

CONTROL VALVES**JGS 210-120-1-60E**

Rev. 1 DATE JUL.-31-'96

CONTENTS**PAGE**

1. SCOPE.....	3
2. WORK PROCEDURE.....	3
2.1 Data Preparation.....	3
2.1.1 Source of Process Conditions.....	3
2.1.2 Data for Valve Sizing.....	3
2.2 Products of Basic Design.....	4
2.3 Work Steps.....	4
2.4 Computer Programs.....	4
3. DESIGN.....	5
3.1 General.....	5
3.2 Control Valve Design Data.....	5
3.2.1 Flow Rate.....	5
3.2.2 Pressure Drop of Control Valve.....	5
3.2.3 Fail-Safe Action.....	6
3.2.4 Seat Leakage.....	7
3.2.5 Maximum Shut-off Pressure.....	7
3.2.6 Shut-off Speed.....	8
3.3 Noise and Vibration.....	8
3.4 Control Valve Manifolds.....	8
3.4.1 Block and Bypass Valves.....	8
3.4.2 Piping without Block and Bypass Valves.....	9
3.4.3 Vent and Drain Valves and Steam Traps.....	10
3.5 Accessories.....	10
3.6 Miscellaneous.....	10
4. RELATED DOCUMENTS.....	11
5. DEFINITIONS.....	12
6. ABBREVIATIONS.....	13
7. REFERENCES.....	14
BIBLIOGRAPHY.....	14
LITERATURE.....	14

APPENDIX-1 FLOW CHARACTERISTICS	15
A1.1 Inherent Flow Characteristics.....	15
A1.2 Installed Flow Characteristics.....	17
A1.3 Selection Guide for Flow Characteristics.....	17
APPENDIX-2 TYPE OF CONTROL VALVES	18
APPENDIX-3 ESTIMATION OF CONTROL VALVE SIZE	20
A3.1 Calculation of Flow Coefficient, Cv.....	20
A3.1.1 Critical Flow Factor.....	20
A3.1.2 Liquid Service.....	20
A3.1.3 Gas and Steam Service with Conventional Valve.....	22
A3.2 Valve Size Selection.....	22
APPENDIX-4 NOISE ESTIMATION	24
A4.1 General.....	24
A4.2 Aerodynamic Noise.....	24
A4.3 Hydrodynamic Noise.....	25
APPENDIX-5 TYPE OF ACTUATORS	27

1. SCOPE

- (1) This standard practice provides the guidelines for the preparation of basic design information concerning control valves in refineries, petrochemical plants and similar plants.
Selection and sizing method of control valves given in Appendixes are only for reference, to outline the method.
- (2) Specific instructions given in the Project Specifications take precedence over requirements given in this standard practice.

2. WORK PROCEDURE**2.1 Data Preparation****2.1.1 Source of Process Conditions**

The data to be used for the preparation of the control valve data sheets should be clarified on the following points :

- (1) Source of data

The data will be obtained from, but not limited to, the following documents:

- Process Flow Diagram (PFD)
- Basic Engineering Design Data (BEDD)
- Piping & Instrument Diagram (P&ID)
- Equipment data sheets
- Hydraulic calculation sheets
- Piping material specification
- Line index

- (2) Related documents to be used as a part of the input data
- (3) Related documents to be checked or revised based on the design results of control valves

2.1.2 Data for Valve Sizing

The following is a summary of data to be prepared for the control valve sizing :

- (1) General data

- Tag number for identification
- Service for identification

- (2) Operating conditions

- Fluid name
- Flow rate - normal or maximum
- Flow rate - minimum, if any
- Inlet pressure at normal or maximum flow rate
- Pressure drop across valve at normal or maximum flow rate
- Operating temperature
- Physical properties at inlet conditions for single phase flow or at inlet and outlet conditions for flashing flow

Liquid service : Specific gravity, Vapor pressure, Critical pressure

Vapor service : Molecular weight, Specific heat ratio (k), Compressibility factor (Z)

Viscosity, when larger than 50 cs.

- % flash, if applicable
- % solid, if applicable

- (3) Construction data
 - Design pressure
 - Design temperature
 - Fail-safe position
 - Required seat tightness, if specifically required
 - Maximum shut-off pressure
 - Line size, inlet and outlet
 - Line class, inlet and outlet
- (4) Note regarding sizing
 - Maximum Cv-selected to limit the flow rate, if specifically required
 - Requirement of minimum stopper
 - Other process requirement, if any

2.2 Products of Basic Design

The products of basic design will include, but not limited to, the following.

- (1) Data sheets, containing data listed in 2.1.2 above.
- (2) The following data shall be determined and prepared on P&ID ;
 - fail-safe action of the control valve
 - accessories on the control valve such as hand wheel, limit switch, solenoid valves, etc.
 - necessity of block valves
 - necessity of bypass valve
 - necessity, location and size of drain valve
- (3) The following data shall be shown on P&ID, if they are available at the basic design stage;
 - size and type of control valve
 - size of block valves
 - size of bypass valve
 - size of connecting fittings
 - special requirement such as tight shut-off, etc.

2.3 Work Steps

The preparation of control valve design data will be done as follows.

- (1) Hydraulic calculation in accordance with JGS 210-120-1-37E "Hydraulic Design".
- (2) Prepare data sheets of control valves.
- (3) Check the critical items for size, Cv value, and noise; and specify any requirements of the basic design.
- (4) Evaluate piping design around control valve as stated in 2.2(2) above.
- (5) Sizing will be done by other parties.
- (6) Add the sizing data around the control valves on P&ID, if sizes of control valve are available during the basic design stage.

2.4 Computer Programs

Computer program is available as a part of the computer system, BEST, working on PC.

3. DESIGN**3.1 General**

- (1) The pressure drop across the control valves and the basis of flow rate will be determined in accordance with JGS 210-120-1-37E "Hydraulic Design".
- (2) Preparation of P&ID will be described in JGS 210-120-1-71E "Design Criteria for P&ID Preparation".

3.2 Control Valve Design Data**3.2.1 Flow Rate**

- (1) Flow rate and pressure drop to be provided on the data sheets shall be consistent with each other. The data at the normal flow condition or maximum flow condition shall at least be provided. Data at the minimum flow rate condition is optional where specially required by contract document.
- (2) For 3-way control valve in heat exchange service
Flow to the exchanger side shall be the maximum flow with zero flow to the bypass side, or vice versa. All normal, exchanger-max., and bypass-max. conditions shall be provided on the data sheets.
- (3) For 3-way control valve in mixing or divergency service
All possible conditions, normal and each side's maximum, shall be provided on the data sheets.
- (4) For alternate operating conditions such as start-up or shut-down
When critical operation of the control valve is expected, such conditions shall be examined and clearly provided in the data sheets.

3.2.2 Pressure Drop of Control Valve

The pressure drop of the control valve at the normal flow rate should be determined as follows.

- (1) Liquid pumping service

$$\Delta P_{CV} \geq k_f \sum \Delta P_{fric} \quad (1)$$

Where :

ΔP_{CV} = control valve pressure drop at normal flow rate (kgf/cm²)

ΔP_{fric} = friction losses at normal flow rate (kgf/cm²)

: 0.5 $\sum \Delta P_{fric} \geq 5 \text{ kg / cm}^2$

: 0.4 $5 \text{ kg/cm}^2 < \sum \Delta P_{fric} < 10 \text{ kg / cm}^2$

: 0.4 $\sum \Delta P_{fric} \geq 10 \geq \text{kg / cm}^2$

- (2) Vapor centrifugal compressor service

$$\Delta P_{CV} \geq 0.5 \sum P_{fric} \text{ and } 5\% \text{ of suction absolute pressure.}$$

- (3) Other general services

$$\Delta P_{CV} = \Delta P_{total} - \sum \Delta P_{fric} - \Delta P_{eq} \quad (2)$$

Where :

ΔP_{CV} = control valve pressure drop (kgf/cm²)

ΔP_{fric} = friction losses (kgf/cm²)

ΔP_{total} = upstream pressure - downstream pressure (kgf/cm²)

ΔP_{eq} = equipment pressure drop (kgf/cm²)

(4) Minimum pressure drop of the control valve

The control valve pressure drop should be greater than, but not limited to, the following:

Liquid service (Pump discharge) $\Delta P_{cv} = 0.5 \sim 1.0 \text{ kg/cm}^2$ (0.7 kg/cm² Recommended)

General vapor service $\Delta P_{cv} = 0.1 \sim 0.35 \text{ kg/cm}^2$ (0.2 kg/cm² Recommended)

Control valves in some special services may require smaller pressure drops than the above, depending on the system pressure, rangeability, available pressure difference, and so on. Engineer should carefully evaluate the control valve pressure drop.

(5) Static pressure fluctuations

In the case where large fluctuations in the static pressure are expected, sufficient pressure drop of the control valve should be considered to absorb the fluctuation and to reduce the detrimental effects of external disturbances.

3.2.3 Fail-Safe Action

(1) Fail-safe control valve action (fail-open "FO", fail-close "FC", or locking in the last position "FL" on the loss of supply air or signal failure) shall be considered from proper plant design viewpoint.

(2) The fail-safe characteristics shall be decided so that the failure action may cause the plant to move into safe condition.

(3) The fail-safe characteristics shall be decided so that the failure conditions will minimize to affect to other plant. Also, it is necessary to eliminate the possibility of disposal of toxic, flammable, or extremely cold/hot fluids.

(4) Typical fail-safe characteristics

(a) Temperature

The fail-safe action shall be considered to prevent the increase of temperature; however, rapid cooling of fired heater or subcooling of fluids below their freezing or pour point shall be avoided. Typical applications are ;

- Fuel to fired heaters	Fail-Close
- Heat source to reboilers	Fail-Close
- Cryogenic cooling medium	Fail-Close
- Reflux to tower top	Fail-Open
- Cooling water to coolers/condensers	Fail-Open
- Process fluid to fired heater	Fail-Open
- 3-way temperature control	Close bypass for valves provided in cooling service Open bypass for valves provided in heating service

(b) Pressure

The fail-safe action shall be considered to block-in the system. Typical applications are ;

- Control valve discharged to low pressure	Fail-Close
- Control valve connected to flare	Fail-Close (sometimes clients requests Fail-Open)
- Minimum flow bypass	Fail-Open
- Spill-back or kick-back	Fail-Open

(c) Material balance (liquid level or flow)

The fail-safe action shall be considered to block-in the system. Typical applications are ;

- Feed to the system	Fail-Close
- Product to other system	Fail-Close

3.2.4 Seat Leakage

(1) Seat leakage specification and classes are described in ANSI/FCI 70-2 as follows.

Table-1 Leakage class

Leakage Class	Maximum Seat Leakage (Note)	Description
Class I	No test is required.	A modification of any Class II, III or IV valve where design intent is the same as the basic class, but by agreement between user and supplier, no test is required.
Class II	0.5% of rated valve capacity	This class establishes the maximum permissible leakage generally associated with commercial double-port, double-seat control valves or balanced single-port control valves with a piston ring seal and metal-to-metal seats.
Class III	0.1% of rated valve capacity	This class establishes the maximum permissible leakage generally associated with Class II, but with a higher degree of seat and seal tightness.
Class IV	0.01% of rated valve capacity	This class establishes the maximum permissible leakage generally associated with commercial unbalanced single-port, single-seat control valves and balanced single-port control valves with extra tight piston rings or other sealing means and metal-to-metal seats.
Class V	5×10^{-12} m ³ / sec-water / mm-orifice diameter / bar-differential	This class is usually specified for critical applications where the control valve may be required to be closed, without a blocking valve, for long periods of time with high differential pressure across the seating surfaces. This class is generally associated with metal seat, unbalanced single-port, single seat control valves or balanced single port designs with exceptional seat and seal tightness.
Class VI	Bubble-tight, as per specified in FCI 70-2	This class establishes the maximum permissible seat leakage generally associated with resilient seating control valves either unbalanced or balanced single port with "O" rings or similar gap-less seals.

(Note) This standard does not apply to control valves with a rated Cv less than 0.1.

Leakage specification for Class VI is detailed further in ANSI/FCI 70-2.

- (2) Seat leakage class should be specified on the data sheets, if specifically required. Leave the data sheet blank, if any leakage requirement is not specified.
- (3) Leakage class in some specific services should be specified as follows.
 - (a) Class IV (0.01%)
 - Larger control valve of parallel (large and small) control valves installation
 - (b) Tight shut-off, to be specified on the data sheets for following services:
 - Control valves on discharge lines to flare or to blow-down system
 - Control valves used for shut-off services as well.

3.2.5 Maximum Shut-off Pressure

(1) The maximum shut-off pressure for actuator sizing should basically be as follows :

$$\Delta P_{\text{shut}} = P_{\text{up}}^* - P_{\text{down}}^* \quad (5)$$

Where :

$$\begin{aligned} \Delta P_{\text{shut}} &= \text{Maximum shut-off pressure for actuator sizing} && (\text{kg/cm}^2) \\ P_{\text{up}}^* &= \text{Design pressure of upstream line} && (\text{kg/cm}^2\text{G}) \\ P_{\text{down}}^* &= \text{Atmospheric pressure (Except for vacuum services)} && (0.0 \text{ kg/cm}^2\text{G}) \\ P_{\text{down}}^* &= \text{Full Vacuum (for vacuum services)} && (-1.0 \text{ kg/cm}^2\text{G}) \end{aligned}$$

When the valves are provided in the closed loop circuit, such as closed hot oil system, the shut-off pressure is not likely to exceed the pump shut-off head even if the system pressure is elevated by external source of pressure.

The shut-off pressure, that may be developed under the normal operating, start-up or shut-down conditions, shall be evaluated carefully in each individual cases.

- (2) Refer also to JGS 210-120-1-18E "Determination of Design Conditions" and JGS 210-120-1-37E "Hydraulics".

3.2.6 Shut-off Speed

- (1) The shut-off speed requirement of the control valves shall be evaluated, considering the requirements on process control. The results shall be specified on the data sheets, as required.
- (2) Standard shut-off speed is 10 seconds for valve of sizes 4 inch and smaller, or 15 seconds for valve of sizes 6 inch and larger.
- (3) For anti-surge control valve for centrifugal compressor, the shut-off speed should be 5 seconds or shorter (2 to 8 seconds depending on the operational requirements). The requirement shall be accepted by the compressor and anti-surge controller vendors to ensure the design safety.
- (4) For shut-off service in long liquid pipelines, the shut-off speed requirements shall be evaluated to prevent pressure surging (2 to 15 minutes depending on the line length).

3.3 Noise and Vibration

- (1) When the pressure drop across control valve is significantly high, check that the high noise and/or vibration will not occur in downstream piping. The general prediction method of noise from the control valves is provided in Appendix-4.
- (2) Final noise level calculations of the control valve shall be carried out by the valve vendor.
- (3) The requirement of noise level limitation shall be described in Project Specifications.
- (4) When specific noise level limitation is not required in Project Specification, assume that the limitation to be equal to or lower than 85dB(A).

3.4 Control Valve Manifolds**3.4.1 Block and Bypass Valves**

In case where block and bypass valves are installed, the following criteria will be applied, unless otherwise specified in the Project Specifications.

- (1) Bypass valves in sizes of 6 inches or smaller shall be globe valves to allow throttling. For larger sizes, gate valves are to be used. Block valves shall be gate valves for all sizes.
- (2) The bypass valve shall have a capacity equal to the Cv-required of the control valve as minimum, but not greater than twice the Cv-selected.

The values of Cv for manually operated globe and gate valves may be assumed as follows if other source of data is not available.

Table-2 Values of Cv for globe and gate valves [KITS catalogue]

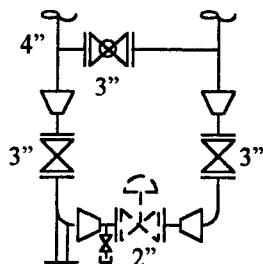
Valve size (inches)	½	¾	1	1½	2	3	4	6	8	10	12
Globe valve	(3)	(6)	(12)	33	51	121	189	442	(793)		
Gate valve								(2800)	5320	8590	12600

- (3) Block valves shall be one size larger than the control valve, but not exceeding line size. However, with Clients agreement, block valve size can be selected as the same size as the control valve size from economical viewpoint.

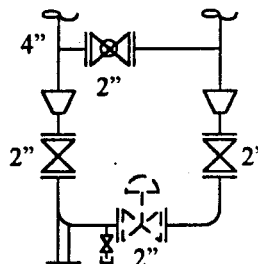
- (4) The size of bypass valve may be as same as the size of control valve from economical viewpoint with client's agreement.

Fig. 3.4.1 The cost comparison of control valve and bypass valve arrangement

Case-1



Case-2



Case-2 is about 20% cut off compared with Case-1.

- (5) Recommended minimum sizes for block and bypass valves are given in Table-3 below.

Table-3 Block and bypass valve size [API RP 550 Table 3-1]

Control Valve Size (inches)	Type of Valve	Line Size (inches)										
		½	¾	1	1½	2	3	4	6	8	10	12
½	Block	½	¾	1	1½							
	Bypass											
¾	Block		¾	1	1½	2						
	Bypass											
1	Block			1	1½	2	2					
	Bypass											
1½	Block				1½	2	2	3				
	Bypass											
2	Block					2	3	3	4			
	Bypass											
3	Block						3	4	4	6		
	Bypass											
4	Block							4	6	6	8	
	Bypass											
6	Block								6	8	8	10
	Bypass											
8	Block									8	10	10
	Bypass											
10	Block										10	12
	Bypass											
12	Block											12
	Bypass											

- (6) For flashing service or gas expansion service where the control valve outlet piping may become larger than the inlet piping size, the block valve of downstream of the control valve should be equal to or one size smaller than the downstream piping size.