

PM controller and jet pump with examples of application



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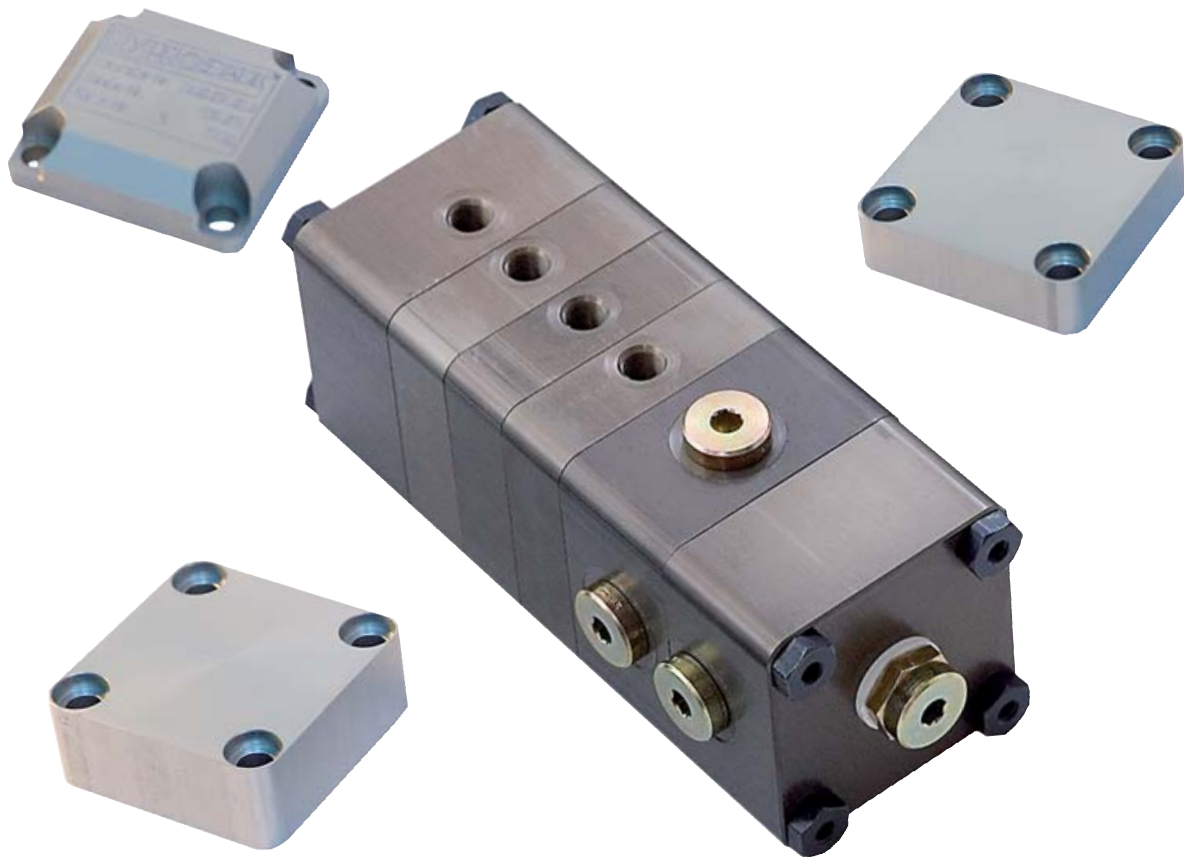
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Part I:
PM controller

1. Controller name

The name PM controller is derived from the “**Progressiv-Mengen (Progressive Quantities)**” controller description. The Progressive Quantities Controller description was cho-

sen due to the progressive (increasing) characteristic curve of the controller. ■

2. Advantages of the PM controller

Before development of the PM controller, the fluid flow was regulated in the hydrostatic pockets using capillaries, refraining from the less suitable methods with one pump per pocket. The capillary is a constant resistance so that with laminar flow the flow rate through this capillary is proportional to the differential pressure above this capillary.

This means that with a constant input pressure (= pump pressure) at the capillary, the flow rate through the capillary and thereby through the hydrostatic pocket drops with increasing pressure in the pocket (= output pressure at the capillary). Thus using capillaries results in significantly

larger changes in the hydrostatic column, i.e. less stiffness than with constant flow rate. In contrast the PM controller due to its unique design - only controlled by the differential pressure between controller input and output – delivers an also increasing fluid flow into the pocket when the pocket pressure increases! Thus compared with constant fluid flow in the pocket, a smaller column change and thereby higher stiffness are achieved with the PM controller.

Compared with capillaries approx. four times the stiffness can be achieved for comparable ratios on account of this using PM controllers. ■

3. Features of the PM controller

The PM controllers show the following features.

- practically wear-free and hysteresis-free by means of practically purely elastically operating regulators
- relatively insensitive to contamination by means of throttle gaps with large rectangular cross section or regulators with a certain self-cleaning effect
- excellent dynamic behaviour on account of minimal regulation paths (approx. 0.025 mm), smaller to accelerate masses and larger actuating forces
- both types are self-ventilating if the recommended installation position of the series PM controller is observed
- small space requirement – see Fig. 5-15
- low weight, the controllers are mainly made of aluminium
- corrosion-resistant, the liquid to be regulated only comes into contact with anodised aluminium and the membrane
- in the case of unacceptably high differential pressure on the membrane, this is counteracted by support pads on a spherical area on the controller case so that damage to or even destruction of the membrane is largely ruled out
- with the PM controller – without reserve – pocket pressures up to approx. 90 % of the pump pressure can be used. With capillaries and pocket pressures close to the pump pressure, the flow rate (and thus the column height) of the pockets is very small, because usually only pocket pressures up to approx. 75 % of the pump pressure are possible with capillaries ■

4. Behaviour with different oil viscosities

As the flow in the fixed throttle column of the PM controller is always laminar, the controller flow rate is inversely proportional to the oil viscosity. It also shows the same behaviour as the downstream columns of the hydrostatic pockets. In this way the properties of bearings or guides – e.g. of machine tools – are practically unaffected by the oil temperature or viscosity. The flow rate through the PM controller and thus the oil requirement for the guide or

bearing increases with falling oil viscosity, i.e. with rising oil temperature. Therefore the minimum possible oil viscosity must be taken into account for the dimensioning of the oil supply system. This arises at the maximum oil temperature taking account of the minimum permitted viscosity of the selected types of oil. DIN 51519 permits a viscosity tolerance of +/- 10 % of oil viscosities! ■

5. Controller characteristic curve

Figure 2 shows the characteristic curve of the flow rate through a regulating disc of the series PM controller or a side-mounted controller depending on the output pressure p_T at the controller (= pocket pressure). For comparison, Fig. 1 shows the characteristic curve for a capillary. As regards the comparison of the effects of both these characteristic curves, please see the publication “Neuentwickelter PM-Regler verbessert hydrostatische Führungen” (Recently developed PM controller improves hydrostatic guides). As can be seen from the characteristic curve of the PM controller in Figure 2, the PM controller delivers more oil in pockets with high p_T pressure and less oil in pockets with low p_T pressure. Due to this behaviour approx. **4 times** the stiffness and an equally large reduction in the column height change are achieved with PM controllers as opposed to solutions with capillaries for comparable technical data, particularly the same **minimum column height** (at maximum load).

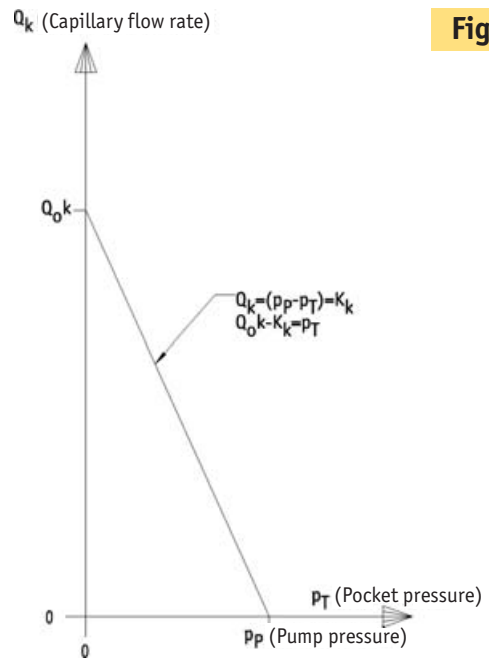


Fig. 1

6. Flow rate and pressure magnitudes of the PM controller

6.1 Influence of the pump pressure on the control mode

The flow rate magnitudes of a PM controller only apply respectively for the stated pump pressure! If the pump pressure deviates from the intended pressure (p_{P0}), the controller characteristic curve for the pump pressures p_{P1} and p_{P2} changes approximately as shown in Fig. 3. Available PM controllers are PMRO for pump pressures of 20 to 80 bar, PMR1... and PMR2... for the pump pressures 20 to 125 bar.

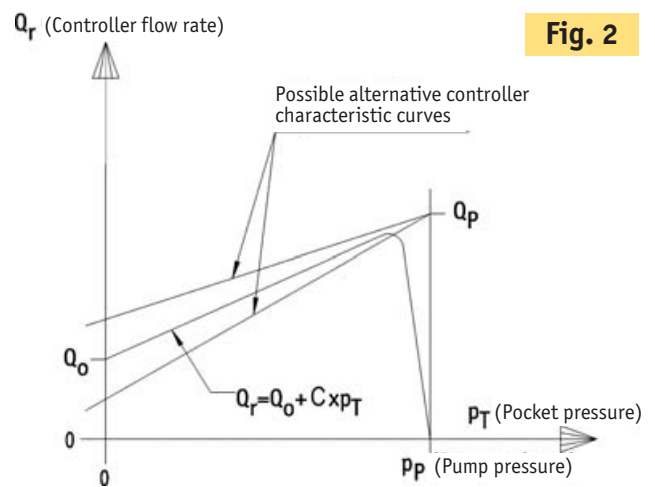


Fig. 2

6.2 Flow rate factors, related to the oil viscosity 10 mPas.

As the flow rate values of the controller stages are dependent on the viscosity of the oil, all flow rate values are related to a standard dynamic oil viscosity of $\eta = 10$ mPas ($1 \text{ mPas} = 10^{-3} \text{ Pas} = 10^{-3} \text{ Ns/m}^2$). This also applies even if the PM controller is not authorised for this oil viscosity. The flow rate values given can be converted for other oil viscosities with the following formula:

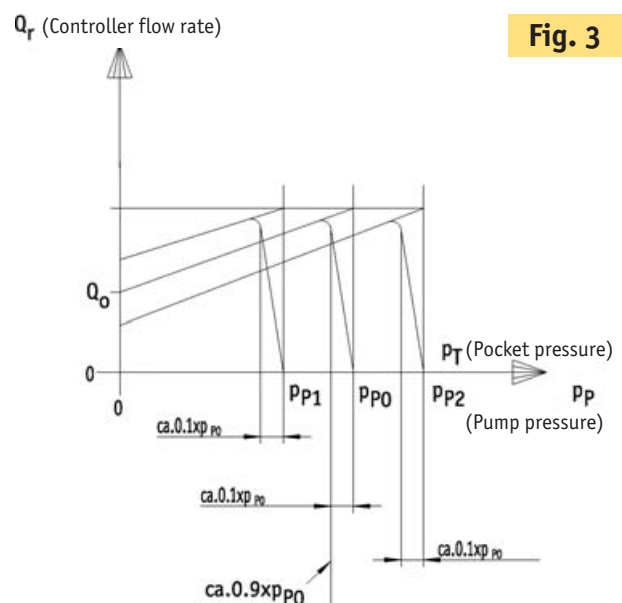


Fig. 3

$$Q_{new} = Q_{10mPas} \times 10(mPas) / \eta_{new}(mPas)$$

Q_{10mPas} : flow rate for 10mPas
 η_{new} : Dynamic viscosity of the real oil
 Q_{new} : Flow rate of the real oil

The flow rate data of a controller are defined by the flow rate values Q_0 (for $p_T = 0$ bar) and Q_p (for $p_T = p_p$) and the pump pressure p_p , see Fig. 2. The value for the slope of the controller characteristic curve is determined by these values.

$$K_r = Q_p / Q_0$$

Output pressure p_T of the oil flow results for the controller from the value K_r :

$$Q_r(p_T) = Q_0 \times (1 + (K_r - 1) \times p_T / p_p)$$

applicable to p_T : pocket pressure p_p : Pump pressure
 $p_T = 0$ to $p_T = 0.9 \times p_p$
 Q_0 Flow rate for pocket pressure = 0
 Q_r : Flow rate for pocket pressure p_T

K_r -values between 1.2 and ∞ are possible by modification of the controller dimensions. Controllers with K_r -values from 1.6 to 3.5 are useful and available.

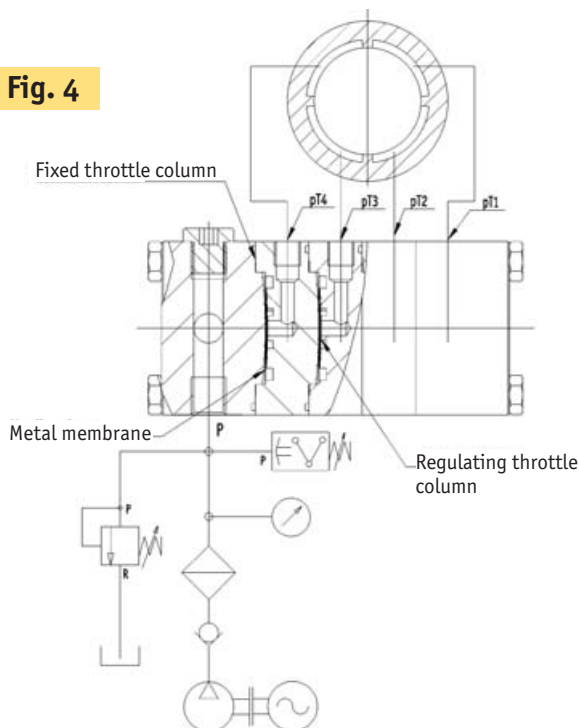
The controllers are uniquely defined with these definitions by both the values " Q_0 " and " K_r ".

The PM controller flow rate values are tiered approximately according to the R10 standards series (1.0 - 1.26 1.6 2.0 - 2.5 - ...) and always related to a dynamic oil viscosity of 10mPas. The maximum flow rate values of the individual controller types and sizes depend on the viscosity and on the pump pressure. As the PM controllers are used with different membranes for different pump pressures and oil viscosities, no "round" values for Q_0 and K_r can be achieved. Therefore the regulating discs have been made with true dimensions which have determined the flow rate data of these controllers and have converted to the oil viscosity of 10 mPas. ■

7. Types of PM controller

7.1 PM controller in "series construction"

7.1.1 Configuration of the PM controller in "series construction"



A PM controller in "series construction", partly cut open, is shown in Fig. 4. This controller is integrated in an hydraulic circuit for an hydrostatic centre sleeve guide with 4 pockets.

The PM controller consists of the pump pressure connection block shown, a variable number of regulating discs (three regulating discs in Fig. 4) and, shown on the right, a regulating disc designed as an end piece. Each regulating disc consists only of the controller case, a metal membrane and an O-ring and supplies one or more coupled hydrostatic pockets.

A regulating disc has a fixed throttle column which always has a laminar flow and a regulating throttle. The regulating throttle controls the differential pressure via the fixed throttle column at constant pump pressure only dependent on the output pressure p_T at the respective regulating disc. The connection block and the regulating disc are held together by four tie-rods. The thread on the tie-rod nuts is used for fixing the PM controller. ■

7.1.2 Use of the PM controller in “series construction”

The series construction controller is usually mounted on the machine component in which the products to be supplied by this controller are arranged. The connection from the controller to the hydrostatic pockets is made with metal pipes and drilled holes in the machine components.

As the connection between controller and hydrostatic pockets must be made with metal pipes and not with hoses, the controller must be mounted on moving carriages equipped with hydrostatic pockets. The advantage of this concept and of the controller in series construction is that all pocket pressures on a branch of the controller-hydrostatic pocket connection near the controller can be measured centrally and that the controller, e.g. in the case of contamination, can be replaced easily.

The disadvantage as compared with the side-mounted controller solution described below is the cost for the pipe connections. A further disadvantage, a dynamically adverse behaviour, particularly for high oil flows and/or low viscosity oils, results due to the kinetic energy of the oil in the connection lines between controller and hydrostatic pockets and the larger suspension of the oil volume between controller and pocket. In order to keep these disadvantages as small as possible, it is recommended to keep the lines between controller and hydrostatic pockets short.

In order to improve the dynamic behaviour of the controller and thereby also that of the machine components, a damped version of the controller has been developed and subjected to extensive practical tests. These damped controllers were originally developed for low viscosity oils and larger oil flows like those needed for fast-running bearings (see the following section 7.2).

Based on the extremely positive results with these damped series controllers, “damped” PM controllers (with significantly stronger damping) are today practically exclusively also recommended for the guides and slow-running bearings with the usually high-viscosity oils used and small oil flows.

The PM controller in series construction is used almost exclusively for linear guides and slow-running bearings, e.g. for rotary tables and for special tasks. Oil types corresponding to the ISO viscosity classes VG 32, VG 46 or VG 68 are usually used for these tasks. Therefore, the PM controllers in series construction are designed so that the fixed throttle column with oil types corresponding to VG 22 or higher viscosities always has a laminar flow. For this reason, the series controllers are authorised without restriction for the VG 22 oil types or oils with higher viscosities.

The controllers PMR0 with square size 50, PMR1 with square size 65 or PMR2 with square size 80 mm (special configuration) are available corresponding to the flow rate quantity needed in order to always achieve laminar flow rate in the fixed throttle column depending on the size of the controller flow rate and the oil viscosity.

Regulating discs with any flow rate data can be used in any sequence inside a PM controller in series construction. Only the pump pressure, due to the common pump connection, and the type of oil are the same for all regulating discs of a PM controller in series construction.

Even in the damped version, the series controller is not or only limited suitable for fast-running bearings. ■

7.2 Side-mounted PM controller

The side-mounted controller described below has been developed in order to avoid or reduce the disadvantages mentioned above.

As experience has shown, dynamically stable and well-damped fast-running bearings can only be achieved if the behaviour of the controller, hydrostatic bearings and the hydraulic power unit are optimally matched to each other

and the perceptions for this have also been consequently implemented in practice. For this reason, side-mounted PM controllers for guides and slow-running bearings are only sold as single elements, however only completely assembled with spindle bearings for low viscosity spindle oils. Side-mounted PM controllers are thus only available for types of oil more than VG 15. ■

7.2.1 Design of the side-mounted PM controller

As an alternative to the PM controller “in series production”, two installation sizes of side-mounted PM controllers, “side-mounted controllers” in short, each with “internal” or “external” oil supply are also available (see the following Figures 10

to 15).

Each of these side-mounted PM controllers supplies only one or several combined hydrostatic pockets. ■

7.2.2 Use of the side-mounted PM controller

These side-mounted controllers are usually fixed to a flat grinded surface of a machine component with hydrostatic pockets so that the connection from the central connection of the side-mounted controller to the hydrostatic pocket is achieved by means of an only as short as possible drilled hole.

The oil supply from the pump to the side-mounted controller can also be made “internally” via the screw-on surface for the side-mounted controller (see Fig. 10 to 13). Here the supply drilled hole can be arranged at less than 45° (see Fig. 10 and 12) or on the main axes of the controller (as shown in Figures 11 and 13). Alternatively, the oil supply can also be done “externally” via the casing (see Figures 14 and 15). Then only one ring line is needed for the oil supply of the side-mounted controller.

The pocket pressure for these side-mounted controllers can only be measured via a branch bore of the controller-

hydrostatic pocket connection bore in the machine component or via an intermediate plate with branch pipe clamped under the side-mounted controller.

The advantage of this solution with side-mounted controllers is the usually better dynamic behaviour, the reduced expense for pipelines and the favourable optical appearance.

The disadvantages are that a flat grinded screw-on surface with fixing drilled holes is needed for every side-mounted controller and that the side-mounted controller is marginally more expensive than the series controller. Furthermore, checking the pocket pressures is more difficult and associated with higher costs as either a grinded plate with branch pipe on both sides for pressure measurement must be mounted underneath the controller or a branch pipe drilled hole must be provided in each machine component. ■

8. Controller dimensions

The dimensions shown in Figures 5 - 9 apply to the PM controllers PMR0, PMR1 and PMR2 in series construction.

The dimensions of PM controllers in series construction with integrated jet pump are shown in Figures 6 and 8.

Please refer to Part II of this “Technical Information” document for the jet pump technical data.

Dimensions of the various side-mounted PM controllers are shown in the Figures 10 to 15. ■

9. Installation instructions and regulations

9.1 Filling the PM controller for the first time

The hydraulic power unit and the supply line to the PM controller must be thoroughly rinsed (they could contain chips!) before installing the PM controller. The pipes and drilled holes between PM controller and pocket must also

be absolutely clean otherwise the guide surface can be damaged. During first-time operation the PM controller must be filled with oil at approx. 10% of the intended pump pressure and ventilated (see section 9.2). ■

9.2 Ventilation

Vibrations in the controller are always caused by air in the controller or in the supply or discharge lines, by contamination in the controller or by the use of an unauthorised too-low viscosity oil. Fluctuations of the pocket pressures due to fluctuating loads do not result in vibrations in the

controller for properly ventilated controller and pipeline system, for correct types of oil and properly laid out connection lines between controller and the hydrostatic pockets. ■

9.3 Recommended installation position

If the controller in series construction is installed upright with horizontal longitudinal axis and the controller downstream flow connections (M8 x 1 or G 1/8), it ventilates itself automatically and continuously. If the controller has

to be installed with the longitudinal axis vertical, the pump connection P must be arranged on the controller at the bottom. ■

9.4 Ventilation procedure

Depending on the magnitude of the oil flow through the controller and the oil viscosity, the ventilation procedure during commissioning can take some time.

Vibrations in the controller during first-time ventilation do not endanger the controller!

The ventilation process is improved if it is ventilated with a reduced pump pressure of approx. 10 % of the intended pump pressure (the air bubbles are larger!).

Dead-end lines leading upwards in the supply and discharge lines where air can build up (e.g. manometer) must be avoided. The depth of drilled holes going upwards must be checked.

It must be ensured there is good "outgassing" of the oil in the hydraulic power unit!

9.5 Fixing the PM controller

The four threaded bores on the front side in the tie-rod nuts are provided for fixing.

It must be absolutely ensured that no additional axial tractive forces of any kind have an effect on the tie-rods due to the fixing.

9.6 Connection

The connection between PM controller outputs and hydrostatic pockets must be made with steel pipes. The connec-

tion between hydraulic power unit and the PM controllers can be made using hoses and/or pipes.

9.7 Dismantling

PM controllers must only be dismantled by the manufacturer. If a PM controller is dismantled by the customer, the guarantee is void!

10. Oil filtering

The necessary filter mesh is determined by the requirements of the oil pump, the minimum size of the columns of the hydrostatic guide and/or bearing and by the desired service life of the oil.

The filter mesh 10 µm is absolutely sufficient. The recommended filter mesh of 6 µm is of course better!

Inasmuch as longer lines, particularly hose lines, between the filter and the PM controller are necessary, we recom-

mend installing at least a small screen filter directly on the controller input (connection P).

For example, the screen filter HF1F for controllers with the connection size G 1/4, and the screen filter HF2F for connection size G 3/8, each from Heilmeier & Weinlein, D-81673 Munich, are possible.

In any case, this screen filter is absolutely required for PM controllers with integrated jet pump.

11. Controller labeling

Every controller is identified by the assembly number and an item number of the manufacturer. The respective customer of the manufacturer receives an order sheet and all the data relevant to him for each controller assembly.

The outputs (M8 x 1 for PMR0, G 1/8 for PMR1, G1/4 for PMR2) on the regulating discs are only marked where the flow rate data of the individual regulating discs are different. The type of marking is agreed with the customer and noted in the order sheet.

12. Flow rate data selection (see section 6)

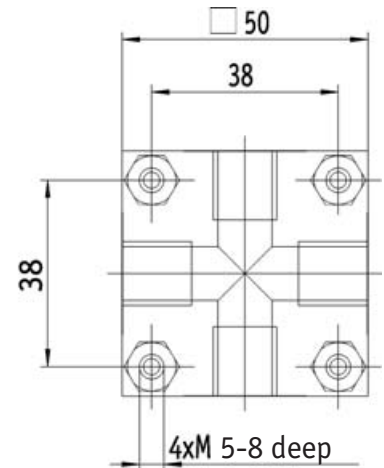
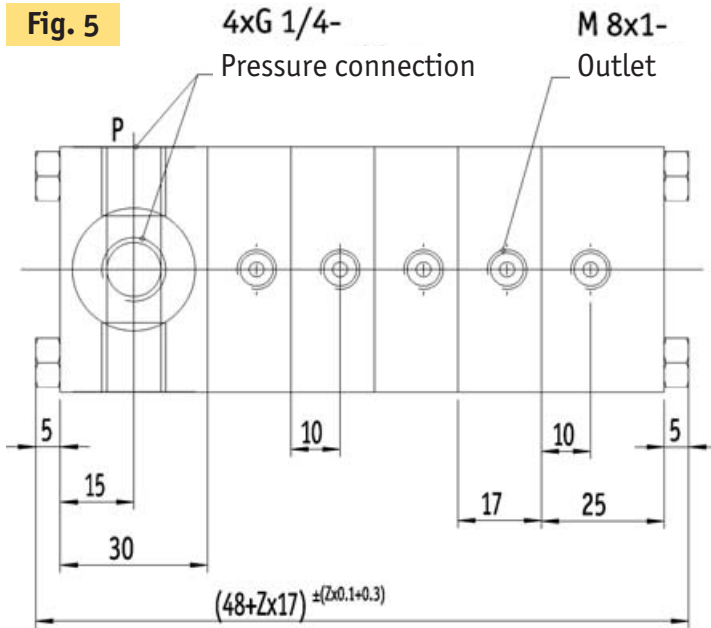
Experience shows that the design of hydrostatic guides and particularly hydrostatic bearings requires extensive specialised knowledge and experience with these guides and bearings. Therefore we emphatically recommend having the design of the hydrostatic guides and bearings performed by us. We have comprehensive design and calculation programs, with whose support hydrostatic guides and bearings can be optimally designed. With these programs, hydro-

static bearings and guides can not only be optimised for static loads but also for dynamic loads, whereby the best possible damping values are obtained.

If this work should not be performed by ourselves, the desired controller data (Q_0 , K_r , minimum oil viscosity, pump pressure, number of regulating discs) can be disclosed to us. We will then propose suitable controllers whose flow rate data come close to the desired values. ■

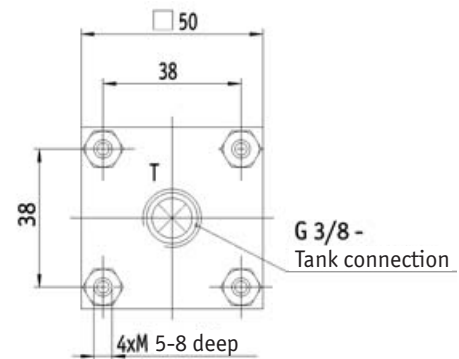
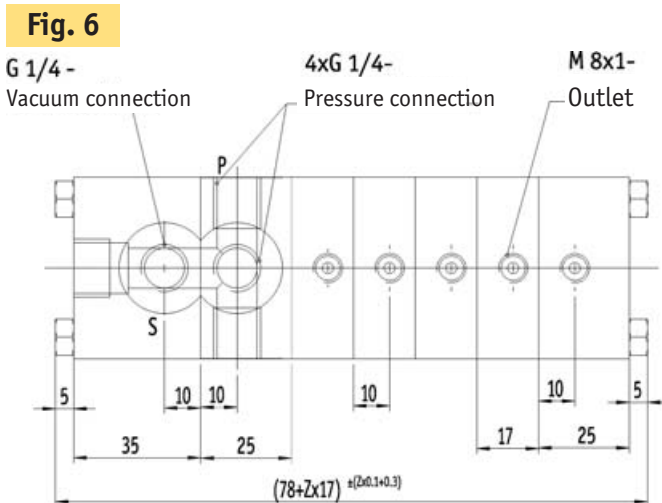
13. Technical diagrams 5 to 15

PMRO without jet pump

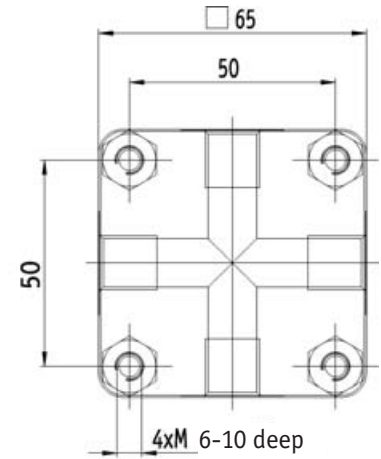
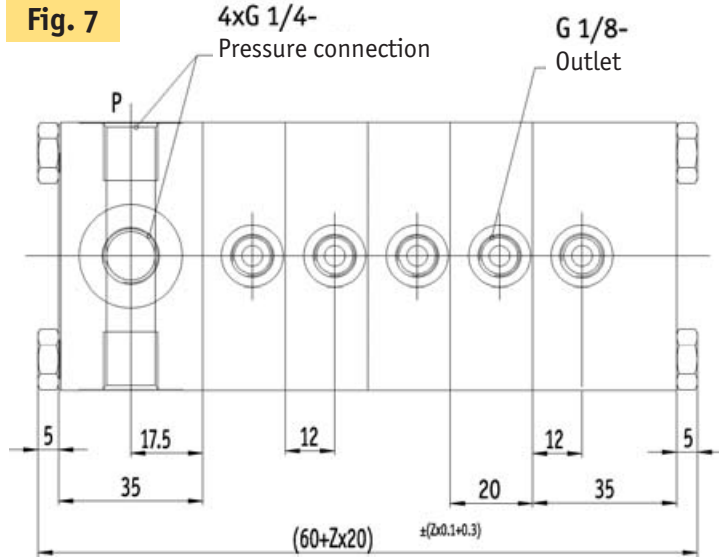


Z = Number of controller outputs

PMRO with jet pump

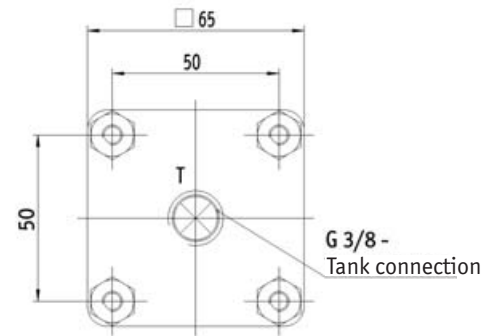
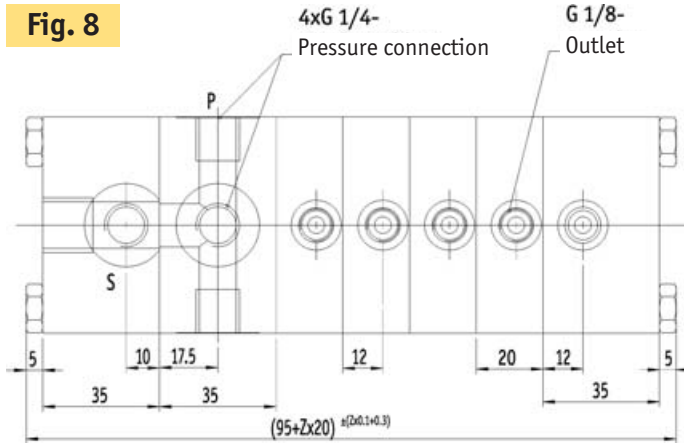


PMR1 without jet pump

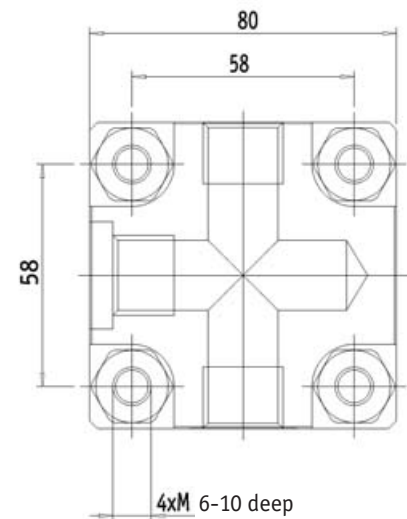
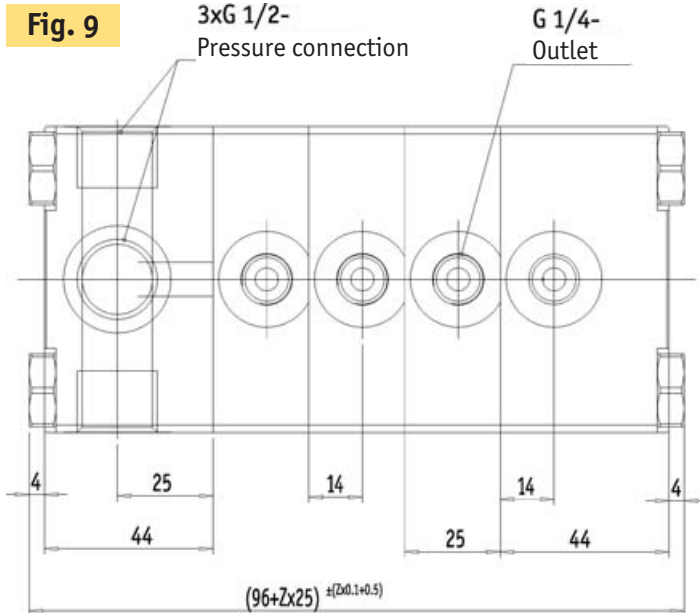


Z = Number of controller outputs

PMR1 with jet pump

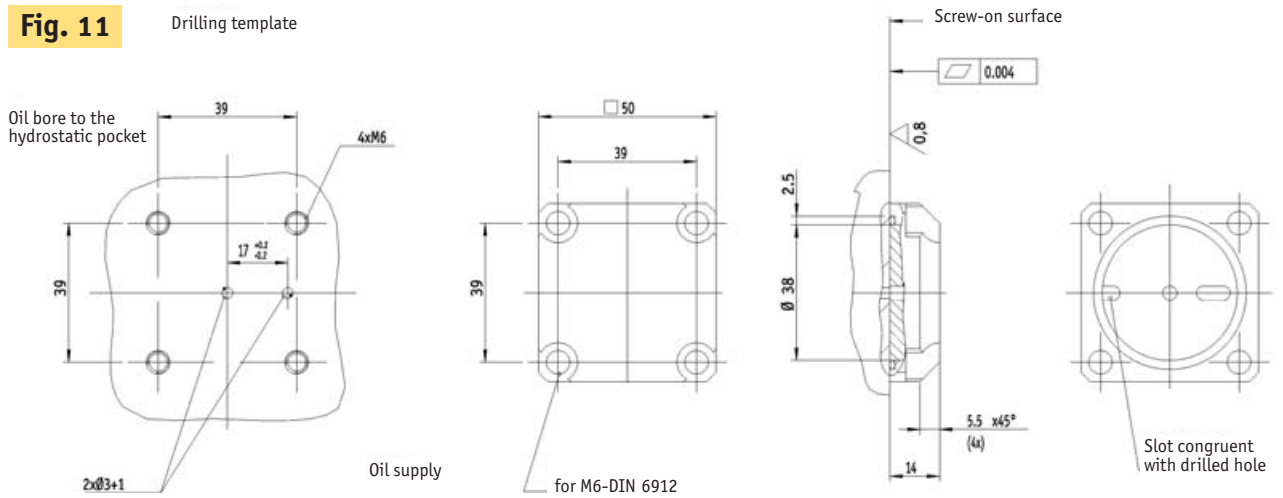
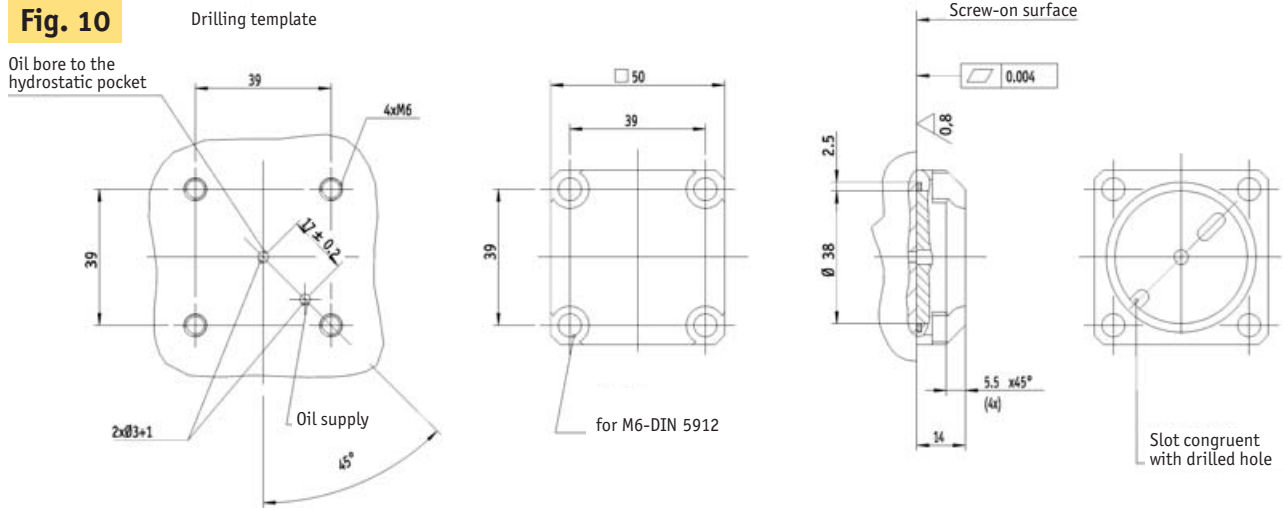


PMR2 without jet pump



Z = Number of controller outputs

Side-mounted PM controller with internal oil supply size 50



Side-mounted PM controller with internal oil supply size 65

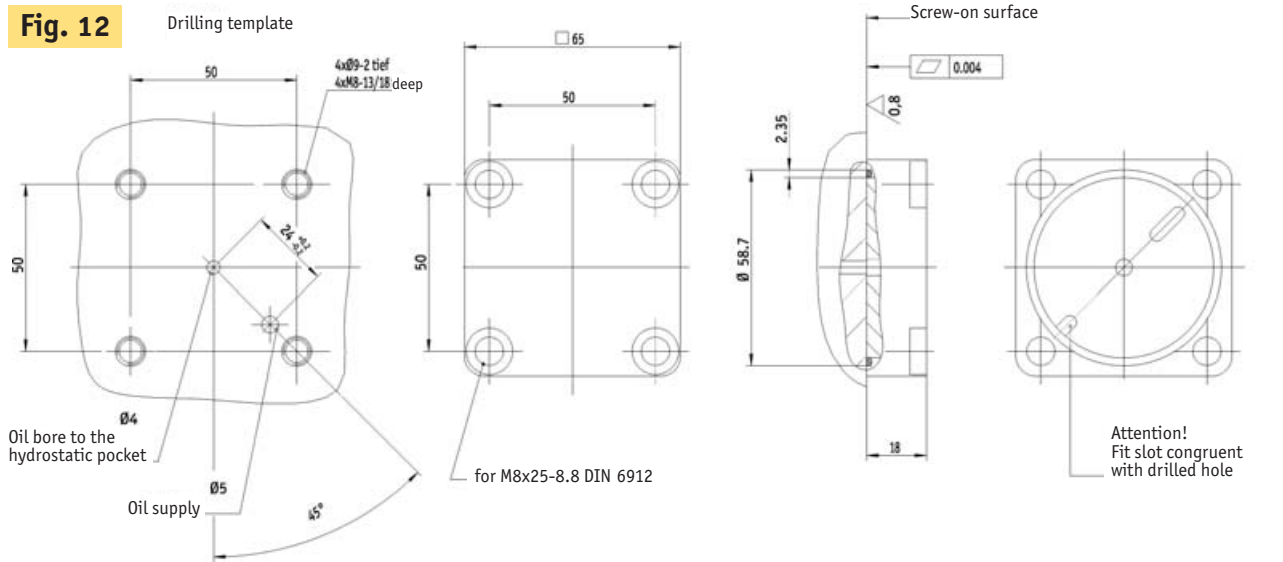
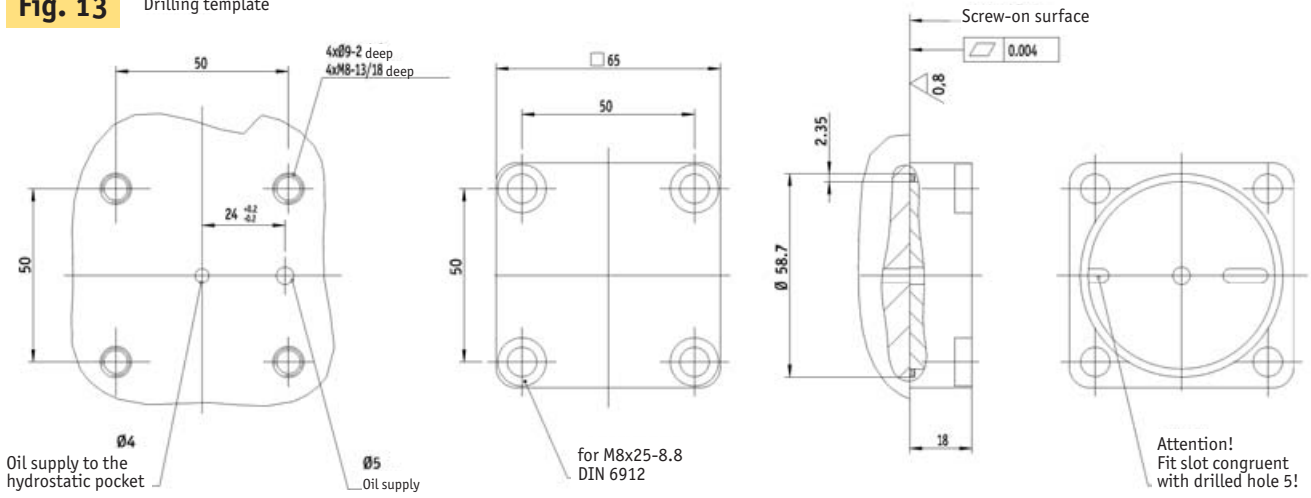
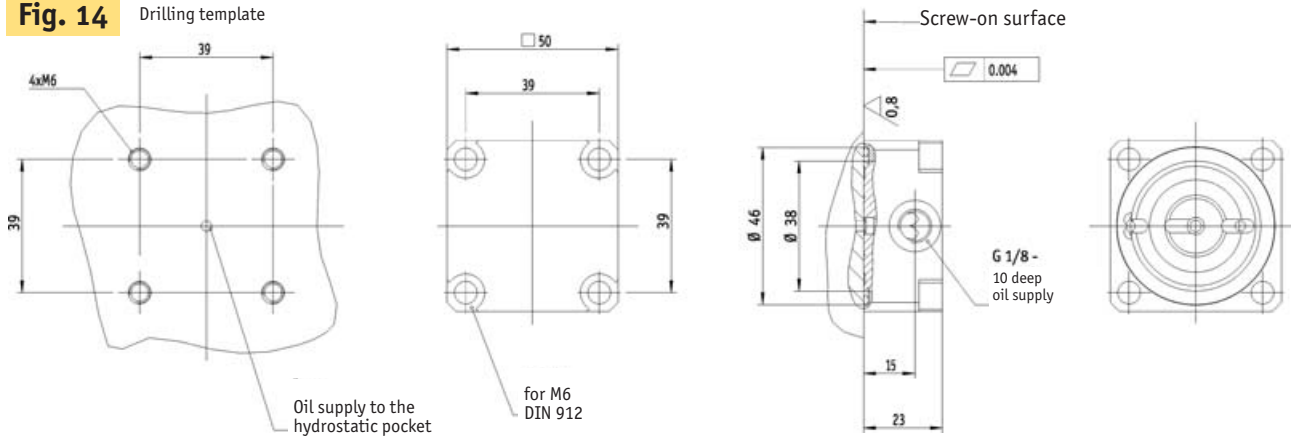


Fig. 13 Drilling template



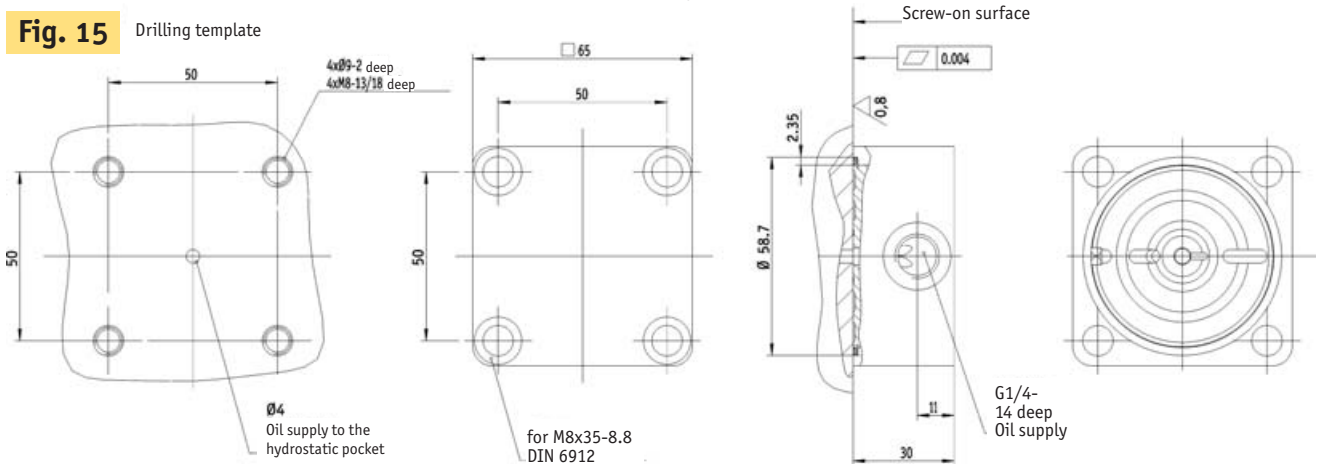
Side-mounted PM controller with external oil supply size 50

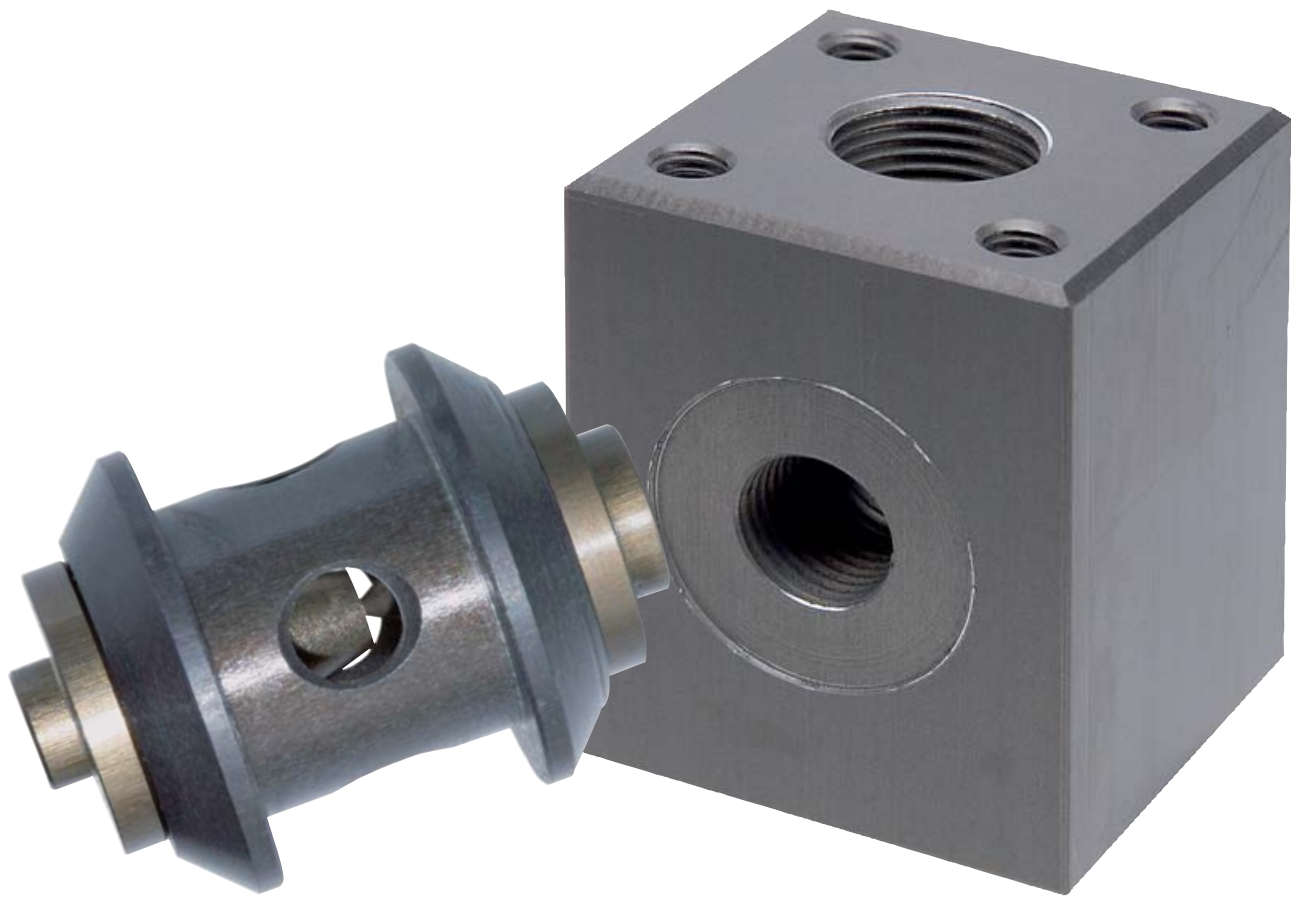
Fig. 14 Drilling template



Side-mounted PM controller with external oil supply size 65

Fig. 15 Drilling template





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Part II:
Jet pump

1. Jet pump possible applications

With a relatively small “drive flow” (e.g. 0.5 l/min at 25 bar pump pressure), the jet pumps generate a relatively high vacuum (approx. 0.9 bar negative pressure, 0.1 bar absolute pressure!) at the vacuum connection “S”.

1.1 Initial tension of guides without wrap-around

The jet pumps have been developed for initial tensioning of hydrostatic guides without wrap-around equipped with our PM controllers.

Using the jet pump, oil is extracted from the additional oil-rinsed “vacuum pockets” arranged between or next to the hydrostatic pockets. In this way, a negative pressure is formed in these pockets, using which the carriage guide is additionally pre-tensioned. Using the jet pump, the stiffness of open hydrostatic guides (= guides without wrap-around) can be approximately doubled or even trebled. Thus an horizontal hydrostatic guide can be designed more economically by dispensing with wrap-around provided the maximum lifting forces are smaller than the gravitational forces.

Fig. 16 shows how such a jet pump is used together with our PM controllers for the hydrostatic guide of a carriage with V-flat track.

The jet pump and vacuum pocket are shown in Fig. 17.

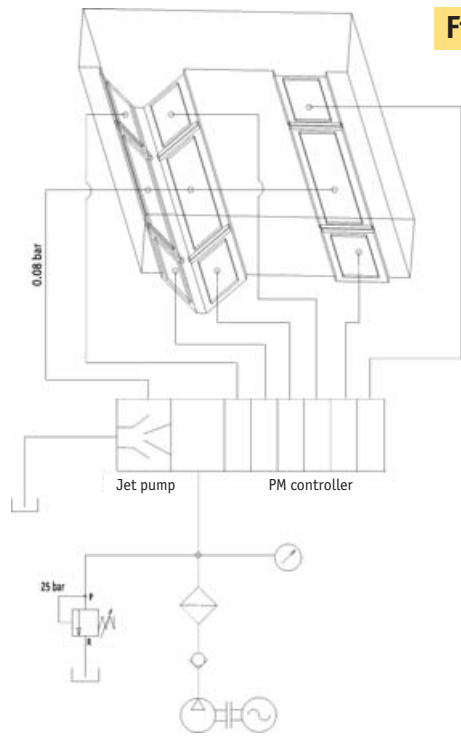
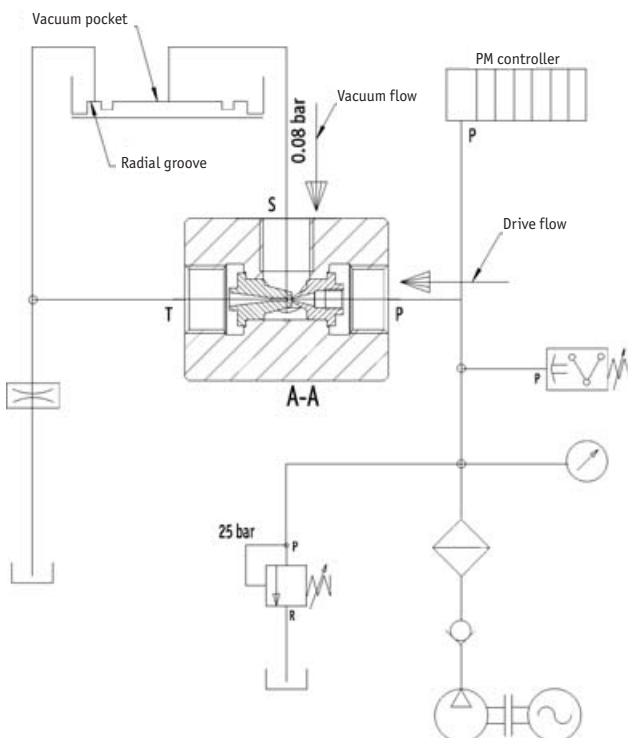


Fig. 16

Fig. 17



1.2 Clamping functions

Alternatively, our jet pump with corresponding oil-rinsed pockets can also be used for clamping machine components or carriages.

2. Design and principles of operation of the jet pumps

The jet pumps operate according to the injector principle. They consist of a “drive nozzle” (see Fig. 17) by means of which the pressure of the “drive flow” is converted into the speed of the “drive jet”. The drive jet mixes itself with the vacuum flow in the “mixing nozzle”. The vacuum flow is delivered from the vacuum connection to the tank connection by the drive flow. If the vacuum line is throttled accordingly, a negative pressure is produced in the vacuum line the size of which depends on the capacity of the jet pump. With our SPU jet pumps designed for the generation of a negative pressure as high as possible, negative pressures up to 0.90 bar (0.1 bar absolute pressure) can be achieved.

3. Jet pump features

- wear-free and hysteresis-free to a large extent as no moving parts are used.
- smaller drive oil flow
- higher negative pressure (up to approx. 0.9 bar)
- less space required
- low weight
- any installation position
- corrosion resistant as all parts which come into contact with the medium are made of anodised aluminium
- self-ventilating
- field tested for the types of oil corresponding to VG 22 to VG 68 which are predominantly used for hydrostatic guides.

4. Behaviour with different oil viscosities

Up to now the jet pumps have been field tested and used with the types of oil VG 22 to VG 28 usually used for hydrostatic guides. Here, the oil viscosity only shows a very small effect on the technical data of the jet pump.

Different measurements with low-viscosity spindle oil (corresponding to VG 5) show that jet pumps with optimum data require modified nozzles for such low-viscosity oils.

5. Characteristic curves of the jet pumps for oil types corresponding to VG 32 to VG 68

The characteristic curves of two jet pumps are shown in Fig. 18. The suction oil flow depending on the negative pressure in the suction line is shown. The characteristic curves have been measured with an oil corresponding to VG 32.

For an input pressure of 25 bar at the connection P, a drive oil flow of 0.8 l/m for the pump SPU 05/15 and a drive oil flow of 0.5 l/min for the pump SPU 04/13 are needed.

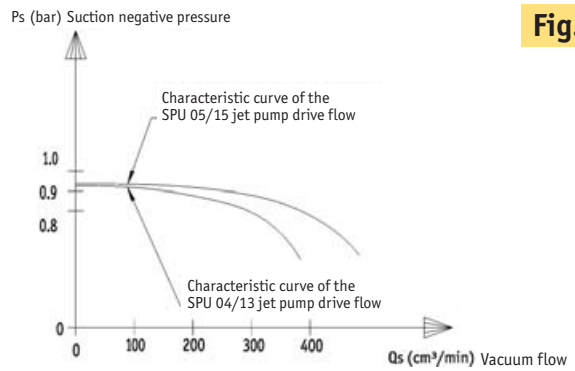


Fig. 18

6. Type

The jet pumps can be supplied in three different models:

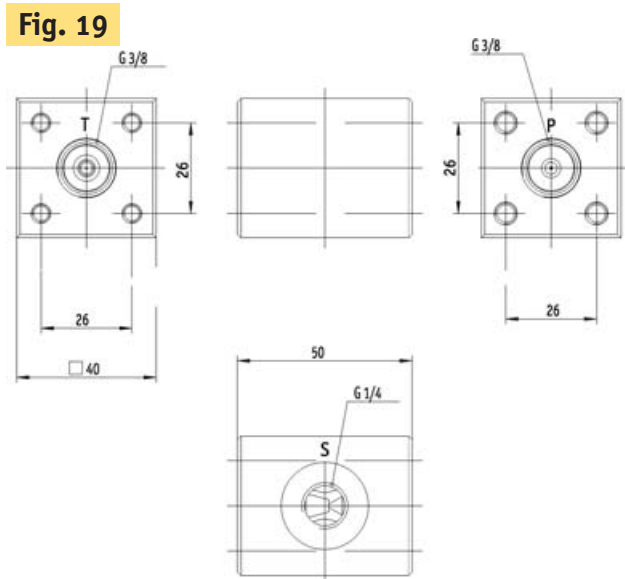


Fig. 19

6.1 Case – Jet pump (Fig. 19)

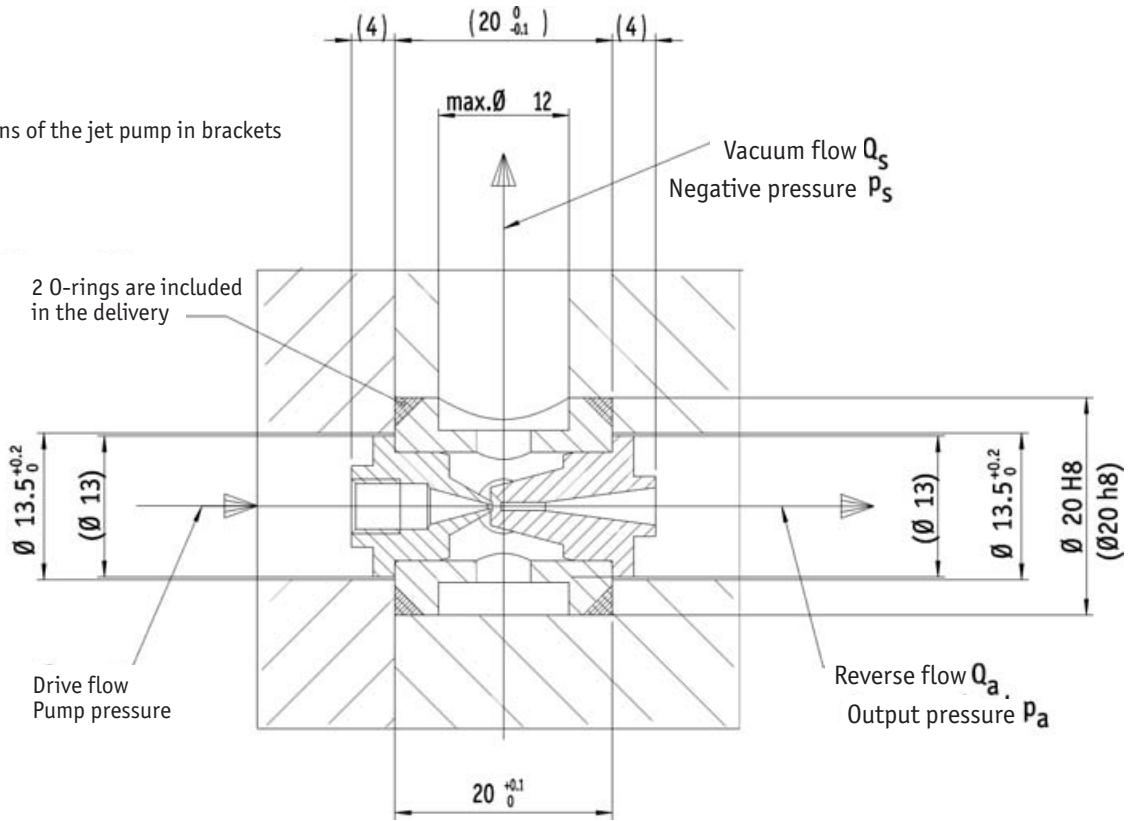
The jet pump is integrated in a small case with the dimensions 40x50 mm. There are 4 threaded bores on the front of this case for fixing the jet pump. In order to rule out incorrect installation, these fixing drilled holes are different sizes.

6.2 Installation – Jet pump (Fig. 20)

The jet pump can be used to save space in a case or machine component, whereby many connection lines can be saved and the “optics” of the machine are improved. Both the 0-rings necessary for sealing the jet pump are supplied. ■

Fig. 20

Dimensions of the jet pump in brackets



6.3 Jet pump installed in a line in the PM controller (Fig. 6 and 8, Chapter PM Controller)

The jet pump can also be supplied integrated in the PM controller. Jet pump and PM controller are then supplied via a common pump connection. However, different pump pressures for the jet pump and the controller are not possible. ■

7. Suction cup version (see Fig. 21 and Fig. 22)

The suction cups must be designed so that a suction flow as small as possible is achieved. Thereby, it is possible to use jet pumps a smaller drive flow. In addition, the jet pump is operated in the area of the characteristic curve (Fig. 18) where relatively large percentage changes in the drive flow only cause small changes in the negative pressure. In the case of a change in the negative pressure oil flow caused by a change in the column height or change in the oil viscosity, the negative pressure and thus the pretensioning force remain largely unchanged.

If air is drawn in by the columns of the vacuum pockets, this air expands very strongly due to the lower pressure in the pockets whereby the negative pressure flow suddenly increases and thus the negative pressure drops. The negative

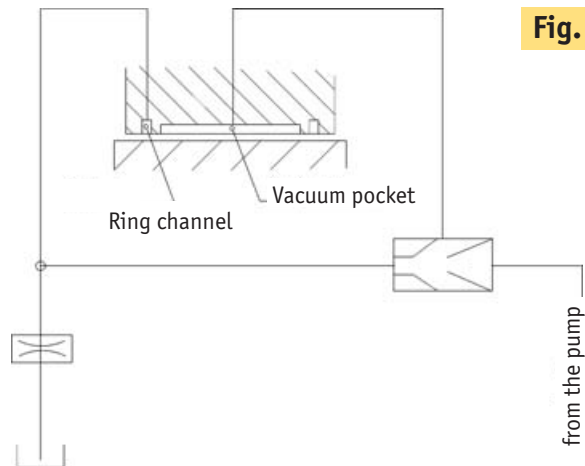


Fig. 21

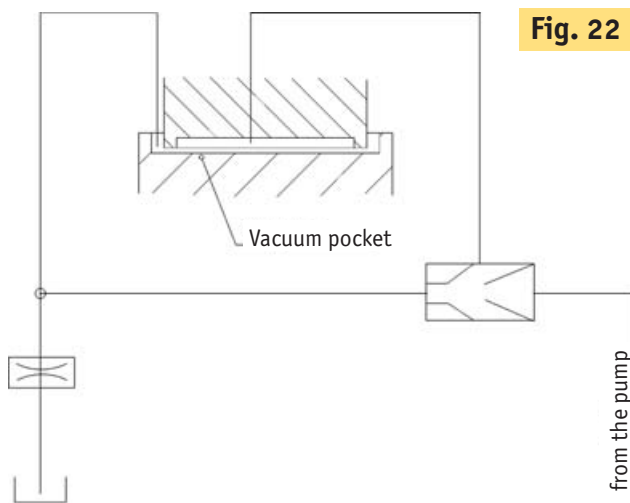


Fig. 22

pressure also falls again during the passage of this air through the jet pump.

It must therefore be ensured that only oil but no air is drawn through the columns of the vacuum pockets. As shown in Fig. 21, this can be achieved using a ring channel around the vacuum pockets which is filled with oil at low positive pressure (approx. 0.01 - 0.1 bar).

An alternative solution according to Fig. 22 is also possible. Here the oil is restrained by partition walls around the mating track. Transversal grooves, which the oil is dragged through during the carriage movement, must be provided in front of and behind each vacuum pocket for this solution. **Small quantities of air separated from the oil do not affect the operation of the jet pump.** ■

8. Installation instructions and regulations

8.1 Connecton pipes, connection bores for built-in jet pump according to Fig. 20

In order for the available negative pressure at the vacuum connection of the jet pump to also be effective in the pockets, the vacuum lines must be dimensioned as long and/or as short so that the throttle loss in this connection line is only a fraction of the negative pressure.

A line inside diameter of 8 mm is usually sufficient for a length of the negative pressure line up to 2 m for the SPU 04/13 jet pump. We recommend an internal diameter of 10 mm for the same length of negative pressure line for the SPU 05/15 jet pump. **Direction changes in the negative pressure line must be made as bends and not as sharp bends in the line.**

During installation, strict attention must be paid to the leak tightness of the negative pressure line. Stop-cocks and

valves are in many cases indeed pressure-tight, however leaky against negative pressure so that air is drawn in by these components!

A tank line with no tailbacks is particularly important for the operation of the jet pump. **Direction changes in the tank line must be made as bends and not as sharp bends.** We recommend using the same line sizes for the tank line as for the vacuum line. Both the jet pumps SPU 04/13 and SPU 05/15 are certified for a straight tank line of approx. 2 m in length and 6 mm inside diameter.

It must particularly be ensured for the jet pump (Fig. 20) that the T-connection (the oil outlet, on the right in Fig. 20) is under the oil level and cannot thus run empty. ■

8.2 Height difference between jet pump and vacuum suction cup

In extreme conditions, the height difference between jet pump and the vacuum pocket can affect the attainable - negative pressure. A jet pump arranged below the vacuum

pocket enhances, and a jet pump arranged above the vacuum pocket reduces the effect of the jet pump. ■

8.3 Oil filtering

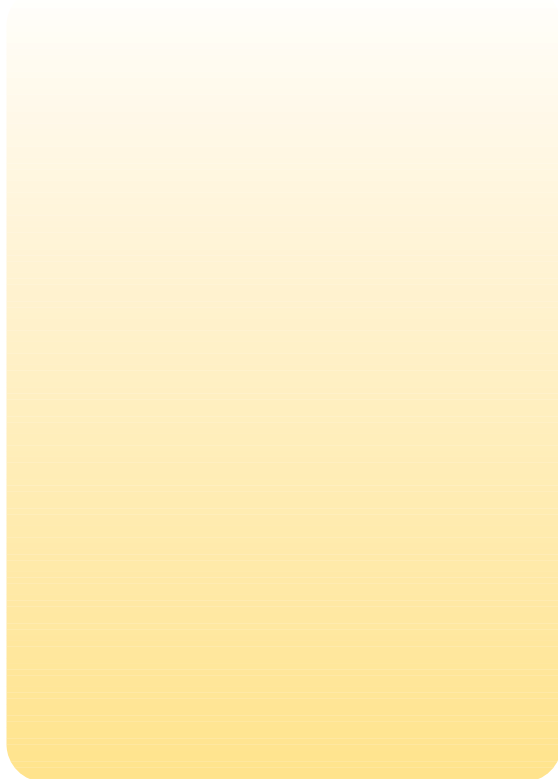
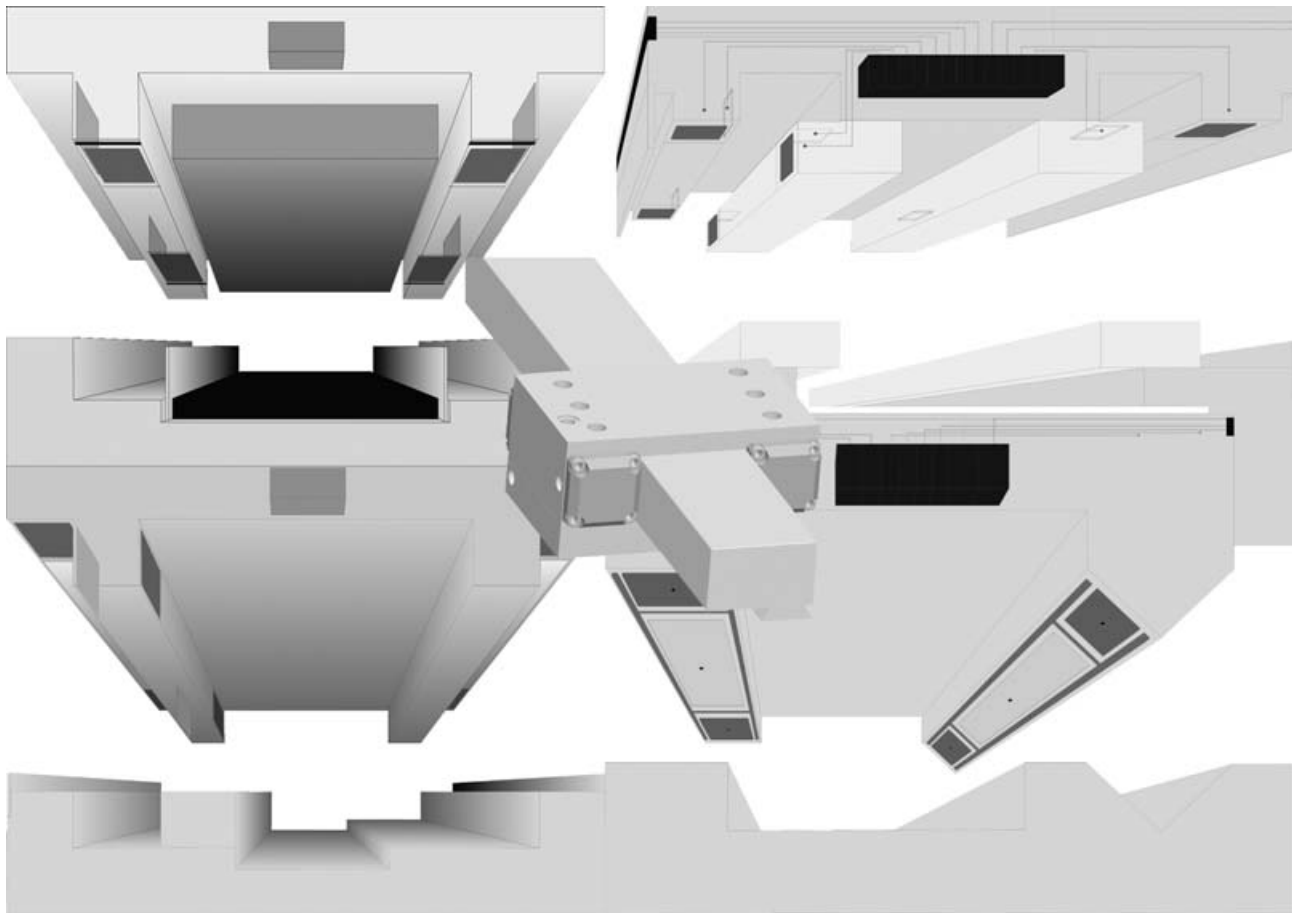
The jet pumps contain nozzle drilled holes with minimum 0.4 mm diameter. The filter unit of 10 µm usually used for the hydraulic pump is therefore absolutely sufficient. However, experience shows that larger pieces of dirt peel away from the lines between filter and jet pump during operation of the machine which block the drive nozzle of the jet pump. If the filter is not installed immediately before the

jet pump, we therefore strongly recommend installing a screen filter with filter mesh 0.1 mm in the pump connection of the jet pump or of the PM controller with jet pump. For example, filter HF1F for connection size G 1/4 and filter HF2F for connection size G 3/8 from the company Heilmeyer & Weinlein, D-81673 Munich are possible. ■

8.4 Installation

The jet pump can be installed in any position. Before installing the jet pump, the hydraulic power unit and the line

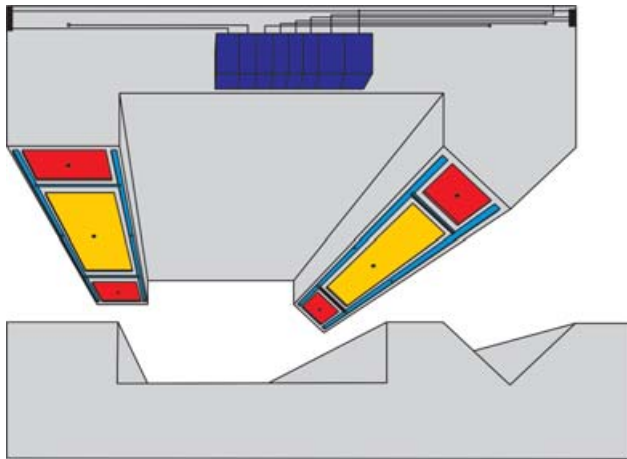
to the jet pump must be thoroughly rinsed (chips, dirt). ■



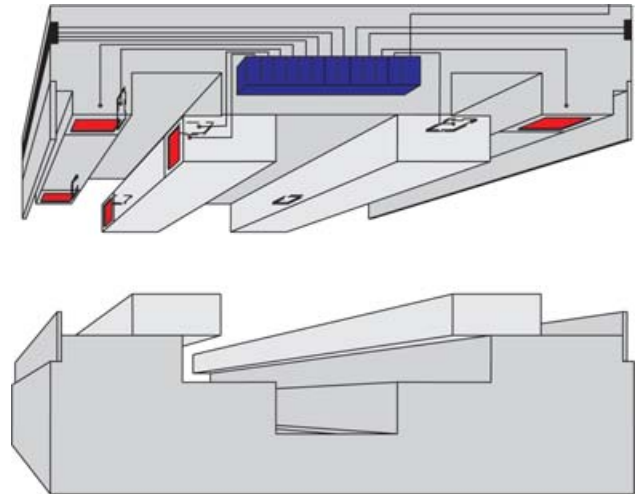
HYPROSTATIK®

Part III:
Application Examples

Hydrostatic V-flat guide



Hydrostatic guide with wrap-around



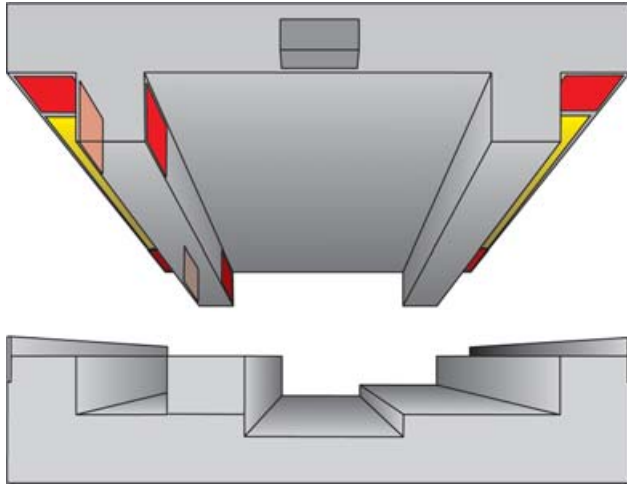
Technical features:

- no distortion by bolts, thus highest precision
- low manufacturing costs as no surfaces have to be ground to size and no guide rails are needed
- for horizontal applications, provided machining and acceleration forces on the pockets are significantly smaller than gravitational forces
- increase of the pretensioning and thus stiffness using vacuum pockets is possible (shown in yellow)
- suitable for round parts grinding machines, surface grinding machines, measuring and ultra precision machines
- the stiffness of the direction guide increases with the load on the V-track
- for guides with loads in any directions, this also lifting forces
- simple to make, high-precision and extremely parallel vertical hydrostatic columns.
- low production costs as no part has to be grinded in parallel and to size
- the size of the vertical total column is produced by step grinding on one side of two strips
- for horizontal and vertical carriages with large forces, torques and high stiffness

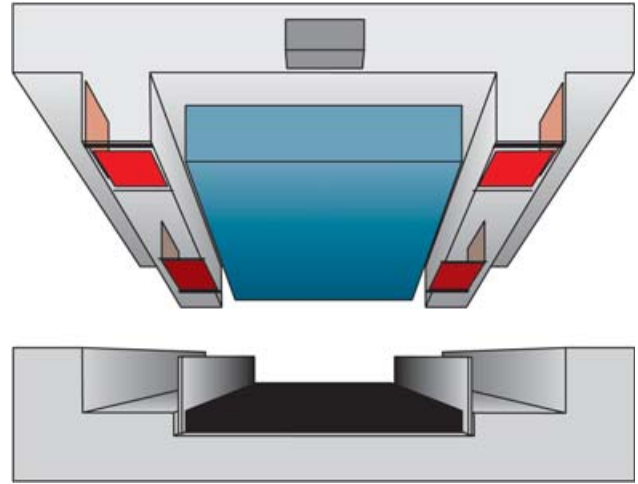
Features (applies to all examples):

- wear-free even at maximum load, thus no loss of precision with increasing usage duration
- ten times better damping, thus significantly better work piece surface and tool service life
- no vibrations and friction fluctuations as with roller guides due to bearing circulation
- no feed pressure jump when changing direction of movement
- practically friction free at low speeds
- no slip-stick effect
- traverse path smaller than 0.1 μm possible
- slip properties of the material, the carriage and the guide track are immaterial, moulded plastic, aluminium or casting compound can also be used.

Hydrostatic guide without wrap-around



Hydrostatic linear motor guide



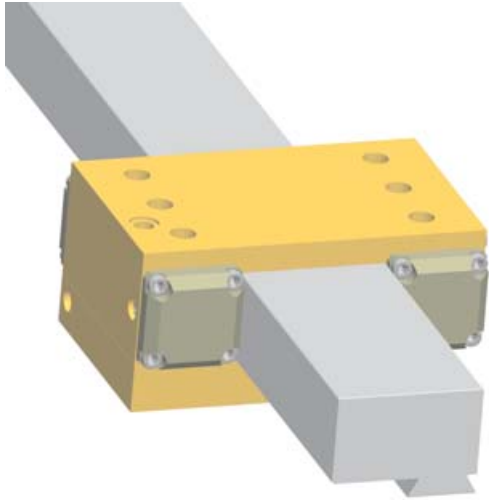
Technical features:

- hydrostatic guide with highest precision and excellent stiff direction guide
- for horizontal applications, provided machining and acceleration forces on the pockets are significantly smaller than gravitational forces
- increasing the pretensioning by weights using vacuum pockets possible
- particularly suitable for round parts grinding machines, surface grinding machines and work piece axes of large milling machines
- the bending load by the pull-down force of the motor on the carriage and the guide track is relatively low
- the support pockets are pretensioned by the magnet force
- for horizontal and vertical carriages providing the lifting forces are significantly smaller than the pretensioning by gravitational and magnet forces

The hydrostatic guide is adapted (applies to all examples) to:

- gravitational, machining and acceleration forces
- maximum speed and acceleration and desired stiffness and optimum damping

Hydrostatic compact guide



Technical features:

- the rail is clamped to the dovetail foot using wedges
- no distortion of the rail due to bolts going through it
- attachment surface can be made by fine milling or grinding
- modular guide shoe available with and without side guide, with and without wrap-around
- all pockets with automatic control are in the guide shoe
- the guide shoe can be adapted via pressure and oil viscosity to the load and maximum speed.



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