MANUAL

CONTROL VALVES - SELECTION, SIZING AND SPECIFICATION

DEP 32.36.01.17-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the selection and specification of control valves and their actuators for throttling and on-off services. This includes the requirements for the design, construction, functioning and testing of control valves. Sizing of control valves has now also been included in this DEP.

This DEP is a revision of the DEP of the same number dated December 1994.

Appendix 1 of this DEP replaces DDD 32.36.01.16-Gen. ("Sizing of Control Valves") which is now withdrawn.

Appendix 2 of this DEP gives details on procurement aspects.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors and Manufacturers/Suppliers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, 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 DEP 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 which 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 which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which 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** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions and abbreviations

For control valve terminology and related terms, refer to IEC 534-1.

For definitions regarding control valve sizing, see Appendix 1.

For the purpose of this DEP, the following definitions apply:

Blow-down or Depressurising	Reducing the pressure in process equipment at a controlled rate in emergency conditions or for operational purposes.
Emergency shut-off/ shutdown	Shutting off a fluid flow in an emergency condition, e.g. as part of an IPF.
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.
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 DEP 31.38.01.12-Gen. and DEP 31.38.01.15-Gen.
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-534-4).

1.4 CROSS-REFERENCES

Where cross-references are made, the number of the section or sub-section referred to is shown in brackets.

All publications referred to in this DEP are listed in (18).

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

The control valve Manufacturer shall be selected from the Principal's "List of Selected Instrument Vendors".

The Manufacturer shall:

- check the calculation of the selected C_v value for the given data;
- quote/supply a C_v value for each valve in the fully open position;
- complete the attachments where requested;
- quote for control valves, meeting the requirements of the relevant requisition;
- inform the purchaser 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 conditions specified in the requisition.

If a control valve is provided with an actuator and/or accessories from an other 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.

All accessories shall be as specified on the site vendor list or the project specification vendor list, whichever is applicable.

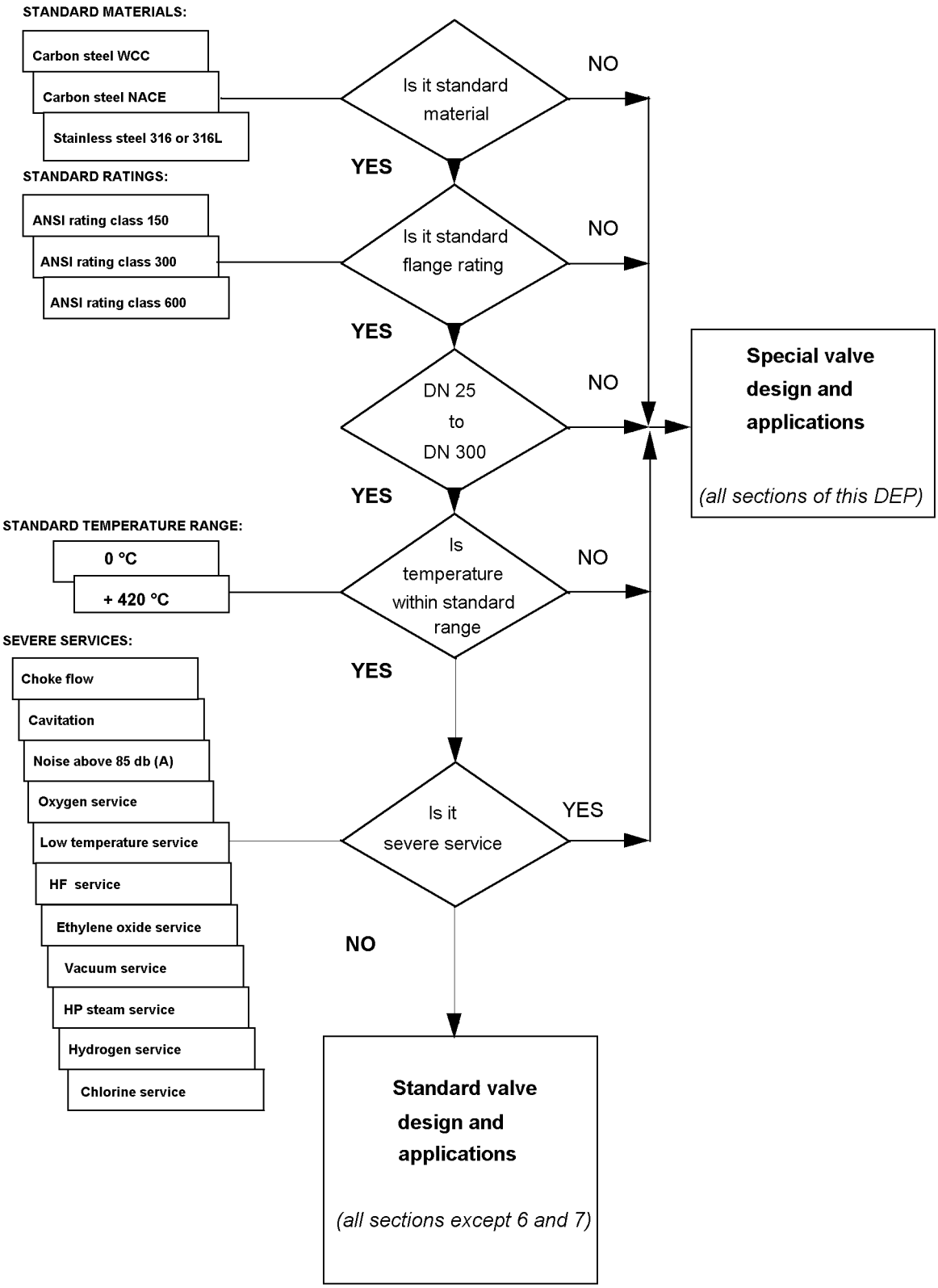
The variety of types and sizes of control valves and supplied related materials ordered under the requisition shall be minimised.

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

Figure 1 shows the flow chart of this selection process. Figure 1 is typical only and for any particular Manufacturer may be amended by the Principal. 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 DEP.

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

Figure 1 Control valve selection process



3. TYPES OF CONTROL VALVES AND THEIR APPLICATION

3.1 GENERAL

Unless otherwise specified in the instrument data sheets or dictated by its application, the selection of a type of valve should be in the following order of preference:

- rotary valve (eccentric plug or segmented ball) or globe valve (linear motion);
- butterfly valve;
- ball valve;
- other types.

To minimise fugitive emissions, the use of valves with a rotating spindle should be considered first.

The materials and rating of a control valve shall be in accordance with the piping class. All identification and/or instruction plates on the valve, actuator and accessories shall be of stainless steel and be fixed with screws or rivets.

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

Sizing of control valves shall be in accordance with IEC 534-2-1 and IEC 534-2-2 (see Appendix 1).

3.2 CONTROL VALVE CHARACTERISTIC

The required control valve characteristic shall be obtained by using a characterised trim or by characterisation in the valve positioner using a cam or software. Characterisation in a control system may be employed only with the approval of the Principal.

For guidelines for the selection of the control valve characteristic, refer to Appendix 1.

3.3 ROTARY VALVES AND GLOBE VALVES

Rotary valves (eccentric plug or segmented ball) or globe valves (linear motion) shall be used for all services except where the allowable pressure drop is so low that a globe valve would not function.

Cage-guided globe valves and balanced type valves, with the exception of double seated control valves, shall not be used in services where coke may form.

Cage-guided globe valves shall not be used for fluids that contain solid particles.

Throttling globe valves should not be used if an IEC-534-4 Class V or IEC-534-4 Class VI shut-off is required, as these shut-off classes cannot be maintained over a prolonged period. If a Class V or Class VI shut-off is required, a dedicated TSO valve (i.e. ball valve) should be installed in series with the control valve. The necessity for these additional shut-off classes shall be examined with care.

For depressurising service, two valves in series shall not be employed.

3.4 ANGLE VALVES

Angle valves should be considered for:

- hydrocarbon services where coke may form;
- erosive services, e.g. slurries;
- applications where solid contaminants might settle in the body of a globe valve.

A special type of angle valve, the choke valve (6.4), is used for wellhead services.

3.5 BUTTERFLY VALVES

Butterfly valves shall comply with the piping class and shall be considered for the following circumstances:

- if the required size (usually due to a high flow rate with a low pressure drop) would make it economically attractive;
- if it is impossible to use eccentric plug / segmented ball or globe valves;
- for corrosive services, where body lining of globe valves becomes economically unattractive.

Special butterfly valves (known as "high performance butterfly valves") are now proven. These butterfly valves can handle high temperatures and high differential pressures, and can have a Class V or Class VI shut-off performance.

NOTES:
1. Spring-opening butterfly valves should not be of the wafer or lug type but should have a valve body (in order to allow removal of the valve from the piping system). If a wafer or lug type butterfly valve is used, a hand wheel or spool pieces (upstream and downstream) may be specified to permit removal of the valve. The provision of a hand wheel shall be subject to the approval of the Principal.

2. Where butterfly valves are installed in vertical piping, it shall be arranged that the diaphragm actuator remains clear of the piping.

3.6 BALL VALVES

Ball valves shall be considered for on-off service.

Ball valves shall comply with the piping class. The type of actuator shall be as specified by the Principal.

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

Ball valves 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, care should be taken with the selection of ball valves for high differential pressures.

3.7 DIAPHRAGM VALVES

Diaphragm valves should only be considered for on/off applications in slurry service. The use of diaphragm valves shall be subject to the approval of the Principal.

3.8 PLUG VALVES

Plug valves should be considered for special applications such as throttling control in slurry service. The use of plug valves shall be subject to the approval of the Principal.

Plug valves shall be in accordance with BS 5353.

3.9 GATE VALVES

Gate valves should only be considered for remotely-operated on/off applications. They are normally equipped with an electric actuator (8.8) or hydraulic actuator (8.9) and do not have a fail-safe action. Typical applications are storage tank isolating valves, remotely operated on/off valves on blenders, pump suction emergency shut-off services and emergency shut-off services on wellheads in oil and gas production facilities.

Gate valves shall be in accordance with BS 1414.

3.10 SELF-ACTING REGULATORS

3.10.1 Self-acting pressure-reducing regulators

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

Regulators in gas blanketing service shall be installed on the blanketing inlet connection of

the relevant tank. Special attention shall be given to the application of self-acting regulators with internal self-relieving capability. For details of tank blanketing, refer to API 2000.

3.10.2 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 compressor bearing sealing applications.

The use of self-acting back-pressure regulators shall be subject to the approval of the Principal.

3.10.3 Self-acting differential-pressure regulators

Self-acting differential-pressure regulators shall only be considered for clean fluids in applications which need no operator intervention, such as for secured instrument air systems or for compressor bearing sealing services.

Except for secured instrument air supply systems, the use of self-acting differential-pressure regulators shall be subject to the approval of the Principal.

3.10.4 Self-acting temperature regulators

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

The use of self-acting temperature regulators shall be subject to the approval of the Principal.

3.11 THREE-WAY GLOBE VALVES

In selecting three-way globe valves, special attention shall be paid to the sizing of each flow path of the valve.

Except for instrument air dryers, the application of three-way globe valves shall be subject to the approval of the Principal.

3.12 SOLENOID VALVES

Apart from their use in instrument air signal lines (9.8), solenoid valves may only be considered for on-off control in hydraulic utility services, such as hydraulic control systems for loading arms, remotely operated valves and wellhead control units.

4. BODY CONSTRUCTION AND MATERIALS

4.1 GENERAL

Control valves, other than wafer/wafer lug type butterfly valves (3.5), shall be provided with process flanges.

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

Control valve bodies shall not be fitted with bottom drain plugs. A bottom flange shall be provided for valves that require bottom access for trim removal.

Valve bonnets shall be of bolted construction with fully retained gaskets.

To enable process line cleaning, butt-welding-end control valves shall be supplied with a blind bonnet flange, together with bonnet gasket(s) sufficient for three changes. The blind bonnet flange shall be of carbon steel and shall have the same rating as the valve body. Alternative methods shall be subject to the approval of the Principal.

4.2 BODY SIZE

The body size of a control valve in throttling service should have the same size as the calculated trim size, but oversized bodies may be required up to the size of the adjacent piping (e.g. to reduce the outlet velocity or to allow for future capacity increase).

Emergency shut-off valves shall be sized for the process conditions, and the pressure drop shall be kept to a minimum. If process conditions are not stated, the valve shall be line size.

NOTE: For ball valves, a one-size reduced bore valve may be considered for economy.

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 25 shall be subject to the approval of the Principal.

4.3 END CONNECTION

The ANSI rating class of flanges shall be in accordance with the piping class unless otherwise specified. Flanges shall be in accordance with ASME/ANSI B16.5 or ASME/ANSI B16.47, as applicable.

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

4.4 FACE-TO-FACE DIMENSIONS

The face-to-face dimensions of flanged globe-body control valves of body size DN 25 to DN 400 and ANSI rating class 150, 300 and 600 shall be in accordance with IEC 534-3.

The face-to-face dimensions of lug and wafer type butterfly valves shall be in accordance with BS 5155.

The face-to-face dimensions of flanged rotary valves (eccentric plug or segmented ball), shall be in accordance with either IEC 534-3-1 (as for globe valves) or IEC-534-3-2 (as for flangeless control valves).

4.5 MATERIALS

4.5.1 General

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

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 fluid impact area may be required for:

- fluids containing erosive particles (slurries);
- ported plugs for wet gas or wet steam service with a pressure drop across the valve above 10 bar;
- other services if the pressure drop is above 40 bar.

Internal lining of the entire body shall be considered for valves in sea water services (such as for fire protection deluge valves).

4.6 STUFFING BOX AND PACKING

4.6.1 General

The packing materials shall be:

- PTFE-based for temperatures at the packing below 200°C;
- graphite-based, for temperatures at the packing between 200°C and 600°C.

Packing shall not contain asbestos.

External lubricators or grease nipples shall not be used.

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

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. For example, this may be the case with compressor recycle (anti-surge) valves.

For valves in cryogenic service that are intended for installation inside a "cold box", an extended bonnet shall be fitted for bringing the stuffing box outside the cold box. The minimum required length shall be specified on the requisition. The stuffing box shall be on top of the extended bonnet.

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

For valves in vacuum service, special attention should be paid to the type of stem packing/sealing facilities as well as to the stem surface finish. The packing box shall be suitable for vacuum service.

4.6.2 Bellows-sealed valves

Bellows-sealed bonnets shall be used if specified by the Principal.

The bellows shall be of AISI 316 type stainless steel, unless otherwise specified in the requisition.

As an alternative to a bellows seal, special double packings with a leak-off connection between the sets or a special environmental packing may be used if approved by the Principal.

For bellows-sealed control valves 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 ANSI rating class 300 without the approval of the Principal.

4.7 GASKETS

Body-to-bonnet and, if required, body-to-bottom flange gaskets shall be of the spiral wound type. Unless otherwise dictated by the process conditions, the gasket material shall be AISI 316 type stainless steel, graphite filled.

The filler material shall be expanded graphite with the following specification:

- maximum 1% ash content;
- maximum 50 mg/kg chloride content;
- density range 0.7 to 1.8 g/cm^3.

Other types of gasket shall be subject to the approval of the Principal.

5. VALVE TRIM AND SEAT RING

5.1 SEAT LEAKAGE AND FLOW DIRECTION

Unless otherwise required, on-off and emergency shut-off valves should be specified and installed as "flow-tending-to-close".

For throttling control applications with unbalanced valves, the direction should be "flow-tending-to-open" in order to avoid a very large unstable force in the nearly closed position.

The requirements for TSO shall be clearly specified in the requisition. The direction of the shut-off requirement (for one or both directions) shall be as indicated on the relevant PEFS and instrument data base.

Balanced-type single-seated control valves of the pilot-operated type shall not be used as TSO valves.

Balanced-type single-seated control valves shall be used only in clean services and only with the approval of the Principal.

For seat leakage testing, reference is made to (13.6).

5.2 CONSTRUCTION

5.2.1 Rotary valves (eccentric plug or segmented ball) and globe valves

The plug and the seat ring(s) shall be of the easy/quick replaceable type.

On butt-welding-end control valves, the entire assembly of trim and seat shall be removable from the top.

If specified by the Principal, the design shall also be suitable for services that are susceptible to coking.

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. Locking devices shall not be fitted through holes in the pressure casing.

Special attention shall be paid to fixing of the seat ring in order to prevent loosening due to vibration. Adhesive compounds shall not be used for the locking of seat rings.

If required, the valve stem part that is exposed to the surrounding atmosphere shall be completely covered by a protection bellows. This protection bellows shall be of a material which is resistant to corrosion by the product and the environment.

5.3 MATERIALS

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

Where soft (resilient) inserts are required for meeting the specified leakage rate, the selection shall be based on their suitability for the specified process conditions. The resilient insert shall be properly clamped between metal parts and/or locked in position to prevent blow-out in the closed position.

For globe valves, soft seats can deteriorate quickly and shall not be used except for class VI shut-off service.

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

- erosive services, cavitating services and choked flow;
- 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 AISI 440C type stainless steel (hardness approximately 550 BHN) may be considered as trim material if approved by the Principal.

NOTES:
1. For choke valves and valves in other extremely erosive services, special materials like tungsten carbide and ceramics may be applied.

2. Stellite, Colmonoy and other hard facings may be partially or fully applied; the choice of which shall be made in consultation with the valve Manufacturer.

6. SPECIAL DESIGNS

6.1 LOW NOISE VALVES

Limits for the noise generated by control valves shall comply with DEP 31.10.00.31-Gen.

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 economical merits. Two types of techniques are available: source treatment (such as trim design, diffusers, attenuator plates) and path treatment (such as by acoustic insulation or by using heavy wall piping). The most reliable and economical solution shall be chosen in consultation with the control valve Manufacturer. Acoustic insulation shall be in accordance with DEP 31.46.00.31-Gen.

Noise prediction calculation and testing shall be in accordance with the relevant section of IEC 534-8-3 or IEC 534-8-4 as appropriate. If the Manufacturer cannot meet this requirement, any alternative prediction method shall be subject to the approval of the Principal.

6.2 ANTI CAVITATION VALVES

If cavitation is still unavoidable after proper selection and location of the control valve then hardened trim materials (5.3) should be used (or, for single seated valves, a change in flow direction through the valve may be sufficient). If a change in flow direction is not feasible and/or hardened trim materials are not adequate, other remedial actions, as listed in Appendix 1, section 3.6, shall be considered.

Special anti-cavitation trims shall only be used if other methods are considered unacceptable, as these trims are expensive and prone to blockage.

6.3 STEAM DESUPERHEATING VALVES

Special control valves with internal water injection for desuperheating purposes may be used for high pressure steam reducing services. The make and type of these valves shall be subject to the approval of the Principal.

6.4 CHOKE VALVES

6.4.1 Gas choke valves

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:

- It should be possible to remove the internals of the valve without disconnecting, re-adjusting or removing the actuator from the valve or the valve from the process line. Changing of internal parts should be possible by using hand tools only.
- 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.
- The valve shall be Class V or Class VI shut-off, in accordance with IEC 534-4.
- The plug and seat should be stilted.

NOTE: During initial start-up of a well, a stilted trim should be used to cope with sand, dirt etc. After a period of time, typically 2 months of production, the trim may be exchanged for the harder, but more brittle, tungsten carbide.

6.4.2 Liquid choke valves

For special applications, such as 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 which 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.

The following shall apply:

- The valve shall be made up of a number of modular sub-assemblies, such as internals, bonnet, yoke, actuator, coupling, etc.
- To replace any of the sub-assemblies, it shall not be necessary to remove the valve body from the process line.
- The valve shall be Class V or Class VI shut-off, in accordance with IEC 534-4.
- The discs and bean shall be made out of tungsten carbide.

7. CONTROL VALVES FOR SPECIAL APPLICATIONS

7.1 LOW TEMPERATURE SERVICE

Control valves in services below 0° C shall, in addition to the specification in the requisition, comply with MESC specification 77/200.

7.2 VACUUM SERVICE

Control valves in services below 1.0 bar (abs) shall, in addition to the specification in the requisition, comply with MESC specification 77/201.

7.3 HIGH PRESSURE STEAM SERVICE

Control valves in steam service with ANSI rating class 300 and higher shall, in addition to the specification in the requisition, comply with MESC specification 77/202.

7.4 HYDROGEN SERVICE

Control valves in services containing hydrogen with a partial pressure of 7 bar (abs) and higher shall, in addition to the specification in the requisition, comply with MESC specification 77/203.

7.5 HYDROFLUORIC ACID (HF) SERVICE

Stress relieved Monel bellows seal control valves shall be used.

Viton shall be used as the sealing/seating material.

The stem material shall be Hastelloy-C or Monel K500.

Control valves in HF service shall, in addition to the specification in the requisition, comply with MESC specification 77/204.

7.6 OXYGEN SERVICE AND HIGH PRESSURE AIR SERVICE

Control valves for oxygen service and for air service above 50 bar (ga), DEP 31.10.11.31-Gen. and MESC specification 77/205 shall apply.

Control valves for oxygen service shall be clearly marked and shall be packed separately from other valves.

7.7 ETHYLENE OXYDE SERVICE

Control valves for ethylene oxyde service shall, in addition to the specification in the requisition, comply with MESC specification 77/205.

7.8 CHLORINE SERVICE

Control valves for chlorine service shall, in addition to the specification in the requisition, comply with MESC specification 77/206.

7.9 SOUR SERVICE

If sour service is specified in the requisition, NACE MR0175 shall apply to the control valve (but not to the gaskets).

Pressure-retaining bolting (even if not directly exposed to the process fluid) shall comply with NACE MR0175.

8. CONTROL VALVE ACTUATOR

8.1 GENERAL

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

The actuator shall function properly under the minimum, normal and maximum instrument air supply pressures and process conditions as specified in the requisition.

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

Actuators shall be designed for a minimum instrument air pressure of 4.2 bar (ga), unless otherwise required. Actuators requiring an instrument air supply pressure above 4.2 bar (ga) shall not be used unless approved by the Principal.

Emergency shut-off valves of IPF (Instrument Protective Function) class III and higher (see DEP 32.80.10.10-Gen.) shall be fitted with a fail-safe spring-return actuator.

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, taking account of the cost implications of piping layout and supports.

The piston-type actuator, if specified, should be of the spring-opposed diaphragm or of the spring-opposed short-stroke type.

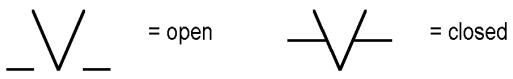
Long-stroke springless piston actuators shall be opposed by a secured instrument air system or provided with lock-up valves to achieve the required action in the event of instrument air failure.

To prevent tampering, the rotating linkages between a butterfly valve and its actuator 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.

Piston or cylinder actuators shall have O-ring sealing and shall be designed to minimise shaft and piston 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 'shut' at the travel limits, or by unambiguous symbols such as:



8.2 ACTUATOR MATERIAL

The material of the actuator case or housing shall be steel or anodised aluminium. Cast iron (e.g. ASTM A48) shall not be used.

Aluminium actuators shall not be used on valves which form part of safety systems, such as ESD valves or emergency depressurising valves.

The yoke shall be of the open type to allow access for adjustment of the packing gland follower.

The diaphragm material shall be nylon-reinforced neoprene or Buna N rubber. If the actuating medium is wet hydrocarbon gas, Buna N shall not be used as diaphragm or seal material.

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

atmospheric corrosion.

8.3 ACTUATOR FORCE

Unless otherwise specified, the maximum process differential pressure for actuator sizing shall be the difference between atmospheric pressure and the maximum upstream pressure with the valve fully closed (for vacuum conditions, add 1 bar).

Actuators shall be sized to provide, under minimum air supply conditions, sufficient torque or thrust to position and fully stroke the inner valve against the maximum differential pressure that may develop under the specified process and/or start-up conditions within the specified time.

For flow-tending-to-close valves the actuator shall be capable of **opening** the valve against the full upstream pressure, and for flow-tending-to-open valves the actuator shall be capable of **closing** the valve against the full upstream pressure.

If the actuator and the valve are from different Manufacturers then the actuator Manufacturer shall be given the necessary torque data.

8.4 STROKING TIME

Unless other stroking times are indicated in the requisition, the following stroking times for both directions shall not be exceeded:

Body size	Maximum stroking time
≤ DN 50	10 seconds
DN 80	15 seconds
DN 100	15 seconds
DN 150	20 seconds
DN 200	35 seconds
DN 250	50 seconds
> DN 250	To be specified by the Principal

If faster stroking times are required, high capacity valve positioners should be considered. If these are not available, then additional boosters or quick-exhaust valves shall be installed.

The stroking times are applicable to throttling control valves complete with valve positioner and other accessories, e.g. solenoid valves, etc.

Valves used for on/off service (e.g. ESD valves, or control valves with a trip function) shall have a stroking time as indicated on the PEFS or in the requisition or instrument data sheet.

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

If air pressure is used to close the valve under emergency conditions or to assist the spring force, the size of the air signal line and fittings and the air capacity of the accessories shall be designed to ensure the specified stroking time.

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.

8.5 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 may be given to the actuator (e.g. red for spring closing valves and green for spring opening valves), as specified in the requisition. For painting requirements, see Section 11.

8.6 ACTUATORS FOR VARIABLE-PITCH FANS

DEP 31.21.70.31-Gen. shall apply for 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:

- If indicated on the PEFS or requisition, variable-pitch fan blade position indicators shall be fitted;
- the actuator shall be of the double-acting piston type unless otherwise specified in the requisition, and shall have sufficient torque to overcome the dynamic forces on the variable-pitch fan blades plus the friction forces in the bearings, etc.;
- the actuator shall be directly connected to the main operating shaft of the variable-pitch fans;
- linkages designed to allow manual operation of the variable-pitch fan blade position shall not be fitted;
- If indicated in the PEFS or requisition, the actuator shall be opposed by a secured instrument air system or provided with lock-up valves to achieve the required action on instrument air failure;
- instrument air lines to actuators and positioners of variable-pitch fans shall be connected via flexible hoses, to allow for movement of the actuating mechanism;
- pneumatic components shall be static. Rotating pneumatic couplings shall not be used.

8.7 ACTUATORS FOR DAMPERS

These actuators shall have sufficient torque to overcome the dynamic forces on the dampers or louvers, plus the friction forces in the bearings, etc. under worst case conditions.

They shall be designed to cope with fouling and distortion of the dampers. Special attention shall be paid to prevent the full force of the actuator damaging damper blades and linkages.

The cylinders shall be double-acting and, where necessary, shall be provided with air lubricators.

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

- a cylinder actuator or a piston actuator. If not opposed by a spring, the actuator shall be opposed by a secured instrument air system or provided with lock-up valves to achieve the required action on instrument air failure;
- a valve positioner with characterising cam 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.

8.8 ELECTRICAL ACTUATORS

The use of electrical actuators for throttling control valves shall be subject to the approval of the Principal. Electrical actuators for on/off valves are outside the scope of this DEP.

8.9 HYDRAULIC ACTUATORS

The use of hydraulic actuators for throttling control valves shall be subject to the approval of the Principal. Hydraulic actuators for on/off valves are outside the scope of this DEP and shall comply with DEP 31.36.10.30-Gen.

9. ACCESSORIES

9.1 VALVE POSITIONERS

Electro-pneumatic valve positioners (input signal 4 - 20 mA) shall be used unless otherwise specified in the requisition.

Intelligent valve positioners with self-diagnostic features (for the purpose of valve condition monitoring) should be considered for critical valves and for valves which are difficult to remove from the process. A listing of such valves shall be prepared by the Contractor for the Principal's approval and this shall include details of the criteria used to decide the criticality.

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

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 in accordance with IEC 529.

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.

Supply and output pressure gauges, graduated in the units specified in the requisition, shall be provided on the valve positioner for the air signals.

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; to achieve the required stroking times. The minimum tubing diameter shall be 6 mm and the fewest possible number of different sizes shall be used. The tubing shall comply with the specification given in the requisition. Bare copper tubing shall not be used.
- the compression fittings shall be of the make, type and composition as specified in the requisition (this should be standardized to minimise variety). All parts of the fittings shall be made by the same Manufacturer. The fittings and tubing shall be installed by skilled personnel and strictly in accordance with the compression fitting Manufacturer's instructions.

Valve positioners having a user-selectable characterising mechanism shall be set correctly by the valve Manufacturer.

The valve positioner shall be provided with an identification plate, marked with the air supply pressure and input signal.

The combination of a separate electro-pneumatic convertor 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.

9.2 HAND WHEELS

Control valves shall not be provided with a hand wheel unless shown on the PEFS.

If a hand wheel is required, the following shall apply:

- the hand wheel shall be of an all-metal design;
- the hand wheel shall be provided with position indicators;
- the operating force, under maximum design conditions, shall not exceed 350 N on the rim of the hand wheel;
- the changeover from actuator operation to hand wheel operation shall be possible in all stem positions.

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 .

9.3 LIMIT STOPS

Limit stops shall be fitted only if shown on the PEFS.

Limit stops shall be mechanical devices mounted on the actuator, but they shall not form part of the hand wheel mechanism (if provided). Bolts screwed in the body shall not be used as a limit stop.

Screwed bolt-type limit stops, e.g. on the control valve stem, shall be used if specified.

Limit stops shall be 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.

The use of non-mechanical limit stops shall be subject to the approval of the Principal.

9.4 LOCK-UP VALVES

Air lock-up valves shall be specified for the following applications:

- all services requiring the control valve to remain in the position immediately prior to a complete failure of the instrument air supply;
- all shut-off control valves requiring an air supply pressure higher than the guaranteed minimum instrument air pressure.

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

The lock-up valves shall be set 0.5 bar above the required control valve air supply pressure unless some other set value is required for a particular 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, this solenoid valve shall be installed between the lock-up valve and the actuator.

9.5 LIMIT SWITCHES

"Open" and/or "close" limit switches shall be fitted only if shown on the PEFS.

Limit switches shall be of the 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 junction box; alternatively, the protection box and the junction box may be combined into one box. These boxes shall be suitable for the electrical hazardous area classification in which they are located.

If not armoured, the flying leads shall be protected by a flexible conduit.

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 mounting instructions supplied by the limit switch Manufacturer shall be followed by the valve Manufacturer. The limit switches shall be properly adjusted by the valve Manufacturer.

Proximity switches shall be adjustable and shall function autonomously, e.g. one switch for the "fully open" position and a separate switch for the "fully closed" position.

The combination of proximitor and proximitor circuit shall be of fail-safe design.

9.6 SECURED INSTRUMENT AIR BUFFER VESSELS

Secured instrument air shall be supplied to springless actuators of control valves, in order to drive the valve to a safe position in the event of air failure.

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

9.7 AIR LUBRICATORS

Air lubricators (if used) 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.

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

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

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

9.8 SOLENOID VALVES

Solenoid valves shall be fitted in air lines to the control valve only if shown on the PEFS.

The solenoid valves shall be provided with a disc and/or seat of resilient material to achieve TSO. The air passages in the solenoid valves 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.

The capability of the solenoid valve (e.g. capacity, pressure rating) shall be checked against the instrument air requirement of the particular actuator.

The minimum port size in the solenoid valve shall be stated by the solenoid valve Manufacturer and this shall be taken into account in the stroking time calculations.

Solenoid valves shall be not be supplied with exhaust port protectors but, to prevent plugging (e.g. during freezing periods), shall be provided with a piece of tubing bent downwards with the end cut off at an angle of 45 degrees.

For long-stroke large-volume pneumatic cylinder actuators, e.g. actuators on rotary star valves, consideration should be given to the use of pneumatically-operated solenoid valves which can handle the required air capacity of the particular actuator. Pneumatically-operated 'primary' solenoid valves shall be activated via a 'secondary' solenoid valve which should be electrically operated.

Solenoid valves with flying leads shall be provided with a junction box for termination of the leads.

The junction box shall be compatible with the electrical hazardous area classification of the solenoid valve. To prevent high voltage induction, solenoid valves operating on direct current shall be provided with reverse diodes.

For emergency shut-off valves, the solenoid valve shall be installed directly on the valve actuator.

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; the use of pilot-operated solenoid valves shall be subject to the approval of the Principal.

Ambient temperatures, including the effects of direct sunlight, shall be specified and the solenoid valve selected accordingly.

9.9 FILTER REGULATORS

If the maximum air supply pressure is greater than the the operating pressure of the actuator or its accessories, or if the valve positioner needs a regulated air pressure, then an air filter regulator shall be installed in the instrument air supply line. The make of filter regulator shall be as specified in the requisition.

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 channelling, 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.

Glass (bowl-type) filter regulators shall not be used.

Filter regulators shall be mounted vertically so that they are self-draining.

If the actuator / positioner is capable of withstanding full instrument air pressure (specified maximum design condition of the instrument air supply system), no regulator shall be installed, only a filter (9.10).

9.10 FILTERS

If a filter regulator is not installed (9.9) an air filter shall be installed in the instrument air supply line to the valve. The air filter shall be provided with a manual drainage facility and a filter cartridge of the rigid structure type, to resist channelling, rupturing, shrinkage or distortion, and having a maximum mesh size of 40 µm. Glass (bowl type) filters shall not be used.

Filters shall be mounted vertically so that they are self-draining.

9.11 QUICK-EXHAUST VALVES

Quick-exhaust valves may be provided for on/off services which require the control valve to open or close faster than is possible with a standard actuator configuration. Fitting quick exhaust valves to throttling services may result in unstable operation and is therefore not recommended.

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

The minimum port size in the quick-exhaust valve shall be verified and taken into account in calculating the stroking time.

Quick-exhaust valves shall be without port protectors but, to prevent plugging (e.g. during freezing periods), shall be provided with a piece of tubing bent downwards with the end cut off at an angle of 45 degrees.

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

9.12 VOLUME BOOSTERS

Volume boosters shall only be provided if needed to achieve the specified stroking times. Volume boosters for pneumatic actuators shall be of the high capacity type with fast throttling to control the required capacity.

9.13 RESTRICTORS

If the slow opening and/or slow closing of a valve is required, this should be achieved within the DCS or other remote electronic system. The use of mechanical instrument air restrictors should be avoided.

If its use is unavoidable, then the mechanical flow restrictor shall be provided with a lockable, variable restriction adjustment facility. The direction(s) of restricted flow shall be

indicated by a permanent mark on the body. The capacity of the flow restrictor shall be sized (and tested) for a normal air supply pressure.

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. EMERGENCY DEPRESSURISING VALVES

Emergency depressurising valves are outside the scope of this DEP and shall be in accordance with DEP 32.45.10.10-Gen.

11. PAINTING

Surfaces to be painted or coated shall be dry and free from burrs, weld spatters, flux, dust, grease, oil and other foreign matter before any paint is applied.

The valves shall be prepared and painted according to Manufacturer's standard. Only if a written justification, listing the factors considered, is presented, shall the valves be prepared and painted to more stringent specifications.

This justification shall detail:

- why the valves require non-standard preparation and painting;
- the additional anticipated cost of this for the valves so specified.

The colour of the final finish shall be to Manufacturer's standard unless otherwise specified in the requisition. See also (8.5).

The valve stem or spindle and gasket-contact surface of flanges shall not be painted but shall be protected against corrosion by a suitable protective fluid.

12. VALVE IDENTIFICATION

The control valve shall be provided with a standard stainless steel identification plate. At least the following information shall be clearly stamped on the plate:

- Manufacturer's name or trade mark;
- Manufacturer's model/type number (valve and actuator);
- Manufacturer's serial number;
- body pressure rating;
- size (body and trim/C_V value);
- material (body and trim);
- type of plug (characteristic);
- bench setting or spring range;
- action on air supply and/or signal failure.

In addition, each control valve shall be provided with a stainless steel tag plate, which shall be fixed to the control valve with a stainless steel wire. This plate shall be marked with the Principal's tag number as stated in the requisition.

Control valves shall be marked in accordance with the applicable design code.

The direction of flow, the valve body rating, the body material and, where applicable, the TSO direction(s) shall be clearly indicated by a permanent mark cast in or stamped on the valve body, not painted.

Three-way globe valves shall clearly indicate the fixed open port by a permanent mark "COMMON" stamped on the flange.

The control valve tag number shall be stamped on the valve body or flange if the identification plate is attached to the actuator.

Control valves for oxygen service shall be tagged:

"SUITABLE FOR **OXYGEN** SERVICE"

Control valves for HF service shall be tagged:

"SUITABLE FOR **HF** SERVICE"

Control valves for ethylene oxide service shall be tagged:

"SUITABLE FOR **ETHYLENE OXIDE** SERVICE"

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 fixed by screws or rivets.

13. INSPECTION AND TESTING

13.1 EXTENT

The Manufacturer shall perform the following inspections and tests (see Note 1):

Inspection/test	Extent		Method and acceptance criteria
Dimensional inspection	All valves		(13.2)
Hydrostatic test	All valves		(13.3)
Functional test	All valves		(13.4)
Hysteresis and dead band test	Random sample (Note 2)		(13.5)
Seat leakage test	Valves with Class V or Class VI shut-off requirement	All valves	(13.6)
	Other valves	Random sample (Note 2)	
Capacity test	Random sample (Note 2)		(13.7)
Low temperature test	Valves with lower design temperature below zero °C	Sample in accordance with MESC spec. 77/306	(13.8)
Vacuum test	Valves in vacuum service	Sample in accordance with MESC spec. 77/307	MESC spec. 77/307
Helium test	Valves in hydrogen service (Note 6) and if specified on requisition	Sample in accordance with MESC spec. 77/308	MESC spec. 77/308

NOTES:
1. The specified extent and acceptance criteria shall be in accordance with the Manufacturer's standard where more frequent or stringent.
2. The number of valves sampled shall be subject to the approval of the Principal.
3. The selected valves for each test shall be listed by the Contractor.
4. Inspection and testing shall include accessories if part of the supply.
5. The test results shall be made available to the purchaser as part of the package of final certified documents and drawings.
6. Hydrogen service means all process conditions with a hydrogen partial pressure greater than 7 bar (abs).

13.2 DIMENSIONAL AND FLANGE FACE FINISH CHECK

The face-to-face dimensions of flanged globe-body control valves 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).

13.3 HYDROSTATIC TEST

Hydrostatic testing shall be in accordance with IEC 534-4, with the test duration as follows:

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

The water quality shall be as specified in MESC specification 77/101.

13.4 FUNCTIONAL TEST

The control valve shall be completely assembled and fitted with all accessories such as positioner, solenoid valve(s), etc. The stuffing box shall be correctly packed and soap tested with 3.5 bar (ga) air pressure inside the valve body.

The valve positioner shall be checked for correct calibration.

The stroking time at the specified air pressures shall comply with (8.4). All required stroking times shall be checked.

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.

If the control valve is equipped with limit switches, they shall be checked for functional operation with a proximity tester.

13.5 HYSTERESIS AND DEAD BAND TEST

For definitions and test procedures refer to IEC 534-1 and IEC 534-4.

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 the approval of the Principal.

The above test results should be recorded on an X-Y recorder or similar.

13.6 SEAT LEAKAGE TEST

The seat leakage test shall be in accordance with IEC 534-4, with the acceptance criteria for the specified shut-off class. 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).

13.7 CAPACITY TEST

The actual C_v value shall be demonstrated by a test in accordance with IEC 534-2-3.

13.8 LOW TEMPERATURE TEST

Low temperature testing shall be in accordance with MESC specification 77/306.

In addition, a hysteresis and dead band test (13.5) shall be performed at the temperature of the low temperature test.

13.9 VACUUM TEST

Vacuum testing shall be in accordance with MESC specification 77/307.

13.10 HELIUM TEST

Helium testing shall be in accordance with MESC specification 77/308.

14. MATERIALS INSPECTION AND CERTIFICATION

Material inspection and certification requirements shall be in accordance with MESC specifications 77/302, 77/303, 77/304 and 77/305.

15. WITNESSING BY PRINCIPAL

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

DEP 62.10.09.11-Gen. and MESC specifications 77/304 and 77/305 may be used as guidance for the Principal to decide on this extent.

Upon request, a quality plan shall be submitted by the valve Manufacturer.

16. PROTECTION AND PACKAGING

All necessary precautions shall be taken for adequate protection of the valves, including accessories, during shipment and outdoor storage at their destination. These precautions shall include the following:

- Before leaving the factory, all openings in the valve body shall be provided with temporary closures to prevent entry of dirt or other materials.
- During transport and storage, the valve ends shall be protected with suitable close fitting protectors (e.g. plastic caps) or covers of at least 3 mm thick and securely fastened by an adequate number of bolts.
- Open threaded connections, e.g. air connections of actuators, positioners and accessories, shall be fitted with thread protectors to prevent the ingress of moisture.
- The stuffing boxes of valves with graphite-based packing shall be protected against the ingress of moisture.

17. DOCUMENTATION

The Manufacturer shall submit the following documents with the quotation:

- details of the selected actuator and torque figures;
- calculations of control valve capacity (C_V), calculations of the predicted noise level, and, where applicable, details of the secured instrument air vessel;
- dimensional outline drawing of the control valve, including accessories, air lines and, where applicable, the secured air vessel;
- if specified, a completed equipment noise limitation sheet (DEP 31.10.00.94-Gen.);
- details of where the full valve specifications will be held.

The results of the inspections and tests by the Manufacturer (13) shall be made available to the purchaser as part of a package of final certified documents and drawings.

The Manufacturer shall complete a spare parts list and interchangeability record (E-SPIR) for all equipment supplied. See DEP 70.10.90.11-Gen.

Unless otherwise specified by the Principal, only the minimum necessary quantity of documentation shall be provided. For example, if a number of valves of the same type are ordered a separate operating and instruction manual is not required for each valve.

18. REFERENCES

In this DEP, 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.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Requisitioning binder	DEP 30.10.01.10-Gen.
Noise control	DEP 31.10.00.31-Gen.
* Data/requisition sheet for equipment noise limitation	DEP 31.10.00.94-Gen.
* NOTE: Data/requisition sheets are contained in the Requisitioning binder DEP 30.10.01.10-Gen.	
Gaseous oxygen systems	DEP 31.10.11.31-Gen.
Air-cooled heat exchange equipment (amendments/supplements to API 661)	DEP 31.21.70.31-Gen.
Hydraulic systems for remote operation of shut-off valves	DEP 31.36.10.30-Gen.
Piping - general requirements	DEP 31 38.01.11-Gen.
SIOP Piping classes	DEP 31.38.01.12-Gen.
EP Piping classes	DEP 31.38.01.15-Gen.
Acoustic insulation for piping	DEP 31.46.00.31-Gen.
Instrumentation of depressuring systems	DEP 32.45.10.10-Gen.
Classification and implementation of instrumented protective functions	DEP 32.80.10.10-Gen.
Factory inspection and testing of instruments and instrument systems	DEP 62.10.09.11-Gen.
Spare Parts	DEP 70.10.90.11-Gen.
Valves in low temperature or cryogenic service	MESC 77/200
Valves in vacuum service	MESC 77/201
Valves in steam service	MESC 77/202
Valves in hydrogen service	MESC 77/203
Valves in hydrofluoric (HF) acid service	MESC 77/204
Valves in oxygen and ethylene oxide service	MESC 77/205
Valves in chlorine service	MESC 77/206
Valves and Accessories	MESC 77/101
Material acceptance requirements for valves (general service)	MESC 77/302
Material acceptance requirements for valves (special service)	MESC 77/303
Inspection, testing and certification of valves (general service)	MESC 77/304
Inspection, testing and certification of valves (special service)	MESC 77/305
Acceptance test for valves, low	MESC 77/306

temperature/cryogenic service	
Acceptance test for valves in high vacuum service	MESC 77/307
Acceptance test for valves in hydrogen service	MESC 77/308

AMERICAN STANDARDS

Pipe flanges and flanged fittings, NPS $^1/_2$ through NPS 24	ASME/ANSI B16.5
Valves - flanged, threaded and welded end	ASME/ANSI B16.34
Large diameter steel flanges NPS 26 through NPS 60	ASME/ANSI B16.47

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BRITISH STANDARDS

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Specification for butterfly valves	BS 5155
Specification for steel plug valves	BS 5353

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Germany.

INTERNATIONAL STANDARDS

Degrees of protection provided by enclosures (IP code)		IEC 529
Industrial process control valves:		
Part 1:	Control valve terminology and general considerations.	IEC 534-1
Part 2:	Flow capacity:	
	Section 1 - Sizing equations for incompressible fluid flow under installed conditions	IEC 534-2-1
	Section 2 - Flow capacity, sizing equations for compressible fluid flow under installed conditions	IEC 534-2-2
	Section 3 - Test procedures	IEC 534-2-3
Part 3:	Dimensions	
	Section 1 - Face-to-face dimensions for flanged, two-way, globe-type control valves	IEC 534-3-1
	Section 2 -Face-to-face dimensions for flangeless control valves except wafer butterfly valves	IEC 534-3-2
Part 4:	Inspection and routine testing	IEC 534-4
Part 5:	Marking	IEC 534-5
Part 8:	Noise Considerations	
	Section 1 - Laboratory measurement of noise generated by aerodynamic flow through control valves	IEC-534-8-1
	Section 2 - Laboratory measurement of noise generated by hydrodynamic flow through control valves	IEC 534-8-2
	Section 3 - Control valve aerodynamic noise prediction method	IEC 534-8-3
	Section 4 - Control valve hydrodynamic noise prediction method	IEC 534-8-4

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CH 1211 Geneva 20
Switzerland.

Copies can also be obtained from national standards organisations.

APPENDIX 1 SIZING OF CONTROL VALVES

1. INTRODUCTION

1.1 GENERAL

Sizing of control valves shall be in accordance with IEC 534-2-1 and IEC 534-2-2

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 which 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 is a situation in which, for either compressible or incompressible fluids with fixed inlet conditions, decreasing downstream pressure fails to produce further increases in flow rate at a constant valve opening.

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 drop across the control valve at a certain relative travel to the pressure drop across the control valve in its fully closed position.

Design condition is the set of process conditions under which the total plant or part of the plant is calculated, main equipment is ordered, etc.

NOTE: During a plant start-up or shutdown situation, conditions other than design condition may exist.

Flashing occurs, for liquids only, when the pressure in the valve body falls below the liquid's vapour pressure. The bubbles thus formed remain as vapour in the fluid, owing to the fact that the downstream pressure of the control valve is below the liquid's vapour pressure.

Flow coefficient is the flow capacity of a control valve, commonly expressed by the C_v factor or K_v factor.

* The $\mathbf{C_V}$ of a control valve is defined as the quantity of water, at 60 °F, in US gallons per minute, that will flow through the valve at a specified travel with a pressure drop of 1 psi.
* The $\mathbf{K_V}$ of a control valve is defined as the quantity of water in m^3/h, at a temperature between 5 and 40 °C, that will 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 type of mixtures, such as with solids, etc., are not considered.

Incompressible fluid is a liquid or it is a gas whose density change within the system is less than 10%.

Inherent equal percentage characteristic	of a control valve is a characteristic whereby equal increments of relative travel yield equal percentage changes of the relative flow coefficient.
Inherent linear characteristic	of a control 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.

2. CONTROL VALVE SIZING

2.1 SIZING CRITERIA

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

Unless otherwise specified, the following should apply:

- the valve shall be sized for 10% more than the maximum operating flow rate in order to allow control at this flow rate, i.e.:

$$Q_+ = 1.10\ Q_d$$

- the flow rate through a fully open control valve shall be equal to or greater than the maximum required flow rate, i.e.:

$$Q_o \geq Q_+$$

- in order to avoid excessive loop gain variations (larger than 2), the control valve authority at design conditions should not be less than 0.23, which results in:

$$Q_s \geq 1.15\ Q_d$$

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 which 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_+).

The effect on system behaviour of the selected C_v value shall be verified, e.g. with respect to overfiring of heaters, etc.

For critical design situations, the tolerance of quoted C_v values shall be taken into consideration.

NOTE: A reduced trim shall be selected if flashing is predicted.

3. CONSIDERATIONS

3.1 GENERAL

In addition to the calculation of the C_v value of a control valve, the following items shall also be taken into account:

- selection of the control valve characteristic;
- piping geometry around the control valve;
- requirements with respect to noise;

- presence of fluid mixtures;
- presence of flashing or cavitation;
- presence of a choked flow.

3.2 CONTROL VALVE CHARACTERISTIC

Two main valve characteristics are commonly taken: the linear and the equal percentage.

Selection of the control valve characteristic shall be based on **design** conditions.

The preferred method for the selection of the control valve characteristic (see note 2) is not always practical, in which case the following method should be used:

1. Choose an equal percentage characteristic if the pressure drop available for the valve is $\leq$ 70% of the pressure drop across the whole system, i.e. if the control valve authority $\gamma_d \leq 0.7$.
2. Choose a linear characteristic if the pressure drop available for the valve is > 70% of the pressure drop across the whole system, i.e. if the control valve authority $\gamma_d > 0.7$.
3. For certain critical applications, the Principal may require an additional restriction upstream of the control valve in order to decrease the control valve authority γ_d to below 0.5 (see note 2).

In any of the following cases, the control valve shall have a linear characteristic:

- level control in gravity service;
- compressor anti-surge control;
- split range control (see note 3);
- where, for increasing the rangeability, two control valves are used in parallel;
- control valves that are only operated via a manual control station;
- minimum flow protection for pumps.

NOTES:

1. 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.

2. The preferred approach for selecting the valve characteristic is 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 an additional frictional pressure drop (e.g. a restriction plate) upstream of the control valve

3. If the split range function is in the DCS or other remote electronic system, the control valve may have an equal percentage characteristic.

4. The inherent characteristic of a control valve may be achieved by the cam of the positioner or by characterising in the positioner.

5. The inherent characteristic of a control valve may be modified to suit the dynamic behaviour of the process.

3.3 PIPE GEOMETRY AROUND THE CONTROL VALVE

The geometry of the surrounding piping shall be taken into consideration for the C_v value calculation.

If reducers and/or expanders are present in the surrounding piping, the piping geometry factor will affect the control valve's C_v factor.

3.4 CONTROL VALVE NOISE

Control valve noise predictions shall be in accordance with IEC 534-8-3 and IEC 534-8-4.

3.5 FLUID MIXTURE

3.5.1 Liquids or gases

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):

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

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 AND FLASHING

Cavitation should be avoided since it limits the valve capacity, generates noise and will physically damage the control valve.

A control valve with a higher characteristic pressure ratio factor shall be selected if cavitation is predicted (see note*).

If cavitation is predicted and cannot be avoided by control valve selection, the following remedial actions, indicated in order of preference, shall be considered:

- check the system upstream of the control valve (e.g. rationalise the pump head);
- relocate the control valve in the system to a higher inlet pressure or to a lower inlet temperature;
- select a different flow direction through the control valve (see note*);
- install a restriction orifice directly downstream of the control valve, provided that flow rate variations are small (see note*);
- install a valve with a special anti-cavitation trim (see note*);
- install two (or more) control valves in series (see note*).

Liquids which are **flashing** have the same starting phenomena as those which are cavitating but develop differently as the pressure drop across the valve increases, especially mixtures of liquids with different vapour pressures.

Control valves shall be selected so that flashing will not occur (because this would have a negative impact on the control valve capacity).

In situations where flashing in the control valve is unavoidable, the control valve body size should be equal to the line size, but with a reduced trim. If necessary, a hardened body

material shall be selected (see note*).

* NOTE: The control valve Manufacturer shall be consulted.

3.7 CHOKED FLOW

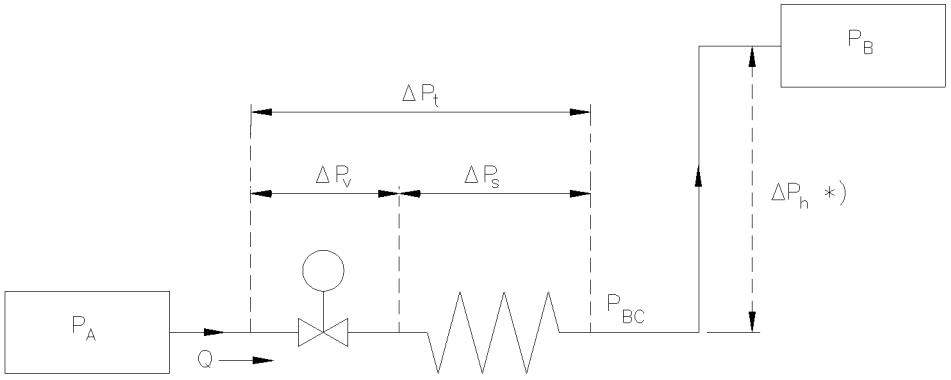
Choked flow shall be avoided since it will physically damage the control valve.

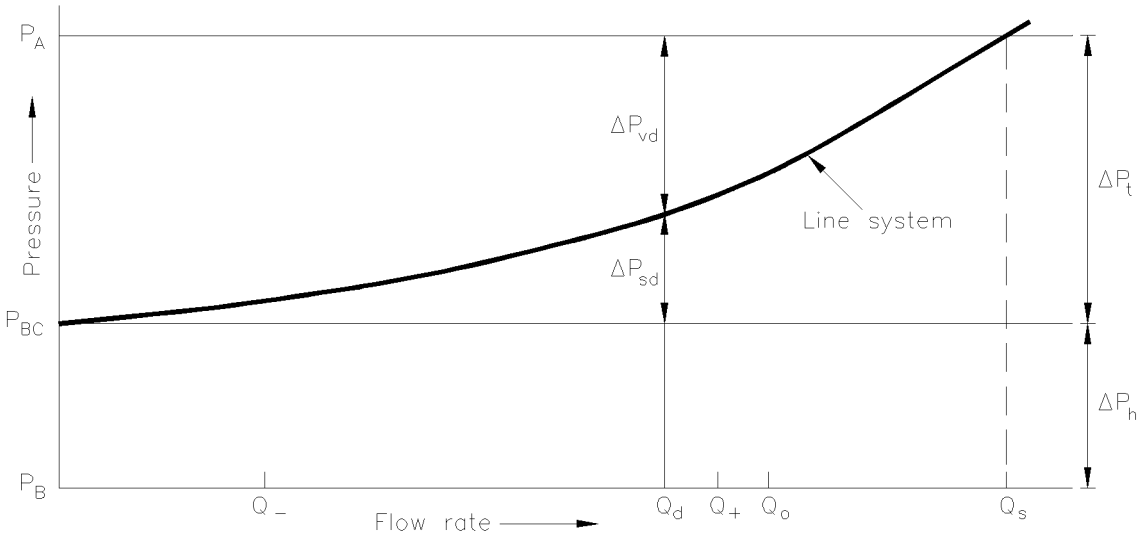
If a choked flow is predicted, a different control valve shall be selected as follows:

- for compressible fluids, select a higher gas ratio factor (consult control valve Manufacturer);
- for incompressible fluids, select a higher liquid recovery factor (consult control valve Manufacturer).

For compressible services, the control valve outlet and the direct downstream piping shall be checked for velocities. High fluid velocity will occur under choked flow and has a detrimental effect (e.g. erosion) on the life of a control valve.

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



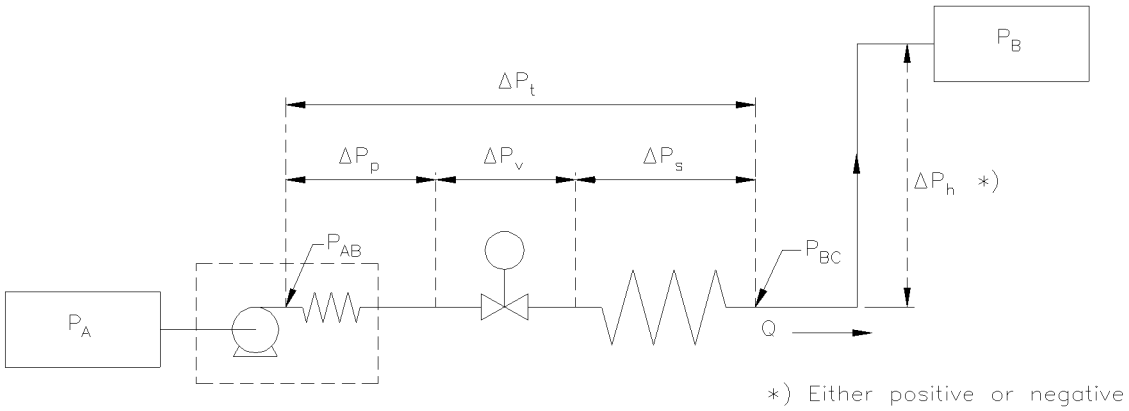


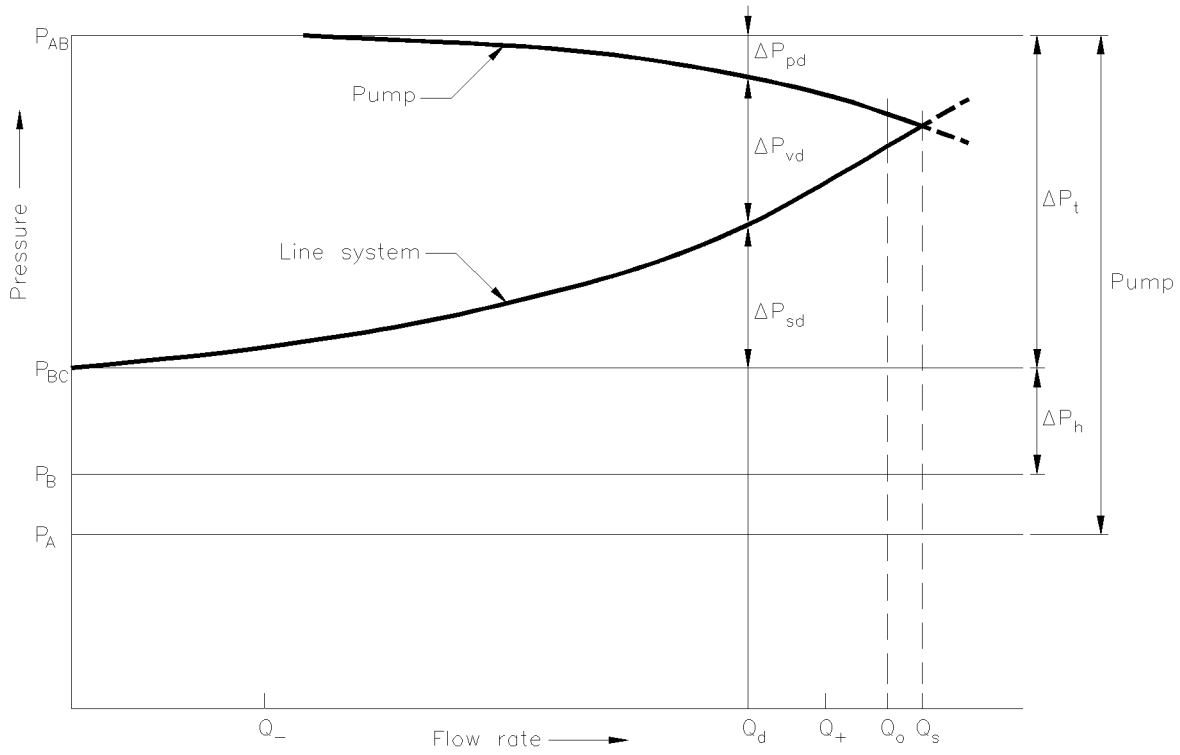
Symbols and subscripts:

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_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 2 PROCUREMENT ASPECTS

1. INTRODUCTION

1.1 GENERAL

This Appendix describes a recommended process of procurement of control valves. It was instituted as a result of a Shell cost reduction Initiative and developed in a collaborative effort with selected Vendors and an Engineering Contractor. The process described is valid for purchasing valves both in the CAPEX and OPEX phase of the plant life cycle.

The resultant process and delivered product provides the opportunity for savings in the enquiry and engineering phase and optimises the use of standard products and the Manufacturer's order management and manufacturing processes.

2. CONSIDERATIONS

The following principles should be considered in the design, engineering and procurement of control valves:

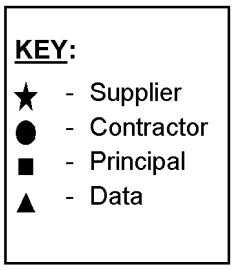
- An integrated Engineering Contractor and Manufacturer process that eliminates duplication of effort and utilises the best available practice to engineer the product.
- The control valve Manufacturer shall be selected at the earliest possible point in the engineering process.
- Through a pre-selection process, the traditional enquiry and quotation process can be eliminated.
- Manufacturers' standard products shall be used as far as possible provided they meet the process requirements.
- Special products will follow the same engineering process as standard products but may require more detailed and unique specifications. The engineering process between the engineering Contractor and the valve Manufacturer will endeavour to design out special products through careful review of the process design consideration.
- Manufacturers' standard paint specifications will be used as applicable for the environment.
- Standard Manufacturers' documentation will be used as much as possible, which includes product drawing, material certification, test certification, quality plans, specification sheets, calculation sheets and instruction manuals. Electronic data exchange between the contractor and Supplier should be maximised.
- The Manufacturer's product engineering and database tools should be used as the project control valve sizing and selection mechanism.
- A Manufacturer's engineer should be available in the engineering Contractor's project team to facilitate a closer working relationship and closer management of product delivery to the plant build programme.
- Control valves should be released to manufacture as late as possible in the schedule and with all the process data frozen to eliminate change orders.
- Self-expediting and proactive reporting shall be the responsibility of the Manufacturer.
- Product inspection shall be the responsibility of the Manufacturer and witnessing shall be restricted to special cases only.

3. PROCESS DIAGRAM

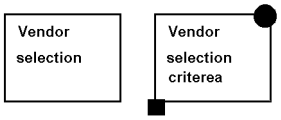
This section and the associated diagrammatic representation describe the best practices in the selection, design, engineering and delivery of control valves in a project. The division of activity between the Contractor and the Manufacturer are defined and depicted on the process diagram (Figure 3) by the use of symbols.

3.1 PROCESS DESCRIPTION

Guidelines and Explanatory Notes to the Working Process. The following is a description of the activity in each process box of Figure 3.

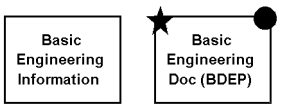


Vendor selection



The Principal and/or the Contractor select the control valve vendor, preferably in the basic engineering phase of a project. Criteria for selection shall be based on the specific project requirements and on quantity.

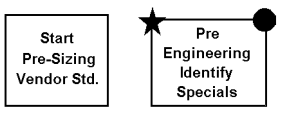
Basic Engineering requirements



Contractor collects and distributes to the valve Manufacturer the basic engineering documents, which include:

- Basic Design and Engineering Practice (BDEP)
- PEFS (Process Engineering Flow Schemes)
- Piping Specification
- Instrument Engineering Database

Pre-Engineering - Identification of Specials



Contractor and Manufacturer jointly study the basic documents to identify control valves outside the Manufacturer's "standard" product range. Where possible, corrective measures will be suggested to turn 'specials' into standard valves. This may require revisions to process data or design criteria.

Control valves which remain ‘special’ will be requisitioned separately according to the traditional route as the delivery time may be longer and test and inspection requirements more detailed.

NOTE: The Control valve sizing and selection software used during the basic engineering phase shall be aligned between the Contractor and Manufacturer.

Process and Mechanical Data Frozen

Based on the overall project plan, the latest starting date for the detailed engineering, procurement and manufacturing of the control valves is determined.

Certified process and mechanical data will then normally be available at the start of control valve engineering, whilst most of the changes caused by PEFS reviews, HAZOP studies and information of packaged units should be incorporated at this stage.

NOTE: It is advisable to allow some flexibility in the lead time for control valve engineering and manufacturing to accommodate control valves which may become ‘special’ at a later stage, and to allow for unexpected late changes and resolution of errors.

At this stage, regular review meetings are held between the Contractor and the Manufacturer.

In the period prior to the commencement of control valve engineering, the Contractor shall continue to ensure that new "specials" are identified. For this reason the control valve database shall be kept as up-to-date as possible. It is also recommended that regular review meetings be held between Contractor and the Manufacturer.

Pre-Sizing Confirmed

Apart from incorporating all frozen process and mechanical data, confirmation of pre-sizing will ensure that the Contractor and the Manufacturer have jointly checked for irregularities, noise, cavitation problems, trim characteristics, valve authority and gain.

Outline Specification

The Contractor will prepare a temporary document containing the calculation printouts together with information, per tag number, about basic materials, air failure action and (standard) accessories.

The process condition, (including composition) shall be shown on the calculation sheet. The outline specification will be issued to the Manufacturer directly, with no copy to the Principal.

At this point, if the Contractor is not utilising the Manufacturer’s sizing software, the database will be transferred to the Manufacturer. From this point onwards, the Manufacturer takes the responsibility for sizing and for maintaining the database. Ideally there should be a joint database with protected fields for each party, together with a system to implement changes in a controlled manner.

Sizing and Selection

The Manufacturer will execute the final sizing and selection of control valves utilising his own software which links to his manufacturing system.

These control valves shall be selected from the Manufacturer's "standard" product range on the basis of optimum maintenance and performance criteria.

Possible new "specials" identified at this stage shall be discussed with the Contractor for resolution. It is expected that the number remaining as "specials" at this stage will be relatively low.

It should also be realised that requirements such as additional certificates, drawings and external inspection make control valves "special" as they lie outside the commercial agreement.

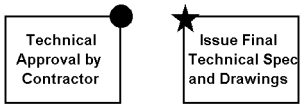
Calculations, technical specifications and dimensional drawings shall be issued by the Manufacturer to Contractor along with a priced equipment list that conforms to the overall commercial agreement.

Review of Technical Specification

The Contractor will review the calculations of the Manufacturer and check the specifications of the selected control valves.

This may result in requests to the Manufacturer for modification and re-issue of the documents. Also, control valve selection should be optimised (technically and commercially) in close liaison with the Principal.

Technical Approval by Contractor



Upon approval by the Contractor, the Manufacturer shall submit his final commercial bid together with the final technical specifications, calculations and drawings.

Commercial Approval and Commercial Check by Principal

Check of the bid against the pre-agreed commercial agreement.

Freeze Scope / Release for Manufacturing

Upon commercial approval by the Principal, the scope of work is frozen and the control valve specification is released for manufacturing by loading the engineering database into the in-house ordering system of the Manufacturer.

Scope of work frozen means that no more changes can be accepted without possible consequences for on-time delivery at site.

Requisition for Purchase

To formalise the purchase order and enable the distribution of information, the purchase requisition will be issued. This requisition consists of the Manufacturer's final specification sheets with the Principal or Contractor's cover sheets on top.

Manufacturing Period / Project Management

From the in-house order entry system at the Manufacturer's sales office, the data is loaded into the manufacturing auto write-up system at the factory.

On major projects, as there will be no expediting or vendor document control, regular progress meetings should be held between the Contractor and the Manufacturer. During these meetings problems and possible changes and the impact thereof should be discussed. The Manufacturer has the responsibility to alert the Contractor and/or Principal to any possible slippage of delivery schedule.

Therefore, the Manufacturer's project manager shall be an integral part of the Contractor's project team. There will be regular consultation regarding the project schedule and valve delivery programme to ensure that they are in synchronisation.

Test, Inspection and Certification

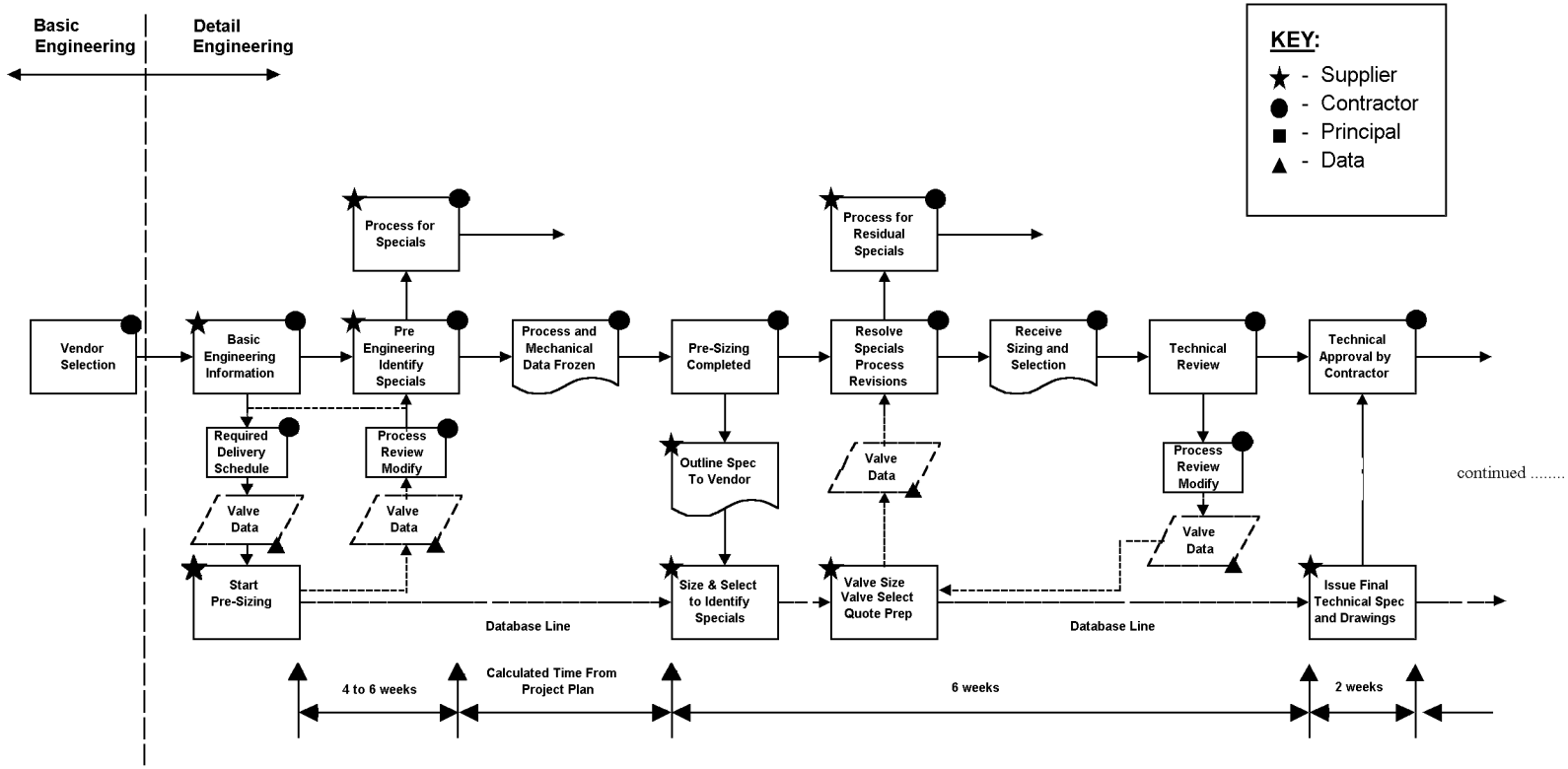
The Manufacturer will provide self-inspection of the products and provide linkage into the overall Contractor's inspection plan.

Only in exceptional cases will external witnessing of tests and inspection take place. See Section 13 for details of checks and acceptance criteria.

Certificates and documentation will be supplied according to the commercial agreements. The Manufacturer's standard documents will be used.

After inspection delivery will be directly to the site, or to the Contractor's warehouse, if the site is not ready to receive the equipment.

Figure 3 Process chart showing data flow



Note: Lead-times shown are typical for a 50 valve order

Figure 3 Process chart showing data flow (.... continued)