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PRODUCTS OF AUTOMATIC CONTROL ENGINEERING - **TECHNICAL INFORMATION**

CONTENT

INTRODUCTION

Fluid flow ratio regulation appliances, which keep the required regulation characteristics, are critical in industrial automatics systems. The main component of such appliances are controllers, which adjust the resistance for flowing fluid, and drives (actuators), which provide mechanic energy required in setting of controllers.

The following are representatives of this group of appliances, manufactured by Zakłady Automatyki POLNA SA:

- globe and angle control valves,
- three-way control valves,
- butterfly valves.

Regarding the type of drive, controllers are manufactured in following executions:

- with spring diaphragm pneumatic actuators,
- with electric and electro-hydraulic actuators,
- with pneumatic piston actuators,
- with hand operated drive,
- without drive.
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Regarding the fact that valves are the largest group of controllers, the expression "valves" is hereinafter often interchangeable with expression "controllers".

While selecting valves for specific working conditions one should consider the following aspects:

1. valve design version,
2. material execution,
3. nominal pressure,
4. flow coefficient,
5. flow characteristics,
6. internal tightness,
7. bonnet type and packing,
8. body connection types,
9. hardening of valve internal parts,
10. selection of drive,
11. harmful effects in valve operation.

1. DESIGN VERSIONS

The design version aspect applies only to valves.

Valves can be subdivided using the following criteria:

a) position of body inlet and outlet
- globe,
- three-way,
- angle,

b) closing component
- with linear motion valve plug,
- with rotary motion valve plug,

c) shape of closing component
- profile valve plug,
- perforated valve plug,
- multi-stage valve plug,
- cage valve plug,

d) balancing of axial forces
- unbalanced,
- balanced,

e) reversibility of operation
- reversible design double-ported valves,
- irreversible design single-ported valves.

Globe valves with linear situation of input and output are the basic, most common group of valves. Three-way valves are used in installations where mixing or separation of fluid is required. Angle valves are preferred option in applications where flashing (evaporation) and large pressure drops occur. A variation of angle valves are „ ˥˪ ” valves, with parallel but not axial body ends.

Rotary plug globe valves are recommended in cases of large flows. Perforated (perforated) components are used mostly to reduce noise emissions. Multi-stage valve plugs reduce cavitation and choked flow.

In cage valves there is a piston valve plug, working with perforated control cage. They are used for large pressure drops applications.

Pressure balancing of valve aims at equalization of static pressure on both sides of valve plug, by means of balance holes or internal valve plug (pilot).

For selection of the valve balancing method the following factors must be taken into account:

a) plug - pilot

- flow direction - above the plug (Flow To Close - FTC),
- high leakage class - (V class),
- enhanced rangeability,
- limited possibility to manufacture two-stage plugs to apply throttling cages.

b) balancing and relieving holes in the plug

- flow direction under the plug (Flow To Open - FTO), - max. leakage class (IV class),
- plug sealing subjects to wearing - it must be replaceable, - possibility to manufacture multi-stage plugs to and apply throttling cages.

Reversibility of valve operation denotes possibility of changing its function (pressing the valve plug stem can cause opening or closing of valve) in the consequence of different assembly of valve internal parts.

While selecting valve design one should consider the following aspects:

- leakage class

Single-ported valves are more tight than double-ported ones.

- balancing of axial forces

Double-ported valves require smaller resetting forces and allow transferring of larger pressure drops than in the case of single-ported valves with same actuators.

- flow coefficient

Single-ported valves feature better possibility of flow reduction, whereas double-ported valves and rotary plug valves feature better flow coefficients than single-ported ones, with same valve diameter.

- nominal pressure

Irreversible valves are used in applications with higher nominal pressure than in the case of reversible valves.

- fluid viscosity

It is recommended, that single-ported valves are used with dense fluids, with viscosity $v>10^{-5}$ [m^2/s], where laminar flow may be observed.

2. MATERIAL EXECUTIONS

Material execution is determined by material in which body is executed.
Basic material executions of the body casts:

- cast iron:	EN-GJL 250,	per PN-EN 1561
- spheroidal iron:	EN-GJS-400-15,	per PN-EN 1563
	EN-GJS-400-18LT,	per PN-EN 1563
- carbon steel:	GP240GH, (1.0619),	per PN-EN 10213-2
	G20Mn5, (1.6220)	wg PN-EN 10213-3
	WCB,	per ASTM A216
- alloy steel:	G17CrMo9-10, (1.7379),	per PN-EN 10213-2
	WC9,	per ASTM A217
- stainless steel:	GX5CrNiMo19-11-2, (1.4408),	per PN-EN 10213-4
	CF8M,	per ASTM A351

Criteria for selection of material:

- corrosion proofness,
- working temperature,
- nominal pressure,
- requirements of technical specifications (AD 2000 Merkblatt, WUDT-UC, ASME Code)

Material corrosion proofness depends on type of fluid, its temperature, concentration, etc. It is to be assessed base don generally available tables and recommendations, or information by valve manufacturer. Relationship between working temperature and pressure are illustrated in tables in catalog product charts. Minimum operating temperature for all materials is -10°C.
There is a possibility of lowering operating temperature, as below:

- 90°C	for carbon steels G20Mn5, (1.6220),
-196 °C	for stainless steels, GX5CrNiMo19-11-2, (1.4408) i CF8M, provided that:

- design pressure is reduced respectively,
- results of impact strength tests at working temperature are positive,
- heat treatment (stress relieving) of casting is performed.

Requirements of AD 2000 Merkblatt specification, sheet A4, do not allow pressure equipment execution in grey iron, with exception of products executed under Article 3.3 of Pressure Equipment Directive in accordance with Technical Specification WUDT-UC.

3. NOMINAL PRESSURE

Nominal pressure is a dimensionless marking of maximum operating pressure at ambient temperature, preceded with PN or CL symbol.
Control valves are executed in following nominal pressures:

PN6; 10; 16; 25; 40; 63; 100; 160; 250; 320; 400	per PN-EN 1092-1, DIN2548, DIN2549, DIN2550, DIN2551, PN-H-74306, PN-H-74307
CL150; 300; 600; 900; 1500; 2500	per ANSI/ASME B16.5, PN-EN 1759-1
PN20; 50; 110; 150; 260; 420	per PN-EN 1759-1, PN-ISO 7005-1

Pressures PN20…420 are equivalent to CL150…2500.

4. FLOW RATIO

Flow coefficient Kv is the stream of water in [m^3/h], with temperature 5°C to 40°C, flowing through the valve, at pressure drop 1 [bar], for specific stroke of valve.
Kv coefficient describes minimum hydraulic resistance of valve. Familiarity with Kv coefficient allows to directly determine valve nominal size DN and diameter of pipe the valve is to be connected to.
Many different Kv values can be obtained for same nominal sizes DN, in the consequence of application of reduced passages of valve seats. Nominal (catalog) value of flow coefficient is marked Kvs.
Relationships between flow coefficient, flow rate and pressure drop for various states of aggregation and flow conditions can be determined using formulas on page 5.

Said formulas allow approximation of Kv coefficient. They however do not account for effects of fluid viscosity, change in density of flowing fluid, critical flow, etc. For more details refer to PN-EN 60534-2-1 “Industrial-process control valves. Flow capacity-sizing equations for fluid flow under installed conditions.

It is advised that DIVENT valve calculation and calculation program is used, which can be downloaded from the following website

www.polna.com.pl

To ensure correct work of automatic controls and to avoid oversizing of the valve, adopted catalog value of flow coefficient is to be higher than calculated. It is assumed that maximum value of calculated flow coefficient is to be achieved within the 70…90% range of valve plug stroke.

5. <u>FLOW CHARACTERISTIC</u>

Valve flow characteristics is the relation between flow value and closing component stroke. Regarding pressure drop we can divide characteristics into internal and working characteristics.
Internal characteristics describes relation between relative flow coefficient “kv” and relative stroke “h” at constant pressure drop in valve, where:

$$k_v = \frac{K_v}{K_{v100}} \qquad h = \frac{H}{H_{100}}$$

Working characteristic describes change in flow in function of stroke at variable pressure drop in valve, in installation conditions.
Valves have the following flow characteristics:

- linear - „L”
- equal percentage - „P”
- modified - „M”
- quick opening - „S”

Valve characteristic is obtained by proper design of fluid flow area between valve choking components regarding the stroke. This function is realized through contoured valve plugs or perforated components (perforated valve plugs, control cages):
- <u>linear characteristic:</u> equal increase in relative stroke “h” correspond with equal increase in relative flow coefficient “kv”.

$$k_v = k_{v0} + m \cdot h$$

where: k_{v0} is a minimum controlled relative flow ratio,

$$k_{v0} = \frac{K_{v0}}{K_{vs}}$$

m - characteristic inclination
For POLNA valves: k_{v0} = 0,02; m = 1

- <u>equal percentage characteristic:</u> equal increase in relative stroke “h” corresponds with equal per cent increase in relative flow coefficient „kv”

$$k_v = k_{v0} \cdot e^{n \cdot h}$$

where: n is characteristic inclination drawn in semi-logarithmic coordinates (h, lg kv).

$$n = \ln \frac{1}{k_{v0}} = \ln 50 = 3{,}912$$

- <u>modified characteristic:</u> is a characteristics in between “L” and “P”, created for individual needs and specific installations. It mostly is of equal percentage nature at the beginning of stroke (h=0…0.3) and linear in the subsequent part of stroke.
- <u>quick opening characteristic:</u> used for “open-close” on-off operation; it allows achievement of nominal flow at low stroke (h=0.6…0.7) and increase in flow coefficient by ca. 20% regarding catalog value, at full stroke.

Selection between value with equal percentage and linear characteristics depends on requirements concerning changes in flow rate and pressure on valve.
With small changes in flow rate during valve operation, up to 50%, selection of characteristics has no material effect to performance of control system. However for valves operating at large changes in flow rate, with variable pressure drop, and in case of doubt selection of constant per cent characteristics is recommended.

Valves with linear characteristics are recommended for systems, where pressure drop on valve is independent from flow rate, e.g. control of fluid level.

Valve plugs with quick opening characteristics are designated exclusively for on-off operation. Limitations in application of perforated components are due to their susceptibility to contaminants suspended in fluids, hence the need for their permanent filtering.

Flow type	Fluid	Gas	Steam
Subcritical $p_2 \rangle \frac{p_1}{2}$ $\Delta p \langle \frac{p_1}{2}$	$K_v = \frac{Q}{31{,}6}\sqrt{\frac{\rho_1}{\Delta p}}$	$K_v = \frac{Q_N}{504}\sqrt{\frac{\rho_N \cdot T_1}{\Delta p \cdot p_2}}$ $K_v = \frac{G}{504}\sqrt{\frac{T_1}{\rho_N \cdot \Delta p \cdot p_2}}$	$K_v = \frac{G}{31{,}6}\sqrt{\frac{v_2}{\Delta p}}$
Supercritical $p_2 \langle \frac{p_1}{2}$ $\Delta p \rangle \frac{p_1}{2}$	$K = \frac{G}{31{,}6}\sqrt{\frac{1}{\rho_1 \cdot \Delta p}}$	$K_v = \frac{Q_N}{252 \cdot \rho_1}\sqrt{\rho_N \cdot T_1}$ $K_v = \frac{G}{252 \cdot \rho_1}\sqrt{\frac{T_1}{\rho_N}}$	$K_v = \frac{G}{31{,}6}\sqrt{\frac{2v}{\rho_1}}$

Kv [m^3/h] - flow coefficient (calculated)
Q [m^3/h] - fluid flow volume intensity
Q_N [Nm^3/h] - gas flow volume intensity in normal conditions (0°C, 760 mm Hg)
G [kg/h] - flow mass intensity
p_1 [bar(a)] - absolute pressure upstream valve
p_2 [bar(a)] - absolute pressure downstream valve
Δp [bar] - pressure drop on valve (available pressure drop)
ρ_1 [kg/m^3] - fluid density upstream valve
ρ_N [kg/m^3] - fluid density in normal conditions
T_1 [K] - fluid temperature before agent
v_2 [m^3/kg] - specific volume of steam for parameters p_2 and T_1
v [m^3/kg] - specific volume of steam for parameters (p_1/2) and T_1

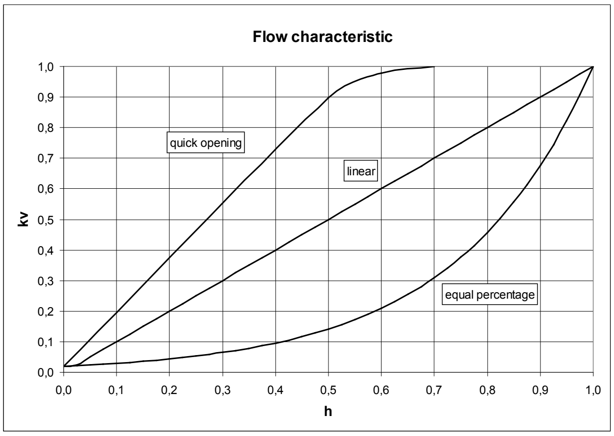

Fig. 1. Flow characteristics for valves

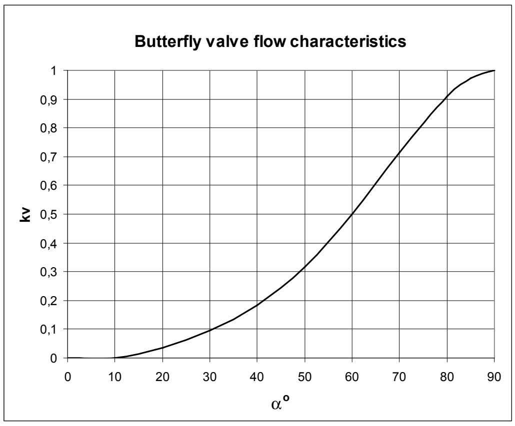

Fig. 2. Flow characteristics for butterfly valves

Three way and rotary valve plug valves feature linear characteristics, whereas butterfly valves feature characteristics similar to equal percentage characteristics in the range of opening angles 0°…60° (Fig. 2).

6. INTERNAL TIGHTNESS

Maximum leakage of closure by valve choking components (“plug - seat”) is described in leakage classes as per PN-EN 60534-4.

Leakage class	Allowed leakage
II	- $5 \cdot 10^{-3}$ Kvs
IV	- 10^{-4} Kvs

V - $3 \cdot 10^{-4} \cdot \Delta p \cdot D$ [cm³/min]
VI - 1 [blister/min] do D = 25

Allowable leakage [blister / min.]	Seat diameter D [mm]
1	25
2	40
3	50
4	65

Allowable leakage [bubble / min.]	Seat diameter D [mm]
6	80
11	100
27	150
45	200

Checking the internal tightness is carried out as part of acceptance tests of the product with the use of air with pressure 3…4 [bar] (for valves in classes II, IV and VI) and with water with working pressure conforming to the order (for valves in class V).

Valves in class VI have seats (single-seat valves) or plugs (two-seat valves) equipped with packing rings made of PTFE reinforced with glass fibre.

Because of durability of the packing material, pressure drop on the valve must not exceed 35 bar.

Valves in class V require careful and laborious fitting of closing elements and a greater disposition force of the drive.

Another acceptance criterion is the norm PN-EN 12266-1 “Industrial valves. Testing of metallic valves. Part 1: Pressure tests, test procedures and acceptance criteria. Mandatory requirements.”

The following can be used as test media:

• Air (for pressure 6 bar),
• Water (for pressures 1,1 • $\Delta p_{max.}$).

Acceptable leakage [mm³/s] can be calculated for the given class according to the following formulas:

Medium	Class A	Class B	Class C	Class D	Class E	Class F	Class G
Water	0	0,01 · D	0,03 · D	0,1 · D	0,3 · D	1,0 · D	2,0 · D
Air	0	0,3 · D	3,0 · D	30 · D	300 · D	3000 · D	6000 · D

where: Δp [bar] - working pressure drop
D [mm] - valve seat diameter
Internal tightness is checked during acceptance tests, using air at pressure 3…4 [bar] for valves of class II, IV, VI, and using water at working pressure as per order, for valves of class V.
Class VI valves valve seats (single-ported valves) or valve plugs (double-ported valves) are equipped with PTFE seal ring reinforced with glass fiber. Due to durability of sealing material pressure drop on valve cannot exceed 35 bar.
Class V valves require precise and time-consuming fitting of valve closing components and higher available force of drive.

7. BONNETS, TYPES AND PACKINGS

Bonnet is a pressure equipment used to contain and seal the component (valve plug stem, shaft) transmitting motion from drive to closing component.
Bonnet can be integral part of body or be separated from body.
Control valves are fitted with following types of bonnets:
- standard bonnet
- extension bonnet
- bellow seal bonnet

The basic criterion in selection of bonnet is fluid temperature. Extension bonnets are used in both high and low temperatures. There is a execution of extension bonnet specially designed for cryogenics (temperatures up to -196°C).
Bellow seal bonnets ensure absolute internal tightness and they are used mostly for aggressive media. Standard bellow seal bonnets can be used up to pressure 35 bar. Application for higher pressures require to use multi-layer bellows.
Cast iron valves are only fitted with standard bonnet. Control valves DN150…250, PN160…CL2500 can be equipped with self-sealing bonnets. Type of valve plug stem packing in bonnet depends on temperature and type of fluid. In majority of cases PTFE rings with graphite are applied. Pure graphite packing is recommended for steam and high temperature operations. Such packing does not require lubrication, although they do require adjustment during operation, due to relaxation and wearing-off.

Among maintenance-free packings are PTFE-V and TA Luft packings. PTFE-V ones are executed in PTFE in the form of V-profile rings, pressed to sealed surfaces with spiral spring. TA Luft packing comprises two kits of seal rings loaded with package of disk springs, and compliant in terms of tightness requirements of TA Luft:2002, Clause 5.2.6.4, and VDI 2440:2000.

8. END CONNECTIONS, TYPES

Body connections are used to connect valve to pipeline and they should provide tightness, pressure resistance, vibration resistance and pipeline deformations.
Valves are executed with following types of connections:

- flanged,
- flangeless,
- welding.

Flanged connections are executed as per European (PN-EN 1092-1, PN-EN 1092-2, PN-EN 1759-1, DIN 2548, DIN 2549, DIN 2550, DIN 2551, PN-ISO 7005-1, PN-H-74306, PN-H-74307) and American (ANSI/ASME B16.5) standards.
Regarding sealing surface type flanges can be executed with:

- raised face type B1, B2, B, RF
- groove, type D, D1, GF, DL
- recess type F, F1, FF
- ring-joint, type J, RTJ

Rotary plug valves and butterfly valves have flangeless connections of Sandwich type. Body is fitted between pipeline counter-flanges by means of bolted ends.
Valves with welding connections are designed for butt welding, BW type, or socket welding, SW type. Pipe dimensions and body lengths specified in catalog apply to execution of connections from body casting. Application of smaller pipe dimensions is limited due to minimum internal diameter of pipe that can be achieved from casting (D1 min). In such case reduction stub is to be welded to body, which shall cause elongation of valve body by 100 mm (DN15…50), 150 mm (DN80, 100), 200 mm (DN150) and 300 mm (DN200, 250) – in case of stubs fixed on both sides of the valve.

9. HARDENING OF VALVE INTERNAL PARTS

In standard execution valve internal parts: valve plugs, valve seats, valve plug stems, cages, guiding sleeves are executed in high-alloy austenitic steel X6CrNiMoTi 17-12-2 (1.4571) as per PN-EN 10088-1.

In order to improve mechanical and chemical resistance to fluid the following hardening methods of internal parts are used: stelliting, nitriding, heat treatment, protective coatings.
Stelliting hardens the surface down to ca. 1 mm, to hardness of ca. 40 HRC. Stelliting can be applied to sealing phases of valve plug and valve seat, or additionally valve plug trim surfaces, openings of valve seats and guiding sleeves, valve plug stem friction surfaces.
Plugs with the diameter smaller than 10mm can be made of solid stellite.

Nitriding (CrN) consists in hardening of component surfaces down to ca. 0.1 mm, to hardness of ca. 900HV, in the effect of plasma or diffusion processes. Nitriding is recommended for application with surfaces exposed to friction or erosion. Heat treatment is applied in order to achieve high durability and resistance to wear. Depending on the material type hardness achieved is up to 45 HRC (1.4057) or 55 HRC (1.4125).
Composite protecting coatings (BELZONA) are applied on body internal surfaces in order to protect them from erosion (flashing, abrasive fluids).

Hardening of valve internal parts is recommended in the following cases:

- handling of erosive fluids,
- wet gas or saturated steam,
- dry, pure gas
($\Delta p > 25$ bar (up to DN100), $\Delta p > 12$ bar (DN>100)),
- chocked flow,
- initial cavitation: (liquid $\Delta p > 10$ bar, temp. > 315°C).

Contraindications for stelliting

- boiler water pre-treated with hydrazine,
- perforated components,

10. SELECTION OF DRIVE

Valves and butterfly valves can be equipped with spring diaphragm pneumatic actuator, piston actuator, electric actuator, electro-hydraulic actuator, handwhell, or no drive at all.

Equipment without drives can be completed by end user with other types of actuators, such as springless diaphragm pneumatic, piston pneumatic acutator, crank actuator, and others, provided that such actuators are adapted to connection with valve bonnet and valve plug stem.

Hand operated equipment is mostly used for applications requiring on-off regulation.

While selecting spring diaphragm pneumatic actuator the following is to be determined:

- actuator type,
- actuator size,
- spring range,
- supply pressure,
- stroke,
- requirements concerning accessories.

Selection of pneumatic actuator (whether direct or reverse action) depends on equipment operation control signal failure. Whether the valve is to stay open or closed on control signal failure is the technical requirement of installation.

Actuator size, spring range and supply pressure are to be taken from tables in catalog, depending on required available force of actuator.

Available force of actuator is to be lower than Fs calculated using the below formula:

$$F_s = 0{,}785 \cdot 10^{-4} \cdot \Delta p \cdot D^2 + F_d$$

where: F_s [kN] - available force
Δp [bar] - pressure drop on closed valve
D [mm] - valve seat diameter
F_d [kN] - tightening force

Values D and Fd are to be taken from catalog charts, and Δp from order.

Disposition force of type „P" actuators - F_{SP} [kN] is dependent on the active flank of the actuator A [cm^2], supply pressure p_Z [kPa] and the final spring travel p_2 [kPa].

$$F_{SP} = 10^{-4} \cdot A \cdot (p_Z - p_2)$$

Disposition force of type "R" actuators – F_{SR} [kN] is dependent on the active flank of the actuator A [cm^2] and the initial spring travel p_1 [kPa].

$$F_{SR} = 10^{-4} \cdot A \cdot p_1$$

Disposition forces F_{SP} and F_{SR} calculated that way are established without consideration of friction force of movable elements (spindle of the actuator and the valve) or tolerances of spring manufactures, hence they should be treated with a 20% reserve regarding those factors.

The calculations refer to single-seat valves type Z, Z1A and Z1B in a closed position.

Catalog charts provide allowable pressure drops for various pneumatic actuators and various internal leakage classes of valves.

Those values apply to single-ported valves, unbalanced, with fluid fed under the valve plug (FTO).

With fluid fed above the valve plug (FTC) allowable pressure drop may be higher, however such an arrangement causes valve plug hitting the valve seat when closing and disturbances to control. Hence it is used mostly in on-off operations, with actuator equipped with higher stiffness springs. For valves with valve plug unbalanced it is assumed that available force Fs is at least equal to tightening force for class V leakage.

In the case of double-ported valves it is not possible to procure a table of allowable pressure drops, due to dynamic forces occurring, which depend on i.a. actual flow conditions (pressure, fluid type, valve plug type, valve operation type). In case when knowledge of forces acting on double-ported valve plug stem is required, please contact manufacturer, stating all the data related to valve operation.

Pneumatic actuator accessories may comprise the following:

- top-mounted or side-mounted handwheel,
- positioner: pneumatic, electro-pneumatic with analog or digital signal (smart positioner),
- air set,
- three-way solenoid valve,

- position transmitter,
- limit switches,
- lock-up valve,
- volume booster,
- quick exhaust valve.

Handwheel is applied in case of control signal failure, as well as to limit valve stroke.

Application of positioners is recommended in following cases:

- for systems requiring large pressure drops on valve,
- for high working pressure,
- for valves of nominal diameter DN > 100 mm,
- for distance between valve and reducing valve exceeding 50 m,
- for three-way valves,
- for systems requiring high-speed action,
- for viscous or highly contaminated fluids sedimenting on valve seat,
- for media of temperature higher than 250°C or lower than -20°C,
- when spring range does not correspond with range of out signal from controller.

Designation of accessories:

- filter reductor is used to reduce supplying pressure to required value and to clean incoming air.
- solenoid valve assists remote switching of control circuit on and off.
- position transmitter is used to reflect position of valve plug stem in the form of unified pneumatic (e.g. 20…100 kPa) or electric (e.g. 4…20 mA) signal.
- limit switches are used to signal preset positions of actuator stem.
- lock-up valve is used to block valve plug stem movement in current position with control signal missing.
- volume booster is used to accelerate actuator time of action.
- quick drain valve allows to reduce actuator chamber drainage time.

11. HARMFUL EFFECTS IN VALVE OPERATION

Harmful effects in valve operation, such as noise, cavitation, choked flow, flashing, are discussed in the study titled „Harmful phenomena in the work of valves”.

NOTES: