sleeve-spacer, see Figure 6); 62 — Pushers assembly to be installed for IPS 0.2-0.5.

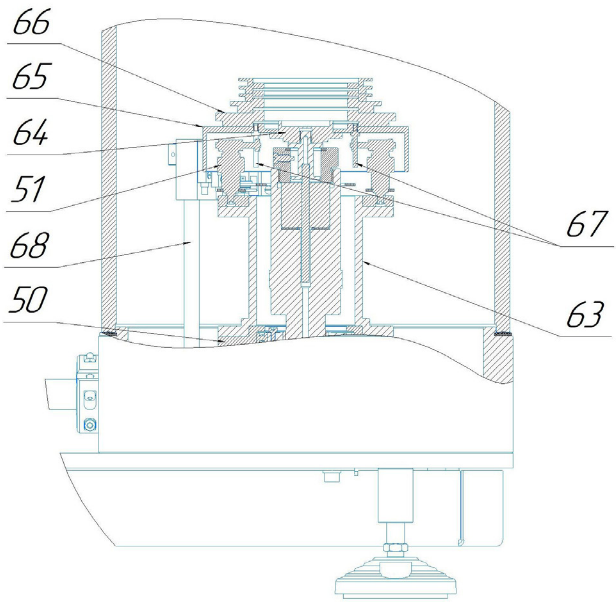

Figure 6. Adapter plate use:
50 — Rotation assembly for installation of IPS pushers assemblies;
51 — Pushers assembly for IPS MGP 1-100 (Conditionally); 63 — Adapter sleeve; 64 — IPS weight hanger; 65 — Adapter plate for work on lower limits of measurements, tracking the position of the IPS and transmitting rotation to it; 66 — Loads of the adapter plate; 67 — Leashes for rotation transmission to IPS; 68 — Sensor carriage guide.

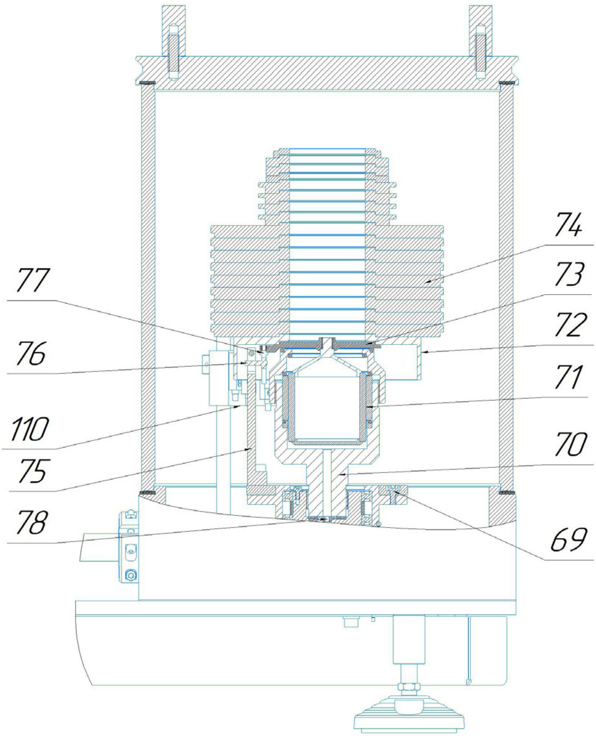

Figure 7. Installation on the main device of IPS MGP 0.2-0.5:
69 — Mounting screws Din 912 M4x10; 70 — Housing of IPS MGP 0.5;
71 — IPS MGP 0.5; 72 — Plate for tracking the IPS position by sensors;
73 — Weight hanger; 74 — Load of IPS MGP 0.5; 75 — Pushers assembly lever;
76 — Pusher axis; 77 — Leash; 78 — Seal package (see Figure 4 pos. 57, 58, 59)
110-Bottom, base surface of the sensor carriage designed to adjust the working height of the position sensors using the attached templates.

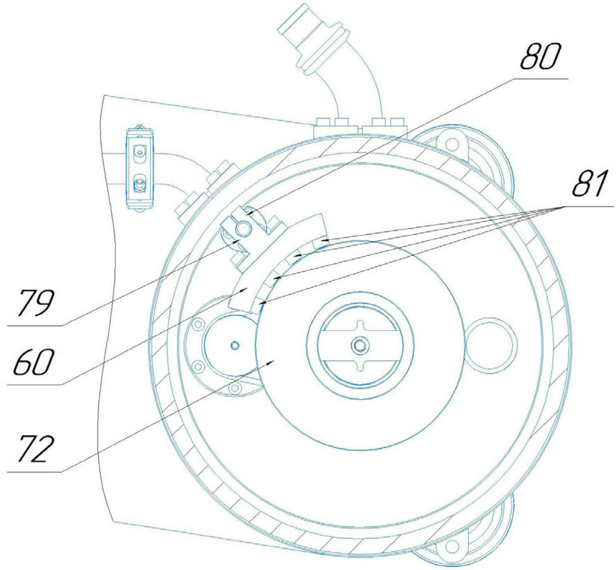

Figure 8. Location of the sensor carriage, on the top view
(on the example of IPS MGP 0.5):
60 — IPS position sensor carriage; 72 — IPS position sensor plate;
79 — Carriage position collet lock; 80 — Collet lock screw (Not shown);
81 — Inductive IPS position sensors.

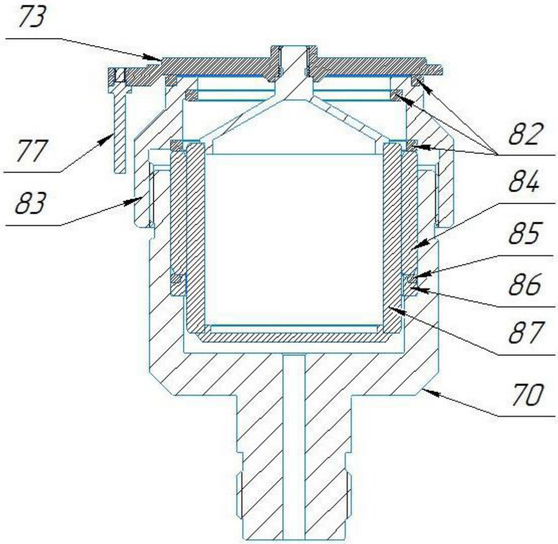

Figure 9. IPS MGP 0.2-0.5 design:
70 — IPS housing; 73 — Weight hanger; 77 — Leash;
82 — Damping rings; 83 — Hold-down nut; 84 — IPS Cylinder (Tungsten Carbide); 85 — Round cross-section O-ring 061-065-025; 86 — Centering ring; 87 — IPS composite piston, hollow (Duralumin and silicon carbide).

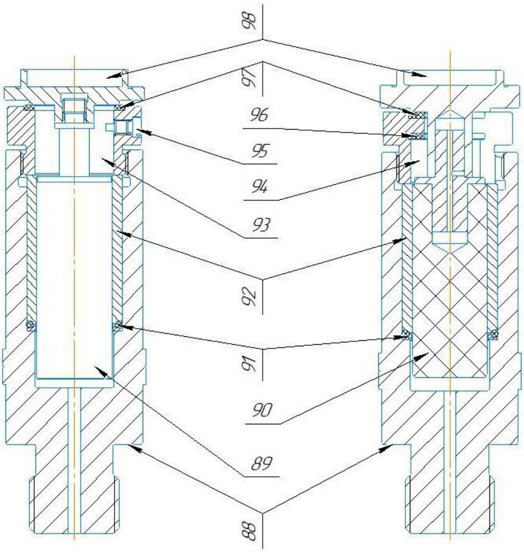

Figure 10. IPS MGP 1-4 design.
(There are several versions of IPS design for this measurement limit):
88 — IPS housing; 89 — Hollow thin-walled tungsten carbide piston;
90 — Silicon carbide solid piston; 91 — Rubber O-ring 028-032-25 mounted
in a centering metal ring; 92 — Tungsten carbide cylinder; 93 — Hold-down nut;
94 — Split lock/hold-down nut; 95 — Lock screw; 96 — Stretch damping ring;
97 — Stretch damping ring; 98 — Weight hanger.

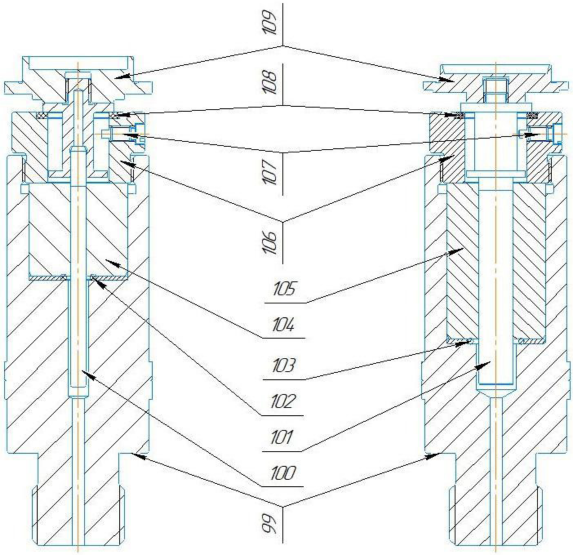

Figure 11. IPS MGP 10 and MGP 100 design (IPS MGP 10 on the right.): 99 — IPS housing; 100 — IPS MGP 100 piston made of tungsten carbide; 101 — IPS MGP 10 piston made of tungsten carbide; 102 — Special sealing, diameter 11.2mm, rectangular section, inserted inside the metal ring; 103 — pecial sealing, diameter 18mm, rectangular section, inserted inside the metal ring; 104 — IPS MGP 100 cylinder of tungsten carbide; 105 — IPS MGP 10 cylinder of tungsten carbide; 106 — Hold-down nut; 107 — Fixing screw; 108 — Stretch damping ring; 109 — Weight hanger.

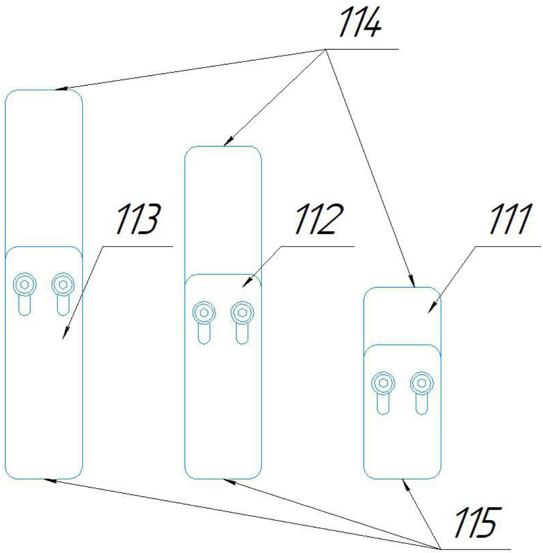

Figure 12. Templates for adjusting the height of the sensor carriage position: 111 — “Small” template is designed to adjust the height of the sensor carriage when loading the IPS located on the bell; 112 — “Medium” template is designed to adjust the height of the sensor carriage when using a special plate MGP 0.2-0.5; 113 — “Large” template is designed to adjust the height of the sensor carriage when loading the IPS located on the adapter plate; 114 - Top surface of the template; 115 - Bottom support surface.

4.3 Air-operated deadweight gauge of absolute and over-pressure consists of a set of meters, devices, USD connected into one system. The general view is shown at Figure 1 and suggests the possible arrangement of the MPA parts. The main device in the composition of the vacuum chamber and measuring instruments is shown at position 1. To work with the instrument, it is also necessary to use the USD MGP shown at position 2. Operation by using USD is described in a separate manual. It is also necessary to use a vacuum pump 3 to pump out the IPS vacuum chamber. To measure pressure less than 1 atmosphere, in an absolute measurement system, a vacuum pump 4 is required. Pumps are conditionally located under the table, but for the best pumping speed of the vacuum chamber it is necessary to choose the location of pump 3 as close as possible to the vacuum chamber (possibly on a separate stand, table), but not on the same table as the measuring part of the instrument to avoid transmission of vibrations. To simplify the control of vacuum pumps there is a panel 5 which consists of 2 parts: under-table sockets for power cords of the pumps and desktop console for switching on/off the pumps. The parts of the console are connected by an electric cable. At one end of the cable there is a plug to connect pumps to the 220 volt 50Hz network.

4.4 Figure 2.1 shows the front view of the main device. On the right there is a vacuum chamber designed to work with IPS MGP inside. On the left of the main device there is housing 7 with the necessary meters and electrical units for the MPA operation. Position 6 shows a video recorder that can display: temperature values of the IPS, vacuum chamber pumping process, residual pressure in the vacuum chamber, operation status of the IPS drive, position of the IPS. Values are represented both as a graph and as numerical ones. The video recorder setup by an user is not required. See all details related to its interface in a separately attached manual. Key 11 is designed to turn on/off the main device of the MPA. Button 12 is designed to discharge the vacuum from the vacuum chamber. When it is pressed, the vacuum is discharged. The discharge valve is automatically locked when the discharge is completed. Item 8 shows the removable part of the vacuum chamber in the form of a pipe made of transparent organic glass. The top of the chamber is closed with a separate cover 9 (The cover should be removed immediately after the vacuum is discharged, in order to avoid small pressure drops, which due to the large area of the cover will not allow the vacuum chamber to be opened.). The base of the vacuum chamber is shown at position 10 and contains the components necessary for the IPS operation.

4.5 Figure 2.2 shows the left view of the main device. It is prohibited to cover any ventilation grating (for example, position 13), in order to avoid overheating as well as the MPA deviation from the stated metrological characteristics. The main device is connected to the 220V AC network via connector 14. For this purpose, a standard power cable is included in the MPA kit.

4.6 Figure 2.3 shows the rear view of the main device. On the rear side of the main device there is a fitting to supply the measured gas pressure. The connection is made by a steel or plastic tube with a diameter of 6mm, according to the maximum pressure required by the user. Under the base (plate) of the main device there is a protective enclosure 16. Ventilation grille 17 (below) is used for air intake. Grille 19 is used to exit the air. The main device is mounted on non-slip adjustable supports 18 designed to adjust the vertical position of the IPS, as well as, if necessary, fixing the main device to the table through mounting holes in the supports.

4.7 Figure 2.4 shows the top view. The upper part of the enclosure shows the forced ventilation grille 20. The main device is mounted on a rigid base made in the form of steel plate 21. For easier handling of the vacuum chamber cover, T-handles 23 are provided. To connect the vacuum pump on the base of the vacuum chamber, a nozzle 22 is provided, fixed through a 45 degree bending tube to facilitate the bending of the hose in the desired direction. The adapter can be rotated when the screws on the body of the vacuum chamber are loosened. It is also possible to remove the adapter to connect the vacuum pump directly to the vacuum chamber (under 90 degrees to the body of the measuring instruments of the main device).

4.8 Pneumatic connection diagram of MPA parts and assemblies is conditionally shown at Figure 3. Sectional view of the vacuum chamber is shown at position 24. The IPS MGP (position 25) is placed inside the chamber. The inner part of the chamber is connected by pipelines with diaphragm capacitive absolute meter of residual pressure 26, indicator-vacuum gauge 27, relief valve 29. The meters and the vacuum pump are protected with 30 meshed filters at the inlet to the vacuum chamber, which are designed to prevent large particles entering the line. These filters do not create pneumatic resistance in the lines. The sintered filter 28 is provided to prevent the ingress of fine dust from the atmosphere, into the vacuum chamber and meters when the vacuum is discharged. This filter also works in the system as a throttle, producing vacuum discharge at a permissible speed. For the installation of the MI on test standard threads and adapters 36 for USD MGP are used, position 37. The larger vacuum pump 33 is connected directly to the vacuum chamber, through a flexible vacuum hose with quick couplings. The smaller vacuum pump 34 is used to create a measured absolute and excess gas pressure of less than 1 atm. And it is connected to the USD MGP by means of a plastic tube. Oil traps 31, 32 are required to prevent oil fog entering the room air. It is assumed that user has its own nitrogen supply system. For example, by using cylinder 38 and pressure regulator 35. A mandatory condition is the presence of pressure regulating valves at the inlet of the USD (e.g. Regulator 35). The regulator serves both to limit the input pressure of the system and for easy use of the MPA, it will allow more accurate handling of the feed valves as part of the USD and prevent the device and MI failure in case of operator error and excessive opening of valves on the USD. The regulator should be adjusted to a pressure not exceeding the maximum for a specific MI and even more correctly - for a specific loading the IPS.

4.9 Figure 4 shows sectional view of the main device. The rotation of the IPS is provided by an electric motor 39 with smooth acceleration and braking. The drive is started automatically when the IPS emerges from the lower stop. The drive is also stopped automatically when the IPS approaches the upper or lower stop. You can also force the rotation by pressing the key 116 (Figure 2.1). When you switch this key, the automatic algorithm of switching on/off the rotation of the IPS drive is blocked and the drive goes to constant rotation mode. When switching back, the automatic mode of the IPS drive is activated. The manual mode of rotation of the IPS is necessary for operation with minimal loading of the IPS, when using adapter plates (and without them, in the case of IPS MGP 0.2-0.5) without surfaces to control the IPS pop-up. To prevent an emergency/abrupt stop of the IPS, a slip clutch 40 is included in the kinematic circuit, Figure 4. The rotation is transmitted through the round section ring 41 to the vacuum rotation inlet 42. O-ring 43 is used to seal the vacuum inlet. For the transmission of rotational motion inside the chamber, the round section ring 44 is used, by which the rotary motion is transmitted to the pulley of the rotation assembly 50 intended for installation pushers assembly 51 on it. The base intended for the installation of the IPS and sealed by O-ring 45. Also the resistance thermometer 46 to measure the IPS temperature is installed in this base. For transmission of electronic signals from IPS position sensors to the video recorder the vacuum connector 48 is used. O-ring 47 is intended to seal this connector. IPS housing 53 is installed in the central nozzle and compacted with a package of seals: plastic centering ring 57, round section O-ring 58, steel snap ring 59. IPS 54 is also compacted in its housing with a package of seals (two-part package — steel ring and rubber/special seal). On the weight hanger of the IPS can be dressed a bell of a special version 52 or an adapter plate (no bell is provided for IPS MGP 0.2–0.5). IPS loads 55. Inside the vacuum chamber there is a special guide with the moving IPS position sensor carriage 60. The position is tracked by the bell plate, the adapter plate or the special plate for IPS MGP 0.2–0.5 depending on the installed IPS and the specific pressure measurement point. To seal the vacuum chamber the viton seals of special profile 49, 56 are used.

4.10 Figure 5 shows pushers assemblies for different IPS versions. Pushers assembly for IPS from 1 to 100 bar, used with bell 61. Pushers assembly to be installed for IPS 0.2–0.5, position 62.

4.11 Figure 6 shows the operation process of the IPA with IPS MGP 1-100 equipped with the adapter plate. For this purpose, the necessary IPS shall be installed. The rotation assembly 50 must be fitted with an extension adapter sleeve 63. Then the pushers assembly 51 shall be installed. Then the adapter plate 65 is installed on the IPS weight hanger 64 for operation at the lower limit of measurements. For the transmission of uniform rotational motion of the IPS, a complex system of levers of the pushers assembly is provided. These levers with bearing units uniformly push leashes 67 causing the rotation of the GPU and the piston of the IPS. The maximum load of the adapter plate 66 should not be in total greater than the weight of the bell. Position 68 shows the cylindrical guide of the sensor carriage.

4.12 Figure 7 shows the correct installation on the main device of IPS MGP 0.2–0.5.

4.13 The IPS housing 70 shall be sealed on the central nozzle by means of seal package 78 (same as other IPs). The pushers assembly shall be secured to the rotation assembly by means of fixing screws 69. The rotation is transmitted through one lever 75, the axle of the pusher with bearing 76, and further through the leash 77 to the weight hanger 73. The given IPS 71 shall be used in conjunction with a special plate 72 to monitor the position of the IPS pop-up. Load 74 is shown for IPS MGP 0.5.

4.14 Figure 8 shows the position sensor carriage location in the top view. The IPS position sensor carriage 60 shall be installed so that sensors 81 do not touch the plate 72. The distance between the sensors and the plate should be about 0.5mm. The carriage can slide up and down along the guide and can be fixed on it with a collet lock 79 by using the screw 80.

4.15 The design and assembly of IPS MGP 0.2–0.5 are shown in Figure 9. The IPS consists of a housing 70 with a cylinder seal consisting of a centering ring 86 with a rubber round section ring 85. Then the IPS cylinder 84 is inserted into the housing, the piston 87 is inserted with the hold-down nut 83 put on it and previously screwed GPU 73. Nut 83 should be tighted untill a noticeable stop. Damping rings eliminate the single-point engaging of the IPS cylinder to the nut, and also allow to lower the IPS on the stop without deformations of the GPU. Rotational motion is transmitted through a leash 77.

4.16 The design of IPS MGP 1–4 is shown at Figure 10. There are several versions of IPS design for this measurement limit. They differ by the design of the locking nut of the cylinder as well as by the design of the IPS piston. In general view, the IPS consists of housing 88. A cylinder seal consisting of a centering ring with a rubber round section ring 91 on it is inserted into the housing. The piston 89 is made of thin-walled tungsten carbide and the piston 90 is solid (full-body) made of silicon carbide. Cylinders 92 are made of tungsten carbide. Structurally, the hold-down nut 93 is standard and has a locking screw 95 to prevent the piston going out the cylinder. Nut 94 is executed with a slot through which it is installed on the neck of the piston without removing the GPU. A split thrust ring 96 is used in this nut to limit the piston going out the IPS. For safe lowering of the IPS, stretch damping rings 97 are provided. GPU 98 on the left figure is fixed on the piston through a threaded connection, on the right figure - glued and is fixed.

4.17 The design of IPS MGP 10–25 and IPS MGP 50–100 differs only in size and by piston area. Both IPS use similar housings 99. In the working position the working edges of pistons 100, 101 (all IPS) are always on the same level. Cylinder IPS MGP 10–25 is compacted by sealing package 103 consisting of a special seal with a diameter of 18mm, rectangular section, inserted inside a metal thrust ring. Cylinder IPS MGP 50–100 is compacted by means of sealing package 102 consisting of a special seal with diameter of 11.2 mm, rectangular section, inserted inside the metal thrust ring. Nuts 106 press the cylinders to the seals. Screws 107 prevent pistons from leaving the cylinders. Stretch damping rings 108 are designed for safe lowering of the IPS. Weight hangers 109 are intended for loading the IPS by means of bells or adapter plates.

5 Safety precautions

Attention. This section provides general information on the main aspects of safety, safe operation, health of personnel and safekeeping of property, including this device. A number of instructions will be described in more detail in other sections of this Manual.

5.1 Use for intended purposes.

The MPA is designed for verification and calibration of measuring instruments (MI) used in measuring absolute and overpressure of gases, as well as the standard of pressure in the absolute measuring system. The MPA should be used strictly for its intended purpose. Otherwise, the device is considered to be misused. This can lead to injuries and other serious consequences.

5.2 Allowed gases for operation with the MPA.

— Purified dried air (depending on the IPS, as agreed);

— Nitrogen.

5.3 Possible risks when using the MPA for its intended purpose. It is necessary to remember that even when using the device for its intended purpose there are risks caused by human factor and force majeure circumstances.

5.3.1 Hazard of gases under pressure.

It must be remembered that gas under pressure/vacuum has a certain potential energy. Uncontrolled release of this energy can lead to serious consequences. In case of improper handling of the pneumatic system, gas (the operating environment of the IPS) can escape it, which can lead to serious injuries.

5.3.2 Danger caused by vacuum.

It is necessary to remember that any vacuum pump poses a specific danger to the user, having the ability to create a deep vacuum which, taking into account the area of action of the vacuum, can to create forces of huge value. For example, a distributed force of approximately 500 kg is applied to the lid of the vacuum chamber of the device in a vacuum state. Therefore, it is necessary to be careful not to overlap the suction tubes, parts of the vacuum system by foreign objects and parts of your body in order to avoid serious injuries and equipment damage.

5.4 When assembling and disassembling units and parts of the device, performing maintenance and any other non-standard work — always drop the pressure/vacuum in the system. If defective parts and malfunctions are found, scratches (damage) on the transparent tube of the vacuum chamber, work on the device is prohibited, until replacement of parts and troubleshooting. Only qualified personnel authorized to access the relevant equipment shall carry out the work.

5.5 Danger of working medium.

It must be remembered that gas, unlike air, when entering the room can cause toxic poisoning, suffocation and even death. For example, in case of uncontrolled opening of the discharge valves and filling the room with gas. Gas can displace oxygen necessary for breathing or change the composition of the air, leading to loss of consciousness and death. It is necessary to equip the working area with exhaust, ventilation equipment in case of gas ingress into the room.

5.6 If dizziness and suspicion of poisoning appear, immediately stop work and provide medical assistance to the victims. It is also necessary to observe safety measures when using flammable working medium in the device.

5.7 Responsibility of the operating facility.

5.7.1 Operating facility — the one using this device shall be legally responsible for the protection of the user, personnel and third parties.

5.7.2 The facility operating the MPA shall ensure the safety of works in accordance with the law.

5.7.3 In addition to the safety instructions contained in this Manual, the applicable safety regulations, labor protection regulations and environmental regulations must be observed.

5.7.4 The operating facility shall collect information on the applicable occupational safety regulations and further identify possible hazards arising at the site of use of the MPA in connection with the specific working conditions. On the basis of this, it should develop a manual on labor protection when working with the MPA in a given workplace.

5.7.5 The developed instruction shall comply with the regulations throughout the life of the MPA.

5.7.6 The operating facility shall regulate and determine the responsible persons using the MPA and the responsibility for installation, maintenance, troubleshooting and maintenance.

5.7.7 The operating facility shall ensure that all operations related to the operation are carried out exclusively by personnel with the necessary qualifications and approvals for such kind of works. It is necessary that all persons who work with the MPA read and understand this Manual. In addition, staff should be regularly trained and informed of hazards.

5.7.8 The operating facility shall provide personnel with the necessary personal protective equipment and require personnel to use them.

5.7.9 The operating facility shall maintain the MPA serviceable. Check the presence and legibility of plates, inscriptions on the device. Carry out maintenance work at every commissioning event.

5.7.10 The operating facility shall ensure that only approved working medium is used. It is also necessary that the compressed air, gases, be properly pre-connected and stored properly.

5.7.11 The operating facility ensure that all components and assemblies connected to the MPA are designed and matched in accordance with the characteristics of the MPA.

5.7.12 Requirement for personnel.

Involve only qualified personnel to perform all kinds of the work. Do not allow unqualified personnel to enter the danger area. The operating facility should regularly instruct its personnel. To ensure control, it is necessary to draw up a briefing report.

5.8 Features when using the MPA.

5.8.1 When degreasing and processing the individual parts with gasoline (B 70 — TU 38.101913-82, Galosha — TU 38.401-67-108-92, Nefras — GOST 8505-80), it is necessary to observe safety measures when working with gasoline. And also with other fuel and lubricants.

5.8.2 It is prohibited to create pressure that exceed the upper limit for the specific MPA model.

5.8.3 Protect the loads against mechanical damage.

5.8.4 Avoid jolts and bumps of the IPS.

5.8.5 Use only standard O-rings.

5.8.6 Loads shall be placed on a solid, flat and clean surface near the MPA.

5.8.7 The IPS loads must be removed and installed with two hands one at a time.

5.8.8 It is prohibited to place on the adapter plate loads those total weight is greater than the weight of the bell.

5.8.9 Store the IPS piston preferably separately from the IPS cylinder. Keep the piston in a stable position, in a place that excludes its breakage (accidental shocks, fall).

Attention. When using the IPS, in addition, follow the instructions for this IPS as part of the attached manuals.

5.8.10 The use of personal eye protective equipment is mandatory when working with the device.

Attention. Protect IPS parts against mechanical and chemical damage. Despite the fact that the working surfaces of the IPS are made of wear-resistant hard alloys, they are characterized by increased fragility. Even a small drop is often enough to break the piston and cylinder unit. Conventional fingerprints can also have an extremely high destructive corrosion effect on the material of the IPS working parts. Because the piston and cylinder surfaces have to be touched during disassembly and assembly, it is necessary to protect them against contact contamination. It is strongly recommended that IPS work surfaces be touched with perfectly clean lint-free paper towels, gloves or other lint-free materials.

5.8.11 The IPS piston must be kept separately from the cylinder. It is necessary to maintain low humidity at the place where the parts of the IPS are stored. This is necessary since the working surfaces of gas IPS MGP are ground to each other practically without a gap, this provokes a gradual condensation of moisture from the air in this gap, which gradually leads to the corrosion of the working surfaces. Which, in turn, subsequently leads to the inoperability of the IPS.

5.8.12 In order to ensure that the vacuum chamber is leakproof, the end surfaces of the acrylic pipe and the retaliation seals shall be protected against damage and contamination. To ensure the safety of the end surfaces of the acrylic pipe the device is equipped with a soft mat used to install the pipe on it when removed. It is forbidden to wipe the acrylic pipe with solvents (alcohol, acetone, gasoline, etc.). Cleaning to be done with soap solution followed by rinsing with clean water and wiping with a lint-free cloth.

5.8.13 All devices and assemblies of the MPA must be connected to an alternating current network of 220 Volts 50 Hz, to a socket with a grounding contact. For the safety of the user, the connection must be made through a protective cut-off device (GFCI) with a shut-off current of 10…30 mA.

5.8.14 The grounding reliability of MPA electrical equipment housings shall be checked periodically in accordance with the “Electrical Installations Code”.

Attention. Do not apply asymmetric loads to the loaded IPS to avoid its damage. Do not allow bumps of the piston of the IPS on the upper or lower stops as a result of a sudden change in the generated pressure, as this can lead to the breakdown of the IPS.

6 Preparation for work

6.1 Unpack the main device. Unpack the vacuum pumps, USD, loads and IPS. Unpack the rest of the equipment — connecting hoses, extension cord, vacuum chamber parts, pushers, etc. Wipe all parts of the MPA with a clean soft cloth. Read all the attached manuals.

6.2 Consider the recommended installation option proposed at Figure 1 and described in paragraph 4.3 (If you need an installation with individual requirements, please contact the manufacturer for consultation.). Generally the device must be installed on a strong, rigid base that prevents deflection and vibration. If necessary, secure the MPA with screws (not included in standard delivery). The USD MGP may also be attached to the table.

6.3 Fans blowing vacuum pumps shall not produce direct and upward flow of warm air to the MPA. It is also necessary to avoid getting the device into direct air flows created by climate control equipment. It is also necessary to exclude radiation from heating systems, direct sunlight, other systems with increased heat dissipation/heat absorption.

6.4 Connect the pneumatic lines according to Figure 3 and paragraph 4.8 of this Manual (USD may differ from shown in the figure). Install oil fog traps on pumps. Attach the vacuum hose to the larger vacuum pump and to the inlet of the vacuum chamber on the back of the MPA. Attach the second vacuum pump to the USD according to the MGP Manual. Connect MAD and USD (In case of using a steel tube diameter of 6mm, bend it to the necessary shape (minimum bending radius = 15mm), cut the excess, make 0.5-1mm chamfer on the ends and check the absence of burrs at the tube edges. Wash thoroughly and purge the prepared tubes with clean, dry, compressed air. See the Annex to the Manual for recommendations on the crimping of a steel tube).

6.5 The vacuum hose attached to the vacuum chamber from a larger pump may be shortened by the user if it is too long. It is important to remember that the shorter it is, the faster the vacuum chamber will be pumped out, it will also be possible to achieve a higher degree of vacuum, which ultimately improves the performance of MPA.

6.6 Connect the MPA to the mains 220V 50Hz AC using the supplied power cable. Connect the vacuum pumps to the mains 220V 50Hz AC with the attached extension console.

6.7 Prepare the IPS for work by using the MPA Manual. Install the selected IPS on the nozzle in the MPA vacuum chamber. Put the verticality control device (level) on the GPU IPS. Calibrate the verticality of the IPS installation with the help of adjustable supports of the device (Detailed technique for controlling the deviation from verticality is described in "Verticality control device. Operating Manual".).

6.8 Install the acrylic tube on the base of the vacuum chamber and close it with the top cover. Check that the pipe and cover are installed without distortion.

6.9 Install the MI on test (i.e. in need of verification/calibration) on the USD. Connect the MPA nitrogen supply line.

7 Operating procedure

7.1 Check the pressure measuring instruments (MI) calibration in accordance with the calibration methods for the specific MI.

7.2 Carefully review the safety precautions when working with the MPA (Section 5).

7.3 Make the necessary steps (paragraphs) of Section 6 (preparation for work).

Attention. The system must be properly assembled, all installed additional parts and MI must technically correspond to the planned work. When installing MI, special attention should be paid to the accuracy of sealing installation.

Useful information. The cleanliness of the surface of the vacuum chamber and all the products installed and to be installed in it, as well as the used gasket materials and vacuum lubricants are of great importance for the normal operation of the MPA. It is almost impossible to completely clean all parts of dirt, fats and liquids. Therefore, during the initial vacuum (or after the MPA is idle), the remaining liquids evaporated/boiled out of the inside surfaces of the vacuum chamber.

The processes of evaporation and boiling of liquids during vacuuming occur even when the inner parts of the chamber are perfectly cleaned. Liquids can be found in micropores on the surfaces of materials and have different residual vapor pressures. As a result, the vacuum first evaporates water and other easily volatile liquids and then, as the vacuum increases, other substances with lower vapour pressure begin to evaporate, such as fats from fingerprints on the surfaces of the chamber, residual traces of machine oil. This is why it is impossible to allow contamination of those parts that are and will be in the vacuum chamber. Therefore, for lubrication, if required, it is necessary to use only high-quality vacuum lubricants and oils. The time required for initial pumping out depends on many factors and is conditionally equal to one hour. In the future, with direct operation, pumping will occur much faster. For example, the level of humidity in the room has a great influence on the speed of vacuum generation. Excessive air humidity leads to condensation and even frost in the pump fittings during air evacuation. This water inevitably evaporates and is absorbed by the pump, getting into the oil bath of the crankcase, eventually leading to deterioration of the maximum achieved vacuum.

The absolute residual pressure in the chamber is limited by the technical characteristics of the pump, the pumping time of the chamber and the evaporation of liquids inside the chamber. Also, the absolute residual pressure in the vacuum chamber depends on the installed IPS and the pressure applied to it. Since the IPS piston is not compacted, a small amount of working medium passes through the gap of the piston and cylinder unit which creates additional flow and increases pressure in the vacuum chamber itself. When the chamber is closed correctly, the flow of gas (air) from outside is practically absent. In case of long idling the vacuum chamber parts, IPS, loads, etc. under atmospheric pressure, it is necessary to carry out the initial pumping again.

These phenomena to some extent also apply to the cavities working with the measured gas pressure. When MPA is operating at the lower limit of absolute pressure measurement, less than 0.003 MPa at laboratory air temperature, water particles may boil inside the USD (Water can settle on the walls of the USD cavities from the air). In the process of using the MPA, due to the difference between the measured gas pressure and the pressure inside the vacuum chamber, the water vapor will move towards the exit — in the gap between the cylinder and the piston of measuring deadweight tester system, that will result in the "loss of sensitivity" of the IPS or its stop. This phenomenon can lead to frequent disassembly of IPS and its drying. Therefore, using nitrogen is strongly recommended for the MPA. If it is necessary to use MPA in the air up to 1MPa, it is recommended to drain and clean the air supplied to the MPA.

Attention. Carry out all work related to the vacuum chamber and the components installed in it (IPS, loads, etc.) only with clean, lint-free gloves.

7.4 Open the vacuum chamber and install the necessary IPS into it (Figures 9,10,11).

7.5 Set up the sensor carriage, position 60, Figure 8 (hereinafter referred to as the carriage) on the adapter plate, bell plate or IPS plate 0.2-0.5, position 72, (Figure 7) to track the IPS position by sensors. To do this, do the following (Pushers assemblies, position 61 or 62, Figure 5, should not be installed.). By the key 116 (Figure 2.1) turn on automatic mode of operation of the IPS drive. Power on the main device. When you configure the carriage, the IPS drive will be switched on or off depending on your actions, this is normal. Setting the sensors in height without using templates consists in bringing the carriage up and down until the LEDs start to light up confidently on all four sensors. This position will be considered as the lower position of the IPS (If the IPS is lifted to the upper stop, accordingly, all sensor LEDs should go out). If the sensors are installed correctly, the IPS drive must stop in the lowermost position and in the uppermost position of the IPS piston. At the beginning of setting process the IPS itself should be at the lower stop (in the lower position).

7.6 The carriage, in a horizontal position, must be installed in such a way that, when the IPS is rotated by hand, a gap is maintained between the plate and position sensors 81 (Figure 8).

7.6.1 To facilitate the height adjustment of the sensor carriage, the device is equipped with special templates (Figure 12). The required template, by its upper part, is installed under the carriage surface marked in Figure 7, position 110. The carriage together with the template is brought up and down until it stops by the surfaces of the templates, position 115 (Figure 12) into the bottom of the vacuum chamber. This ensures the correct installation of the sensor carriage in height. In a horizontal position, the carriage must be rotated so that the gap between the sensors and the plate is maintained to track the position. If the sensors are installed correctly, the IPS drive must stop in the lowermost position and in the uppermost position of the IPS piston. At the beginning of setting process the IPS itself should be at the lower stop (in the lower position).

7.6.2 In order to correctly display the position of the IPS on the display of a graphic video recorder, you may need to turn the power of the main device off and on again after correctly installing the sensor carriage.

7.6.3 The main device shall be switched off when the IPS drive is stopped. The IPS itself should be at the lower stop.

7.6.4 When the main device is switched on, the video recorder reads and calibrates the IPS position displayed on the screen as lower (lower stop).

Attention. If the previous shutdown of the main device was performed with the IPS drive not fully stopped, it will continue to rotate the IPS, which in turn may not be correct.

7.7 Turn off the power of the main device. If IPS 0.2-0.5 was installed, remove it, install the corresponding pushers assembly (Figure 5) and reinstall the IPS. If IPS 1-100 was installed, it is sufficient simply to remove the bell or the adapter plate and then install the pushers assembly without removing the IPS. If you need to work with an adapter plate, install the adapter sleeve 63 under the pushers assembly (Figure 5). Install the required quantity of loads on the IPS. In this case, first install heavier loads and then lighter ones. If necessary, remove the lighter ones, install the heavier ones, and reinstall the lighter ones.

7.8 Connect the MI on test to the USD MGP. Check the reliability of the connections. Vacuum the USD at the IPS loaded to create pressure less than 1 atm of absolute and overpressure (by a value less than the expected created pressure in absolute value). Example: If it is planned to create a pressure of 0.5 atm abs, it is necessary to vacuum to a value less than 0.5 atm abs. Pump out the vacuum chamber to a value of not more than 100 Pa abs (depending on the installed IPS and the required metrological characteristics). The vacuum pump pumping out the vacuum chamber with IPS should constantly work with the direct operation of the device, to compensate for gas leakage through the IPS gap and other phenomena.

Attention. It is necessary to remember that when evacuating a vacuum chamber with an IPS loaded to create a pressure of less than 1 atm abs, without preliminary vacuuming of the USD, it will immediately rise and hit the upper limit stop of the piston stroke. That in turn threatens the breakage of the IPS.

Therefore, this feature imposes a certain sequence of actions of the operator excluding arbitrary pop-up of the piston when vacuuming the camera with the IPS. More precisely, the preliminary evacuation of the internal cavities of the USD to a slightly larger vacuum than it will be necessary for the IPS to emerge.

7.9 Create the required absolute pressure in the USD, for doing this gradually increase the pressure in it until the IPS pops up. When the IPS is detached from the lower stop, the IPS drive will automatically turn on (If the automatic mode of the IPS drive is switched on). Based on the video recorder readings, take the IPS into the working area. Wait for thermodynamic processes to stop. Record the readings of the absolute and excess residual vacuum sensor, and the temperature of the IPS that will be needed in further calculations. Record the MI readings (Perform the MI calibration in accordance with the calibration methods for the specific MI).

7.10 Lower the IPS to the lower stop (If you do not first lower the IPS to the stop, then the subsequent vacuum release will press the IPS sharply to the lower stop, which is an emergency). The IPS drive must stop. Stop the vacuum pump of the chamber. Equalize the pressure in the vacuum chamber with the atmospheric one by pressing button 12 (Figure 2.1), as a result of which the electric valve will open connecting the cavity of the vacuum chamber with the atmosphere for a time of approximately 20 s. The presence of even the lowest vacuum in the chamber, due to the large area of the cover, will not allow it to open. If you need extra time to adjust the pressure in the chamber to atmospheric one, just press the button 12 again.

7.11 Adjust the quantity of loads and close the chamber.

Attention. Reducing the quantity of loads with the remaining pressure in the USD can cause a sudden rise of the piston following the removed load. Therefore, the operator needs to make sure that the pressure in the USD during these manipulations is less than the pressure that the IPS will create with the amount of load removed.

Useful information. If the user finds it convenient, it is allowed to remove and install small diameter loads without removing the acrylic tube of the vacuum chamber. In any case, only one piece, by two hands, is allowed to be removed and installed on the IPS.

7.12 Repeat the measurements with the required number of measurement points and then lower the IPS to the lower stop, turn off the vacuum pumps, shut off the gas supply system of the device, vent the vacuum in the chamber, and then vent the measured gas from the USD. Turn the device off.

7.13 It is recommended that the vacuum chamber be closed between measurements.

8 Maintenance

8.1 To maintain the air-operated deadweight gauges of absolute and overpressure in working condition, daily and routine maintenance is necessary.

8.2 Daily maintenance.

8.2.1 During daily maintenance, an external inspection is carried out. Besides the parts must be cleaned of dirt and dust with a dry clean rag (if necessary soaked with clean gasoline (B 70 — TU 38.101913-82, Galosha — TU 38.401-67-108-92, Nefras — GOST 8505-80)). For the maintenance of individual parts of the MPA, such as pumps, UDS, etc., see the attached manuals. The maintenance of the IPS MGP is also discussed in a separate manual. When working with fuel and lubricants, it is necessary to comply with the applicable safety rules.

8.2.2 It is necessary to check the integrity of the acrylic pipe, the absence of chips, cracks and scratches. In case of defects, further work with the device is prohibited until replacement of the pipe. Ignoring this requirement is potentially life-threatening.

8.2.3 The integrity of the power cord of the device and other power cables shall be verified.

Attention. It is forbidden to wipe acrylic pipe and video recorder screen with combustible substances, solvents. These actions can cause a fire due to the electrification of acrylic, as well as chemical damage.

It is recommended to rinse the pipe under running water, soft rags, with neutral synthetic detergents containing surface-active substances. Followed by wiping with a dry, clean, soft, lint-free cloth and then drying.

The parts that have just been rubbed with fuels and lubricants cannot be installed in the vacuum chamber in order to prevent flammable vapors from entering the pump. It is also prohibited to evacuate the chamber with parts not dried from water, in order to avoid condensation of water vapor in the pump oil, which will lead to deterioration of its characteristics. Determine this situation is possible by increased amount of oil in the pump sump. The supplied pumps have the function of gas ballast — the ability to clean the oil from water vapor. This feature is described in the attached Manual.

Refer to the attached manual for the care of the video recorder screen.

8.3 Routine maintenance

8.3.1 For routine maintenance of individual parts of the MPA, see the attached manuals.

8.3.2 Check the integrity of the sealing rings.

8.3.3 Rubber static seals in ISO-KF connections may be lubricated by vacuum grease.

8.3.4 The bearings in the pushers assemblies shall be checked for smooth running. IPS drive bearings located in the vacuum chamber operate without lubrication. It is forbidden to apply any lubricants to them in order to avoid deterioration of the device performance.

8.3.5 Check the amount of oil in vacuum pumps.

8.3.6 Maintain routine maintenance as required, but at least once a month.

9 Storage

9.1 Storage of the air-operated deadweight gauges of absolute and overpressure in laboratory conditions.

9.1.1 When storing MPA in laboratory conditions, it is necessary to wipe it with a clean rag, disconnect it from the AC mains and cover up it with a polyethylene cover. The USD MGP should also be wiped and covered with a plastic bag. Store the IPS in a place with low humidity, disassembled (piston separately from the cylinder). Remove the loads in the box intended for them.

9.2 Storage of the MPA in a warehouse.

9.2.1 Before placing the MPA in storage, it is necessary to carry out maintenance in accordance with paragraph 8.

9.2.2 Wipe the MPA and its constituent parts with a clean rag and pack in factory packages (or similar).

9.2.3 Boxes with MPA shall be stored in accordance with the designated handling instructions.

9.2.4 The MPA shall be stored in a dry, heated room at a temperature not lower than +5°C and relative humidity of not more than 80%

9.2.5 Represervation once every 6 months.

10 Possible malfunctions and solutions

Malfunction	**Cause of malfunction**	**Solution**
MPA does not turn on.	No mains voltage. The electrical cable is faulty. Blown fuse.	Check the voltage. Contact an authorised technician. Replace fuse.
The proper degree of vacuum of the IPS chamber is not created	The vacuum hose is pinched. The wire mesh filter at the inlet to the vacuum chamber is clogged. No tightness in ISO-KF vacuum connections. Vacuum chamber seal has been damaged. Fluids with high residual vapor pressure came into the chamber. Vacuum pump oil reached the end of useful life.	Straighten the hose/replace. Rinse and dry the filter. Check the integrity of the seals. Tighten the connections. Replace seal. Carry out maintenance, rinse contaminated parts. Replace the oil.

Malfunction	Cause of malfunction	Solution
The IPS drive does not turn on	Sensor carriage is not configured. The ring belt flied down or torn.	Set up according to the user manual. Replace the ring.
The tube of the vacuum chamber is damaged.	Blows, falls, scratches.	Replace pipe.
IPS piston jam	Dust infiltration in the IPS	Rinse the IPS according to the manual.

11 Warranty

11.1 The manufacturer guarantees that the air-operated deadweight gauge of absolute and over-pressure comply with the requirements of KD — АП. 064.000.000, subject to the conditions of transportation, storage and operation.

11.2 The warranty period of MPA operation is 18 months from the date of shipment of the air-operated deadweight gauge of absolute and over-pressure to the consumer.

11.3 Warranty period of operation of vacuum pumps according to the documentation attached to them.

11.4 Average service life is not less than 8 years.

11.5 The warranty does not cover all types of seals and defects caused by intensive use of the device.

12 Complaint details

In case of a malfunction, draw up a certificate of repair necessity and send it to: LLC “Alfapascal”, 2nd Paveletskaya Str., 36, Chelyabinsk, 454047, tel.: +7 (351) 725-74-50, e-mail: q@alfapascal.ru

13 Acceptance Certificate

Air-operated deadweight gauge of absolute and over-pressure, model MPA________ accuracy class ________ factory number ________ corresponds to KD AP. 064.000.000 and recognized as valid for use.

Date of manufacture

Person in charge ____________ ____________ LS

Signature Surname

14 Packaging Certificate

Air-operated deadweight gauge of absolute and over-pressure, model MPA ________ accuracy class _________ factory number ________ is packed in accordance with KD AP. 064.000.000.

Packing date

Person in charge ________________ ________________ LS

Signature Surname

15 Note

The manufacturer reserves the right to make changes to the design of the device without prior notice.

Annex A (reference)

The tables, formulas and constants from this Annex should be used to calculate the reference absolute and overpressure at the nozzle edge of the MI on test (hereinafter referred to as reference pressure).

To calculate the reference pressure, it is necessary that:

— the actual weight of loads was determined with an error not exceeding 1/6 of the accuracy class, for loads with a nominal weight of 50 grams or less - 1/3 of the accuracy class;

— the nominal density of materials of the load and the moving part of the measuring deadweight tester system (hereinafter referred to as “IPS”) was known;

— the coefficient of thermal linear expansion and the coefficient of deformation of the piston and cylinder unit were known;

— the residual pressure did not exceed 10 Pa;

— free fall acceleration had at least 6 significant digits. For accuracy classes 0.008 and 0.01, 5 significant digits are allowed;

— the height difference between the piston edge of the IPS and the nozzle of the MI on test was known;

— the temperature deviation at the time of measurement did not exceed 0.1°C relative to the temperature used for the calculation;

— put the piston in the middle working position;

— the temperature, pressure and humidity of the air were known.

Table 1 — Piston and cylinder pair deformation factor

<table>
<tr><th></th><th>MPA
0.2...0.5</th><th colspan="2">MPA
1...4</th><th>MPA
10...25</th><th>MPA
50...100</th></tr>
<tr><td>Piston material</td><td>Silicon carbide</td><td>Silicon carbide</td><td>Tungsten carbide</td><td colspan="2">Tungsten carbide</td></tr>
<tr><td>Deformation factor β</td><td>$4.953 \cdot 10^{-12}$</td><td>$3.267 \cdot 10^{-12}$</td><td>$3.599 \cdot 10^{-12}$</td><td>$1.004 \cdot 10^{-12}$</td><td>$8.026 \cdot 10^{-13}$</td></tr>
</table>

Table 2 — Material nominal densities of the loads

Name of load	**Nominal density, kg/m³**
Piston MPA-0.2... 0.5	2857

Name of load	Nominal density, kg/m³
Piston MPA-1… 4 of silicon carbide	2904
Piston MPA-1… 4 from tungsten carbide	3300
Piston MPA-10… 25	10017
Piston MPA-50… 100	4586
Adapter plate	2780
Bell	7900
Load 0.025 kg	2780
Load 0.05 — 2 kg	7900

Calculation of m_r is made according to the formula:

$$m_r = m_a \bullet \frac{\rho_э - \rho_в}{\rho_э} \bullet \frac{\rho}{\rho - \rho_в},$$

where, m_r is the weight of the load, the value of which is obtained taking into account the actual density of the material of the load and the actual density of the air at the time of measurement;

m_a — weight of the load, the value of which is obtained by the method of comparison with the reference weight in the airspace;

ρ — nominal density of load, kg/m³;

$\rho_э$ — the density of the reference weight, kg/m³;

$\rho_в$ — air density (if the deviation of the design value from the nominal value of 1.2 kg/m³, does not exceed 10%, then the air density is assumed to be equal to the nominal value).

The calculation of the absolute pressure is as follows:

$$P = \frac{\sqrt{1 + 4 \bullet \frac{m_r \bullet g}{A_t} \bullet \beta} - 1}{2 \bullet \beta} + P_{ocm},$$

where, P is the pressure generated by load of weight m_r, Pa;

g — local gravity acceleration, m/s²;

A_t — the effective area of the IPS at the temperature t, m²;

β — deformation factor of IPS, Pa^{-1};
$P_{ост}$ — residual pressure in the vessel, Pa.

The calculation of the overpressure is as follows:

$$P = \frac{\sqrt{1 + 3{,}9994 \bullet \frac{m_a \bullet g}{A_t} \bullet \beta} - 1}{2 \bullet \beta}$$

where, P is the pressure generated by load of weight m_r, Pa;
g — local gravity acceleration, m/s^2;
A_t — the effective area of IPS at the temperature t, m^2;
β — deformation factor of IPS, Pa^{-1};

The calculation of the effective area at temperature t is carried out according to the following formula:

$$A_t = A_0 \bullet (1 + \alpha \bullet (t - 20)),$$

where, A_t is the effective area of the IPS at the temperature t, m^2;
A_0 — effective area of IPS at a temperature of 20 °C, m^2;
α — coefficient of thermal linear expansion of IPS, $°C^{-1}$.

The coefficient α for silicon carbide and tungsten carbide materials is $4 \cdot 10^{-6}$ $°C^{-1}$, so the total coefficient for the piston and cylinder init is $8 \cdot 10^{-6}$ $°C^{-1}$.

Correction for the difference between the lower edge of the IPS piston and the nozzle of the instrument on test

The correction should be introduced if there is a working medium column between the levels of the lower edge of the piston of the IPS and the nozzle of the instrument on test; the column of the working medium exerts pneumostatic pressure.

In general, the correction is as follows:

$$\Delta P = \rho_c \bullet g \bullet h,$$

where, ΔP is the value of correction, Pa;
ρ_c — the density of the working medium at pressure P;
g — local gravity acceleration, m/s^2;

h — the difference of levels between the nozzles of the standard and the MI on test, m.

Note. The correction is added to the readings of the instrument with a higher endcap level.

The level difference is convenient to calculate relative to the base of the MPA (plate). The piston edge in the average working position for MPA-0.2… 0.5 is located at a distance of 15.0 cm from the base, for MPA-1… 4, MPA-10… MPA-25, MPA-50… MPA-100-11,8cm.

Calculation of air density should be carried out according to the following formula:

$$\rho_в = \frac{0,0034848 \cdot P - 0,009024 \cdot \varphi \cdot e^{0,0612 \cdot t}}{273,15 + t}$$

where, $\rho_в$ is the air density at pressure P, kg/m^3;

φ — relative humidity of the air at pressure P, %;

P — the generated absolute pressure, Pa;

t — the temperature at the time of measurement, °C.

The relative humidity of the air at pressure P should be calculated using the formula:

$$\varphi = \varphi_0 \cdot \frac{P}{P_б},$$

where, ϕ is relative humidity of the air at pressure P, %;

P — the generated absolute pressure, Pa;

φ_0 — relative humidity of air at pressure P_0, %;

P_0 — barometric pressure, Pa.

Note. If the pressure generated exceeds the barometric pressure and the calculated relative humidity value exceeds 100%, the φ value for air density calculations is taken to be 100, in this case the excess moisture during air compression are released in the form of condensate.

The nitrogen density should be calculated according to the following formula:

$$\rho_a = \frac{(1,250 - 4,55 \cdot 10^{-3} \cdot t + 1,8 \cdot 10^{-5} \cdot t - 1,6 \cdot 10^{-7} \cdot t) \cdot P}{101325}$$

where, ρ_a is the density of nitrogen at pressure P, kg/m^3;

P — the generated absolute pressure, Pa;

t — the temperature at the time of measurement, °C.

Note. The formula is valid provided that air is previously evacuated from the system.

Weight calculation of loads in the vacuum pressure area to achieve the expected value of the reference pressure:

$$m_r = \frac{(\mathrm{P} - \mathrm{P}_{ocm} - \rho \cdot g \cdot h) \cdot A_t \cdot (1 + (\mathrm{P} - \mathrm{P}_{ocm} - \rho \cdot g \cdot h) \cdot \beta)}{g}$$

where, m_r is the weight of the load, the value of which is obtained taking into account the actual density of the material of the load and the actual density of the air at the time of measurement;

P — the expected absolute pressure, Pa;

$P_{ост}$ — expected residual pressure in the vessel, Pa;

ρ — the density of the medium at pressure P, kg/m^3;

g — local gravity acceleration, m/s^2;

h — the difference of levels between the piston edge of the IPS and the nozzle of the MI on test, m;

A_t — the effective area of the IPS at the expected temperature t, m^2;

β — deformation factor of IPS, Pa^{-1}.

Weight calculation of loads in the vacuum pressure area to achieve the expected value of the reference pressure:

$$m_a = \frac{(\mathrm{P} - \rho \cdot g \cdot h) \cdot A_t \cdot (1 + (\mathrm{P} - \rho \cdot g \cdot h) \cdot \beta)}{g} \cdot 1,00015$$

where, m_a is the weight of the load, the value of which is obtained by the method of comparison with the reference weights in the airspace;

P — the expected absolute pressure, Pa;

ρ — the density of the medium at pressure P, kg/m^3;

g — local gravity acceleration, m/s^2;

h — the difference of levels between the piston edge of the IPS and the nozzle of the MI on test, m;

A_t — the effective area of the IPS at the expected temperature t, m^2;

β — deformation factor of IPS, Pa^{-1}.

Note. As an additional mass, it is allowed to use weights from a set of gram/milligram weights of accuracy class not lower than F1 without recalculating their mass values for airless space, provided that their total mass does not exceed the load with the lowest nominal mass from the standard set of MPA loads.