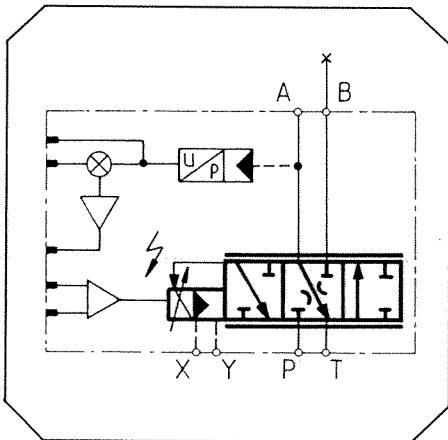


# MOOG



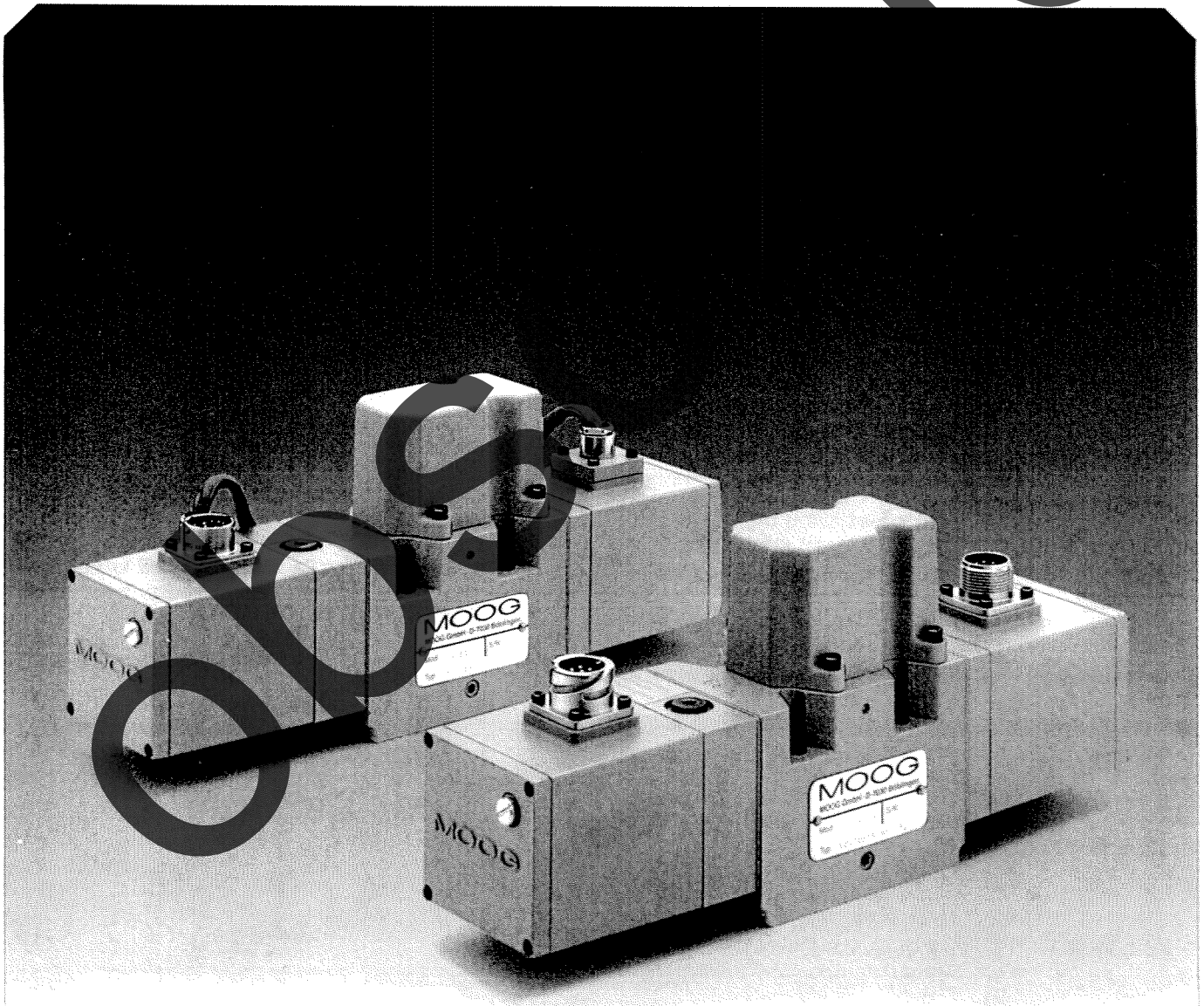
## Series D 656 PQ-Proportional Control Valves with integrated electronics

Rated flow 8 . . . 80 l/min ( $\Delta p_N = 5$  bar)

Operating pressure up to 350 bar

Mounting pattern to DIN 24 340 / ISO 4401

Form A 10



# MOOG PQ-Proportional Control Valves for flow and pressure control / pressure limiting control · Series D 656

With more than 15 000 valves delivered, the MOOG PQ-Proportional Control Valves Series D651 have proved to be reliable in many applications of pressure control. The experience gained there has helped to develop the second valve generation Series D656

- New valve bodies for higher valve flow
- Optional external pilot flow over X and Y
- Optional new pilot stage using jet-pipe principle
- Greater robustness through longer spool stroke
- Improved integrated valve electronics
- 4-way PQ-Valve available

The MOOG PQ-Proportional Control Valve is a dual function valve for precise and fast control of both fluid flow and pressure. It is a compact unit with integrated electronics and transducer (LVDT) for spool position control and integrated electronics and pressure transducer for pressure control, which can be optimized for the individual application. A PQ-Proportional Control Valve can replace several conventional valves in hydraulic systems in order to fulfil and improve the same functions.

## Advantages of the PQ-Proportional Control Valve

- Compact unit for fast and precise control of fluid flow and pressure thus allowing a simplification of hydraulic systems.
- With integrated electronics, completely assembled, adjusted and tested as complete unit. This helps to ease installation and service by the end user.
- High resolution of valve flow function through electrically closed loop. This increases the reproducibility.
- Electronic pressure control or pressure relief control with high precision, independent of valve flow.
- Extended range of rated flow for application in main line (meter-in mode) and by-pass line (bleed-off mode) through hydraulic double flow.
- Low electrical driving power.
- Robust pilot stage which has proven reliable for many years.
- Optional: New pilot stage using jet-pipe amplifier with lower pilot leakage flow for equivalent useful pilot flow and with improved pressure gain.
- High driving forces which ensure reliable movement of the spool.
- Wide adjusting range for pressure setting (minimal pressure only limited by return pressure).

## Note

This catalogue is for users with technical knowledge.

To ensure that all necessary characteristics for function and safety of the system are given, the user has to check the suitability of the products described here. In case of doubt please contact factory.

All data subject to change without notice.

## Technical data

### Operating pressure range:

Mainstage	
port P, A, B	up to 350 bar
port T	see data for individual models
Pilot stage	15 to 210 bar (nozzle-flapper pilot, standard) 5 to 210 bar (jet-pipe pilot) up to 350 bar on request

**Seal material** NBR (FPM, EPDM on request)

**Temperature range** -20 to +80°C

**Operating fluid** mineral oil based hydraulic fluid (DIN 51524)  
viscosity recommended 15 to 45 mm<sup>2</sup>/s  
allowable 5 to 400 mm<sup>2</sup>/s

class of cleanliness at least class 6 (NAS 1638), resp. 15/11 (ISO 4406)

### System filtration

Pilot stage	high pressure filter (without bypass, but with dirt alarm) mounted in the main flow and if possible, directly upstream of the valve
Main stage	high pressure filter as for the pilot stage. Depending upon the system return or bypass filtration may be required

### Filter rating

main stage and pilot stage  
recommended  $\beta_{10} \geq 75$  (10  $\mu\text{m}$  absolute)  
allowable  $\beta_{15} \geq 75$  (15  $\mu\text{m}$  absolute)

**Installation options** any position, fixed or movable

**Degree of protection** IP65 (with water-proof mating connector mounted)  
(DIN 40050)

# Operation modes

## Flow rate setting mode

An electrical command signal (flow rate set point = spool position set point) is applied to the integrated control amplifier which drives the pilot stage. The flow from the pilot stage moves the spool.

A non-contact position transducer measures the spool position. This actual value is being fed back to the control amplifier where it is compared with the command value. The control amplifier drives the pilot stage until command voltage and feedback voltage are equal. Thus, the position of the spool is proportional to the electrical command signal. The actual flow depends on the electrical command signal and the valve pressure drop.

For different values of valve pressure drop, the flow may be calculated by the square root function for a sharp-edged orifice:

$$Q = Q_N \sqrt{\frac{\Delta p_{Valve}}{\Delta p_N}}$$

- Q = calculated flow
- Q<sub>N</sub> = rated flow
- Δ p<sub>Valve</sub> = actual valve pressure drop
- Δ p<sub>N</sub> = rated valve pressure drop

The flow value Q calculated in this way should result in an average flow velocity of no more than 30 m/s in ports P, A, B, T.

If large flows with high valve pressure drop are required, an appropriately higher pilot pressure has to be chosen to overcome the flow forces.

An approximate value can be calculated as follows:

$$p_x \geq 1,7 \cdot 10^{-2} \cdot \frac{Q}{A_S} \cdot \sqrt{\Delta p_{Valve}}$$

- Q [l/min] = max. flow
- Δ p<sub>Valve</sub> [bar] = valve pressure drop with Q
- A<sub>S</sub> [cm<sup>2</sup>] = spool drive area
- p<sub>x</sub> [bar] = pilot pressure

## Pressure control mode With this function the following can be selected

### Flow rate setting with superimposed pressure limiting control.

Both command signals — external flow command signal and limiting pressure command signal — always have to be applied. The difference between external flow command signal and output signal of the pressure limiting controller results in a spool position command signal. The output signal of the pressure limiting controller is zero as long as the actual pressure value is smaller than the limiting pressure command signal. If the actual pressure value exceeds the limiting pressure command signal, the pressure limiting controller reduces the spool position command signal until the actual pressure value equals the limiting pressure command signal. Since the pressure limiting controller can only reduce the spool position command signal, the external flow command signal has to be chosen that high, so that the limiting function actually occurs. The external flow command signal should be larger than 30% of rated signal.

### Flow rate setting or pressure control.

Selector switch position 2 → 1:

Flow rate setting. The pressure controller is inactive.

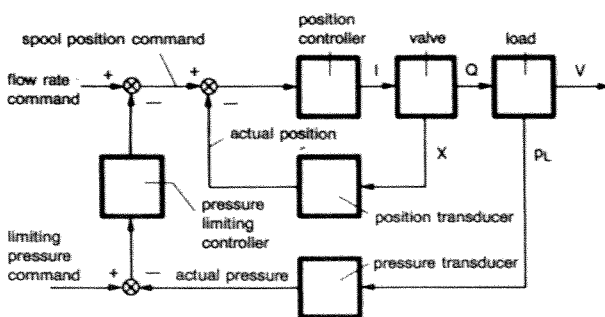
Selector switch position 3 → 1:

Closed loop pressure control. The output signal of the pressure controller then is the spool position command signal (flow command). The pressure to be controlled in port A is being measured by an integrated pressure transducer and this actual pressure value is being compared with the pressure command signal. If there is a difference between pressure command signal and actual pressure value the pressure controller changes the valve flow command signal in a way that the difference becomes zero. Thus the controlled pressure is proportional to the applied pressure command signal.

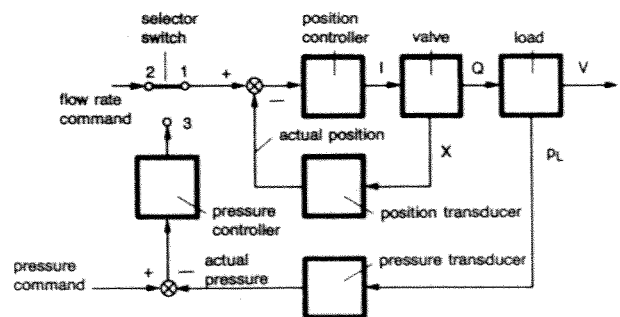
Note: Since the pressure controller has no regulator lock, undesirable transient phenomena can occur upon switching from flow rate setting to closed loop pressure control.

## Block diagram

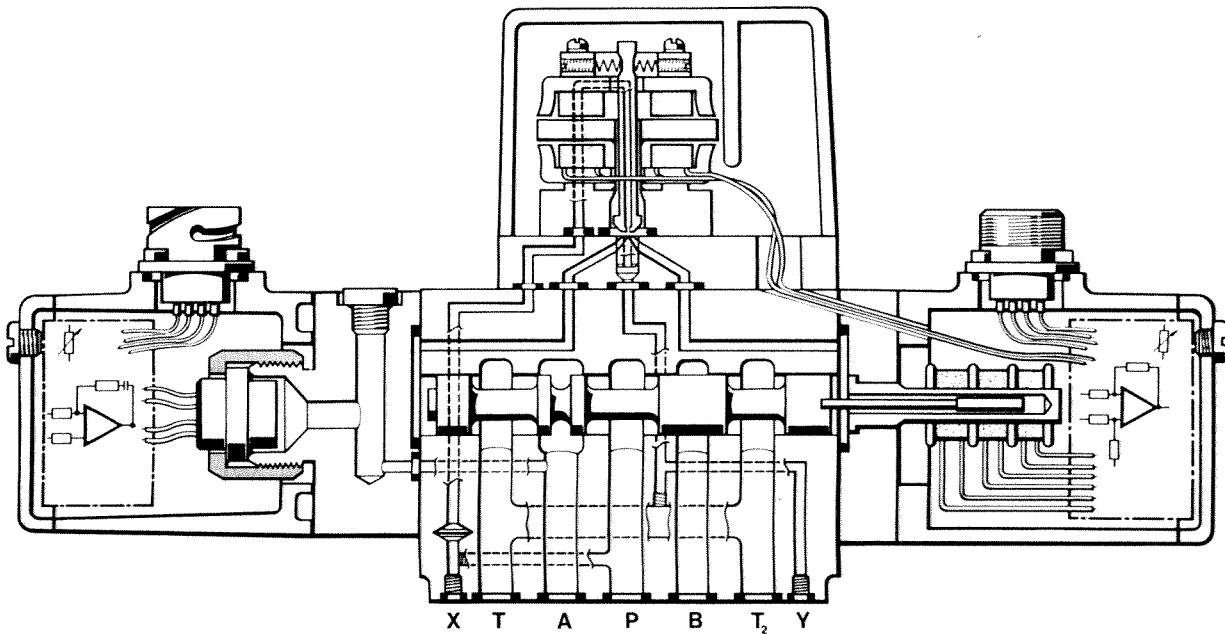
Flow rate setting with superimposed pressure limiting control



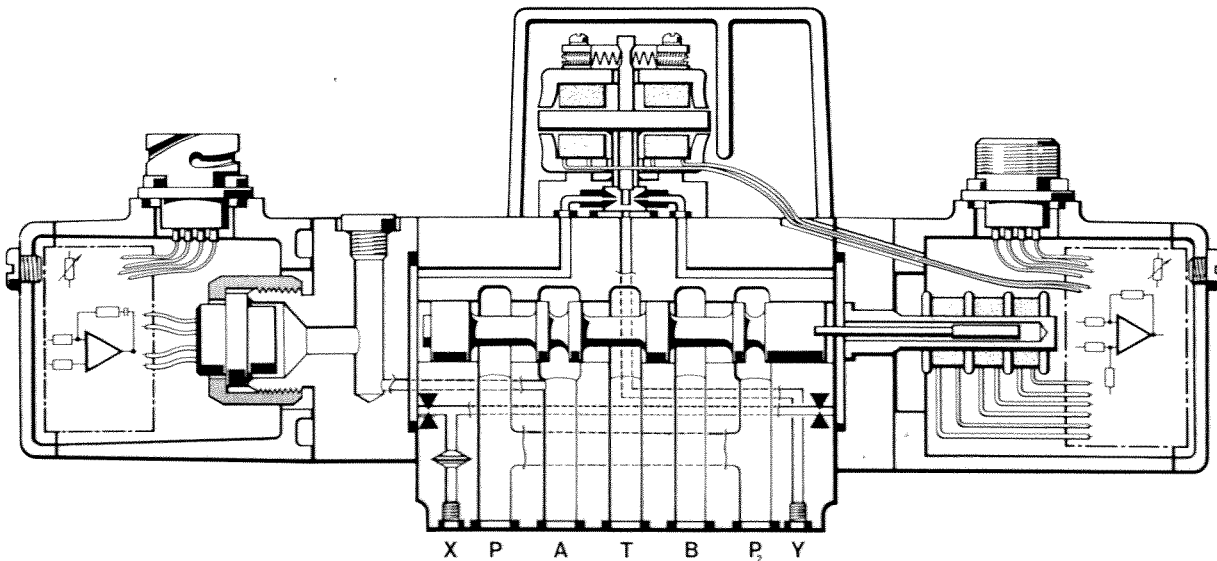
Flow rate setting or pressure control



**PQ-Proportional Control Valve Series D 656, 3-way version**  
**Pilot stage: Jet-pipe principle**



**PQ-Proportional Control Valve Series D 656, 5-way version**  
**Pilot stage: Nozzle-flapper principle**



With 2x2-way and 5-way versions  
 double flow function possible,  
 but only with external pilot flow over  
 X and Y ports.  
 Return pressure  $p_T = 100\%$  supply  
 pressure  $p_P$  only possible with  
 external Y port.

# General characteristics

Mounting pattern according to DIN 24340/ISO 4401

Robust pilot stage

Low constant internal leakage flow through pilot stage

Dropping orifice reduces pressure when  $p_x > 210$  bar.

No leakage afflicted pressure reducing valves needed

Easily replaceable filter elements with 100/200  $\mu\text{m}$  meshsize

Long stroke, robust spool

High resolution and very low hysteresis through electrical position control of the spool

Integrated electronics using SMD-technology

High precision pressure control through integrated pressure transducer and integrated pressure control electronics

# Application notes

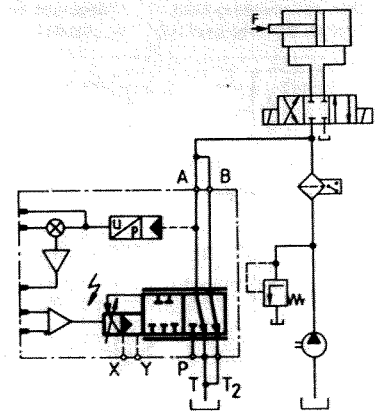
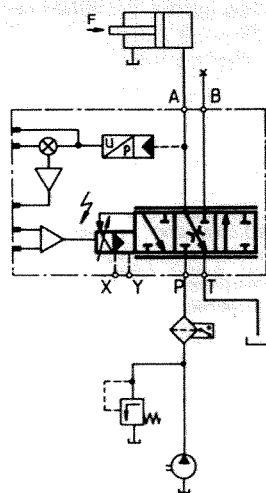
The PQ-Proportional Control Valve is preferably used for open loop velocity setting and closed loop pressure control. By additional feedback of load velocity and use of suitable electronics the system can be modified to be a closed loop velocity control which means an increase in precision.

PQ-Proportional Control Valve in main line (meter-in mode).

The PQ-Control Valve operates as electrically adjustable throttle from  $P \rightarrow A$  and from  $A \rightarrow T$  and as electrically adjustable pressure reducing valve.

PQ-Proportional Control Valve in bypass line (bleed-off mode).

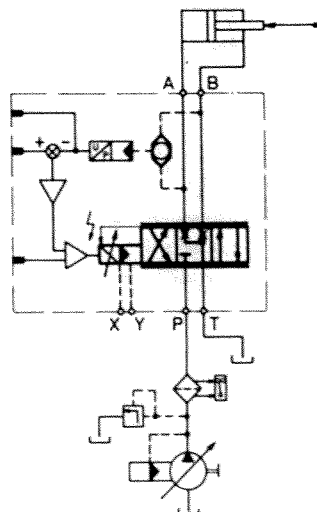
The PQ-Control Valve operates as electrically adjustable bleed-off throttle and as electrically adjustable pressure limiting valve.



4-way PQ-Proportional Control Valve in main line

For applications where pressure or force limiting is required for both motion directions a special 4-way PQ-Proportional Control Valve with integrated shuttle valve is available. The shuttle valve transmits the driving (higher) load pressure to the single pressure transducer of the PQ-valve. The selection of the motion direction is done by polarity selection of the flow command.

Note: Altered installation dimensions!



# Valve Series D656 Electronics

Since 1975 MOOG has built proportional control valves and servovalves with integrated electronics. The experience gained together with the most modern technology have also been used for the new valve series D656.

- Improved dynamics, especially in the small signal range which is important for pressure control.
- Standardized spool position monitoring signals with extremely low residual ripple, with symmetrically adjusted valves  $\pm 10$  V or  $\pm 10$  mA or + 4 to + 20 mA.

- Highly sensitive null adjustment with better access
- Improved false polarity protection and over-voltage protection.
- High maintenance friendliness through clearly differentiated connections for P- and Q-side or through 12-pole connector.
- Supply voltage control. In case of under-voltage or cable break the pilot stage is disconnected and the main spool moves to the hydraulically determined position.

## General requirements

Supply:  $\pm 15$  V  $\pm 3\%$ .  
Current consumption  $\pm 300$  mA maximum.  
Power supply unit with safety transformer to VDE 0551.

All signal lines (also those of external transducers) shielded. Shielding connected radially to  $\perp$  (0 V).

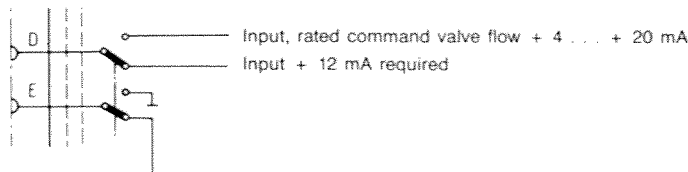
## Important notes:

Before applying electrical signals the pilot stage has to be pressurized.  
External relay contacts must be gold plated and encased.

## Connector wiring for valves with 6-pole connector (Q-side) and 7-pole connector (P-side)

Connector wiring		Type of signal			
Flow rate setting with pressure limiting control	Flow rate setting or pressure control	Voltage command 0 ... 10 V	Current command 0 ... 10 mA	Current command 4 ... 20 mA	
		6-pole connector			
		Supply	$+ 15$ V $\pm 3\%$		
		Supply	$- 15$ V $\pm 3\%$		
		Supply	$\perp$ (0 V)		
		Input rated command Valve flow	0 ... $\pm 10$ V Input resistance 100 k $\Omega$	0 ... $\pm 10$ mA app. ohmic res. 400 $\Omega$	+ 4 ... + 20 mA app. ohmic res. 200 $\Omega$
		Input signal (from pressure controller)	see pin E of P-connector		
Output actual value Spool position	0 ... $\pm 10$ V output resistance 10 k $\Omega$	0 ... $\pm 10$ mA app. ohmic res. max. 500 $\Omega$	+ 4 ... + 20 mA app. ohmic res. max. 500 $\Omega$		
		7-pole connector			
		Supply	$+ 15$ V $\pm 3\%$		
		Supply	$- 15$ V $\pm 3\%$		
		Supply	$\perp$ (0 V)		
		Output actual value Pressure	0 ... + 10 V output resistance 10 k $\Omega$	0 ... + 10 mA app. ohmic res. max. 500 $\Omega$	+ 4 ... + 20 mA app. ohmic res. max. 500 $\Omega$
		Output Pressure / press. lim. controller	0 ... + 10 V for pressure limiting control 0 ... $\pm 10$ V for pressure control		output resistance 10 k $\Omega$
		Input rated command Pressure	0 ... + 10 V input resistance 100 k $\Omega$	0 ... + 10 mA app. ohmic resist. 500 $\Omega$	+ 4 ... + 20 mA app. ohmic resist. 250 $\Omega$
not used					

Special wiring only for flow rate setting or pressure control with command signal 4 ... 20 mA



The PQ-valve of series D656 has an integrated electronics for the pressure function (P-side) and the valve flow function (Q-side). Depending on the application pressure control or flow rate setting with pressure limiting control, the valves have to be wired and commanded in a different way. The valves can be delivered for signals 0 to 10 V, 0 to 10 mA or also 4 to 20 mA. For valves with current command the corresponding apparent ohmic resistances have to be taken into consideration.

The electrical plugs are protected against mix-up. The valves are delivered with a 6-pole connector (screw coupling) on the Q-side and 7-pole connector (bayonet coupling) on the P-side. Upon request a single 12-pole connector for all signals is possible.

### Flow rate setting mode (Q)

The position control loop of the main spool is being closed through position transducer, pilot stage and integrated electronics of the Q-side. A command signal for the valve flow causes a corresponding displacement of the spool and at the same time of the valve throttle opening.

### Pressure control modes (P)

The pressure in port A is being measured with a pressure transducer and this signal is compared with the pressure command signal. The output signal of the pressure controller is applied to the Q-side as command signal for the valve flow.

With **pressure limiting control** always an external valve flow command signal must be applied. As soon as the measured actual pressure value is larger than the pressure command signal, the pressure controller reduces the spool position command signal until the actual pressure value equals the pressure limit command signal.

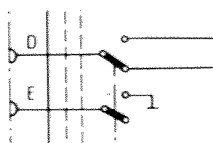
With **pressure control** mode the pressure controller adjusts the actual pressure to the given pressure command signal. If flow rate setting mode is needed, the external switch must be operated.

PQ-valve versions for application in the by-pass line are available on request. They are not described here.

## Connector wiring for valves in special design with 12-pole connector

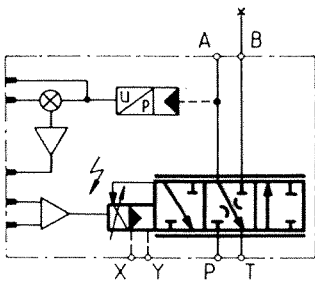
Connector wiring		Type of signal				
Flow rate setting with pressure limiting control	Flow rate setting or pressure control	Voltage command 0 ... 10 V	Current command 0 ... 10 mA	Current command 4 ... 20 mA		
		Supply	+ 15 V ± 3 %			
		Supply	- 15 V ± 3 %			
		Supply	⊥ (0V)			
		Input rated command Valve flow	0 ... ± 10 V Input resistance 100 kΩ	0 ... ± 10 mA app. ohmic res. 400 Ω	+ 4 ... + 20 mA app. ohmic res. 200 Ω	
		Output Pressure / press. lim. controller	0 ... + 10 V for pressure limiting control 0 ... ± 10 V for pressure control		Output resistance 10 kΩ	
		Output actual value Spool position	0 ... ± 10 V output resistance 10 kΩ	0 ... ± 10 mA app.ohmic res. max. 500Ω	+ 4 ... + 20 mA app.ohmic res. max. 500Ω	
		Measuring output of internal pos. controller	0 ... ± 12 V output resistance 10 kΩ			
		Output actual value Pressure	0 ... + 10 V output resistance 10 kΩ	0 ... + 10 mA app.ohmic res. max. 500Ω	+ 4 ... + 20 mA app.ohmic res. max. 500Ω	
		Not used				
		Input rated command Pressure	0 ... + 10 V input resistance 100 kΩ	0 ... + 10 mA app.ohmic resist. 500 Ω	+ 4 ... + 20 mA app.ohmic resist. 250 Ω	
		Relay output	24 V DC max. 0,5 A. For inductive loads a corresponding commutating diode is necessary. The relay contact deenergizes and the pilot stage is disconnected, when a supply voltage becomes less than 12 V (thus also in case of a cable break). The spool then moves to the determined position without electrical supply. Cable break of the ⊥-wire is not monitored.			

Special wiring only for flow rate setting or pressure control with command signal 4 ... 20 mA

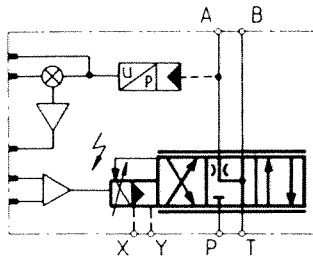


Input, rated command valve flow + 4 ... + 20 mA  
Input + 12 mA required

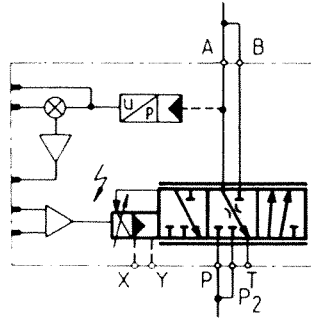
# Series D 656



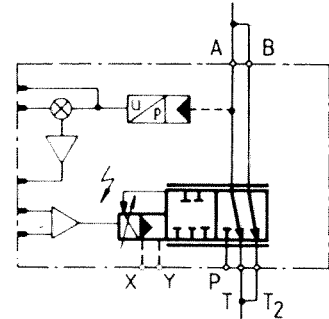
Valve in the main line  
3-way version



Valve in the main line  
4-way version



Valve in the main line  
5-way version



Valve in the by-pass line  
2 x 2-way version

## Model . . . Type

Mounting pattern DIN 24340 / ISO 4401 / Cetop

Valve body version

## Valve version

Pilot stage type

Pilot stage code no.

Pilot connection option, internal or external

Rated flow ( $\pm 10\%$ )

at  $\Delta p_N = 5$  bar per land [l/min]

Operating pressure max.

Main stage

Port P, A, B [bar]

Port T with Y internal

with Y external

Pilot stage

Standard [bar]

on request with dropping orifice [bar]

Spool stroke [mm]

Spool drive area [cm<sup>2</sup>]

Null leakage flow\* max. total [l/min]

Pilot leakage flow\* ( $\pm 10\%$ ) [l/min]

Mass [kg]

## Valve used in flow rate setting mode:

Response time 0 to 100% stroke\* ( $\pm 10\%$ ) [ms]

Threshold\* [%]

Hysteresis\* [%]

Null shift with  $\Delta T = 55^\circ\text{C}$  [%]

## Valve used in pressure control mode:

Threshold\* [%]

Hysteresis\* [%]

Linearity

Null shift with  $\Delta T = 55^\circ\text{C}$  [%]

## D 656-...D....1

Form A 10 / Cetop 5, port dia 11,5 mm

3-way version

4-way version with 5 chambers

5-way<sup>1)</sup>: P  $\rightarrow$  A, P<sub>2</sub>  $\rightarrow$  B, A  $\rightarrow$  T.

P and T interchanged at manifold

2 x 2-way<sup>1)</sup>: A  $\rightarrow$  T, B  $\rightarrow$  T<sub>2</sub>

2-stage

Nozzle-flapper

1

Jet-pipe

3

X and Y<sup>1)</sup>

8/20/30/60/80/2 x 80

350

20% of pilot pressure, max. 100 bar

100% supply pressure acceptable

15 to 210

25 to 350

5 to 210

$\pm 3,0$

2,0

4,0

2,9

2,5

1,4

6,4

7,0

35

30

< 0,25

< 0,1

< 1,0

< 0,5

< 1,5

< 1,5

< 0,05

< 0,2

see ordering information

< 1,5

\* measured at 140 bar pilot pressure or operating pressure, resp., and a fluid viscosity of 32 mm<sup>2</sup>/s

<sup>1)</sup> for 2 x 2 and 5-way applications pilot ports X and Y **must** be used



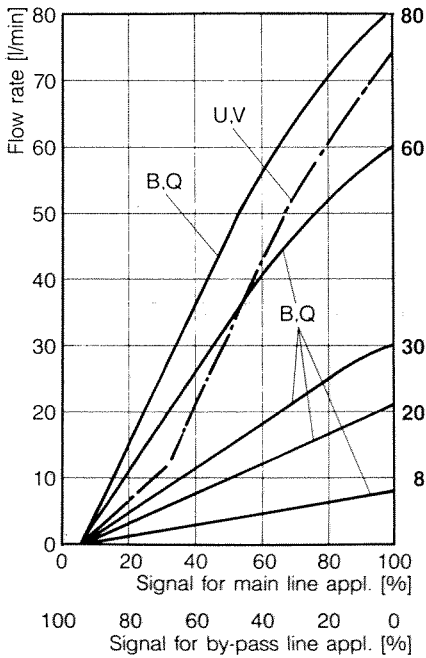
**Typical characteristic curves** measured at 140 bar pilot pressure and a fluid viscosity of 32 mm<sup>2</sup>/s

Model . . . Type

D 656-...D...1

D 656-...D...3

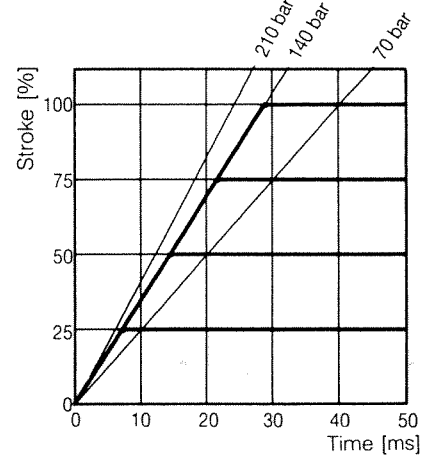
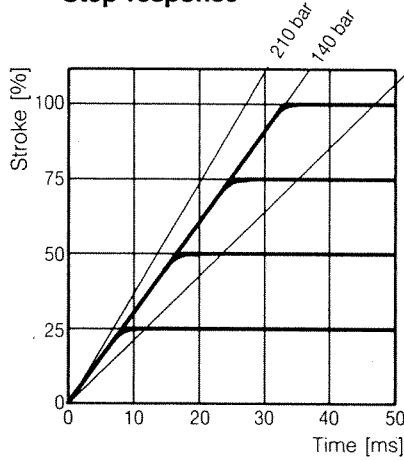
**Flow vs. signal curve**  
at  $\Delta p_N = 5$  bar per land



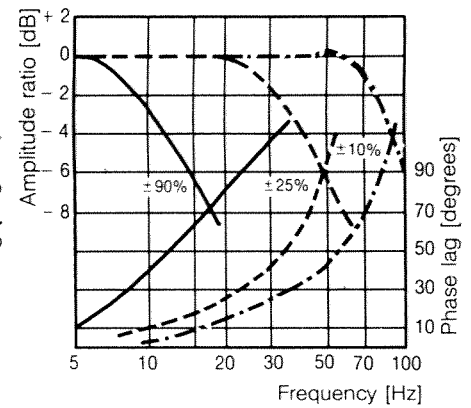
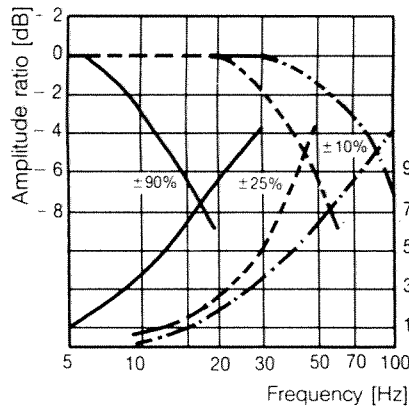
Spools B and Q ~ critical lap, linear characteristic

Spools U and V ~ critical lap, curvilinear characteristic

**Step response**



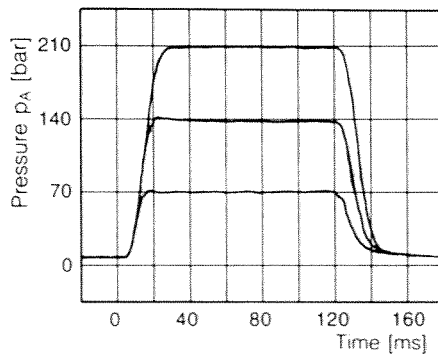
**Frequency response**



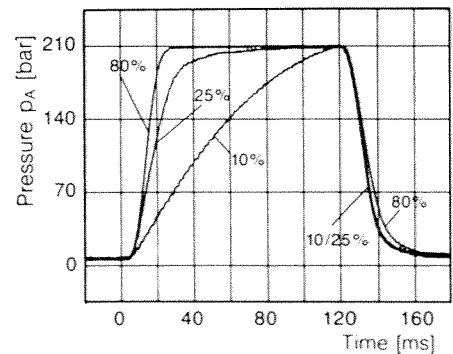
**Pressure step response**

measured at valve mod.  
D 656-...D20KB...3  
with optimized PID pressure limiting controller  
Operating pressure  $p_P = 250$  bar

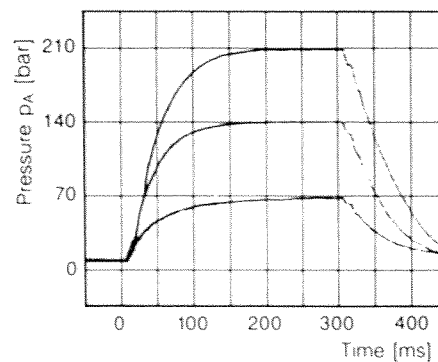
Optimized and measured with entrapped fluid volume 1000 cm<sup>3</sup>, valve flow command 80% of rated



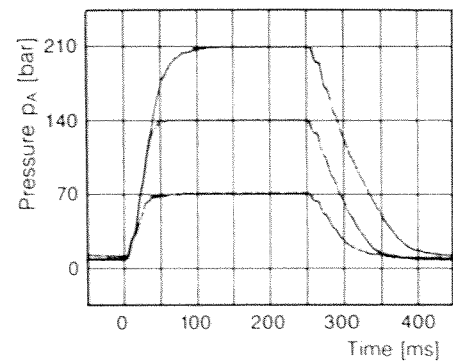
Optimized and measured with entrapped fluid volume 1000 cm<sup>3</sup>, valve flow command 10/25/80% of rated



Optimized for entrapped fluid volume of 1000 cm<sup>3</sup>, but measured with 5000 cm<sup>3</sup>, valve flow command 80% of rated



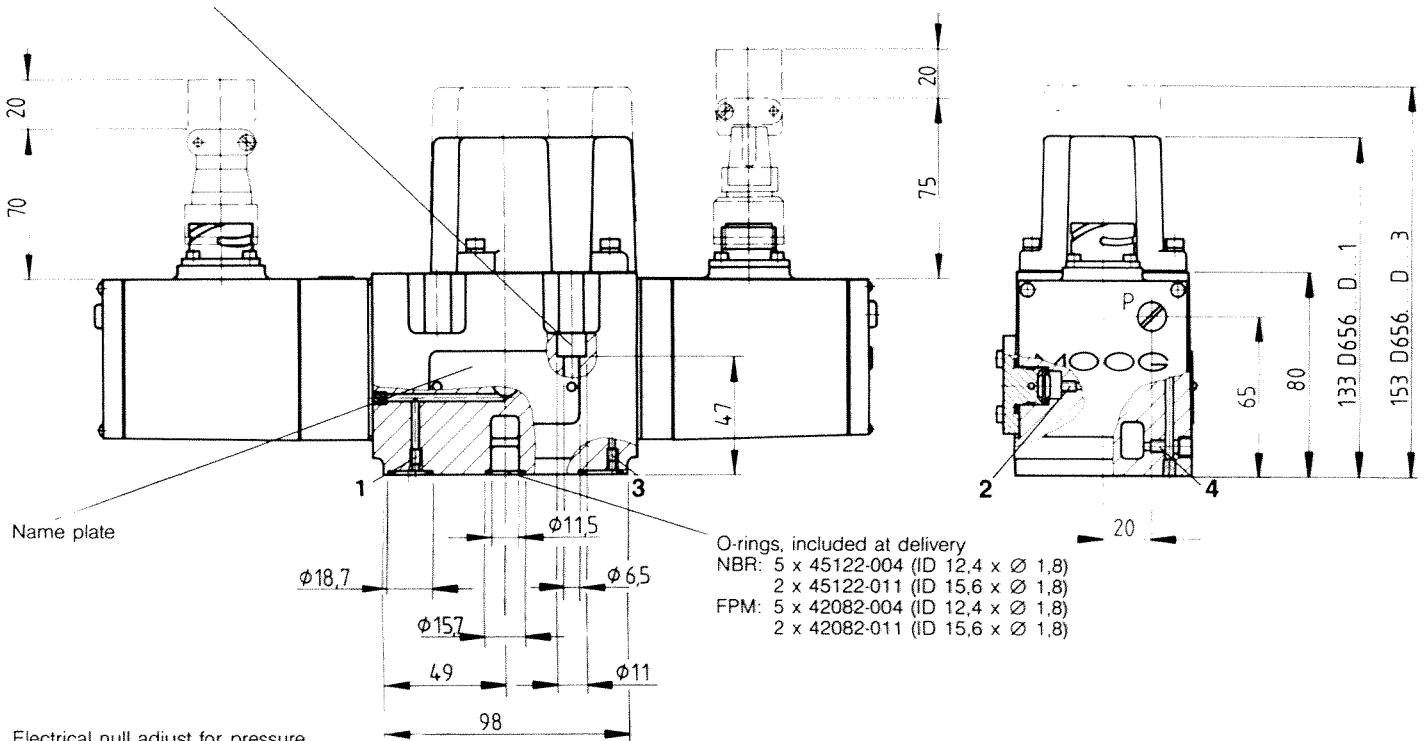
Optimized and measured with entrapped fluid volume of 5000 cm<sup>3</sup>, valve flow command 80% of rated



Examples showing the effect of valve flow setting and entrapped fluid volume on pressure control dynamics

## Installation details

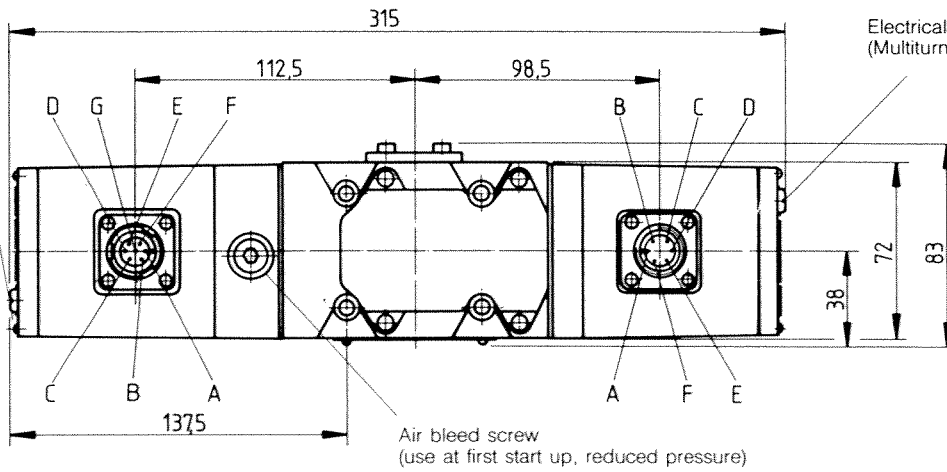
4 mounting bolts (not included)  
 M 6 x 55 DIN 912-10.9 with steel  
 M 6 x 60 DIN 912-10.9 with cast iron  
 (thread length of manifold 14 mm deep)  
 Required torque 13 Nm



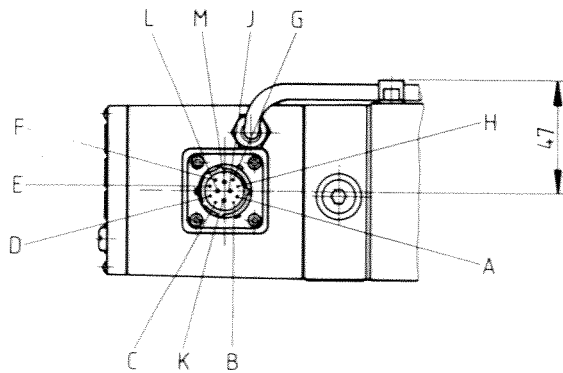
O-rings, included at delivery  
 NBR: 5 x 45122-004 (ID 12,4 x  $\phi$  1,8)  
 2 x 45122-011 (ID 15,6 x  $\phi$  1,8)  
 FPM: 5 x 42082-004 (ID 12,4 x  $\phi$  1,8)  
 2 x 42082-011 (ID 15,6 x  $\phi$  1,8)

Electrical null adjust for pressure  
 (Multiturn potentiometer under screw plug)

Electrical null adjust for flow rate  
 (Multiturn potentiometer under screw plug)



\*Overall length 322  
 with 4-way version  
 with integrated shuttle valve



Optional  
 12-pole connector

## Conversion instruction

for operation with internal or external  
 pilot connection  
 Setscrew M 4 x 6

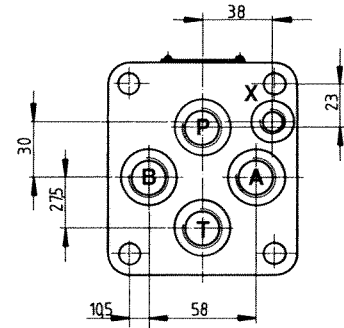
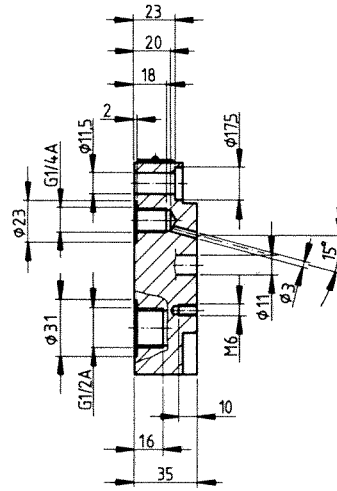
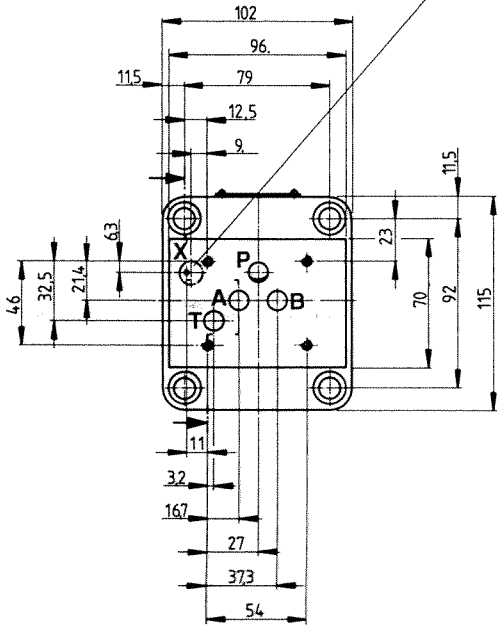
Pilotflow supply	Setscrew bore		Pilotflow return	Setscrew bore	
	1	2		3	4
Internal P External X	closed open	open closed	Internal T External Y	closed open	open closed

# Mounting manifolds

A03230-001: 3- and 4-way, without X  
 A03230-002: 3- and 4-way, with X  
 With 3-way version  
 port B must be plugged

Position of X-port  
 according to ISO 4401 acceptable

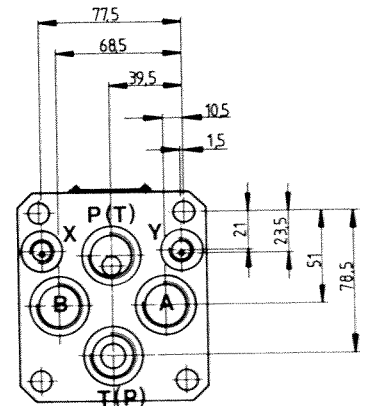
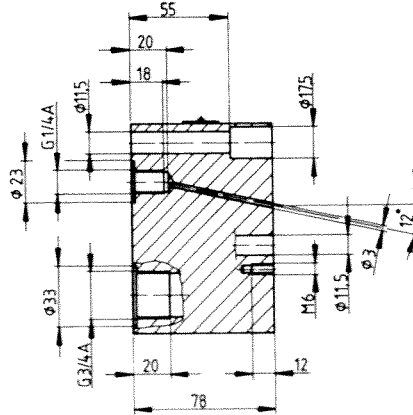
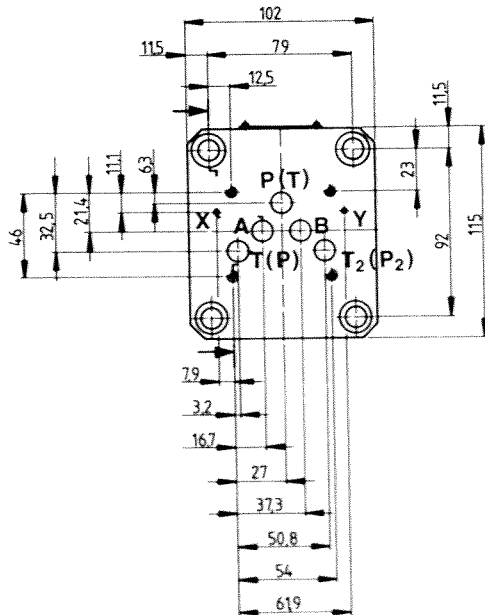
Mounting pattern to DIN 24340 / ISO 4401  
 Form A 10 (Cetop 5), port dia 11 mm  
 Mounting surface flat within 0,02 mm  
 Average surface finish value Ra better than 1 μm



A 88903-001:  
 3- and 4-way, 2 tank ports  
 X and Y plugged  
 A 88903-002:  
 3- and 4-way, 2 tank ports  
 X and Y open  
 With 3-way version  
 port B must be plugged

A 88903-102:  
 5-way  
**P and T interchanged**  
 (see identification letters  
 in brackets)

Mounting pattern to DIN 24340/ISO 4401  
 Form A 10 (Cetop 5), port dia 11,5 mm  
 Mounting surface flat within 0,02 mm  
 Average surface finish value Ra better than 1 μm



## Spare parts

Filter element: A67999-100 (nozzle-flapper)  
 A67999-200 (jet-pipe)  
 O-rings for  
 Filter A25163-013-015  
 Filtercover A25163-017-020

## Accessories

Mating connector:  
 Waterproof (IP 65) B 46744-004 (6 pole)  
 Waterproof (IP 65) B 61097-007 (7 pole)  
 Waterproof (IP 65) B 46746-012 (12 pole)

Flushing plates  
 B 46265-001



B 46265-002



B 46265-003



