

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

MANUAL

CONTROL VALVES - SELECTION, SIZING AND SPECIFICATION

PTS 32.36.01.17

SEPTEMBER 2010



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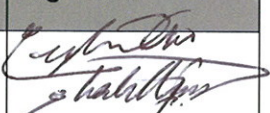
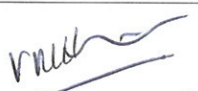
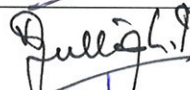
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This revision of **PTS 32.36.01.17– Control Valves – Selection, Sizing and Specification** has been updated incorporating PETRONAS Lessons Learnt, Best Practice and new information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS (**December 2008**) will be removed from PTS binder/ e-repository from herein onwards.

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Revision History

Date	Version	Description of Updates	Author

Summary of Changes

Section	Description of Changes
3.1 GENERAL	Following was replaced (highlighted in bold): Control valves shall be installed with sufficient clearance around the actuator and valve body to allow the control valve actuator to be dismantled without the valve body being removed from the pipe.
3.3.2 ANGLE VALVES	Following were added (highlighted in bold): Angle valves should be considered for: • hydrocarbon services where coke may form; • erosive services, e.g. slurries; • flashing service; • applications where solid contaminants might settle in the body of a globe valve; • anti surge applications (use angle body for anti surge with gas inlet from bottom and the Cv of the valve shall be double of the Cv sized); • liquid service where high differential pressure prevails.
3.3.5 GATE VALVES	Following were added (highlighted in bold): Gate valves should only be considered for remotely operated on-off applications, where a fail-safe action is generally not required. Exceptions to fail-safe applications may be made for specific process applications, such as, fail-safe gate valves used in Surface Safety Valve (SSV) and Wing Valves (WV) at wellheads. They are normally equipped with an electric actuator (8.8) or hydraulic actuator (8.9). Typical applications are storage tank isolating valves, remotely operated on/off valves on blenders, pump suction shut-off services, and shut-off services on wellheads in oil and gas production facilities.
3.5 SOLENOID OPERATED VALVES	Following were added (highlighted in bold): Apart from their use in instrument air signal lines, solenoid operated valves (9.9) should only be considered for on-off control in hydraulic utility services, such as hydraulic control systems for loading arms, remotely operated valves, hydraulic turbine control and wellhead control units.
4.3 END CONNECTIONS	Adding “As a general Best Practice, the minimum flange rating for the control valve body should be ANSI 300 lbs.”
4.6.1 GENERAL	Following were added (highlighted in bold): In order to comply with fugitive emission requirements, such as, for environmentally harmful process medium, the Manufacturer shall select appropriate gasket and packing materials in accordance with the requirements of PTS 31.38.01.11 and ISO15848.
5.1 SEAT LEAKAGE AND FLOW DIRECTION	Following were replaced, deleted and added (highlighted in bold): Unless otherwise required, emergency shut-off valves should be specified and installed as “flow-tending-to-close”. For throttling applications with unbalanced valves trims, the direction should be “flow-tending-to-open” in order to avoid very large unstable forces in the virtually closed position.

Section	Description of Changes
	Depending on the application, the TSO requirement will apply for the forward direction, for reverse direction or for both. The leakage class and TSO direction shall be indicated on the PEFS. Balanced-type single-seated control valves of the pilot-operated type shall not be used as TSO valves. Cage-guided valves or balanced-type valves shall not be used for fluids that contain solid particles (e.g. coke). Balanced-type control valves trims shall be used only in clean services and in high differential pressure applications (around 16 Barg or 220 psig) (above 15 Barg or 200 psig) For seat leakage testing, reference is made to (11.6).
5.3 TRIM MATERIALS	Adding "For oxygen service, trim materials should be austenitic stainless steel. However, for severe services, exotic materials such as Monel or Inconel / Incoloy may be considered."
5.3 TRIM MATERIALS	Following were added in note (highlighted bold): "1) For choke valves and valves in other extremely erosive services, special materials such as tungsten carbide and ceramics may be used. However, for boiler feedwater (BFW) application, with the presence of Hydrazine that is used to treat the boiler feedwater, tungsten carbide shall not be used. The Cobalt binder in the Tungsten Carbide material is rapidly attacked by the hydrazine, allowing the carbide particles to fall away and thus exposed the bare metal to subsequent erosion/corrosion. Instead, the use of stainless steel SS 440C is recommended for BFW application where Hydrazine is present"
6.1.2 PILOT ASSISTED TRIMS	The whole 6.1.2 contents were deleted.
6.4 STEAM DESUPERHEATING VALVES	Adding "For desuperheating application, with dedicated quench water injection valve, the trim shall be able to withstand the severe service, including at start-up conditions, of high pressure drop and high exit velocity that could lead to potential cavitations and erosion, such as, by having multi-stage trims, etc."
6.5.1 GAS CHOKE VALVES FOR WELL	Following were replaced (highlighted in bold): d) The plug and seat trims should be stilted at least tungsten carbide.
6.5.2 LIQUID CHOKE VALVES	Following were replaced, deleted and added (highlighted in bold): For special applications, such as wellheads, the draining of high-pressure separators, a liquid choke valve should be considered. This valve shall be designed for liquids containing solid particles such as grit, sand and scale. The trim of the valve consists of two discs: one fixed in the valve body and one that can be rotated by the actuator. Each disc has one or more eccentric holes and throttling is created by rotating the upper disc in such a way that the holes partly overlap each other. The major part of the pressure drop occurs across a bean downstream of the fixed disc. A built-in filter upstream of the rotating disc shall be fitted to protect the discs against large solid particles in the process fluid.

Section	Description of Changes
	The following shall apply: a) The valve shall be made up of a number of modular sub-assemblies, such as internals, bonnet, yoke, actuator, coupling, etc. b) To replace any of the sub-assemblies, it shall not be necessary to remove the valve body from the process line. c) The valve shall be Class V or minimum Class IV shut-off, in accordance with IEC 60534-4. d) The discs and bean trim shall be of at least tungsten carbide.
6.5.3 STEPPING ACTUATOR	The whole 6.5.3 contents were added.
6.6 FIRE SAFE DESIGN	Following were added (highlighted in bold): For requirements of certified fire safe valve bodies, see PTS 31.38.01.11 / PTS 80.47.10.30. The actuators, accessories and cabling for such valves may also need to be fire resistant.
7.1 LOW TEMPERATURE SERVICE	Following were replaced, deleted and added (highlighted in bold): Control valves in services with a design temperature between 0°C and minus 50°C shall, in addition to the specification in the requisition, comply with MESC SPE 77/209. Control valves in services with a lower design temperature below minus 50°C 45°C shall, in addition to the specification in the requisition, comply with ISO 15848. Cryogenic refers to a service condition where the temperature is significantly below normal atmospheric temperature. Definitions vary with regards to the temperature defined as cryogenic. However, it is generally accepted that any temperature below minus 100°C is considered cryogenic.
8.1 GENERAL	Following were replaced, deleted and added (highlighted in bold): Piston-type actuators, if specified, should be of the spring-opposed diaphragm or of the spring-opposed short-stroke type spring return type or double-acting type. In the event of instrument air failure for double-acting piston type, the required valve action shall be achieved by either automatic spring return long-stroke springless piston actuators providing with lock-up valves, check valves and a local air buffer vessel.
8.4 ACTUATOR MATERIAL	Following were added (highlighted in bold): The diaphragm material shall be nylon-reinforced neoprene or Buna N rubber, unless the actuating medium is wet hydrocarbon gas, in which case Buna N shall not be used as diaphragm or seal material. In such cases, Viton or manufacturer's recommendation shall be considered.
8.5 ACTUATOR COLOUR CODING	Following were replaced and deleted (highlighted in bold): The colour of the actuator shall be in accordance with the Manufacturer's standard unless otherwise specified in the requisition. To identify that the valve is fail-safe, a colour code should be assigned to the actuator (e.g. i.e. red for spring closing fail-close valves and green for spring opening fail-open valves), as specified in the requisition. For painting requirements, see section (10).

Section	Description of Changes
9.2 VALVE POSITIONERS	Following were replaced (highlighted in bold): The positioner shall not be provided with a bypass valve. The positioner shall have a weatherproof enclosure with a degree of protection of at least IP 55 65 in accordance with IEC 60529.
9.2 VALVE POSITIONERS	Following were added (highlighted in bold): The control valve Manufacturer shall determine the tubing diameter so as to achieve the required stroking times. The minimum tubing diameter shall be 6mm (1/4 in). The tubing shall comply with the specification given in the requisition. Copper tubing shall not be used. For areas with a potential H₂S or acetylene atmosphere, or for offshore application, or other corrosive atmosphere locations, tubing and fittings shall be of stainless steel or other materials suitable for the stated atmospheric conditions and shall be subject to the Principal's approval. Use of low carbon, high nickel austenitic stainless steel alloy tubing material, such as, S31803 or better, is recommended to protect against hydrogen stress cracking environment.
9.2 VALVE POSITIONERS	Following were added (highlighted in bold): The valve positioner shall be provided with an identification plate, marked with the air supply pressure and input signal. For high vibration application and/or high temperature areas, the use of remote mounting positioner is recommended.
9.2 VALVE POSITIONERS	Following notes were added: Note: 1) Metric and imperial tubing sizes shall not be interchanged. 2) Every plant shall decide the usage of either metric or imperial sizes at the beginning of the project and shall maintain the same unit throughout the life of the plant.
9.6 LIMIT SWITCHES	Following were added and deleted (highlighted in bold): If limit switches are required, they shall be of the hermetically sealed proximity type. The proximitor(s) and initiator should be mounted inside a box for mechanical protection. The flying leads of the proximitor(s) shall terminate in an attached terminal box; alternatively, the protection box and the terminal box may be combined into one box. These boxes shall be suitable for the electrical hazardous area classification in which they are located with minimum IP65 against water/ dust ingress protection. If not armoured, the flying leads shall be protected against mechanical damage.
9.6 LIMIT SWITCHES	Following were deleted (highlighted in bold): The valve Manufacturer shall follow the mounting instructions supplied by the limit switch Manufacturer. The valve Manufacturer shall properly adjust the limit switches. The vanes should approach the proximity switch perpendicular on its axis.
9.6 LIMIT SWITCHES	Following notes were added: 2) Failure to install suitable interface proximity circuit will cause the IPS to be unstable and not able to recognize the very low input mA signal from the NAMUR type proximity.

Section	Description of Changes
9.10 FILTER REGULATORS	Following were added (highlighted in bold): Air-filter regulators shall be of metallic or metallic alloy. Plastic-type or glass (bowl-type) filter regulators shall not be used for outdoor environment.
11.1 EXTENT	Following were added (highlighted in bold): Valves used in services requiring a fugitive emission limitation, such as, environmentally harmful process medium.
11.4 FUNCTIONAL TEST	Following were added (highlighted bold): If the control valve is equipped with limit switches, they shall be checked for functional operation with a proximity tester. Limit switches shall also be loop tested with the IPS or DCS. If IPS or DCS is not available, limit switches signal compatibility with the IPS or DCS shall be verified with the relevant IPS or DCS vendor.
11.6 SEAT LEAKAGE TEST	Following were added (highlighted bold): The seat leakage test shall be in accordance with IEC 60534-4, as per Appendix IV with the acceptance criteria for the specified shut-off class; see (3.1) for TSO class V or VI. If the shut-off class is not specified, the following acceptance criteria shall apply:
11.9 ACTUATOR LEAKAGE TEST	Following were added (highlighted bold): All pneumatic fittings and actuator diaphragm chamber joints shall be tested for leak by using leak test solution while applying 1.1 times the rated air supply to the actuator, positioner and accessories, to ensure that there is no leak of instrument air supply and signal at the fittings & joints.
13. REFERENCES	Following PTSs were added as a references for these PTS: - Actuated Valve Management Strategy (PTS 32.36.01.19) - Assessment on the fire safety of onshore installations (PTS 80.47.10.30)
APPENDIX 2.1 SIZING CRITERIA	Following were added (highlighted bold): Unless otherwise specified, the calculation of the C_v value should be based on the maximum design flow with its relevant process data. Unless otherwise specified, the following should apply: the valve shall be sized for 110% of the maximum design flow rate (Q_d) in order to allow control at Q_d, i.e.: $Q_+ = 1.10 \times Q_d$
APPENDIX 2.2 SELECTION OF C_v VALUE	Following were added (highlighted bold): As Best Practice, the valve opening at the specified maximum flow rate should not be more than : 80% for linear characteristics 90% for equal percentage characteristics As Best Practice, the valve opening at the specified minimum flow rate should not be less than : 10% for linear characteristics 30% for equal percentage characteristics If the above criteria cannot be met, this shall be taken up with Principal for approval.

Section	Description of Changes
	Trims shall be selected accordingly to the designed flow, Qs. However, in event of a bigger body size available with a reduced trim Vs. lower body size with full port, the first option should be selected.
APPENDIX 3.1 GENERAL	Following notes were added: Note: 1. Failure to consider all of above aspects may result in wrong selection and incorrect sizing of the control valve. 2. Due considerations shall be made for process mediums that comprising of multiple components with respect to changes in vapour pressures, molecular weights, compressibility, etc.
APPENDIX 4 SEAT LEAKAGE TEST	The whole Appendix 4 was added.

PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

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The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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1. INTRODUCTION

1.1 SCOPE

This revised PTS specifies requirements and gives recommendations for the selection and specification of control valves with their actuators and accessories for throttling and on-off services. This includes the requirements for the design, construction, functioning and testing of control valves, as well as control valve sizing. Furthermore, this PTS includes the requirements for self-acting pressure regulators. (Appendix 1) of this PTS gives details on control valve sizing.

Emergency depressuring valves are outside the scope of this PTS and shall be in accordance with PTS 32.45.10.10.

This PTS is a revision of the PTS of the same title and number dated July 1997.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this PTS is confined to companies forming part of PETRONAS or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations. When PTS are applied, a Management of Change (MOC) process should be implemented. This is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this document as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project work and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorised to act for the Principal.

The word **shall** indicate a requirement.

The word **should** indicate a recommendation.

1.3.2 Specific definitions and abbreviations

For control valve terminology and related terms, refer to IEC 60534-1.

For definitions regarding control valve sizing, see ([Appendix 1](#)).

For the purposes of this PTS, the following definitions apply:

AISI	American Iron and Steel Institution
Blow-down or Depressuring	Reducing the pressure in process equipment at a controlled rate in emergency conditions or for operational purposes.
DCS	Distributed Control System
DN	Nominal Diameter
Emergency shut-off / shutdown	Shutting off a fluid flow in an emergency condition, e.g. as part of an IPF.
HAZOP	Hazardous Operability
IPF	Instrumented Protective Function : A function comprising the initiator function, logic solver function and final element function for the purpose of preventing or mitigating hazardous situations.
IPS	Instrumented Protective System : The electromechanical, electronic and/or programmable electronic Logic Solver component of the Instrumented Protective Function, complete with input and output equipment.
On-off	Changing to an open, closed or predetermined state when required, for example, by a sequence control system.
PEFS	Process Engineering Flow Scheme(s).
Piping class	A collection of piping components, suitable for a defined service and design limits in a piping system. Piping classes are compiled in PTS 31.38.01.10, PTS 31.38.01.12 and PTS 31.38.01.15.
PTFE	Polytetrafluoroethylene
Stroking time	The time required to move the valve over the full operational range in response to the command signal. For on-off commands, which include IPF actions, the stroking time should be taken as the time to travel from 100% (fully open) to 0% (fully closed) or vice versa. For manipulating commands, the stroking time should be taken as the time for the valve to travel from 0% to 95% or from 100% to 5% in response to a control signal change from 0% to 100% or from 100% to 0%. Stroking time may be further specified by minimum and/or maximum limitations, for valve opening and/or valve closing, for control signal changes and/or on-off IPF actions.
Throttling control	Continuously manipulating the stem/shaft of a control valve in order to obtain a desired process condition.
TSO	Tight shut-off (to Class V or Class VI, in accordance with IEC 60534-4).

1.4 CROSS-REFERENCES

Where cross references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents referenced in this PTS are listed in (13).

2. GENERAL

2.1 FUNCTION

The function of a control valve is to regulate flow and pressure.

There are several ways to achieve this function (e.g. by using variable speed drives) and these should be assessed before routinely deciding to use control valves.

2.2 REQUISITIONING

There are several commercial engineering design databases that allow the creation of intelligent requisitions and data sheets. If the engineering design is to be produced in paper form only, the following PTS requisitions should be used:

PTS 30.10.01.10 "Requisition"

The Manufacturer of the control valve and its accessories shall be selected from the "List of Selected Instrument Vendors", as agreed for the relevant project.

The Manufacturer shall:

- check the calculation of the selected C_v value for the given data;
- quote a C_v value for each valve in the fully open position;
- quote for control valves, meeting the requirements of the requisition;
- inform the Principal of any irregularities found in the relevant requisition;
- perform noise prediction calculations on all valves under all given process conditions.

The Manufacturer is responsible for the design and construction of the supplied control valves for the services and design conditions specified in the requisition.

If a control valve is provided with an actuator and/or accessories from another source, but supplied as part of the control valve requisition, the responsibility of the overall valve assembly (valve complete with actuator and/or accessories) shall be with one party. The responsible party (valve Manufacturer or actuator Manufacturer) shall be as indicated on the requisition.

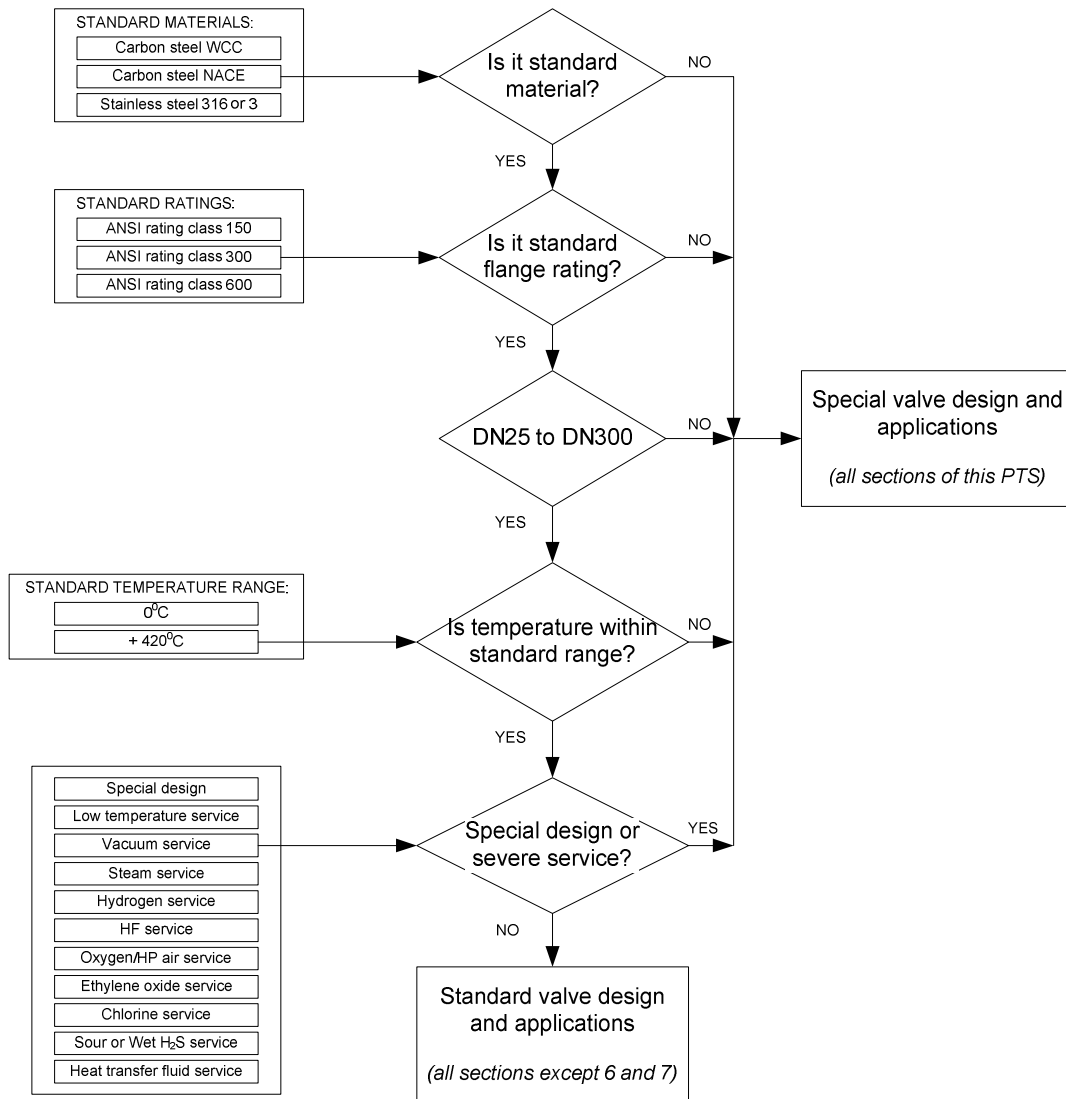
The variety of types and sizes of control valves and related accessories ordered under the requisition shall be minimised.

For economic reasons and for variety control, the Manufacturers' **standard** control valves should be used unless the process conditions, pressure, temperature, etc., are so severe that **special** control valves are needed.

Figure 1 illustrates the flow chart of this selection process. Figure 1 is typical only and may be amended by the Principal for a particular Manufacturer. The purpose of Figure 1 is to allow an early selection in order to concentrate effort on special valves. It is not intended to imply that off-the-shelf valves may be supplied if they do not meet this PTS.

If standard valves offered deviate from the requirements of this PTS, the approval of the Principal is required.

Figure 1: Control valve selection process



2.3 STRATEGY FOR PIPE FLUSHING

To prevent blockage, dirt collection and/or damage to the valve and its internals, control valves (except those with welded ends) should be installed after completion of the pressure testing and flushing of the piping system. A temporary spool piece should replace the valve to allow pressure testing and flushing.

Project timing and scope split between the parties involved should be based on the following sequence of events: spool piece installation, pressure testing, flushing, and replacement of spool pieces by control valves.

NOTE:

This requirement differs from the traditional and 'sharp' scope split and timing between the various parties involved: the construction Contractor's scope was typically defined to end at mechanical completion, i.e. with the control valves installed and functioning properly (dry test), while the commissioning party subsequently started pressure testing and flushing, which required the control valves to be removed again.

Depending on valve size, seat type (soft/metal) and trim construction, control valves may or may not be suitable for flushing. Furthermore, the installation of temporary filters might be considered. Only valves that will safely survive the flushing operation and for which the Principal has given his approval may be installed prior to pressure testing and flushing.

Control valves with welded ends can only be installed prior to pressure testing and flushing, but should be installed without trims at the construction stage, with a blind bonnet for temporary closure of the body. The trims shall only be installed after pressure testing and flushing. Only trims that will safely survive the flushing operation, and for which the Principal has given his approval, may be installed prior to flushing.

The flushing strategy and the resulting effect on project timing and scope splits should be defined in the project specification phase. The strategy should address pressure testing/flushing during commissioning of the new installation as well as during plant preparation for restart. The strategy should include a plan, defining:

- which non-welded valves shall be installed prior to pressure testing and flushing and which measures are required to keep the valves clean and fully open during pressure testing and flushing;
- which non-welded valves shall each be replaced by a temporary spool piece during pressure testing and flushing;
- for which welded valves the trim shall be installed prior to pressure testing and flushing, and what measures are required to keep the valves clean and fully open during pressure testing and flushing;
- for which welded valves the trim shall be installed after flushing and for which a temporary blind bonnet flange is required for body closure during pressure testing and flushing.

3. TYPES OF CONTROL VALVES AND THEIR APPLICATION

3.1 GENERAL

If the application allows, valves with a rotating spindle may be used in place of linear motion valves for reasons of:

- capacity;
- turndown.

Control valves and pressure regulators shall be selected in accordance with the requirements of the piping class.

Cadmium plating or galvanizing shall not be used for any component of the control valve assembly or its accessories.

In applications/locations where freezing may occur, valve stems, solenoid valves and other mechanical moving parts shall be protected against ice formation. The Principal shall approve the method of protection.

Linear motion valves shall be installed with their actuator stem in the vertical position.

Control valves shall be installed with sufficient clearance around the actuator and valve body to allow the actuator to be dismantled without the valve body being removed from the pipe.

There shall be sufficient clearance to lift and remove the valve. Control valves shall be located so that they are accessible for hoisting equipment where needed.

Throttling control valves should not be used if tight shut-off Class V or VI is required as per IEC 60534-4, since these shut-off classes cannot be maintained over a prolonged period. If a Class V or VI shut-off is required, a dedicated on-off TSO valve (e.g. ball or high performance butterfly valve) should be installed in series with the throttling control valve.

NOTE:

Some Manufacturers report good results for metal-seated rotary valves in throttling service, where TSO class V could be maintained over a prolonged period. Such valve designs may be considered for valves without IPF function.

The necessity of assigning such shut-off classes shall be examined with care. For shut-off class VI, rotary valves are preferred.

For depressuring services, two valves in series shall not be employed.

([Appendix 1](#), [Appendix 2](#) and [Appendix 3](#)) covers control valve sizing and noise prediction.

3.2 ROTARY VALVES

3.2.1 VALVES WITH ECCENTRIC PLUG OR SEGMENTED BALL

Rotary valves of the eccentric plug or segmented ball type should be considered as the first choice.

3.2.2 BUTTERFLY VALVES

Butterfly valves shall be considered for the following circumstances:

- if the required size would make it economically attractive (usually due to a high flow rate with a low pressure drop);
- if eccentric plug / segmented ball or globe valves are not suitable;
- for corrosive services, where body lining of globe valves becomes economically unattractive.

Double or triple eccentric butterfly valves, also known as high performance (HP) butterfly valves, can be used in Class V or VI TSO applications in accordance with IEC 60534-4. They can handle high temperatures and high differential pressures.

The applicable buying descriptions and additional requirements (Specifications, or Spas) for butterfly valves shall be selected from the appropriate piping class in accordance with PTS 31.38.01.10, PTS 31.38.01.12 and PTS 31.38.01.15.

NOTE:

Spring-opening butterfly valves should not be of the wafer or lug type but should have a valve body to allow removal of the valve from the piping system with the disc in 'open' position. Alternatively, a spring-opening wafer or lug type butterfly valve may be provided with a hand wheel or upstream and downstream spool pieces. The provision of a hand wheel requires the Principal's approval.

3.2.3 BALL VALVES

Ball valves shall be considered for on-off service.

Ball valves for use in erosive (e.g. slurry) service etc. should be equipped with a scraper type of seat construction.

Ball valves, i.e. valves without specially designed control related internals, shall not be selected for throttling service without the approval of the Principal.

Unless equipped with a special trim, i.e. anti-cavitation or low-noise design, certain ball valves may be unsuitable for high differential pressures.

3.3 LINEAR MOTION VALVES

3.3.1 GLOBE VALVES

3.3.1.1 Two-way globe valves

Globe valves should be considered as the first choice, for ease of characterization and better controllability.

3.3.1.2 Three-way globe valves

Each flow path shall be sized separately for three way globe valves. Except for instrument air dryers, the application of three-way globe valves requires the approval of the Principal.

3.3.2 ANGLE VALVES

Angle valves should be considered for:

- hydrocarbon services where coke may form;
- erosive services, e.g. slurries;
- flashing service;
- applications where solid contaminants might settle in the body of a globe valve;
- anti surge applications (use angle body for anti surge with gas inlet from bottom and the Cv of the valve shall be double of the Cv sized);
- liquid service where high differential pressure prevails.

A special type of angle valve, the liquid and gas choke valve (6.5) is used for wellhead services.

3.3.3 DIAPHRAGM VALVES

Diaphragm valves should only be considered for on/off applications in slurry or corrosive service. The use of diaphragm valves requires the approval of the Principal. Diaphragm valves shall be in accordance with ISO 15848.

3.3.4 PLUG VALVES

Plug valves should be considered for special applications such as throttling control in slurry service. The use of plug valves requires the approval of the Principal. Plug valves shall be in accordance with ISO 15848.

3.3.5 GATE VALVES

Gate valves should only be considered for remotely operated on-off applications, where a fail-safe action is generally not required. Exceptions to fail-safe applications may be made for specific process applications, such as, fail-safe gate valves used in Surface Safety Valve (SSV) and Wing Valves (WV) at wellheads. They are normally equipped with an electric actuator (8.8) or hydraulic actuator (8.9). Typical applications are storage tank isolating valves, remotely operated on/off valves on blenders, pump suction shut-off services, and shut-off services on wellheads in oil and gas production facilities.

3.3.6 RISING STEM BALL VALVES

Rising stem ball valves are particularly suitable for dryer applications. They operate with the aid of a linear actuator, which initially lifts and then rotates the ball valve, by means of a large pitch helical form. They shall be equipped with pneumatic actuators. The breakaway torque shall be carefully calculated so that the minimum instrument air supply pressure will suffice under all service conditions and the actuators shall be sized accordingly.

These valves shall comply with ISO 15848. This specification applies to soft and metal-seated rising stems, which are non-contact and friction-free during the rotation of the ball valves to comply with ISO 14313 for full and reduced bore types.

3.4 SELF-ACTING REGULATORS

3.4.1 Self-acting pressure-reducing regulators

Self-acting pressure regulators shall only be used in clean fluid services and only in applications that need no operator intervention, such as reducing instrument supply pressure or gas blanketing of vessels or storage tanks.

Pressure-reducing regulators in gas blanketing service shall not be provided with an internal self-relieving function.

3.4.2 Self-acting back-pressure regulators

Self-acting back-pressure regulators shall only be considered for clean fluids in applications which need no operator intervention, such as for maintaining a uniform back pressure in utility (e.g. nitrogen) distribution systems or for lubrication, sealing or control oil applications in rotating equipment.

The use of self-acting back-pressure regulators requires the approval of the Principal.

3.4.3 Self-acting differential-pressure regulators

Self-acting differential-pressure regulators shall only be considered for clean fluids in applications that need no operator intervention, such as for secured instrument air systems or for lubrication, sealing or control oil applications of rotating equipment.

Except in secured instrument air supply systems, the use of self-acting differential-pressure regulators requires the approval of the Principal.

3.4.4 Self-acting temperature regulators

Self-acting temperature regulators shall only be considered for simple, non-safety related heating applications where utilities (e.g. instrument air or gas) are not available.

The use of self-acting temperature regulators requires the approval of the Principal.

3.5 SOLENOID OPERATED VALVES

Apart from their use in instrument air signal lines, solenoid operated valves (9.9) should only be considered for on-off control in hydraulic utility services, such as hydraulic control systems for loading arms, remotely operated valves, hydraulic turbine control and wellhead control units.

4. BODY CONSTRUCTION AND MATERIALS

4.1 GENERAL

Control valves in hydrocarbon service should be provided with process flanges or with welded ends.

Wafer or lug type valves may be used, subject to approval by the Principal.

Split-body valves shall only be used with the approval of the Principal.

Control valve bodies shall not be fitted with bottom drain plugs.

Valve bonnets shall be of bolted construction with fully retained gaskets. Pressure seal bonnets shall not be used.

4.2 BODY SIZE

The body size of a control valve in throttling service should at least match the calculated trim size. However, the body size shall not be smaller than half the size of the piping. Oversized bodies (up to the size of the adjacent piping) may be considered for economic reasons (e.g. to allow for foreseen capacity increase in the future) or may for instance be required to reduce the outlet velocity.

On-off valves shall be sized with account being taken of process design conditions, pressure drop requirements and economic aspects.

NOTE: For ball valves, a reduced bore may be considered for economic reasons.

The nominal sizes of control valve bodies should be selected from the following series, DN 25, DN 40, DN 50, DN 80, DN 100, DN 150, DN 200, DN 250, DN 300 and larger.

The use of body sizes smaller than DN 50 is subject to the approval of the Principal.

4.3 END CONNECTIONS

The body end connections and ratings shall be in accordance with the requirements of the piping class. Flanges shall be in accordance with ASME B16.5 or ASME B16.47, as applicable.

As a general Best Practice, the minimum flange rating for the control valve body should be ANSI 300 lbs.

The flange gasket contact surface finish shall be in accordance with ASME B16.5.

4.4 FACE-TO-FACE AND END-TO-END DIMENSIONS

The face-to-face dimensions of flanged rotary valves (eccentric plug or segmented ball) shall be in accordance with either ISO 5752, ASME B16.10 or IEC 60534-3-1 (flanged globe control valves) or IEC 60534-3-2 (flangeless control valves).

For butterfly valves, the face-to-face and end-to-end dimensions shall comply with either API 609, EN 593, MSS SP67, MSS SP68 or Manufacturer's standards.

The face-to-face dimensions of flanged globe-body control valves of body size DN 25 to DN 400 and ASME rating class 150, 300 and 600 shall be in accordance with either ISO 5752, ASME B16.10, or IEC 60534-3-1.

4.5 BODY MATERIALS

4.5.1 General

The material selected for the body (including bonnet and/or bottom flange), bolts, studs and nuts, etc. shall be in accordance with the requirements of the piping class.

Bonnet material shall be same as that of the valve body material.

4.5.2 Lining

If approved by the Principal, internal lining may be used for protection against corrosion or erosion as an alternative to resistant base materials. Internal lining of the entire body shall be considered for valves in seawater services (such as for fire protection deluge valves).

4.6 STUFFING BOX AND PACKING

4.6.1 General

In order to comply with fugitive emission requirements, such as, for environmentally harmful process medium, the Manufacturer shall select appropriate gasket and packing materials in accordance with the requirements of PTS 31.38.01.11 and ISO15848.

Fire safety requirements may entail additional packing requirements; see PTS 31.38.01.11.

Packing shall not contain asbestos or man-made mineral fibers.

Packing requiring external lubrication or grease shall not be used.

Depending upon the design of the valve, an extended bonnet may be required to keep the temperature in the stuffing box at an acceptable value for the applied packing.

NOTES:

- 1) An extended bonnet may also be required if the operating differential pressure across the valve could otherwise cause freezing of the stuffing box/packing and/or ice formation on the yoke. This may, for example, be the case with compressor recycle (anti-surge) valves.
- 2) On valves in cryogenic service, an extended bonnet shall be fitted to bring the stuffing box outside the thermal insulation, see also (7.1).
- 3) For high temperature applications (232 deg C / 450 deg F) finned bonnet should be considered to prevent damage to the packing due to high temperature. Alternatively, Manufacturer may provide high temperature packing with Manufacturer's standards.

The stuffing box shall be provided with an adjustable bolted gland flange and gland follower. The valve Manufacturer shall properly adjust the valve gland. If the valves are delivered with a loose gland, this shall be clearly indicated on the appropriate valve with a warning sign.

4.6.2 Leakage prevention

Leakage prevention measures shall be in accordance with the requirements of the piping class. Fugitive emission leak detection tests shall comply with the requirements of ISO 15848.

Bellows sealed bonnets should be considered as a leakage prevention measure for hazardous application.

For control valves with bellows seal bonnets, an additional stuffing box with the appropriate packing material shall be included. For leak detection and venting purposes, the seal extension shall be provided with a screwed connection between the bellows seal and the packed gland. Bellows-sealed bonnets shall not be used above ASME rating class 300 without the approval of the Principal.

As an alternative to bellows seal bonnets, special packing arrangements may be considered (for instance a double packing arrangement with a leak-off connection between the sets or packing with spring-loaded stuffing boxes).

5. VALVE TRIM

5.1 SEAT LEAKAGE AND FLOW DIRECTION

For throttling applications with unbalanced trims, the direction should be “flow-tending-to-open” in order to avoid very large unstable forces in the virtually closed position.

Depending on the application, the TSO requirement will apply for the forward direction, for reverse direction or for both. The leakage class and TSO direction shall be indicated on the PEFS.

Cage-guided valves or balanced-type valves shall not be used for fluids that contain solid particles (e.g. coke).

Balanced-type trims shall be used only in clean services and in high differential pressure applications (above 15 Barg or 200 psig).

For seat leakage testing, reference is made to (11.6).

5.2 TRIM CONSTRUCTION

The following construction requirements apply to the trims of rotary valves (eccentric plug or segmented ball) and linear motion valves:

- a) The plug and the seat ring(s) shall be of the easy/quick replaceable type.
- b) The seat ring shall be fixed to prevent loosening by vibration. Adhesive compounds shall not be used.
- c) For control valves with welded ends, the entire trim assembly, including the seat, shall be removable from the top.
- d) For trims which are not of the one-piece plug and stem type, the plug and stem construction shall be provided with a locking device to prevent accidental separation, which may result in stem blow-out. Locking devices shall not be fitted through holes in the pressure casing.
- e) Stem protectors should be considered for linear motion valves, if the surrounding atmosphere causes the stem to foul.
- f) Valve shafts shall be designed to prevent shaft blowout.

5.3 TRIM MATERIALS

The control valve trim (consisting of plug, seat rings and stem) shall be corrosion resistant. For fluids that become corrosive when in contact with the atmosphere, suitable valve stem materials shall be considered or precautions shall be taken to prevent contact with air.

Hardened (e.g. Stellite or Colmonoy-coated) or solid Stellite closure members and seat rings shall be selected for the following applications:

- erosive services and choked flow;
- cavitating services, within the constraints of ([Appendix 1](#));
- wet gas or steam service with a pressure drop greater than 5 bar;
- other services in which the pressure drop is greater than 20 bar at temperatures above 300°C.

For economic reasons and if suitable for the specified process conditions, hardened alloy 6 stellite 400 series like AISI 410 or AISI 440C type stainless steel (hardness approximately 550 BHN) or higher if applicable, may be considered as trim material.

Material	Hardness, Rc
440 C SST	57
17-4 H900 SST	44
420 SST	50
316 / Alloy 6	42
316 / Colmonoy	58

The Manufacturer shall indicate the selected trim number with reference to the applicable valve design code, e.g., ISO, API 600 (Table 3), API 602 (Table 9), BS 5353, etc.

For oxygen service, trim materials should be austenitic stainless steel. However, for severe services, exotic materials such as Monel or Inconel / Incoloy may be considered.

NOTES:

- 1) For choke valves and valves in other extremely erosive services, special materials such as tungsten carbide and ceramics may be used. However, for boiler feedwater (BFW) application, with the presence of Hydrazine that is used to treat the boiler feedwater, tungsten carbide shall not be used. The Cobalt binder in the Tungsten Carbide material is rapidly attacked by the hydrazine, allowing the carbide particles to fall away and thus exposed the bare metal to subsequent erosion/corrosion. Instead, the use of stainless steel SS 440C is recommended for BFW application where Hydrazine is present.
- 2) Stellite, Colmonoy and other hard facings may be used for some or all of the trim parts. They shall be selected in consultation with the valve Manufacturer.

6. SPECIAL DESIGNS

6.1 GENERAL ASPECTS

6.1.1 Fouling risks of special trim designs

Most special valve trim designs make use of small passages to gradually reduce the pressure. These passages form a potential risk of trim blockage or stem jamming due to fouling.

If use is made of special trim designs, the fouling risk during normal and abnormal operating conditions (e.g. alternative operating modes, start-up, and emergency operation) and during pressure testing and flushing of the piping system, see (2.3), must be carefully evaluated.

NOTE:

Special valve trims can be separated into self-cleaning designs and non self-cleaning designs. For self-cleaning designs, the passages will be widened as the valve travels in the open direction, thus providing some degree of self-cleaning. For trims without self-cleaning capability, the number of passages will increase when the valve travels in the open direction.

If special trim designs are used, self-cleaning trims should be used for:

- critical services (e.g. anti-surge valves, IPF valves of Safety Integrity Level 1 and above) if identified as fouling;
- non-critical but fouling services.

6.1.2 Other requirements

In addition to the requirements of (6), the control valves shall be designed in accordance with PTS 31.38.01.11.

6.2 LOW NOISE VALVES

Limits for the noise generated by control valves shall comply with PTS 31.10.00.31.

Process conditions at which the calculated noise is found to be above the allowable limit shall be critically reviewed and validated with process engineers.

The type of noise abatement technique shall be selected on technical and economic merits. Two types of techniques are available: source treatment (such as trim design, diffusers, attenuator plates) and path treatment (such as by acoustic insulation). The most reliable and economic solution shall be chosen in consultation with the control valve Manufacturer. Acoustic insulation shall be in accordance with PTS 31.46.00.31.

NOTE : Heavy wall piping is another method of path treatment, but is seldom economically justifiable.

(Appendix 3; 3.4) describes control valve noise prediction.

6.3 ANTI CAVITATION VALVES

For the use of anti cavitation valves, see (Appendix 3; 3.6).

6.4 STEAM DESUPERHEATING VALVES

Special control valves with internal water injection for desuperheated purposes may be used for high-pressure steam reducing services.

For desuperheating application, with dedicated quench water injection valve, the trim shall be able to withstand the severe service, including at start-up conditions, of high pressure drop and high exit velocity that could lead to potential cavitations and erosion, such as, by having multi-stage trims, etc.

The make and type of these valves requires the approval of the Principal.

6.5 CHOKE VALVES

6.5.1 Gas chokes valves for wells

Gas choke valves shall be able to withstand the maximum closed-in well pressure, and shall be capable of delivering the desired maximum and minimum flow rates at varying well pressures. The process fluid is wet gas, which makes the valve subject to erosion.

The following shall apply to gas choke valves:

- a) Changing of internal parts should be possible by means of hand tools only.
- b) The body should be oversized, so as to limit the velocity and consequently the noise and erosion. Noise reducing inserts may also be needed in the inlet and outlet of the valve.
- c) The valve shall be minimum of Class IV shut-off, in accordance with IEC 60534-4.
- d) The trims should be at least tungsten carbide.

6.5.2 Liquid choke valves

For special applications, such as wellheads, the draining of high-pressure separators, a liquid choke valve should be considered.

This valve shall be designed for liquids containing solid particles such as grit, sand and scale.

The following shall apply:

- a) The valve shall be made up of a number of modular sub-assemblies, such as internals, bonnet, yoke, actuator, coupling, etc.
- b) To replace any of the sub-assemblies, it shall not be necessary to remove the valve body from the process line.
- c) The valve shall be minimum Class IV shut-off, in accordance with IEC 60534-4.
- d) The trim shall be of at least tungsten carbide.

6.5.3 Stepping Actuator

Stepping actuators may be considered to adjust choke valve positions.

6.6 FIRE SAFE DESIGN

For requirements of certified fire safe valve bodies, see PTS 31.38.01.11 / PTS 80.47.10.30. The actuators, accessories and cabling for such valves may also need to be fire resistant.

7. CONTROL VALVES FOR SPECIAL APPLICATIONS

7.1 LOW TEMPERATURE SERVICE

Control valves in services with a lower design temperature below minus 45°C shall, in addition to the specification in the requisition, comply with ISO 15848.

Cryogenic service refers to a service condition where the temperature is significantly below normal atmospheric temperature. Definitions vary with regards to the temperature defined as cryogenic. However, it is generally accepted that any temperature below minus 100°C is considered cryogenic.

7.2 VACUUM SERVICE

Control valves in services with a design pressure below 1.0 bar (abs) shall, in addition to the specification in the requisition, comply with ISO 15848.

7.3 STEAM SERVICE

Control valves in steam service with ASME rating class 300 and higher shall, in addition to the specification in the requisition, comply with ISO 15848.

7.4 HYDROGEN SERVICE

Control valves in services containing hydrogen with a partial pressure of 7 bar (abs) and above shall, in addition to the specification in the requisition, comply with ISO 15848.

7.5 HYDROFLUORIC ACID (HF) SERVICE

Control valves in HF service shall, in addition to the specification in the requisition, comply with ISO 15848.

7.6 OXYGEN SERVICE INCLUDING HIGH PRESSURE AIR SERVICE

Any medium containing more than 21% oxygen by volume or a system with air at a pressure above 50 bar (ga) is to be considered as oxygen service. For control valves in oxygen service, PTS 31.10.11.31 and ISO 15848 shall apply.

7.7 ETHYLENE OXIDE SERVICE

Control valves for ethylene oxide service shall, in addition to the specification in the requisition, comply with ISO 15848.

7.8 CHLORINE SERVICE

Control valves for chlorine service shall, in addition to the specification in the requisition, comply with ISO 15848.

7.9 “SOUR” OR “WET H₂S” SERVICE

“Sour” or “Wet H₂S” services are defined in PTS 31.38.01.11. The materials of those valve parts which under whatever process condition are in contact with process water or aqueous condensate shall comply with the requirements of ISO 15156 or NACE MR0103, as applicable, and the relevant piping class.

These requirements shall apply to the control valve and pressure-retaining bolting (even if not directly exposed to the process fluid).

NOTES :

- a) ISO 15156 shall apply to oil and gas production facilities and natural gas sweetening plants. NACE MR0175 is equivalent to ISO 15156.
- b) NACE MR0103 shall apply to other applications (e.g. oil refineries, LNG plants and chemical plants).

7.10 VALVES IN HEAT TRANSFER FLUID SERVICE.

Gate and globe type control valves for heat transfer fluid service shall, in addition to the specification in the requisition, comply with ISO 15848.

8. CONTROL VALVE ACTUATOR

8.1 GENERAL

The Principal shall specify those applications in which PTS 31.40.70.30 should apply to quarter turn on-off actuators.

The requisition shall indicate the mounting position of the actuator relative to the valve.

The actuator shall be suitable for operation on instrument air unless otherwise specified in the requisition.

Pneumatic actuator pressure retaining parts should be capable of withstanding the maximum instrument design supply pressure. If this is not technically possible, all pressure retaining actuator parts shall be fitted with a large, legible, and permanently attached label indicating the maximum pressure allowed. Labels shall be proposed for the approval of the Principal.

The actual bench setting (spring range) shall be indicated on the valve tag plate.

Where a control valve also functions as a SIL 1 or higher IPF valve (see PTS 32.80.10.10 Classification and Implementation of Instrumented Protective Functions), it should be air operated and spring return type. Hydraulically operated valves are less suitable due to complexity of Hydraulic system.

Single-acting actuators are preferred for all applications. The use of such actuators can be prohibitive in terms of cost, size and weight for large valves (typically over DN 300). Under such circumstances, detailed simplification proposals shall be made for the approval of the Principal. The proposals shall include capital cost comparisons between the single-acting and double-acting actuator options, with due consideration of the cost implications of piping layout and supports.

Piston-type actuators, if specified, should be of the spring return type or double-acting type.

In the event of instrument air failure for double-acting piston type, the required valve action shall be achieved by providing with lock-up valves, check valves and a local air buffer vessel.

To prevent tampering, the rotating linkages between valves and their actuators shall be of the integral type, enclosed in a protective metal housing.

Cylinder actuators shall be provided with adjustable end-limit travel stops in both directions. Bolt adjustment type limit stops shall be fitted with a locking facility, e.g. a locking nut, to prevent tampering. The construction shall be leak-tight, with seal gaskets.

Cylinder actuators used for anti-surge applications are recommended to include end of travel cushion action in the open direction to minimize shock and vibration when valve moves to full open position.

Piston or cylinder actuators shall have O-ring sealing and shall be designed to minimize shaft and piston/cylinder friction.

Actuators shall be equipped with a direct-coupled adjustable travel or position indicator for local status indication. The position shall be indicated by a permanent mark on a reversible scale with the words 'open' and 'closed' at the travel limits, or by unambiguous symbols.

8.2 ACTUATOR SIZING

8.2.1 General

The actuator shall be sized to provide, under minimum instrument air pressure conditions, sufficient torque or thrust to position and fully stroke the valve within the specified stroking time against the maximum differential pressures that may develop under the specified design conditions.

The valve Manufacturer shall provide to the actuator Manufacturer the valve operating thrust and torque calculations, including the valve safety factors, the stroke, and the stroking time.

To avoid oversized actuators being supplied, with the associated supporting problems, the actuator Manufacturer shall limit the actuator safety factors by taking into account the valve safety factors, while ensuring that the valve-actuator combination will meet its design conditions. The valve-actuator combination will require the approval of the Principal.

8.2.2 Instrument air pressure used for sizing

The maximum actuator torque or thrust shall not overstress any component of the valve, actuator or accessories. An air filter regulator of the reducing-relief valve type (see [9.10](#)) shall be installed in the instrument air supply line to the valve if the valve, actuator and/or accessories cannot operate safely at the upper design pressure of the instrument air header.

Actuators operating on regular instrument air shall be designed for a minimum instrument air header pressure of 4.2 bar (ga), unless specified otherwise. For actuators operating from local air buffer vessels, the instrument air pressure available for actuator sizing is lower than 4.2 bar (ga) and is related to the buffer vessel volume, see [\(9.7\)](#). The lowest available pressure shall be used for actuator sizing.

8.2.3 Maximum process pressure/differential pressure used for sizing

The actuator shall be designed to re-seat the valve after opening, to keep the valve closed, and to break it away and subsequently stroke it from the closed position under minimum instrument air pressure conditions at the following process conditions:

- A maximum differential pressure in the forward direction, being the difference between the maximum upstream pressure and an atmospheric downstream pressure. Add 1 bar if the lower design pressure of the downstream system is below 1 bar (abs).
- A maximum differential pressure in the reverse direction, being the difference between an atmospheric upstream pressure and the maximum downstream pressure. Add 1 bar if the lower design pressure of the upstream system is below 1 bar (abs).

The actuator shall also be designed to keep the valve fully open and to break it away and subsequently stroke it from the full open position under minimum instrument air pressure conditions and at the maximum operating pressure.

NOTE:

The maximum upstream and downstream pressures are the set pressures of the upstream and downstream system relief valve respectively.

8.3 STROKING TIME

Unless specified otherwise, the following stroking times for both directions shall not be exceeded for throttling control valves under normal operating conditions:

Body Size	Maximum Stroking Time
≤ DN 50	10s
DN 80	15s
DN 100	15s
DN 150	20s
DN 200	35s
DN 250	50s
> DN 250	To be specified by the Principal

The stroking times are applicable to the throttling mode of control valves. If faster stroking times are required, high capacity valve positioner should be considered. If these are not available, high performance volume boosters should be used. Quick-exhaust valves are not recommended to be used, as they are a source of instability and overshoot, especially in critical applications like partial stroke, anti-surge etc.

8.3.1 On-Off Valve

On-off valves (e.g. IPF valves or the on-off mode of combined throttling control/IPS valves) shall have stroking times that meet the process requirements for the on-off service.

NOTE:

For on/off services, the required stroking times in the 'close' direction are independent of those in the 'open' direction and should be defined separately.

The effect of stroking time on the pressure build-up in liquid-filled lines (hydraulic shock or water hammer) should be checked. Similarly, to prevent shock-loading of process equipment downstream of fail-closed shut-off valves, a special design may be required to ensure controlled (re-)opening of these valves.

8.3.2 Anti Surge Valve

Anti-surge valves with spoke plug/fully drilled design are recommended to be used to eliminate the potential for uncontrollable axial motion at any point of valve opening for valve sizes above 12 inch.

Following requirements are recommended to be applied for anti-surge control valves:

- Valve opening dead time to be < 0.4 seconds.
- Valve to open in < 2 seconds and close in < 3 seconds, under positioner (4-20 mA) control. This is inclusive of Dead Time.
- Valve to open in < 1 second under trip condition (through the solenoid)
- Large amplitude response to 10%, 20%, 30%, 80% step changes from a baseline of 10% to result in a maximum of one (1) overshoot per step, 3% of calibrated span. It should have minimal overshoot in the closing direction.
- Valve response to a 20% minimum ramp signal from 20 mA to 4 mA should result in no stick slip motion.
- Terminal based linearity shall be < 1% when measured with an independent travel sensor.
- Maximum control signal change to initiate movement off the seat shall be < 2%.
- Valve opening and closing times shall almost be equal under positioner control.
- It should be possible to automatically and remotely tune the anti-surge valve assembly.

Compressor anti-surge valves require faster stroking times in the open direction than shown above and the required stroking times shall be specified by the Principal.

8.4 ACTUATOR MATERIAL

The material of the pressurised actuator case or housing shall be steel or anodized aluminum. Cast iron (e.g. ASTM A48) shall not be used for the case or housing, but is acceptable for the yoke.

Aluminum actuators shall not be used on IPF valves of Safety Integrity Level 1 and above, due to their low fire resistance.

NOTE: Aluminum actuators may be used if there is no fire risk.

The diaphragm material shall be nylon-reinforced neoprene or Buna N rubber, unless the actuating medium is wet hydrocarbon gas, in which case Buna N shall not be used as diaphragm or seal material. In such cases, Viton or manufacturer's recommendation shall be considered.

The actuator spring shall be fully enclosed in a metal housing and treated to resist atmospheric corrosion.

8.5 ACTUATOR COLOUR CODING

The colour of the actuator shall be in accordance with the Manufacturer's standard unless otherwise specified in the requisition. To identify that the valve is fail-safe, a colour code should be assigned to the actuator (i.e. red for fail-close valves and green for fail-open valves).

8.6 ACTUATORS FOR VARIABLE-PITCH FANS

PTS 31.21.70.31 shall apply as regards the choice between variable pitch control and variable speed fans.

Actuators for variable-pitch fans on air-cooled heat exchangers form an integral part of the fan and shall comply with the following requirements:

- a) the actuator should be single-acting, spring-opposed with a fail action as required by the application. Double-acting piston type actuators should only be used if single-acting actuators cannot meet the torque or thrust requirements or if they are unattractive in terms of cost, size or weight;
- b) actuators shall have sufficient torque or thrust to overcome the dynamic forces on the variable-pitch fan blades plus the friction forces in the bearings, etc. at minimum instrument air supply pressure, see (8.2.2);
- c) the maximum actuator torque or thrust, e.g. during maximum instrument air supply pressure conditions, shall not overstress any component of the fan, actuator or accessories, see (8.2.2);
- d) the actuator shall be directly connected to the main operating shaft of the variable-pitch fans;
- e) linkages designed to allow manual operation of the variable-pitch fan blade position shall not be fitted;
- f) double-acting actuators shall be provided with lock-up valves or a local air buffer vessel to achieve the required action on instrument air failure;
- g) instrument air lines to actuators and positioner of variable-pitch fans shall be connected via flexible hoses, to allow for movement of the actuating mechanism;
- h) pneumatic components shall be static. Rotating pneumatic couplings shall not be used;
- i) actuators should be of the same make and model as those used for control valves for variety limitation reasons.

8.7 ACTUATORS FOR DAMPERS

Damper actuators shall have sufficient torque or thrust to overcome the dynamic forces on the dampers or louvers, plus the friction forces in the bearings, etc. under worst case conditions and at minimum instrument air supply pressure, see (8.2.2). They shall be designed to cope with fouling and distortion of the dampers.

The maximum actuator torque or thrust, e.g. during maximum instrument air supply pressure conditions, shall not overstress any component of the damper, actuator or accessories, see (8.2.2).

The actuator should be single-acting, spring-opposed with a fail action as required by the application. Double-acting piston type actuators should only be used if single-acting actuators cannot meet the torque or thrust requirements or if they are unattractive in terms of cost, size or weight.

For throttling services, the dampers or louvers shall be provided with the following:

- Lock-up valves or a local air buffer vessel to achieve the required action on instrument air failure, if not opposed by a spring;
- A valve positioner with characterizing features;
- Facilities for manual actuation. For small actuators a simple lever may be sufficient, but for large actuators a hand wheel with gear reduction may be required to enable operation by one man. In both cases, a locking device shall be provided;
- A weatherproof enclosure around all the above items (excluding operating handles, links, etc.);
- Flexible hoses to connect the air supply to the damper actuator and positioner;
- Turn-buckles on connecting linkages to allow length adjustment on site;
- Safety guards;
- Minimum stop mechanisms, strong enough to withstand the actuating force in the fail safe position;
- Actuators should be of the same make and model as those used for control valves for variety limitation reasons.

8.8 ELECTRICAL ACTUATORS

The use of electrical actuators for throttling control valves requires the approval of the Principal. Electrical actuators for on-off valves shall be in accordance with PTS 33.64.10.10.

8.9 HYDRAULIC ACTUATORS

The use of hydraulic actuators for throttling control valves requires the approval of the Principal. Hydraulic actuators for on/off valves are outside the scope of this PTS and shall comply with PTS 31.36.10.30.

9. ACCESSORIES

9.1 GENERAL

The accessories discussed in this section should be supplied with the valve. This “total supply” will allow functional testing at the factory, particularly of stroking times.

The accessories may be installed on a separate mounting plate to allow removal of just the valve and actuator, thus reducing risk of damage to the accessories.

The requisition shall indicate from which side(s) the valve and its accessories will be accessible after installation.

All electrical accessories like electro-pneumatic valve positioner, limit switches and solenoid valves shall be suitable for the electrical hazardous area classification specified in the datasheet.

Tubing size for On-Off valves shall be a minimum of 12mm (1/2 inch).

Control valve accessories are considered to be instruments and shall therefore comply with the applicable requirements of PTS 32.31.00.32.

9.2 VALVE POSITIONERS

Valve positioner shall be used for all control valves used for throttling service.

Intelligent electro-pneumatic valve positioner should be used.

If the use of a control valve performance management system is considered, or such a system is already in use, standardisation on one make of intelligent valve positioner is often required. In these instances, the control valve specification shall specify details (i.e., make, model, level of intelligence) of the required intelligent positioner.

If the positioner is not of the same make as the control valve, the control valve Manufacturer shall be responsible for the correct software settings in the configuration (i.e. characteristic, stroke etc.) of the positioner.

For split range applications, the range “split” should reside in the DCS and each of the valves should receive a 4mA to 20mA input signal.

The positioner output shall be direct-acting unless otherwise specified.

The positioner shall not be provided with a bypass valve. The positioner shall have a weatherproof enclosure with a degree of protection of at least IP 65 in accordance with IEC 60529.

The valve positioner shall have sufficient capacity in both directions for pressuring and venting the actuator to maintain the specified response times.

The Manufacturer shall, upon request, specify the air quality, consumption and filter requirements for the elements supplied with the valve.

Tubing between the positioner output and the actuator, or between accessories and the actuator, shall be as follows:

- The control valve Manufacturer shall determine the tubing diameter so as to achieve the required stroking times. The minimum tubing diameter shall be 6mm (1/4 in). The tubing shall comply with the specification given in the requisition. Copper tubing shall not be used. For areas with a potential H₂S or acetylene atmosphere, or for offshore application, or other corrosive atmosphere locations, tubing and fittings shall be of stainless steel or other materials suitable for the stated atmospheric conditions and shall be subject to the Principal's approval. Use of low carbon, high nickel austenitic stainless steel alloy tubing material, such as, S31803 or better, is recommended to protect against hydrogen stress cracking environment.
- All compression fittings in a plant shall be of the same size, make and type. Mixing of fittings of different size (e.g. metric with imperial) or make/type is not permitted. The make/type is subject to the Principal's approval.

The valve positioner shall be provided with an identification plate, marked with the air supply pressure and input signal. For high vibration application and/or high temperature areas, the use of remote mounting positioner is recommended.

The combination of a separate electro-pneumatic converter and a pneumatic valve positioner should be avoided. If this is unavoidable, the output range of the converter and the input required on the pneumatic valve positioner shall be checked in order to prevent possible instability.

The cable entry size shall be M20 × 1.5, unless otherwise specified in the datasheet. If the Manufacturer can not provide the above cable entry size, suitable adaptors to meet the above cable entry size shall be supplied by the Manufacturer.

Note:

- 1) Metric and imperial tubing sizes shall not be interchanged.
- 2) Every plant shall decide the usage of either metric or imperial sizes at the beginning of the project and shall maintain the same unit throughout the life of the plant.

9.3 HAND WHEELS

Control valves shall only be provided with a hand wheel if required for operational reasons.

If a hand wheel is required, it shall comply with the requirements specified in the ISO15848.

The hand wheel of a control valve with de-clutch facilities shall be provided with an instruction plate explaining how it is to be used. When de-clutched, the hand wheel shall not interfere with the full stroking action of the control valve.

9.4 LIMIT STOPS

Limit stops shall be mechanical devices, mounted on the valve or actuator. They shall be constructed so that hand wheel operation does not allow travel/rotation beyond the limit stop setting. Bolts screwed in the body shall not be used as a limit stop.

Limit stops shall be adjustable from outside and fitted with a locking facility, e.g. a locking nut, to prevent tampering or loosening. The limit stops shall be adequately protected against unintentional adjustments.

The Manufacturer shall set the limit/travel stops at the required minimum or maximum valve opening.

9.5 LOCK-UP VALVES

Air lock-up valves shall be specified for all services requiring the control valve to remain in position in case of instrument air supply failure.

To prevent unintentional adjustments, the lock-up valves shall have a bolt adjustment provided with a locking facility, e.g. a locking nut.

The lock-up valves shall be set 0.5 bar above the minimum instrument air supply pressure required by the actuator.

For control valves with a valve positioner, the lock-up valve shall be installed between the positioner output and the actuator. If lock-up valves are fitted on valves operated by a solenoid valve, the solenoid valve shall be installed between the lock-up valve and the actuator.

9.6 LIMIT SWITCHES

If limit switches are required, they shall be of the hermetically sealed proximity type. The proximator(s) and initiator should be mounted inside a box for mechanical protection. The flying leads of the proximator(s) shall terminate in an attached terminal box; alternatively, the protection box and the terminal box may be combined into one box. These boxes shall be suitable for the electrical hazardous area classification in which they are located with minimum IP65 against water/ dust ingress protection.

The cable entry size shall be M20 × 1.5, unless otherwise specified in the datasheet. If the Manufacturer cannot provide the above cable entry size, suitable adaptors to meet the above cable entry size shall be supplied by the Manufacturer.

If fitted, the external linkage between the actuator stem or rotary spindle and the initiator shall be protected against unintentional damage.

Proximity switches shall be in accordance with DIN 19234.

The valve Manufacturer shall follow the mounting instructions supplied by the limit switch Manufacturer. The valve Manufacturer shall properly adjust the limit switches.

Due consideration shall be given to the discrimination between the "closed" and "not closed" status of valves, especially for rotary valves without a dead angle, linear motion valves and valves with quick opening characteristics, with respect to the process requirements of the flow to be detected.

Proximity switches shall be adjustable and shall operate autonomously, e.g., one switch for the "fully open" position and a separate switch for the "fully closed" position. The valve position shall be clearly distinguished in the DCS by the appropriate colour coding adopted by the plant, indicating the valve positions and its status.

NOTE:

If proximity switches are installed to detect a partially-open valve position, the vane shall be shaped so that a distinction can be made whether or not the partial open position has been reached / passed. Example: If an 80% open position is to be detected, a logic '0' might represent a valve opening between 0% and 80% and a logic '1' not just a valve opening at 80%, but any valve position of 80% and above.

The combination of proximator and proximator circuit shall be of fail-safe design for applications with a Safety Integrity Level 1 and above (see PTS 32.80.10.10). For all other applications, fail-safe design is preferred, but cost aspects may justify the use of non-fail-safe limit switches.

NOTE:

- 1) If fail safe and non-fail safe limit switches are applied in a project, the fail-safe design should be used for all switches connected to the IPS (Instrument Protective System) and the non-fail-safe design for all other switches. This practical approach will provide flexibility during the engineering phase and limits the variety of input cards for IPS and DCS.
- 2) Failure to install suitable interface proximity circuit will cause the IPS to be unstable and not able to recognize the very low input mA signal from the NAMUR type proximity.

9.7 INSTRUMENT AIR BUFFER VESSELS

9.7.1 General

Dedicated local instrument air buffer vessels are required for spring less actuators of control valves, variable-pitch fans and dampers, if they must be driven to or held in a predefined position in the event of instrument air failure.

Such air buffer vessels may also be required for actuators with springs to make them instrument air failure robust.

Two types of design can be distinguished: Secured Instrument Air (SIA) design and the Manufacturer's standard air buffer design. Plant safety reviews (e.g. a HAZOP or HSE desk review) should identify the applications for which a secured air supply is needed.

NOTE: An air buffer vessel may require a safety relief device.

9.7.2 Secured Instrument Air design

The secured instrument air supply shall maintain sufficient instrument air pressure in the buffer vessel to allow for at least three valve strokes within 30 minutes. Unless otherwise specified, the capacity of the secured instrument air buffer vessel shall be sized for a minimum pressure of 4.2 bar (ga) in the instrument air header.

NOTE: One valve stroke is a movement from the fully open position to the fully closed position or vice versa.

The specific design requirements for secured instrument air buffer vessels and associated instruments for depressuring systems, as discussed in PTS 32.45.10.10, apply to all applications requiring secured instrument air. The Principal shall approve air buffer vessel capacity calculations.

9.7.3 Manufacturer's standard air buffer design

For applications where the Manufacturer's standard air buffer vessel designs are acceptable, the air buffer vessel capacity shall be sized for a minimum pressure of 4.2 bar (ga) in the instrument air header. The Principal shall approve air buffer vessel capacity calculations.

9.8 AIR LUBRICATORS

Air lubricators shall be considered for pneumatic long-stroke cylinder actuators.

Air lubricators shall be of the oil-mist type and the oil flow shall be externally adjustable.

The oil buffer capacity shall be sufficient for continuous operation for one month.

In addition, the lubricator shall have facilities for oil refilling under pressure, shall have oil level indication and shall be suitable for installing on a mounting plate.

If air lubricators are used for valves operated by a solenoid valve, the lubricator shall be installed upstream of the solenoid valve.

Spherical glass (bowl type) air lubricators shall not be used.

9.9 SOLENOID VALVES

If solenoid valves are required, they shall be provided with a disc and/or seat of resilient material to achieve TSO. The air passages in the solenoid valves (Solenoid valve CV) and the air tubing shall be large enough to achieve the opening or closing time of the valve as specified. If this would lead to unrealistically large passages and consequently high power consumption of the solenoid valve, consideration should be given to the use of quick-exhaust valves.

To prevent plugging (e.g. during freezing periods), solenoid valves shall not be supplied with exhaust port protectors. Instead, they shall be provided with a piece of tubing bent downwards with the end cut off at an angle of 45°.

Solenoid valves with flying leads shall be provided with a terminal box. If not armoured, the flying leads shall be protected against mechanical damage.

The cable entry size shall be M20 × 1.5, unless otherwise specified in the datasheet. If the Manufacturer cannot provide the above cable entry size, suitable adaptors to meet the above cable entry size shall be supplied by the Manufacturer.

To limit induction, DC solenoids shall be de-coupled with shunt/ suppression diodes, connected directly across the solenoid terminals.

For control valves with a valve positioner, the solenoid valve shall be installed between the positioner output and the actuator.

Solenoid valves should be direct-operated. For large-volume actuators, a combination of a standard solenoid valve and separately mounted, pneumatically operated switching valve is preferred for its robustness to the use of a pilot-operated solenoid valve.

If a pilot-operated valve is used, the air supply to operate the pneumatic valve should not be derived internally from the solenoid operated pilot valve, but from an external air supply connection. The use of pilot-operated solenoid valves requires the approval of the Principal.

9.10 FILTER REGULATORS

An air filter regulator shall be installed in the instrument air supply line to the valve if the valve, actuator and/or accessories cannot operate safely at the upper design pressure of the instrument air header, see (8.1).

NOTE:

If the instrument air system is provided with relief valve(s), the upper design pressure of the instrument air header is the set pressure of such relief valve(s).

The air filter regulators shall be of the reducing-relief valve type, with drainage facility and bolt adjustment provided with a locking facility, e.g. a locking nut, to prevent tampering.

The air filter cartridges shall be of the rigid structure type to resist channeling, rupturing, shrinkage or distortion and shall have a maximum mesh size of 40 µm.

The capability, e.g. output capacity and required spring range, of the filter-regulator shall be checked against the instrument air requirement of the particular positioner and/or actuator or pneumatic instrument.

Air-filter regulators shall be of metallic or metallic alloy. Plastic-type or glass (bowl-type) filter regulators shall not be used for outdoor environment.

Filter regulators shall be mounted in the vertical position so that they are self-draining.

Air filter regulators shall be fitted with small pressure gauges indicating the incoming instrument air supply pressure and delivery pressure to the actuator and/or its components.

9.11 FILTERS

An air filter (i.e. without regulator) should be installed in the instrument air supply line to the valve if the valve, actuator and accessories can operate safely at the upper design pressure of the instrument air header.

The air filter shall be provided with a manual drainage facility and a filter cartridge of the rigid structure type, to resist channeling, rupturing, shrinkage or distortion, and having a maximum mesh size of 40µm.

Glass (bowl type) filters shall not be used.

Filters shall be mounted in the vertical position so that they are self-draining.

Air filters shall be fitted with small pressure gauges indicating the incoming instrument air supply pressure and delivery pressure to the actuator and/or its components.

9.12 QUICK-EXHAUST VALVES

Quick-exhaust valves may be provided for on-off services, except for Emergency Shutdown Valves with partial stroke testing, that require the control valve to open or close faster than is possible with a standard actuator configuration. Fitting quick exhaust valves to throttling services e.g. for anti-surge valves applications, may result in unstable operation and hence, should not be used.

Pilot-operated quick-exhaust valves shall not be used.

To prevent plugging (e.g. during freezing periods), quick-exhaust valves shall not be supplied with exhaust port protectors. Instead, they shall be provided with a piece of tubing bent downwards with the end cut off at an angle of 45°.

Quick-exhaust valves shall be fitted directly to the port of the actuator.

9.13 VOLUME BOOSTERS

High capacity volume boosters shall only be provided if needed to achieve the specified stroking times.

9.14 RESTRICTORS

If a throttling valve is required to be opened or closed slowly, this functionality should be implemented in the DCS or other remote electronic system. Mechanical instrument air restrictors should not be used for throttling valves.

If used, a mechanical flow restrictor shall be provided with a lockable, variable restriction. For uni-directional restrictors, the direction(s) of restricted flow shall be indicated by a permanent mark on the body.

If an air flow restrictor is fitted on a control valve equipped with a solenoid valve, care shall be taken in locating the restrictor relative to the solenoid valve. The restrictor shall only affect the required slow-opening or slow-closing of the control valve and shall not influence the other (unrestricted) valve movement.

10. VALVE MARKING

The control valve shall be provided with a standard stainless steel identification plate, showing the mandatory and supplementary marks as defined in IEC 60534-5.

In addition, the TSO direction(s) shall be clearly marked where applicable by a permanent mark cast in or stamped on the valve body. Painted marks are not acceptable.

Three-way valves shall clearly indicate the common inlet or common outlet port by a permanent mark "COMMON" stamped on the flange.

Control valves affecting operational safety shall have warning plates, with text in white letters on a red background and stating, as appropriate, either:

WARNING

TRIM SIZE AFFECTS RELIEF VALVE CAPACITY

or

WARNING

TRIM SIZE AFFECTS FIRING OF FURNACE

Warning plates shall be attached by screws or rivets.

11. INSPECTION AND TESTING

11.1 EXTENT

The Manufacturer shall perform the following inspections and production tests (see Notes 1 through 4)

Inspection / test	Extent		Method and acceptance criteria
Examination and certification	Valves in general service (as defined in ISO 15848)		ISO 15848
	Valves in special services (as defined in ISO 15848)		ISO 15848
Dimensional inspection	All valves		(11.2)
Hydrostatic test	All valves		(11.3)
Functional test	All valves		(11.4)
Hysteresis and dead band test for throttling valves	Random sample (Note 4)		(11.5)
Seat leakage test	Valves with Class V or Class VI tight shut-off requirement	All valves	(11.6)
	Other valves	Random sample (Note 4)	
Capacity test	Random sample (Note 4)		(11.7)
Low temperature test	Valves with a lower design temperature ranging from minus 30°C to minus 196°C	Type approval testing in accordance with specification T-2.253.730 Production testing: Sample in accordance with ISO 15848	(11.8)
Vacuum test	Valves in vacuum service	Sample in accordance with ISO 15848	ISO 15848
Fugitive emission test	Valves used in services requiring a fugitive emission limitation, such as, environmentally harmful process medium	Sample in accordance with ISO 15848	ISO 15848

NOTES:

- 1) The selected valves for each test shall be listed by the Contractor and approved by the Principal.
- 2) Inspection and testing shall include accessories if part of the supply.
- 3) The test results shall be made available as part of the package of final certified documents.
- 4) The Principal shall approve the number of valves sampled.

11.2 DIMENSIONAL AND FLANGE FACE FINISH CHECK

The face-to-face dimensions shall be as given in the relevant standard (4.4). All dimensions (including overall height) shall be as shown on the Manufacturer's drawings. The flange face finish shall be checked (4.3).

11.3 HYDROSTATIC TEST

Hydrostatic testing shall be in accordance with IEC 60534-4, with the test duration as follows:

Valve size	Test duration
≤ DN 50	1 min
DN 80 to DN 200	2 min
≥ DN 250	3 min

For carbon steel valves and low alloy steel valves, the hydrostatic test fluid shall be potable water with a chloride content of maximum 200 mg/kg.

Austenitic and duplex stainless steel valves and valves made of 9% nickel alloy shall be hydrostatically tested with potable water with a chloride content of 50 mg/kg or less.

These valves shall be flushed with condensate or demineralised water (chloride content of 2 mg/kg maximum) immediately after the hydro test.

All valves shall be drained immediately after the test and shall be thoroughly dried immediately after draining.

11.4 FUNCTIONAL TEST

The control valve shall be completely assembled and fitted with all accessories such as positioner, solenoid valve(s), etc.

The valve positioner shall be checked for correct calibration.

The stroking time at the specified air pressures shall comply with the requirements given in this document (see [8.3](#)). All required stroking times shall be checked during the functional testing.

If the control valve is equipped with a hand wheel, it must be possible to fully open and close the valve using the hand wheel; see [9.3](#).

If the control valve is equipped with limit switches, they shall be checked for functional operation with a proximity tester. Limit switches shall also be loop tested with the IPS or DCS. If IPS or DCS is not available, limit switches signal compatibility with the IPS or DCS shall be verified with the relevant IPS or DCS vendor.

If the control valve is equipped with a solenoid valve, it shall be checked for proper operation at the specified minimum voltage and wattage. For I.S applications, the barrier selection shall be suitable for the respective positioner and solenoid valve to ensure the minimum operation voltage.

11.5 HYSTERESIS AND DEAD BAND TEST

For definitions and test procedures, refer to IEC 60534-1 and IEC 60534-4.

The actuating medium for the tests shall be clean, dry air or nitrogen. Testing shall be performed under atmospheric conditions (at zero differential pressure and ambient temperature) and with the minimum specified air supply pressure.

The **hysteresis test** shall consist of measuring the valve stem position in response to the following sequence of input signals: 50%, 75%, 100%, 75%, 50%, 25%, 0%, 25% and 50%. For PTFE-based packing, the hysteresis shall not exceed 1.0% of maximum valve stroke.

The **dead band** is expressed as a percentage of the input span and shall be measured at 5%, 50% and 95% of the input span. For PTFE-based packing, the maximum dead band found shall not exceed 2% of rated input signal.

For packing other than PTFE, the maximum hysteresis and dead band shall be quoted by the Manufacturer for approval by the Principal.

All test results shall be documented.

11.6 SEAT LEAKAGE TEST

The seat leakage test shall be in accordance with IEC 60534-4, as per Appendix IV with the acceptance criteria for the specified shut-off class; see (3.1) for TSO class V or VI. If the shut-off class is not specified, the following acceptance criteria shall apply:

	Acceptance criteria
Single-seated valves	Class III
Double-seated valves	Class II

For each valve tested, the Manufacturer shall state the following data:

- flow direction;
- test medium;
- test differential pressure;
- seat leakage flow rate measured;
- allowable seat leakage flow rate;
- seat leakage class (if applicable).

11.7 CAPACITY TEST

The actual C_v value shall be demonstrated by a test in accordance with IEC 60534-2-3 or ISA S 75.02 when this requirement is specified.

11.8 LOW TEMPERATURE PRODUCTION TEST

Low temperature production testing shall be in accordance with ISO 15848.

In addition, a hysteresis and dead band test (section 11.5) shall be performed at the temperature of the low temperature test.

11.9 ACTUATOR LEAKAGE TEST

All pneumatic fittings and actuator diaphragm chamber joints shall be tested for leak by using leak test solution while applying 1.1 times the rated air supply to the actuator, positioner and accessories, to ensure that there is no leak of instrument air supply and signal at the fittings & joints.

11.10 WITNESSING BY PRINCIPAL

The extent of the Principal's involvement in witnessing inspections and tests at the Manufacturer's works shall be stated in the requisition.

12. DOCUMENTATION

The document requirements to record the valve selection process (2.2) shall be as specified in the requisition. It should include at least:

- calculations of control valve capacity (C_v), calculations of the predicted noise level, and, where applicable, details of the secured instrument air vessel;
- details of the selected actuator and torque or thrust figures;

For spare part requirements, see PTS 70.10.90.11.

13. REFERENCES

In this PTS, reference is made to the following publications:

NOTE:

Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments / supplements / revisions thereto.

PETRONAS STANDARDS

Index to PTS publications	PTS 00.00.05.05
Index to requisitions	PTS 30.10.01.10
Noise control	PTS 31.10.00.31
Gaseous oxygen systems	PTS 31.10.11.31
Air-cooled heat exchangers (amendments/supplements to ISO 13706)	PTS 31.21.70.31
Hydraulic systems for remote operation of shut-off valves	PTS 31.36.10.30
Piping Classes - Basis of Design	PTS 31.38.01.10
Piping - general requirements	PTS 31 38.01.11
Piping classes – refining and chemicals	PTS 31.38.01.12
Piping classes – exploration and production	PTS 31.38.01.15
Quarter turn on/off actuators	PTS 31.40.70.30
Acoustic insulation for piping	PTS 31.46.00.31
Instruments for measurement and control	PTS 32.31.00.32
Actuated Valve Management Strategy	PTS 32.36.01.19
Instrumentation of depressuring systems	PTS 32.45.10.10
Classification and implementation of instrumented protective functions	PTS 32.80.10.10
Electrical engineering guidelines	PTS 33.64.10.10
Spare parts	PTS 70.10.90.11
Assessment of the fire safety of onshore installations	PTS 80.47.10.30
Industrial Valves - Measurement, Test and Qualification Procedures for Fugitive Emissions	ISO 15848
Procedure, technical specification and type approval testing for:	T-2.253.730
• on/off valves	
• swing type and dual plate check valves	
• control valves	
in low temperature and/or cryogenic service	

AMERICAN STANDARDS

Pipe flanges and flanged fittings, NPS ½ through NPS 24	ASME B16.5
Face-to-face and end-to-end dimensions of valves	ASME B16.10
Large diameter steel flanges NPS 26 through NPS 60	ASME B16.47

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY 10017
USA

Steel gate valves – flanged and butt welding ends, bolted and pressure seal bonnets	API 600
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Compact steel gate valves, flanged, threaded, welding and extended body ends	API 602
--	---------

Issued by:
American Petroleum Institute
Publications and Distribution Section
1220 L Street Northwest
Washington DC 20005
USA.

Standard specification for gray iron castings	ASTM A 48
---	-----------

Issued by:
American Society for Testing and Materials
100 Barr Harbor Drive, West Conshohocken,
PA 19428 2959
USA

Materials resistant to sulfide stress cracking in corrosive petroleum refining environments	NACE MR0103
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Petroleum and natural gas industries — Materials for use in H ₂ S-containing environments in oil and gas production	NACE MR0175
--	-------------

Issued by:
NACE International
1440 South Creek Dr.
Houston, TX 77084-4906,
USA

BRITISH STANDARDS

Steel plug valves	BS 5353
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Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
England

GERMAN STANDARDS

Measurement and control; electrical distance sensors; DC interface for distance sensor and signal converter	DIN 19234
---	-----------

Issued by:
Verband Deutscher Elektrotechniker
Stresemannallee 15
Frankfurt, Germany D-60586

INTERNATIONAL STANDARDS

Degrees of protection provided by enclosures (IP code)	IEC 60529
Industrial process control valves:	
Part 1: Control valve terminology and general considerations.	IE 60534-1
Part 2: Flow capacity:	
Section 1 - Sizing equations for fluid flow under installed conditions	IEC 60534-2-1
Section 3 - Test procedures	IEC 60534-2-3
Part 3: Dimensions	
Section 1 - Face-to-face dimensions for flanged, two-way, globe-type control valves	IEC 60534-3-1
Section 2 - Face-to-face dimensions for flangeless control valves except wafer butterfly valves	IEC 60534-3-2
Part 4: Inspection and routine testing	IEC 60534-4
Part 5: Marking	IEC 60534-5
Part 8: Noise Considerations	
Section 3 - Control valve aerodynamic noise prediction method	IEC 60534-8-3
Section 4 - Prediction of noise generated by hydrodynamic flow	IEC 60534-8-4

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Metal valves for use in flanged pipe systems – Face-to-face and centre-to-face dimensions	ISO 5752
Petroleum and natural gas industries – pipeline transportation systems – pipeline valves	ISO 14313
Petroleum and natural gas industries — Materials for use in H ₂ S-containing environments in oil and gas production	ISO 15156

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Butterfly Valves: Double Flanged, Lug- and Wafer-Type	API 609
Industrial valves. Metallic butterfly valves	EN 593
Butterfly Valves	MSS SP67
High Performance of Butterfly Valves	MSS SP68
Control Valve Capacity Test Procedures	ISA S 75.02

APPENDIX 1 : SIZING OF THROTTLING CONTROL VALVES

1. INTRODUCTION

1.1 GENERAL

Control valve sizing shall be based on Manufacturer's standard sizing program. Prior to vendor selection, calculations may be based on IEC 60534-2-1.

1.2 DEFINITIONS, RELATED TO SIZING OF CONTROL VALVES

For the purposes of this Appendix, the following definitions apply:

Cavitation	occurs in liquid service when the pressure in the valve body falls below the vapour pressure of the liquid. The bubbles that are formed will implode immediately or shortly after leaving the valve, due to the downstream pressure of the control valve recovering to rise above the liquid vapour pressure.
Choked flow	occurs for an incompressible or compressible fluids when the fluid velocity at the vena contracta reaches sonic velocity; defined by IEC 60534-1.
Compressible fluid	is a fluid whose density will decrease by 10% or greater if the pressure drop due to the flow of a gas through a system is large enough relative to the inlet pressure.
Control valve authority	is the ratio between the pressure drops across the control valve at a certain relative travel to the pressure drop across the control valve in its fully closed position.
Design conditions	are the set of process conditions under which the total plant or part of the plant is calculated, main equipment is ordered, etc.
Flashing	occurs, for liquids only, when the pressure in the valve body falls below the liquid vapour pressure and when the bubbles thus formed remain as vapour in the fluid, owing to the fact that the downstream pressure of the control valve is at or below the liquid vapour pressure.
Flow coefficient	is the flow capacity of a valve, commonly expressed by the C_v factor or K_v factor. * The C_v of a valve is defined as the quantity of water, at 60°F, in US gal/min, that will flow through the valve at a specified travel with a pressure drop of 1 psi. * The K_v of a valve is defined as the quantity of water in m ³ /h, at a temperature between 5°C and 40°C, which flow through the valve at a specified travel with a pressure drop of 1 bar. * $K_v = 0.856 C_v$.
Fluid mixture	is a mixture of various gases, a mixture of various liquids, a mixture of liquid with a non-associated gas or a mixture of a liquid with its saturated vapour. NOTE: Other types of mixtures, such as those containing solids, are not considered.
Incompressible fluid	is a liquid or gas whose density change within the system is less than 10%.
Inherent equal percentage characteristic	of a valve is a characteristic whereby equal increments of relative travel yield equal percentage changes of the relative flow coefficient.
Inherent linear characteristic	of a valve is a characteristic whereby equal increments of relative travel yield equal increments of relative flow coefficient. NOTE: The term inherent means that it is a control valve property.

APPENDIX 2 : CONTROL VALVE SIZING

2.1 SIZING CRITERIA

Unless otherwise specified, the calculation of the C_v value should be based on the maximum design flow with its relevant process data.

Unless otherwise specified, the following should apply:

- the valve shall be sized for 110% of the maximum design flow rate (Q_d) in order to allow control at Q_d , i.e.:
$$Q_+ = 1.10 \times Q_d$$
- the flow rate through a fully open control valve (Q_o) shall be equal to or greater than the maximum controllable flow rate (Q_+), i.e.:
$$Q_o \geq Q_+$$
- to avoid excessive loop gain variations (> 2), the control valve authority at design conditions should not be less than 0.23, which results in:
$$Q_s \geq 1.14 \times Q_d$$

NOTE: For symbols and subscripts, refer to Figure 1 and Figure 2 of this Appendix.

2.2 SELECTION OF A C_v VALUE

A control valve shall be selected with a C_v value that is equal to the calculated C_v value (or the nearest higher standard size). However, it shall be able to handle at least the maximum required flow rate (Q_+).

As Best Practice, the valve opening at the specified maximum flow rate should not be more than :

80% for linear characteristics

90% for equal percentage characteristics

As Best Practice, the valve opening at the specified minimum flow rate should not be less than :

10% for linear characteristics

30% for equal percentage characteristics

If the above criteria cannot be met, this shall be taken up with Principal for approval.

Trims shall be selected accordingly to the designed flow, Q_s . However, in event of a bigger body size available with a reduced trim Vs. lower body size with full port, the first option should be selected.

The effect of the selected C_v and valve gain (0.5 to 2) on system behavior value shall be verified, e.g. with respect to over firing of heaters, etc. For critical design situations, the tolerance of quoted C_v values shall be taken into consideration.

The control valve shall also be able to operate properly in all operational cases (start-up, normal operation at minimum, normal, maximum flow, alternative operating modes, start-up, commissioning and emergency operation).

APPENDIX 3 : CONTROL VALVE SIZING CONSIDERATIONS

3.1 GENERAL

In addition to the calculation of the C_v value of a control valve, the following aspects shall also be taken into account, considering each operational case (start-up, normal operation at minimum, normal, maximum flow, alternative operating modes, start-up, commissioning and emergency operation).

- selection of the control valve inherent characteristic, (see Appendix 1; 3.2);
- piping geometry, (see Appendix 1; 3.3);
- noise, (see Appendix 1; 3.4);
- fluid mixtures, (see Appendix 1; 3.5);
- cavitation (see Appendix 1; 3.6);
- flashing, (see Appendix 1; 3.7);
- choked flow, (see Appendix 1; 3.8). Refer to ISO 14313.

Note:

1. Failure to consider all of above aspects may result in wrong selection and incorrect sizing of the control valve.
2. Due considerations shall be made for process mediums that comprising of multiple components with respect to changes in vapour pressures, molecular weights, compressibility, etc.

3.2 CONTROL VALVE CHARACTERISTIC

3.2.1 Background to inherent-characteristic versus installed-characteristic

The inherent-characteristic of a control valve is determined by trim design and expresses the relation between valve travel and flow rate for a constant pressure drop across the valve. Globe valves are available with distinct trims, such as trims with a linear or equal percentage inherent-characteristic.

Note:

The inherent-characteristic of the trims of rotary valves cannot be clearly defined as a linear or equal percentage. For these valves, the required characterisation is made in the positioner by other means.

Characterisation in the positioner is preferred over characterisation in the DCS.

The control valve characteristic is selected so as to achieve minimum loop gain variations by approaching a linear installed-characteristic.

An installed-characteristic is linear if under operating conditions a linear relationship exists between the input signal to the valve and the flow rate. Such a linear relationship is a major contributor towards a constant loop gain.

If the pressure drop across a valve remains constant as the valve travels from the closed to the open position (i.e. valve authority $\gamma_d = 1$), a linear inherent-characteristic results in a linear installed-characteristic.

If the pressure drop across a valve drops considerably, as the valve travels from the closed to the open position (i.e., valve authority $\gamma_d < 0.5$), an equal percentage inherent-characteristic approaches a linear installed-characteristic.

3.2.2 Control valve authority

Pressure drop variations across traveling control valves are expressed by the 'control valve authority' parameter, γ_d .

Control valve authority is the ratio between the pressure drops across the control valve at a certain relative travel to the pressure drop across the control valve in its fully closed position.

The control valve authority at design conditions can be calculated as:

$$\gamma_d = \Delta P_{vd} / (\Delta P_{vd} + \Delta P_{sd} + \Delta P_{pd}).$$

For symbols and subscripts, refer to Figure 1 and Figure 2 of this Appendix.

3.2.3 Selection of control valve characteristic

The following method should be used for the selection of the control valve characteristic:

- a) Choose an equal percentage characteristic if the pressure drop available for the valve at the design flow Q_d is $\leq 70\%$ of the dynamic pressure drop across the total system, i.e. if the control valve authority $\gamma_d \leq 0.7$;
- b) Choose a linear characteristic if the pressure drop available for the valve is $> 70\%$ of the pressure drop across the total system, i.e. if the control valve authority $\gamma_d > 0.7$.

The above rule results in a linear valve characteristic for the following applications:

- level control in gravity service;
- minimum flow protection for centrifugal pumps;
- compressor anti-surge control.

For split range valves, the range “split” shall be selected so that loop gain variations are minimised. The valve authority shall be determined for each control valve separately on the basis of the above rules.

NOTE:

For critical applications, the approach for selecting the valve characteristic should be refined as follows:

- If $\gamma_d \geq 0.8$, select a linear characteristic;
- If $\gamma_d \leq 0.5$, select an equal percentage characteristic;
- If $0.5 < \gamma_d < 0.8$: decrease γ_d to below 0.5 by adding additional frictional pressure drop (e.g. a restriction plate).

3.3 PIPE GEOMETRY

Reducers and/or expanders in the piping affect the calculated C_v .

3.4 CONTROL VALVE NOISE

Noise prediction calculation and testing shall be in accordance with the relevant section of IEC 60534-8-3 or IEC 60534-8-4 as appropriate. If the Manufacturer cannot meet this requirement, any alternative prediction method requires the approval of the Principal.

3.5 FLUID MIXTURE

3.5.1 Liquid mixtures or gas mixtures

For a mixture of liquids or a mixture of gases, the total composite density shall be used for the C_v value calculation.

3.5.2 Liquid with associated gas

Liquid with associated gas (two phase flow) should be avoided. The control valve Manufacturer should be consulted for these applications.

3.5.3 Liquid with a non-associated gas

The effective density (ρ_{eff}) shall be used for calculating the C_v value of a fluid mixture. The following formula should be applied to calculate the effective density of a homogeneous mixture of a liquid with a non-associated gas (in turbulence):

$$\frac{1}{\rho_{\text{eff}}} = \frac{A}{Y^2 \rho_{\text{gas}}} + \frac{B}{\rho_{\text{liq}}}$$

in which:

A = weight factor of the gas component;
B = weight factor of the liquid component;
Y = gas expansion factor;
 ρ = density.

The sizing formulae for incompressible fluids shall be used if the liquid weight factor is 5% or greater. The sizing formulae for compressible fluids shall be used if the liquid weight factor is less than 5%.

3.6 CAVITATION

Cavitation should be avoided because it limits the valve capacity, generates vibration and noise and might physically damage the control valve.

If cavitation is predicted during any operational case (start-up, normal operation at minimum, normal, maximum flow, alternative operating modes, start-up and emergency operation), the following remedial actions, indicated in order of preference, shall be considered:

- a) select a valve with a higher liquid pressure recovery factor F_L (refer IEC 60534-2-1);
- b) modify the system upstream of the control valve (e.g. rationalise the pump head) to reach a higher inlet pressure and/or a lower inlet temperature;
- c) relocate the control valve in the system to a higher inlet pressure and/or to a lower inlet temperature;
- d) select a different flow direction through the control valve;
- e) install a restriction orifice directly downstream of the control valve, provided that flow rate variations are small and providing that the restriction orifice is not damaged by cavitation;
- f) apply hardened trims to prevent cavitation damage, see (5.3);
- g) install a valve with a special anti-cavitation trim;
- h) install two (or more) control valves in series.

3.7 FLASHING

The first stage of flashing is identical to that for cavitation (Appendix 1; 3.6), i.e. vapour forms as the vena contracta pressure is reduced to the vapour pressure of the liquid. In the second stage of the flashing process, a portion of the vapour formed at the vena contracta remains in vapour phase as the downstream pressure is equal or less than the vapour pressure of the liquid.

In situations where flashing in the control valve cannot be prevented by relocating the valve, measures shall be taken to prevent damage as a result of high fluid velocities. Consult the control valve Manufacturer for guidance, as the required measures depend on valve and trim geometry.

NOTE:

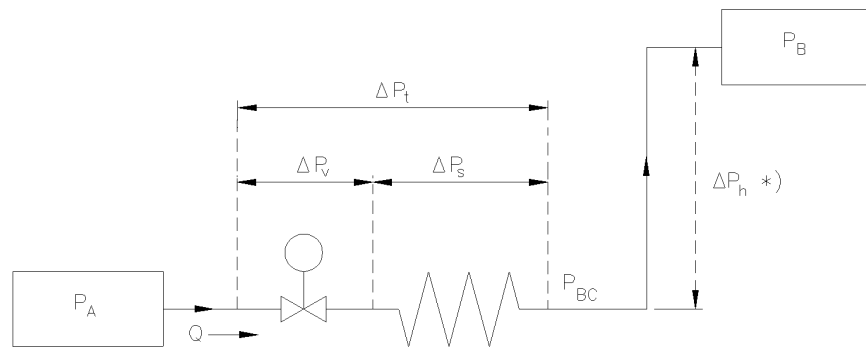
- 1) Rotary valves with hardened trim in reverse flow direction (seat ring at valve outlet) have been successfully applied in flashing service. The reverse flow results in a short, hardened path between the vena contracta and the valve outlet. Upon exit, the fluid velocity is rapidly decreased to a safe level by the larger diameter of the downstream piping. Alternatively, angle valves with hardened trims may be considered.
- 2) Angle body globe valves with hardened trims with lined body outlet are favored for flashing services for high pressure drop applications that cannot be handled by rotary valves. Based on the flashing percentage line sized valves with reduced trim and hardened material may be used to limit the outlet velocity and to prevent damage.

3.8 CHOKED FLOW

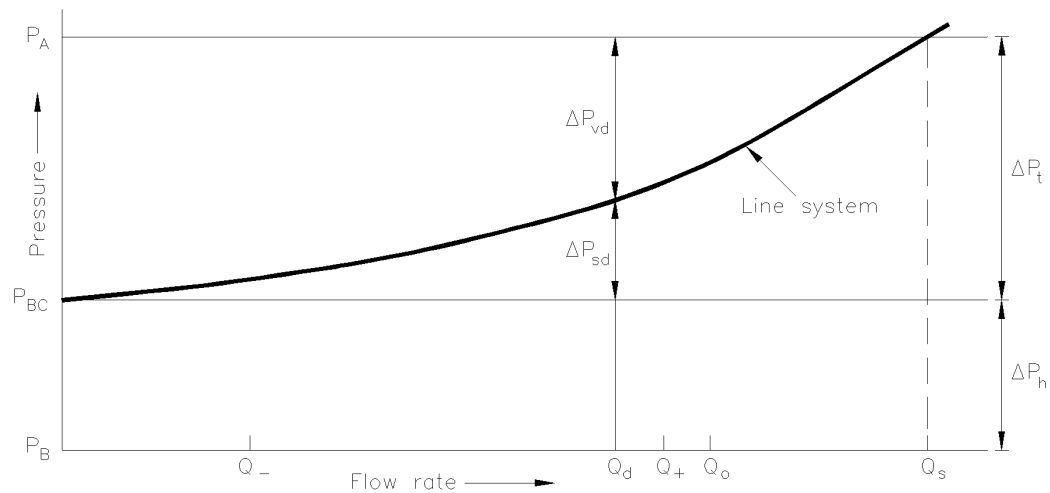
For incompressible fluids, choked flow is associated with cavitation or flashing. For remedial actions, see (Appendix 1; 3.6 and 3.7).

For compressible fluids, choked flow shall be avoided, as the associated high fluid velocities result in high noise levels and physical damage (e.g. erosion) to valves and downstream piping. If choked flow is predicted, a control valve with a higher pressure differential ratio factor X_T (IEC 60534-2-1) should be selected.

Figure 1 Installed control valve and line system (process system WITHOUT pump)



*) Either positive or negative

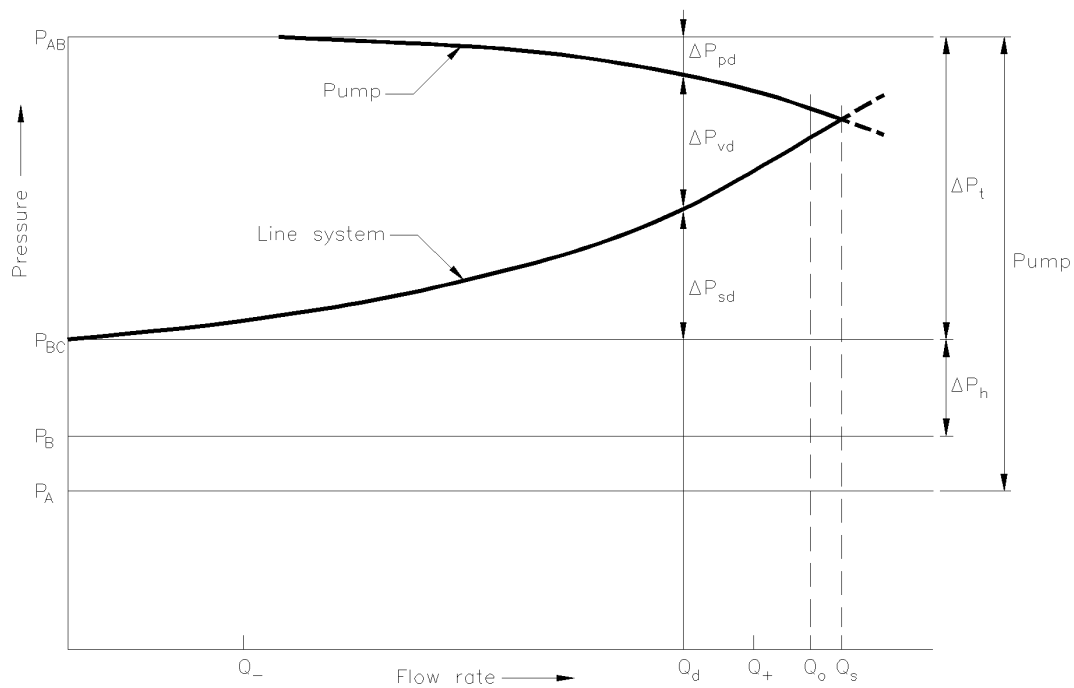
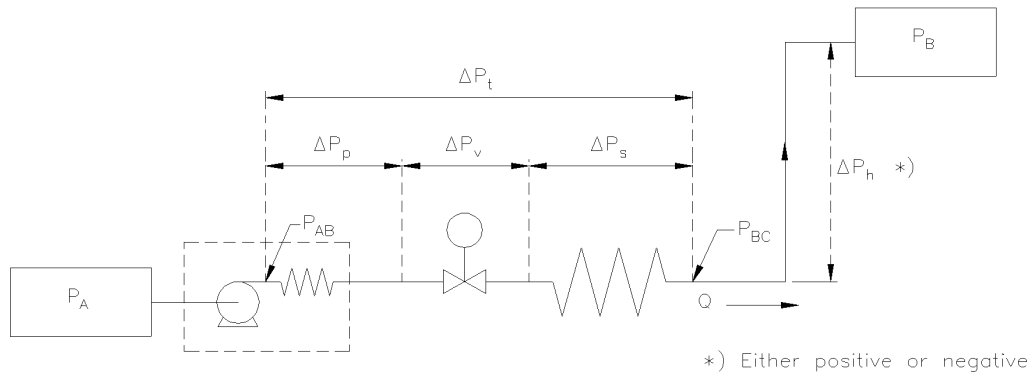


Symbols and subscripts:

Q₋ = Minimum controllable flowrate
Q_d = Design flowrate
Q₊ = Maximum controllable flowrate
Q_o = Flowrate through a fully open control valve
Q_s = System flowrate without control valve

ΔP_v = Pressure drop across control valve
ΔP_s = System dynamic pressure loss
ΔP_t = Total dynamic pressure diff.
ΔP_h = Differential static head
P_A = Terminal A pressure
P_B = Terminal B pressure
(Additional subscript "d" indicates "design conditions")

Figure 2 Installed control valve and line system (process system WITH pump)



Symbols and subscripts:

Q_- = Minimum controllable flowrate
 Q_d = Design flowrate
 Q_+ = Maximum controllable flowrate
 Q_o = Flowrate through a fully open control valve
 Q_s = System flowrate without control valve

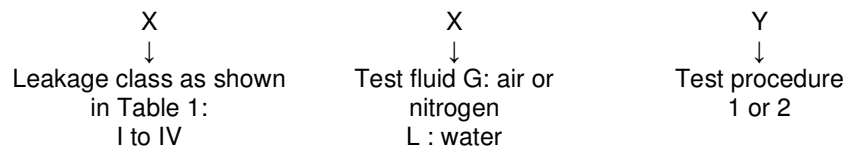
ΔP_v = Pressure drop across control valve
 ΔP_s = System dynamic pressure loss
 ΔP_p = Dynamic pressure loss pump
 ΔP_t = Total dynamic pressure diff.
 ΔP_h = Differential static head
 P_A = Terminal A pressure
 P_B = Terminal B pressure
 (Additional subscript "d" indicates "design conditions")

APPENDIX 4 SEAT LEAKAGE TEST

4.1 GENERAL

The manufacturer shall advise the minimum achievable leak rate.

Leakage shall be specified by the following code:



Example: III L 1

The seat leakage test as described in 5.5 shall be performed on each valve

These seat leakage provisions do not apply to control valves with rated flow coefficients less than the following:

$$K_v = 0,086; C_v = 0,1$$

Class VI is intended to apply to resilient seated valves only.

NOTE: This part of the standard cannot be used as a basis for predicting leakage when the control valve is installed under actual operating conditions.

4.2 TEST MEDIUM

The test medium may be liquid or gas at ambient temperature as specified in each test description:

- Liquid: water at a temperature between 5 °C and 50 °C . The water may contain soluble oil or a rust inhibitor.
- Gas: air or nitrogen in clean condition, at a temperature between 5 °C and 50 °C.

4.3 ACTUATOR ADJUSTMENTS

The actuator shall be adjusted to meet the operating conditions specified. The required closing thrust or torque, as obtained from air pressure, a spring or other means, shall then be applied. No allowance or adjustment shall be made to compensate for any difference in seat load obtained when the test differential is less than the maximum valve operating differential pressure.

On valve body assemblies made for stock, tested without the actuator, a test fixture shall be utilized which applies a net seat load not exceeding the manufacturer's normal expected load under maximum service conditions.

4.4 TEST PROCEDURE

The test medium shall be applied to the normal or specified valve body inlet. The valve body outlet shall be open to atmosphere or connected to a low head-loss flow measuring device with its outlet open to the atmosphere. Provisions shall be made to avoid subjecting the measuring device to pressures above the safe operating pressure resulting from inadvertent opening of the valve under test.

When liquid is used, the valve shall be opened and the valve body assembly filled completely, including the outlet portion and any downstream connected piping. The valve shall then be closed. Care shall be taken to eliminate air pockets in the valve body and piping.

When the leakage flow rate has been stabilised, the rate of flow should be observed over a sufficient period of time to obtain the accuracy specified in 5.1.3.

The maximum allowable seat leakage as specified for each class shall not exceed the values in Table 1 using the test procedure as defined.

4.4.1 Test procedure 1

The pressure of the test medium shall be between 300 kPa and 400 kPa (3 bar and 4 bar) gauge or within ± 5 % of the maximum operating differential pressure specified by the purchaser if it is below 350 kPa (3,5 bar).

4.4.2 Test procedure 2

The test differential pressure shall be within ± 5 % of the maximum operating differential pressure across the valve as specified by the purchaser.

4.5 Leakage specifications

Leakage classes, test mediums, test procedures and maximum seat leakages shall be specified to be in accordance with Table 1.

Leakage class	Test medium	Test procedure	Maximum seat leakage																																										
I	As agreed between purchaser and manufacturer																																												
II	L or G	1	$5 \cdot 10^{-3} \cdot \text{rated valve capacity (note 1)}$																																										
III	L or G	1	$10^{-3} \times \text{rated valve capacity (note 1)}$																																										
IV	L	1 or 2	$10^{-4} \times \text{rated valve capacity}$																																										
	G	1	$10^{-4} \times \text{rated valve capacity (note 1)}$																																										
IV-S1	L	1 or 2	$5 \times 10^{-6} \times \text{rated capacity}$																																										
	G	1	$5 \times 10^{-6} \times \text{rated capacity (note 1)}$																																										
V	L	2	$1,8 \times 10^{-7} \times \Delta p^* \times D \text{ l/h}$ $(1,8 \times 10^{-5} \times \Delta p^{**} \times D) \text{ (note 1)}$																																										
	G	1	$10,8 \times 10^{-6} \times D \text{ Nm}^3/\text{h (note 3)}$ $11,1 \times 10^{-6} \times D \text{ std m}^3/\text{h (note 3)}$																																										
VI (see note 2)	G	1	$3 \times 10^{-3} \times \Delta p^* \times \text{leakage rate factor (note 2)}$ $(0,3 \times \Delta p^{**} \times \text{leakage rate factor) (note 2)}$																																										
* Δp (kPa); ** Δp (bar); D is the seat diameter (mm); L = liquid; G = gas																																													
Note 1:	For the conversion of the compressible fluid volumetric flow rate, use standard conditions which is an absolute pressure of 1 013,25 mbar and 15,6 °C or normal conditions which is an absolute pressure of 1013,25 mbar and 0 °C.																																												
Note 2:	Leakage rate factors for Class VI: <table><tr><th>Seat diameter</th><th colspan="2">Allowable leakage rate factor</th></tr><tr><th>mm</th><th>ml/min</th><th>Bubbles/min</th></tr><tr><td>25</td><td>0.15</td><td>1</td></tr><tr><td>40</td><td>0.30</td><td>2</td></tr><tr><td>50</td><td>0.45</td><td>3</td></tr><tr><td>65</td><td>0.60</td><td>4</td></tr><tr><td>80</td><td>0.90</td><td>6</td></tr><tr><td>100</td><td>1.70</td><td>11</td></tr><tr><td>150</td><td>4.00</td><td>27</td></tr><tr><td>200</td><td>6.75</td><td>45</td></tr><tr><td>250</td><td>11.1</td><td>-</td></tr><tr><td>300</td><td>16.0</td><td>-</td></tr><tr><td>350</td><td>21.6</td><td>-</td></tr><tr><td>400</td><td>28.4</td><td>-</td></tr></table> The number of bubbles per minute as tabulated is a suggested alternative based on a suitable calibrated measuring device, in this case a 6 mm tube (outer diameter; wall thickness 1 mm) submerged in water to a depth of between 5 mm and 10 mm. The tube end should be cut square and smooth with no chamfers or burrs, and the tube axis should be perpendicular to the surface of the water. If the valve seat diameter differs by more than 2 mm from one of the values listed, the leakage rate may be obtained by interpolation, assuming that the leakage rate varies as the square of the seat diameter.			Seat diameter	Allowable leakage rate factor		mm	ml/min	Bubbles/min	25	0.15	1	40	0.30	2	50	0.45	3	65	0.60	4	80	0.90	6	100	1.70	11	150	4.00	27	200	6.75	45	250	11.1	-	300	16.0	-	350	21.6	-	400	28.4	-
Seat diameter	Allowable leakage rate factor																																												
mm	ml/min	Bubbles/min																																											
25	0.15	1																																											
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50	0.45	3																																											
65	0.60	4																																											
80	0.90	6																																											
100	1.70	11																																											
150	4.00	27																																											
200	6.75	45																																											
250	11.1	-																																											
300	16.0	-																																											
350	21.6	-																																											
400	28.4	-																																											

Note 3:	The inlet pressure is 3,5 bar. If different test pressures are required, e.g. test procedure 2, subject to agreement between the user and manufacturer, then the maximum allowable leakage flow rate in Nm³/h with air or nitrogen as the test medium shall be: $10,8 \times 10^{-6} \times ((p_1 - 101)/350) \times (p_1/552 + 0,2) \times D$ where p_1 is the inlet pressure in kPa absolute. Or, $10,8 \times 10^{-6} \times ((p_1 - 1,01)/3,5) \times (p_1/5,52 + 0,2) \times D$ when p_1 is in bar absolute This conversion assumes laminar flow and is only valid with atmospheric outlet pressure and at a test temperature between 10 °C and 30 °C. This conversion must not be used to predict flow rates under actual operating conditions.
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