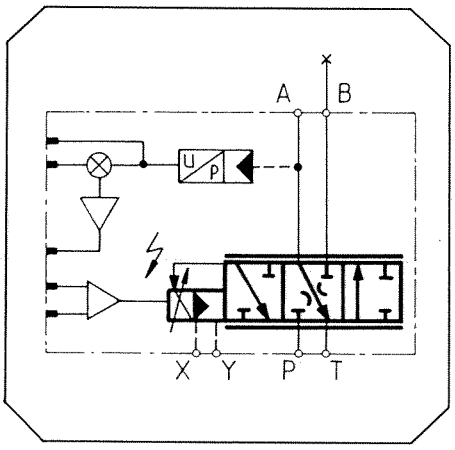
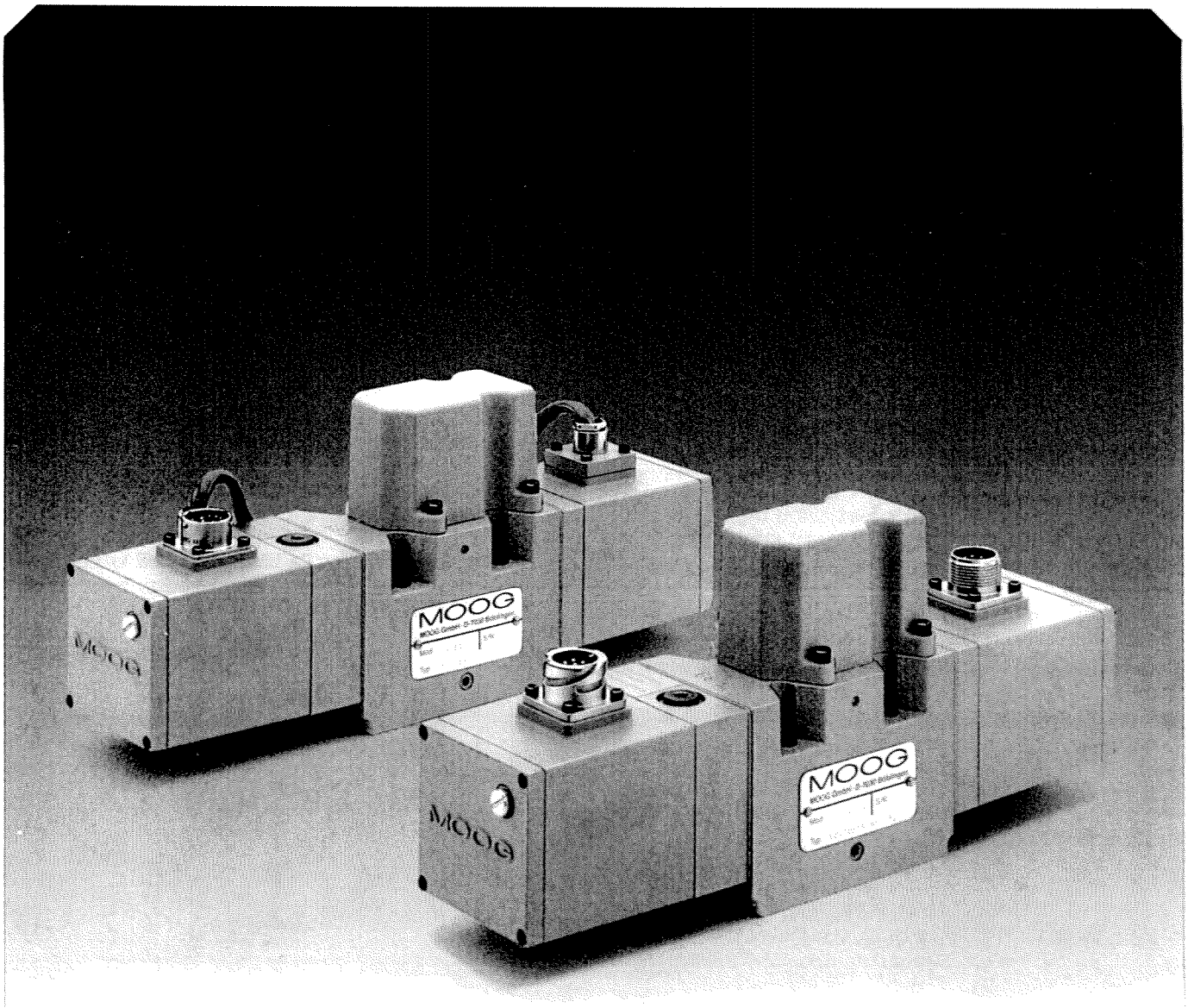
MOOG



Series D 656
PQ-Proportional Control Valves
with integrated electronics

Rated flow 8 . . . 80 l/min (Δp_N = 5 bar)
Operating pressure up to 350 bar
Mounting pattern to DIN 24340 / ISO 4401
Form A 10



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

With more than 15000 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 reproduceability.
- 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 mm²/s allowable 5 to 400 mm²/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 $\beta_{10} \geqq 75$ (10 μm absolute) allowable $\beta_{15} \geqq 75$ (15 μm absolute)
Installation options	any position, fixed or movable
Degree of protection (DIN 40050)	IP65 (with water-proof mating connector mounted)

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_N = rated flow
Δp_{Valve} = actual valve pressure drop
Δp_N = 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:

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

Q [l/min] = max. flow
Δp_{Valve} [bar] = valve pressure drop with Q
A_S [cm²] = spool drive area
p_X [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.

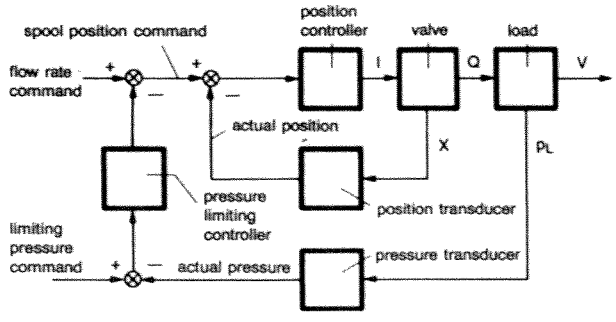
Selector switch position 2 → 1:
Flow rate setting. The pressure controller is inactive.

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.

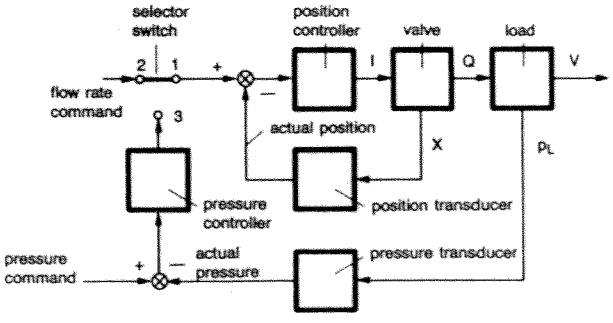
Note: Since the pressure controller has no regulator lock, undesirable transient phenomena can occur upon switching from flow rate setting to closed loop pressure control.

Block diagram

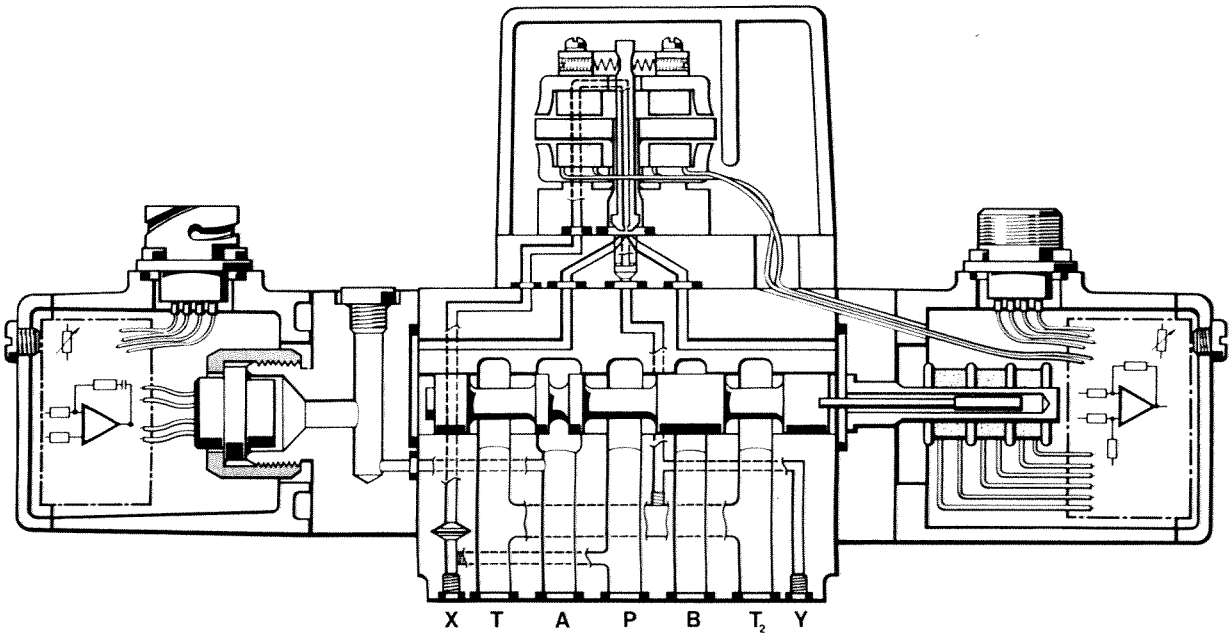
Flow rate setting with superimposed pressure limiting control



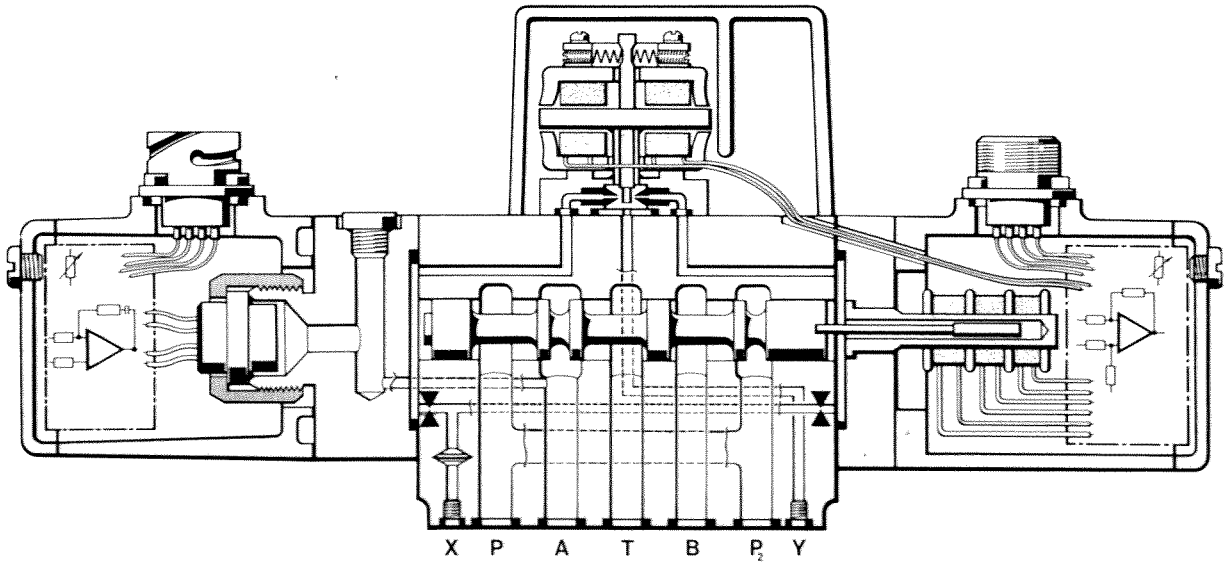
Flow rate setting or pressure control



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 2 x 2-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 μm meshsize

Long stroke, robust spool

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

Integrated electronics using SMD-technology

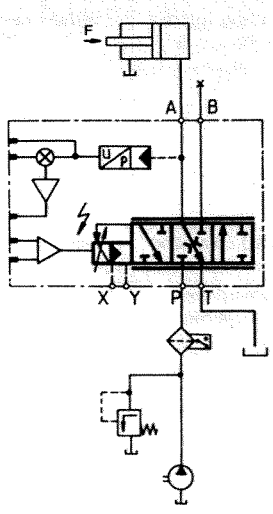
High precision pressure control through integrated pressure transducer and integrated pressure control electronics

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.

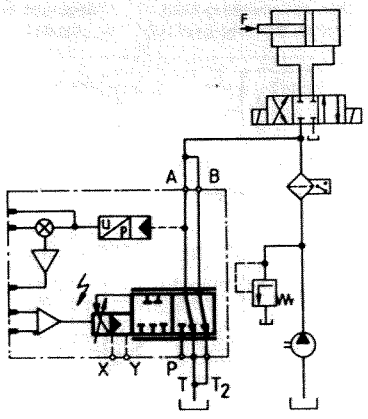
PQ-Proportional Control Valve in main line (meter-in mode).

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



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

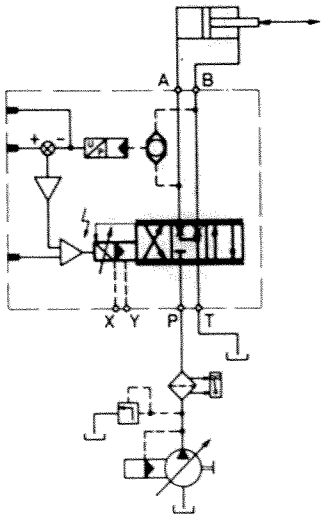
The PQ-Control Valve operates as electrically adjustable bleed-off throttle and as electrically adjustable pressure limiting valve.



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 D 656 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 D 656.

- 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 ± 10 V or ± 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.

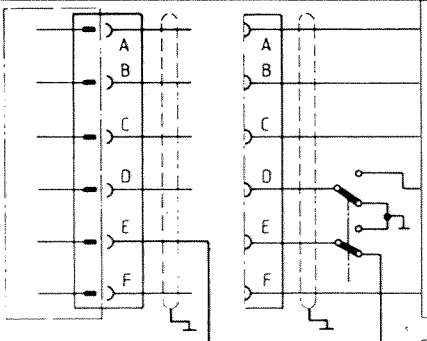
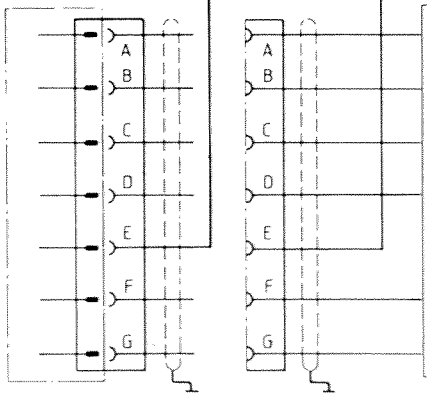
General requirements

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

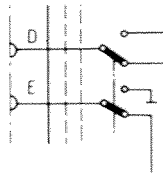
All signal lines (also those of external transducers) shielded. Shielding connected radially to ⊥ (0 V).

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 ± 3%		
		Supply	— 15 V ± 3%		
		Supply	⊥ (0 V)		
		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
		Input signal (from pressure controller)	see pin E of P-connector		
		Output actual value Spool position	0 . . . ± 10 V output resistance 10 kΩ	0 . . . ± 10 mA app. ohmic res. max. 500 Ω	+ 4 . . . + 20 mA app. ohmic res. max. 500 Ω
		7-pole connector: Supply	+ 15 V ± 3%		
		Supply	— 15 V ± 3%		
		Supply	⊥ (0 V)		
		Output actual value Pressure	0 . . . + 10 V output resistance 10 kΩ	0 . . . + 10 mA app. ohmic res. max. 500 Ω	+ 4 . . . + 20 mA app. ohmic res. max. 500 Ω
		Output Pressure / press. lim. controller	0 . . . + 10 V for pressure limiting control 0 . . . ± 10 V for pressure control		output resistance 10 kΩ
		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
		not used			

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

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.

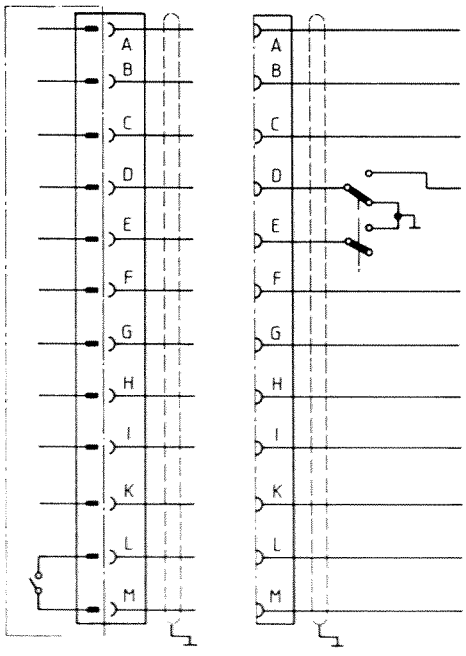
Pressure control modes (P)
The pressure in port A is being measured with a pressure transducer and this signal is compared with the pressure command signal. The output signal of the pressure controller is applied to the Q-side as command signal for the valve flow.

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.

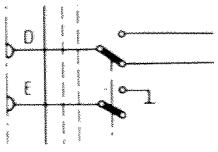
With **pressure control** mode the pressure controller adjusts the actual pressure to the given pressure command signal. If flow rate setting mode is needed, the external switch must be operated.

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

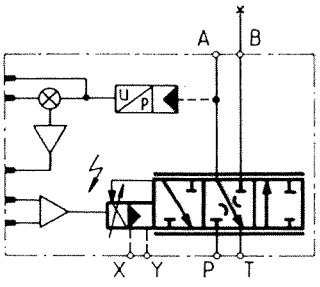
Connector wiring			Type of signal		
Flow rate setting with pressure limiting control	Flow rate setting or pressure control		Voltage command 0 . . . 10 V	Current command 0 . . . 10 mA	Current command 4 . . . 20 mA
		Supply	+ 15 V ±3%		
		Supply	— 15 V ±3%		
		Supply	⊥ (0 V)		
		Input rated command Valve 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. 500 Ω	+ 4 . . . + 20 mA app. ohmic res. max. 500 Ω
		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. 500 Ω	+ 4 . . . + 20 mA app. ohmic res. max. 500 Ω
		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

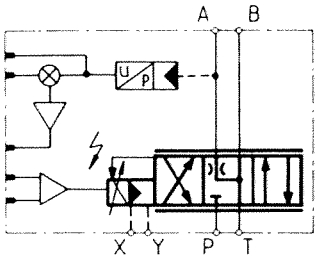


Input, rated command valve flow + 4 . . . + 20 mA
Input + 12 mA required

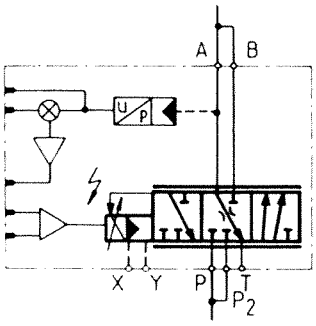
Series D 656



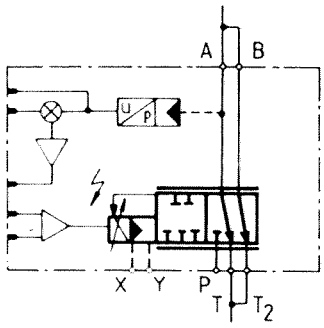
Valve in the main line
3-way version



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		**D 656-...D....1**	**D 656-...D....3**
Mounting pattern DIN 24340 / ISO 4401 / Cetop		Form A 10 / Cetop 5, port dia 11,5 mm	
Valve body version		3-way version 4-way version with 5 chambers 5-way[1]: P → A, P_2 → B, A → T. P and T interchanged at manifold 2 x 2-way[1]: A → T, B → T_2	
Valve version		2-stage	
Pilot stage type		Nozzle-flapper	Jet-pipe
Pilot stage code no.		**1**	**3**
Pilot connection option, internal or external		X and Y[1]	
Rated flow (± 10 %)			
at Δp_N = 5 bar per land	[l/min]	**8/20/30/60/80/2 x 80**	
Operating pressure max.			
Main stage			
Port P, A, B	[bar]	350	
Port T with Y internal		20 % of pilot pressure, max. 100 bar	
with Y external		100 % supply pressure acceptable	
Pilot stage			
Standard	[bar]	15 to 210	5 to 210
on request with dropping orifice	[bar]	25 to 350	
Spool stroke	[mm]	± 3,0	
Spool drive area	[cm²]	2,0	
Null leakage flow* max. total	[l/min]	4,0	2,9
Pilot leakage flow* (± 10 %)	[l/min]	2,5	1,4
Mass	[kg]	6,4	7,0

Valve used in flow rate setting mode:

Response time 0 to 100 % stroke* (± 10 %)	[ms]	**35**	**30**
Threshold*	[%]	< 0,25	< 0,1
Hysteresis*	[%]	< 1,0	< 0,5
Null shift with ΔT = 55 °C	[%]	< 1,5	< 1,5

Valve used in pressure control mode:

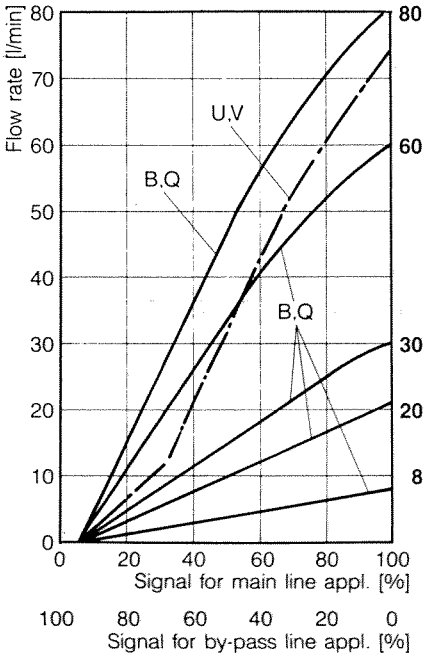
Threshold*	[%]	< 0,05
Hysteresis*	[%]	< 0,2
Linearity		see ordering information
Null shift with ΔT = 55 °C	[%]	< 1,5

* measured at 140 bar pilot pressure or operating pressure, resp., and a fluid viscosity of 32 mm²/s
[1] 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 mm²/s

Model . . . Type | **D 656-...D....1** | **D 656-...D....3**

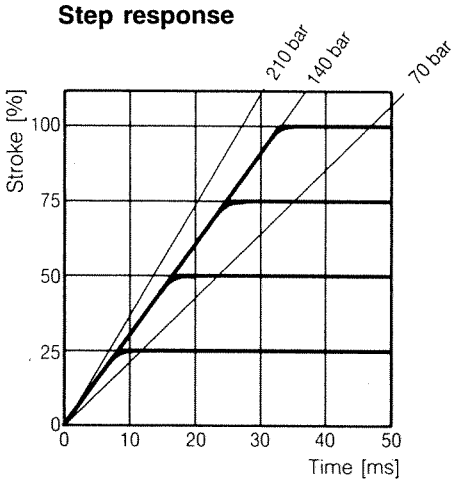
Flow vs. signal curve
at Δp_N = 5 bar per land

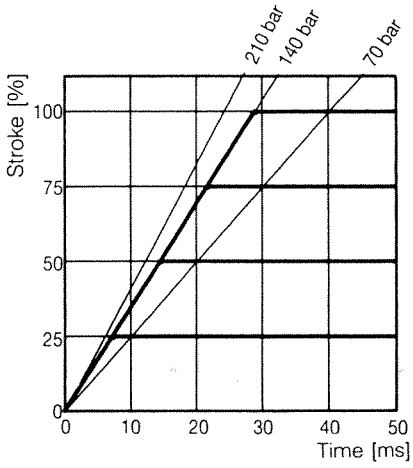


Spools B and Q ~ critical lap, linear characteristic

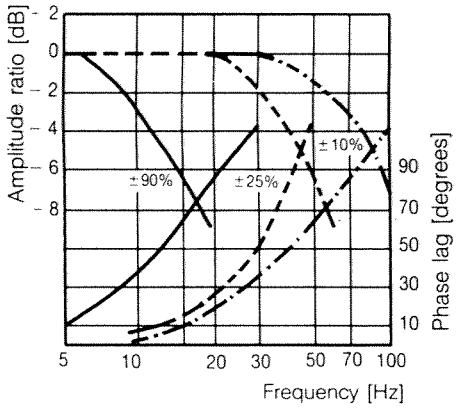
Spools U and V ~ critical lap, curvilinear characteristic

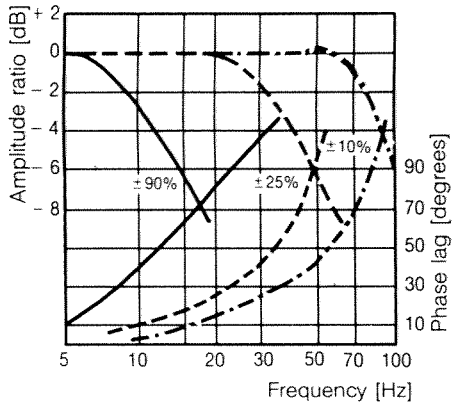
Step response





Frequency response

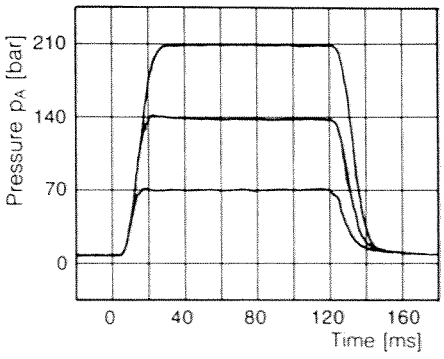




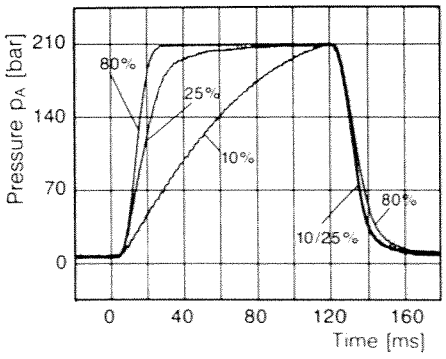
Pressure step response

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

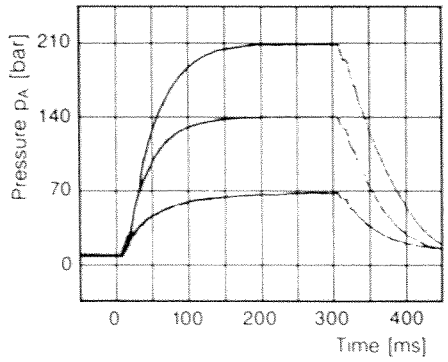
Optimized and measured with entrapped fluid volume 1000 cm³, valve flow command 80% of rated



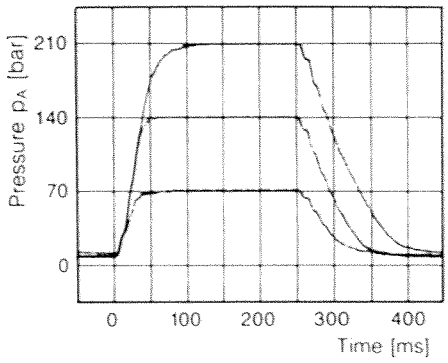
Optimized and measured with entrapped fluid volume 1000 cm³, valve flow command 10/25/80% of rated



Optimized for entrapped fluid volume of 1000 cm³, but measured with 5000 cm³, valve flow command 80% of rated



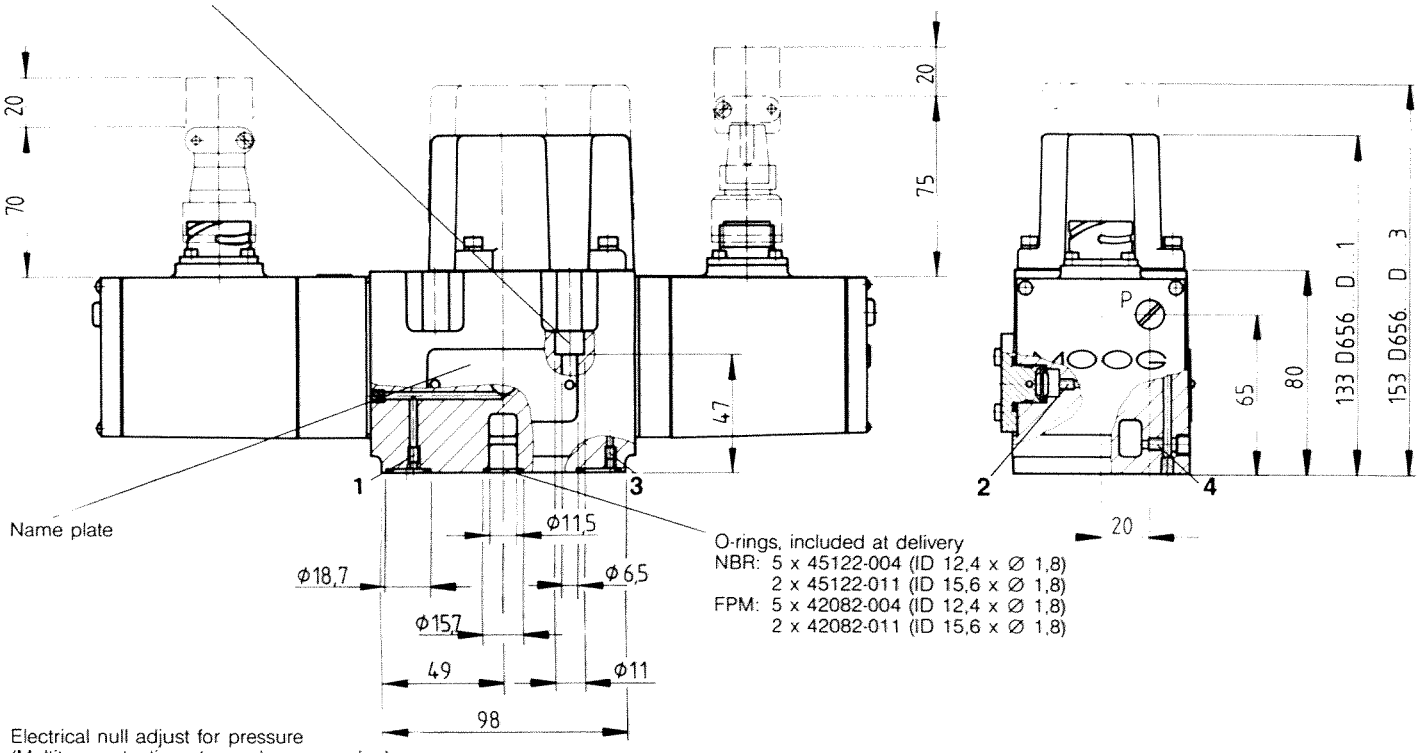
Optimized and measured with entrapped fluid volume of 5000 cm³, valve flow command 80% of rated

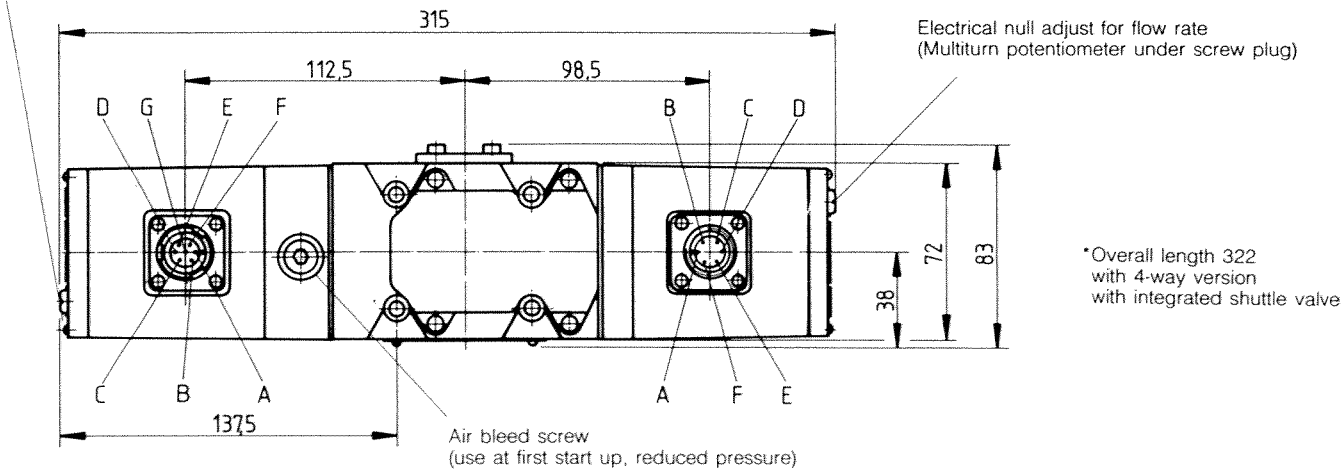


Examples showing the effect of valve flow setting and entrapped fluid volume on pressure control dynamics

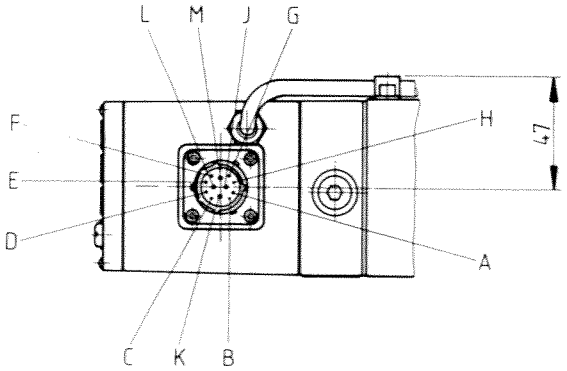
Installation details

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





*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

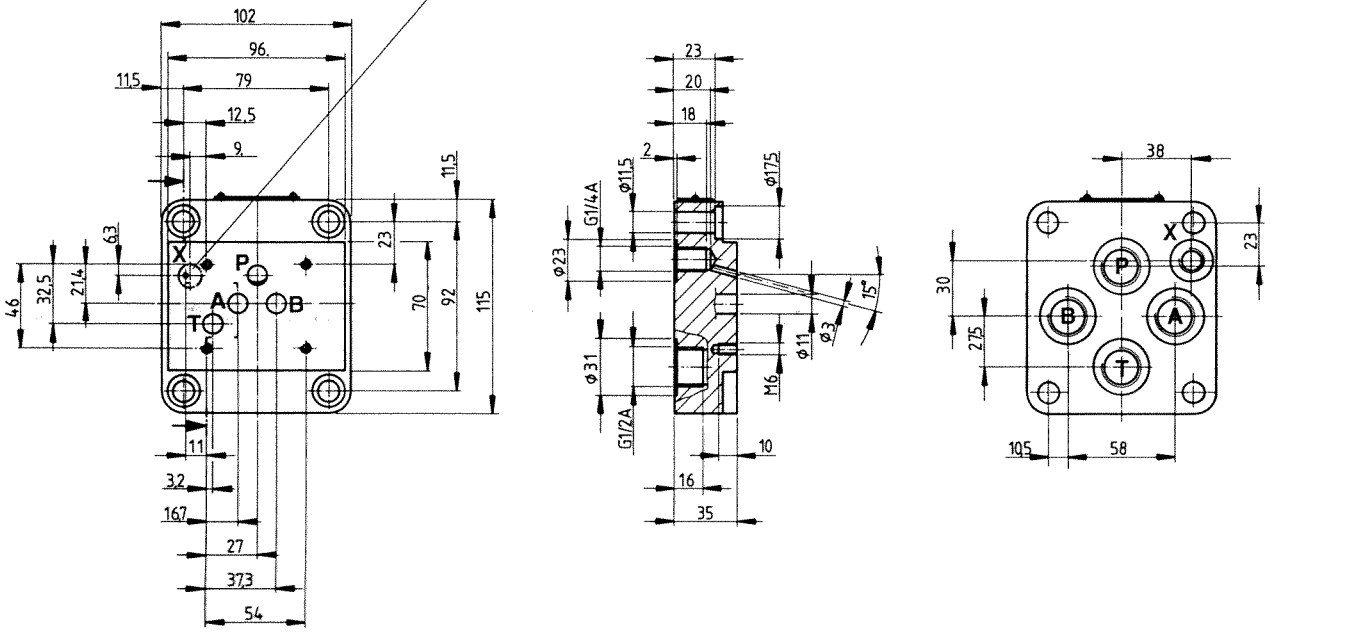
Pilotflow supply	Setscrew bore 1	Setscrew bore 2	Pilotflow return	Setscrew bore 3	Setscrew bore 4
Internal **P**	closed	open	Internal **T**	closed	open
External **X**	open	closed	External **Y**	open	closed

Mounting manifolds

A 03230-001 : 3- and 4-way, without X
A 03230-002 : 3- and 4-way, with X
With 3-way version
port B must be plugged

Position of X-port
according to ISO 4401 acceptable

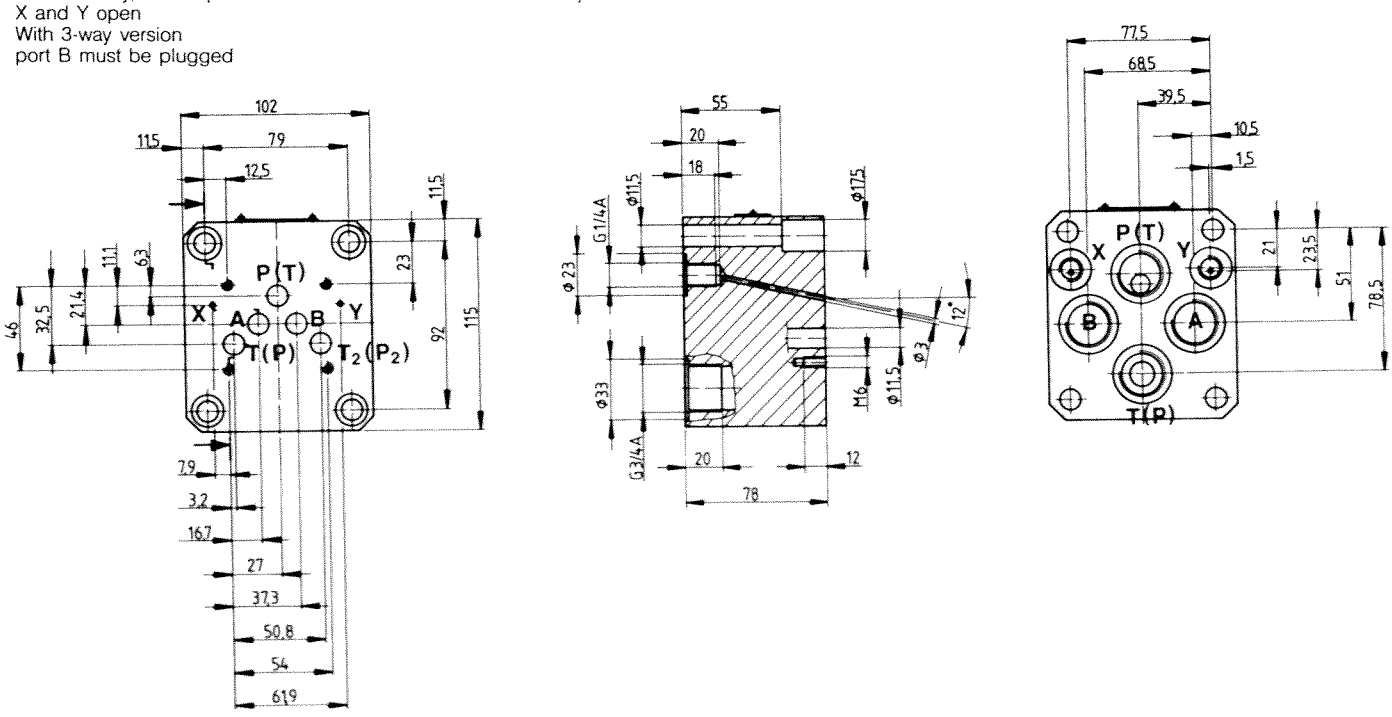
Mounting pattern to DIN 24 340 / ISO 4401
Form A 10 (Cetop 5) port dia 11 mm
Mounting surface flat within 0,02 mm
Average surface finish value Ra better than 1 μm



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 24 340 / 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



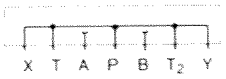
Spare parts

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

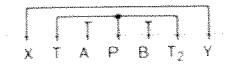
Accessories

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

Ordering information for D656

Model-Number: D656 . ... .

Type designation: D .. . .

Specification status

—	Series specification
E	Preseries specification
Z	Special specification

Model designation

	assigned at the factory

Factory identification

Rated flow

	Q_N (l/min) at Δp_N 5 bar per land
08	8 (only with linear characteristic)
20	20 (only with linear characteristic)
30	30
60	60
80	80

Pressure ranges

	Rated pressure for 100% signal [bar]	max. operating pressure [bar]	Non-linearity [%]
C	100	140	< 0,35
D	140	140	< 0,25
E	175	210	< 0,35
F	210	210	< 0,25
J	315	350	< 0,35
K	350	350	< 0,25
X	Special version		

Spool type

B	3-way: P → A, A → T ~ critical lap, linear characteristic
P	3-way: P → A, A → T ~ critical lap, curvilinear characteristic
Q	5-way: P → A, P_2 → B, A → T ~ critical lap, linear characteristic
U	5-way: P → A, P_2 → B, A → T ~ critical lap, curvilinear characteristic
V	4-way: P → A, A → T ~ critical lap, linear characteristic P → B 50% overlap, linear characteristic B → T 30% underlap, linear characteristic
Z	2 x 2-way: A → T and B → T_2 90% overlap, linear characteristic (by-pass mode only)
X	Special version

Signals Q and P-side

	Q (6-pole)	P (7-pole)
	Command and actual spool position	Command and actual pressure value
A	0...± 10 V	0...+ 10 V
B	0...± 10 mA	0...+ 10 mA
C	+4...+20 mA	+4...+20 mA
	Connector 12-pole	
D	0...± 10 V	0...+ 10 V
E	0...± 10 mA	0...+ 10 mA
S	+4...+20 mA	+4...+20 mA

Seal material

N	NBR (Buna N) standard
V	FPM (Viton) optional
E	EPDM optional

Pilot connections and pressures

	Press. [bar]	Supply	Return
A	15 to 210	internal	internal
B	15 to 210	external	external
C	15 to 210	external	internal
D	15 to 210	internal	external
J	25 to 350	internal	internal
K	25 to 350	external	external
L	25 to 350	external	internal
M	25 to 350	internal	external

Spool position without electrical supply

T	A → T interconnected
P	P → A interconnected

Valve version

M	Valve flow setting or pressure control Valve in main line
	Valve flow setting with pressure limiting control
N	Valve in main line
K	Valve in main line minimum pressure limitation control
C	Valve in by-pass line
A	4-way valve with shuttle valve (only with 12-pole connector D, E, S)
O	without integrated pressure controller
S	only with pressure amplifier (no controller)

Pilot stage version

	Pilot flow at p_X = 140 bar	
1	Nozzle-flapper principle	1,15 l/min
3	Jet-pipe principle	1,3 l/min

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