Refinery Valves and Accessories for Control and Safety Instrumented Systems

API RECOMMENDED PRACTICE 553
SECOND EDITION, OCTOBER 2012

AMERICAN PETROLEUM INSTITUTE

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Downstream Segment

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Refinery Valves and Accessories for Control and Safety Instrumented Systems

1 Scope

1.1 This recommended practice (RP) addresses the special needs of automated valves in refinery services. The knowledge and experience of the industry has been captured to provide proven solutions to well-known problems.

1.2 This document provides recommended criteria for the selection, specification, and application of piston (i.e. double-acting and spring-return) and diaphragm-actuated (spring-return) control valves. Control valve design considerations are outlined such as valve selection, material selection, flow characteristic evaluation, and valve accessories. It also discusses control valve sizing, fugitive emissions, and consideration of the effects of flashing, cavitation, and noise.

1.3 Recommendations for emergency block and vent valves, on/off valves intended for safety instrumented systems, and special design valves for refinery services, such as Fluid Catalytic Cracking Unit (FCCU) slide valves and vapor depressurizing systems, are also included in this recommended practice.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Publication 2218, *Fireproofing Practices in Petroleum and Petrochemical Processing Plants*

API Recommended Practice 521, *Guide for Pressure-Relieving and Depressurizing Systems*

API Recommended Practice 556, *Instrumentation, Control and Protective Systems for Gas Fired Heaters*

API Standard 598, *Valve Inspection and Testing*

API Specification 6FA, *Specification for Fire Test for Valves*

API Standard 607, *Fire Test for Soft-Seated Quarter-Turn Valves*

API Standard 608, *Metal Ball Valves – Flanged, Threaded and Butt Welding Ends*

API Standard 609, *Butterfly Valves: Double Flanged, Lug-and Wafer-Type*

ANSI, B16.34 [1], *Valves—Flanges, Threaded, and Welded End*

ANSI 70, *National Electrical Code*

ANSI/FCI70-2 [2]*, Quality Control Standard for Control Valve Seat Leakage*

ASME *Boiler and Pressure Vessel Code* [3]*, Section VIII, Div. 1, International Society for Measurement and Control Standard S75 Series of Control Valve Standard*s

[1] American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.
[2] ANSI/Fluid Controls Institute, Inc., 1300 Sumner Avenue, Cleveland, Ohio, 44115, www.fluidcontrolsinstitute.org.
[3] ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

ASME *Boiler and Pressure Vessel Code, Part U-1, Section VIII, Division 1 (3.2.6.4)*

EPA, US Code Title 42 Chapter 85 [4], *National Emission Standard for Hazardous Air Pollutants (NESHAP)*

IEC 60534-2-1 [5]*, Flow Capacity – Sizing Equations for Fluid Flow Under Installed Conditions*

IEC 61511, *Functional Safety – Safety Instrumented Systems for the Process Industry Sector Parts 1-4*

ISA Control Valve Standard 75.01.01 [6], *Flow Equations for Sizing Control Valves*

ISA Control Valve Standard 75.02, *Control Valve Capacity Test*

ISA Control Valve Standard 75.17, *Control Valve Aerodynamic Noise Prediction*

ISA Control Valve Standard 75.08.01, *Face to Face Dimensions for Integral Flanged Globe Style Control Valve Bodies (Classes 125, 150, 250, 300, and 600)*

ISA Control Valve Standard 75.08.02, *Face to Face Dimensions for Flangeless Control Valves (Classes 150, 300, and 600)*

ISA Control Valve Standard 75.08.06, *Face to Face Dimensions for Flanged Globe Style Control Valve Bodies (Classes 900, 1500, and 2500)*

ISA Control Valve Standard 75.08.07, *Face to Face Dimensions for Separable Flanged Globe Style Control Valves (Classes 150, 300, and 600)*

ISA Control Valve Standard 75.25.01, *Test Procedure for Control Valve Response Measurement from Step Inputs*

MSS SP-25 [7]*, Standard Marking System for Valves, Fittings, Flanges, and Unions*

NACE Standard MR0103 [8]*, Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

NACE Publication 34103, *Overview of Sulfidic Corrosion in Petroleum Refining*

NACE Standard RP0170, *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During Shutdown of Refinery Equipment*

NACE Standard MR0175, *Petroleum and Natural Gas Industries - Materials for Use in H_2S-containing Environments in Oil and Gas Production – Parts 1, 2, and 3*

NACE RP0472, *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*

OSHA 1910.95 [9], *Occupational Noise Exposure*

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4 U.S. Environmental Protection Agency, Ariel Rios Building, 1200 Pennsylvania Avenue, Washington, DC 20460, www.epa.gov.
5 International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211, Geneva 20, Switzerland, www.iec.ch.
6 International Society of Automation, 67 Alexander Drive, Research Triangle Park, North Carolina, 22709, www.isa.org.
7 Manufacturers Standardization Society of the Valve and Fittings Industry, Inc., 127 Park Street, NE, Vienna, Virginia 22180-4602, www.mss-hq.com.
8 NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.
9 U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, D.C. 20210, www.osha.gov.

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1
actuator
A pneumatic, hydraulic, or electrically powered device used to supply force and motion to open or close a valve.

3.2
bonnet
That portion of the valve that contains the packing box and stem seal. It also can guide the stem. It provides the principle opening to the body cavity for assembly of internal parts.

3.3
cavitation
Is a two-stage continuous phenomenon, the first stage of which is formation of vapor bubbles within the liquid state due to the pressure at the vena contracta being equal to or below the liquid's vapor pressure. The second stage is the collapse or implosion of these bubbles back into the all liquid state as the pressure recovers at the outlet (see Figure 9 for illustration).

3.4
choked flow
Is a condition at constant inlet pressure for which no increase in flow rate is achieved for a decrease in downstream pressure.

3.5
control valve signature
Is a test that measures the position of an actuator (or actuator valve opening) against an input to the valve, such as an actuator pressure or control signal. From this information, a graphical representation (i.e. signature) is produced that depicts valve performance. Some valve performance characteristics that can be determined from a valve signature test could include, but are not limited to, valve friction, actuator torque, dead band and shutoff capability as well as actuator spring rate and bench set. Valve signatures are usually performed when a valve is new to get an initial benchmark of a valve's performance out of the factory. However, valve signatures are not limited to the factory environment. They can also be performed in the field as a predictive tool in assessing whether a valve has performance issues, possibly requiring it to be rebuilt during a unit turnaround.

3.6
dead band
The range an input signal can be varied without initiating an observable change in the output signal. Dead band is the name given to a general phenomenon that can apply to any device.

3.7
dead time
The time interval in which no response of the system is detected following a small (usually 0.25 % to 5 %) step input.

3.8
dynamic time
A measure of how long the actuator takes to get to the T63 (63 %) point once it starts moving.

3.9
emergency block valves
EBVs
Emergency block valves are designed to control a hazardous incident. These are valves for emergency isolation and are designed to stop the uncontrolled release of flammable or toxic materials. These valves should be fire-safe, if they

are within the fire zone. The valves may be referred to as type A, B, C, and D. Refer to their individual definitions within this section.

3.10
equal percentage
An inherent flow characteristic that, for equal increments of rated travel, will ideally give equal percentage changes of the flow coefficient (C_v).

3.11
fail-closed
A condition where-in the valve closure member moves to a closed position when the actuating energy source (air or signal) fails or is lost.

3.12
fail-open
A condition where-in the valve closure member moves to a open position when the actuating energy source (air or signal) fails or is lost.

3.13
fail-safe
A characteristic of a valve and its actuator which upon a loss of actuating energy supply (air or signal) will cause a valve to move to be fully closed, fully open, or remain in its last position, whichever position is defined as necessary to protect the process.

3.14
fire zone
This is an area which is unsafe to enter during an emergency situation. The area is considered to be within a 7.6 m (25 ft) radius minimum surrounding the leak source.

3.15
flammable materials
Low flash liquids [flash point below 38 °C (100 °F)] and high flash liquids [flash point 38 °C (100 °F) or higher] when handled at temperatures above or within 8 °C (46 °F) of their flash points.

3.16
flashing
Is a similar concept to Cavitation, except pressure recovery at the valve outlet remains equal to or below the vapor pressure (see Figure 9 for illustration).

3.17
flow characteristic
Relationship between flow through the valve and percent rated travel as the latter is varied from 0 % to 100 %.

3.18
flow coefficient
C_v
A constant (C_v) related to the geometry of a valve, for a given travel, that can be used to establish flow capacity. It is the number of US gallons per minute of 15 °C (60 °F) water that will flow through a valve with a one pound per square inch pressure drop.

3.19
friction
A force that tends to oppose the relative motion between two surfaces that are in contact with each other.

3.20
globe valve
A valve with linear or rotary motion closure member, one or more ports, and a body distinguished by a globular shaped cavity around the port region. Globe valves can be further classified as: two-way single-ported; two-way double-ported; angle-style; three-way; unbalanced and balanced.

3.21
hysteresis
During a calibration cycle, the maximum difference in output value for any single input value, excluding errors due to dead band.

3.22
inherent characteristic
The relationship between the flow coefficient and the closure member (e.g. plug, ball or disk) as it is moved from the closed position to rated travel with constant pressure drop across the valve. Typically these characteristics are plotted on a curve where the horizontal axis is labeled in percent travel and the vertical axis is labeled as percent flow (or C_v). Because valve flow is a function of both the valve travel and the pressure drop across the valve, conducting flow characteristic tests at a constant pressure drop provides a systematic way of comparing one valve characteristic design to another. Typical valve characteristics conducted in this manner are named Linear, Equal-Percentage, and Quick Opening.

3.23
linear characteristic
An inherent flow characteristic that can be represented by a straight line on a rectangular plot of flow coefficient (C_v) versus rated travel.

3.24
noise
Unwanted sound that takes two forms, Aerodynamic (conversion of mechanical energy of flow into acoustic energy as fluid passes through valve) and Hydrodynamic (energy caused by cavitation and flashing of a liquid fluid as it passes through valve).

3.25
packing box
A sealing system consisting of deformable material contained in a gland that usually has an adjustable compression means to obtain or maintain an effective seal. Commonly used to seal against leakage to outside the valve body during valve disk or stem movements.

3.26
partial stroke testing
PST
Is a technique used in a safety instrumented system to allow the user to test a percentage of the possible failure modes of a valve without the need to physically close the valve all the way.

3.27
positioner
A controller (servomechanism) that is mechanically connected to a moving part of a final control element or its actuator and that automatically adjusts its output to the actuator to maintain a desired position in proportion to the input signal.

3.28
process variability
A precise statistical measure of how tightly the process is being controlled about the set point. Process variability is defined in percent as typically ($2\sigma/m$), where σ the standard deviation of the process variable and m is the set point or mean value of the measured process variable.

3.29
quick opening characteristic
An inherent flow characteristic in which a maximum flow coefficient (C_v) is achieved with minimal valve travel.

3.30
rangeability
The ratio of the largest flow coefficient (C_v) to the smallest flow coefficient (C_v) for a given valve type.

3.31
rotary control valve
A valve style that uses a flow closure member (full ball, partial ball, disk, or plug) rotating in the flow stream to control the capacity of the valve.

3.32
safety critical service
A system composed of sensors, a logic solver, and final control elements for the purpose of taking the process to a safe state when predetermined process conditions are exceeded.

3.33
safety instrumented function
SIF
An action with a specified safety integrity level, and whose purpose is to provide a certain amount of safety risk reduction.

3.34
safety integrity level
SIL
Are categories based on the probability of failure on demand (PFD) of a Safety Instrumented Function. There are four levels of Safety Integrity, SIL 1, SIL 2, SIL 3, and SIL 4. Refer to IEC61511 for further details.

3.35
safety instrumented system
SIS
A system composed of sensors, a logic solver, and final control elements for the purpose of taking the process to a safe state when predetermined process conditions are exceeded.

3.36
seat
The area of contact between the closure member and its mating surface that establishes valve shut-off.

3.37
seat leakage
In the fully closed position the quantity of fluid passing through a valve with pressure differential and temperature.

3.38
servo
A control system which is used to convert a small mechanical motion into one that requires much greater power.

3.39
severe service
Process conditions that result in cavitation, flashing, highly cyclic operations, erosive conditions, and/or high differential pressure.

3.40
T63
The time measured from initiation of the input signal change to when the output reaches 63 % of the corresponding change. It includes both the valve assembly dead time, which is a static time, and the dynamic time of the valve assembly.

3.41
toxic material
A liquid or vapor that can cause damage to humans and for which an exposure limit [either Material Threshold Limit Valve (TLV) or Occupational Exposure Limit (OEL)] has been established by a relevant regulatory agency (e.g. the US EPA). These substances may cause significant negative impact (e.g. severe inflammation, shock, collapse, or even sudden death) if humans are exposed to sufficiently high concentrations for a sufficiently long period of time. Some examples include but are not limited to: Benzene, Xylene, Butadiene, Chlorine, Ammonia, Hydrogen Sulfide, and Hydrogen Fluoride.

3.42
trim
The internal components of a valve exposed and in contact with the line medium, usually consisting of but not limited to the seat ring, valve stem, valve plug, ball or disk, guide bushing, and cage.

3.43
Type A EBV
A manually operated fire-safe block valve installed at the equipment. This type of valve is installed when ignition is not expected in the event of a leak.

3.44
Type B EBV
This fire-safe block valve should be installed at a minimum of 7.6 m (25 ft) from the leak source when ignition is expected. The Type B valve is manually operated and is limited to sizes up to and including DN 200 (8 in.), and pressure classes through ANSI CL300. For reasons of access, the valve should be accessible from ground, or if ground access is not practical, then the valve should be accessible via a platform installed no higher than 4.6 m (15 ft) above grade.

3.45
Type C EBV
The Type C valve is a power-operated Type B valve. The valve should be power-operated if larger than DN 200 (8 in.) or if a pressure class higher than ANSI CL300 is needed. The valve should be installed outside the fire zone a minimum of 7.6 m (25 ft) from the leak source and no higher than 4.6 m (15 ft) above grade. Controls are accessible from the valve location.

3.46
Type D EBV
This is an EBV with remote controls. There is no restriction as to where the valve may be located, but the controls should be a minimum of 12 m (40 ft) from the leak source and should be out of the fire zone. An EBV installed at an elevation greater than 4.6 m (15 ft) above grade will also come under this category. Both the actuator and that portion of the control cable and tubing which is in the fire zone should be fireproofed or designed to operate without failure during fire conditions. Specify that the conduit/tubing/cable supports are required to be fireproofed.

3.47
valve response time
A time usually measured by a parameter that includes both dead time and time constant. (See definitions for T63, and Dead Time.) When applied to the valve, it includes the entire valve assembly.

3.48
vena contracta
Is a point downstream of the flow restriction where the flow stream reaches its minimum cross-sectional area and thus its maximum velocity and minimum pressure (see Figure 9 for illustration).

3.49
vessel
Any drum, column, tower, or reactor associated with the processing or handling of hydrocarbon in a refinery.

3.50
volume booster
A stand-alone relay used as a volume booster or simply booster to boost or amplify, the volume of air supplied to the actuator.

3.51
voting
A system that uses redundancy (at least “m” of the “n” channels or devices) to be in agreement before a SIS takes an action (e.g. 1oo1, 2oo2, or 2oo3 voting).

4 Control Valves

4.1 General

A control valve, as shown in Figure 1, consists of two major subassemblies: a valve body, and an actuator. The valve body is the portion that actually contains the process fluid. It consists of a body, internal trim, bonnet, and sometimes a bottom flange and/or bonnet flange. This subassembly should meet all of the applicable pressure, temperature, and corrosion requirements of the user's design specifications.

The actuator assembly moves the control valve in response to an actuating signal from an automatic (i.e. Basic Process Control System) or manual device (i.e. handwheel). It should develop adequate thrust to overcome the forces within the body subassembly and at the same time be responsive enough to position the valve plug accurately during changing process demands.

4.2 Valve Body

4.2.1 Valve Body—General

4.2.1.1 Process design conditions dictate the ASME pressure classification and materials of construction for control valves, provided the standard offering meets or exceeds all piping and process control requirements. The valve end connections and pressure rating should, as a minimum, conform to the piping specification and ASME B16.34. The valve material should be suitable for the process design conditions.

4.2.1.2 Nickel alloy or stainless steel valve metallurgy should be specified for process design temperatures below –30 °C (–20 °F) with consideration for low temperature impact tested carbon steels. High pressure steam, flashing water applications, and boiler feed water service where differential pressures exceed 14 barg (200 psig) may require harder, chrome-molybdenum alloys. Sour service valve materials should meet the requirements of NACE MR0103. Corrosive and erosive components even in trace quantities may affect the metallurgical choice of the valve.

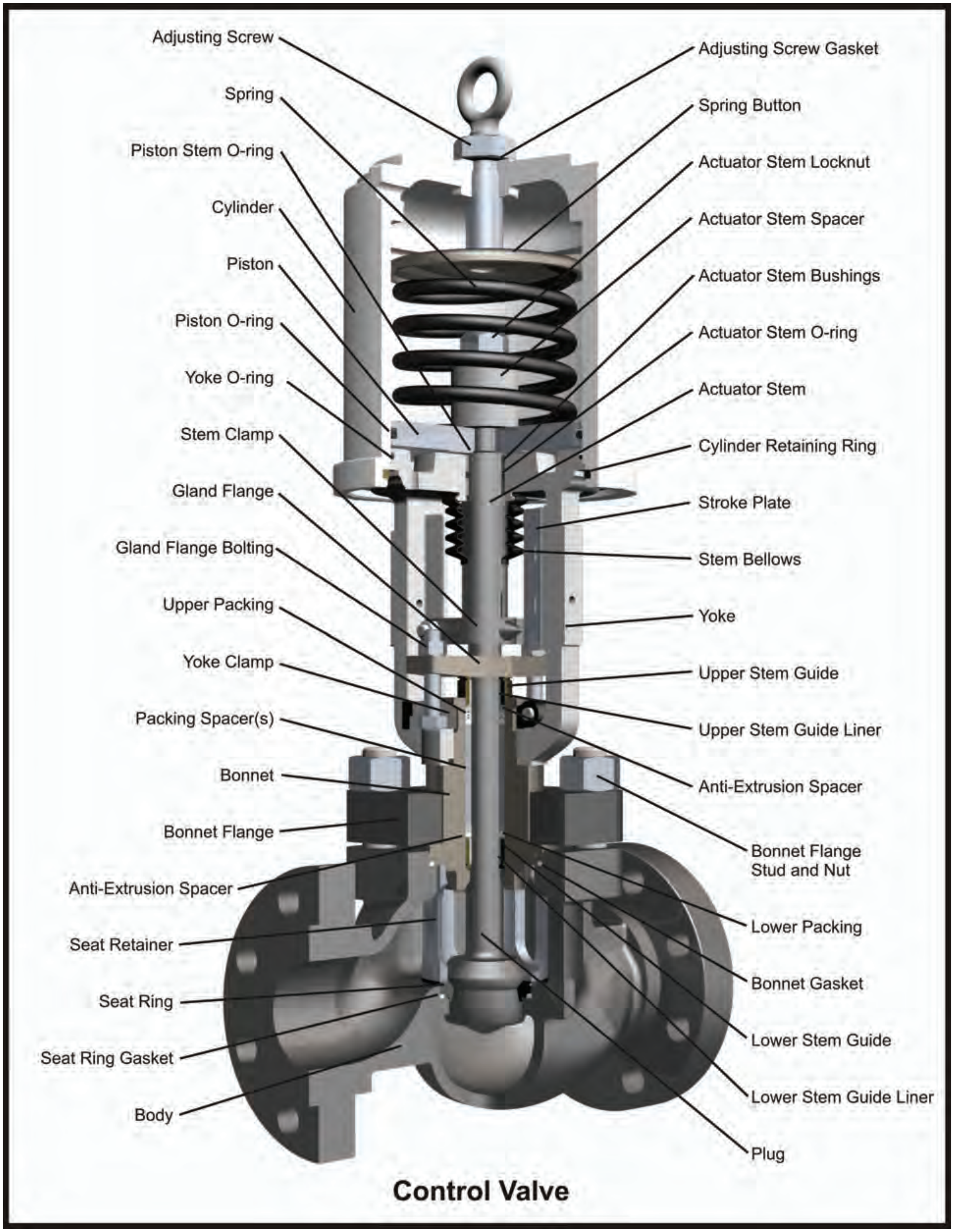


Figure 1—Typical Control Valve Components

4.2.1.3 Valve trim should be the manufacturer's standard where acceptable. Hardened trim could be required for corrosive, erosive, cavitating, or flashing service, and where valve differential pressure exceeds 14 barg (200 psig). If these conditions exist, consult the valve manufacturer for further guidance.

4.2.1.4 Flanges are the preferred end connection for globe-style valves; with butt-weld end connections acceptable for ASME CL900 and above. Threaded valves and valves with welded end connections are not recommended for hydrocarbon service and should be specified only with the end user's prior approval.

4.2.1.5 Flanged control valve bodies are available with either integral flanges (machined as part of the body casting or forging, or flanges welded to the body), or separable flanges (individual removable flanges that usually lock in place on the valve body by means of a two-piece retaining ring).

4.2.1.6 Flangeless valves have no flange connections as part of the valve body and are simply bolted or clamped between the adjoining line flanges. Flangeless valves should be avoided in hydrocarbon service, since their long bolts can expand when exposed to fire and cause leakage. The following limitations should apply to flangeless valves.

a) Flangeless valves should not be used where the process design temperature is above 315 °C (600 °F).

b) Flangeless valves should not be used where the process design temperature is below 315 °C (600 °F) and the service conditions meet the "dangerous" criteria defined below:

   1) toxic materials such as phenol, hydrogen sulfide, chlorine;

   2) highly corrosive materials such as acids, caustic, and similar materials;

   3) flammable materials (including hydrocarbons lighter than 68 °API);

   4) boiler feed water and steam, in systems requiring ANSI CL300 and higher flange ratings;

   5) oxygen in concentrations greater than 35 %.

c) For design temperatures above 205 °C (400 °F), body material should have the same nominal coefficient of thermal expansion as the line bolting material and adjacent flanges.

4.2.1.7 Flange finish describes the depth of the grooves in the surface part of a flange which is available for the sealing gasket. If a special finish is needed for gaskets, it should be specified with the valve. The typical standard is 125 to 250 RMS, which provides a good sealing surface for the gasket.

4.2.1.8 The installed face-to-face dimension of integral flange globe style valves should conform to ANSI/ISA 75.08.01. Face-to-face dimensions of flangeless control valves should conform to ANSI/ISA 75.08.02. Face-to-face dimensions of separable flanged globe style valves should conform to ANSI/ISA 75.08.07 or 75.08.01. Butterfly valves are covered by API 609. Caution should be used when installing flangeless valves so that they will not leak in hydrocarbon service under fire conditions.

4.2.1.9 The valve body size should be no less than two pipe sizes smaller than the line size or half the line size. Smaller valve sizes should be reviewed to make sure that line mechanical integrity is not violated.

4.2.1.10 Final valve sizing and selection should be reviewed by the valve manufacturer or their official representative.

4.2.1.11 Threaded seat rings should be avoided in highly corrosive environments because corrosion may make removal difficult.

4.2.1.12 Control valves in plugging services (e.g. liquid sulfur) should be steam jacketed where steam tracing would not provide enough heat to prevent plugging.

4.2.2 Bonnets

Bonnets should be bolted. Bolting material should comply with ASTM A193/194/320 and should be compatible with the valve body and bonnet. Before replacing any valve bonnet bolting, consult valve manufacturer for limitations and torque requirements.

Extended bonnets should be considered when process temperatures are below the freezing point of water 0 °C (32 °F) or above the temperature limits of the packing materials shown in 4.2.3. The control valve manufacturer should be consulted for guidelines on temperature limitations.

Bonnet gaskets should be fully retained spiral wound, with polytetrafluoroethylene (PTFE) or graphite filler. Flat gaskets made from PTFE sheet stock are acceptable where conditions permit. Insert reinforcements should be stainless steel or other appropriate alloy, as required.

Bonnets could be tapped for the addition of lubricators and steel isolating valves for all control valves with packing other than PTFE or graphite or for all control valves with extended stems in hot service.

4.2.3 Packing

Control valves use packing to help seal the area between where the valve stem exits the valve body and where it connects to the yoke of the valve actuator. Packing is used to reduce the emissions of volatile and harmful fluids to the atmosphere. Several packing materials and designs can be used depending on the process service conditions expected and whether the application must comply with specific environmental regulations. Below are design guidelines to consider.

a) Packing boxes should be easily accessible for periodic adjustment. The packing material should always be 1) elastic and easily deformable, 2) chemically inert, 3) able to withstand applicable process design conditions, and 4) minimize friction. Additionally, when there is an application need, the packing material may also be fire resistant and designed to meet a specific fugitive emission regulatory requirement. Valve manufacturer's packing temperature limits refer to the temperature at the packing box.

b) PTFE has excellent inertness, good lubricating properties, and is one of the most common valve packing materials. It may be used in solid molded, braided, or turned form (V-rings) or as a lubricant for asbestos-free packing. Its temperature limit with standard packing box construction is 230 °C (446 °F). If used to meet fugitive emissions, virgin PTFE should be alternated with carbon-filled PTFE or similar minimal cold-flowing material and live loaded.

c) Graphite laminated or preformed ring packing is chemically inert except when strong oxidizers are handled. This type of packing can be used for temperature applications approaching 540 °C (1000 °F). Increased friction is a concern when applying commercial grade graphite packing. Performance is often compromised because of significant increases in hysteresis and deadband. Packing systems with additives to reduce friction are available. Care should be exercised during actuator sizing.

d) Asbestos packing shall not be used.

e) Valve packing box arrangements should use anti-extrusion rings to minimize extrusion, which causes loss of packing material, and should use a minimum amount of packing to reduce effects of thermal expansion.

f) Valve stem should be retained in a centrally aligned position via a bushing system. Otherwise, the packing load may be excessive.

4.2.4 Fugitive Emissions

Federal Regulations (e.g. EPA's US Code Title 42 Chapter 85) and state/local requirements have established strict limits on emission to the atmosphere of certain hazardous substances and/or worker exposure requirements. These substances are volatile hazardous pollutants listed in the National Emission Standard for Hazardous Air Pollutants (NESHAP).

Increased emphasis on limiting packing leaks has resulted in the development of new packing materials and methods. Individual valve manufacturers are offering increasingly effective designs. See Figure 2 for an example of one of these newer designs. The control valve manufacturer should be consulted for all applications that must adhere to a fugitive emission regulatory requirement.

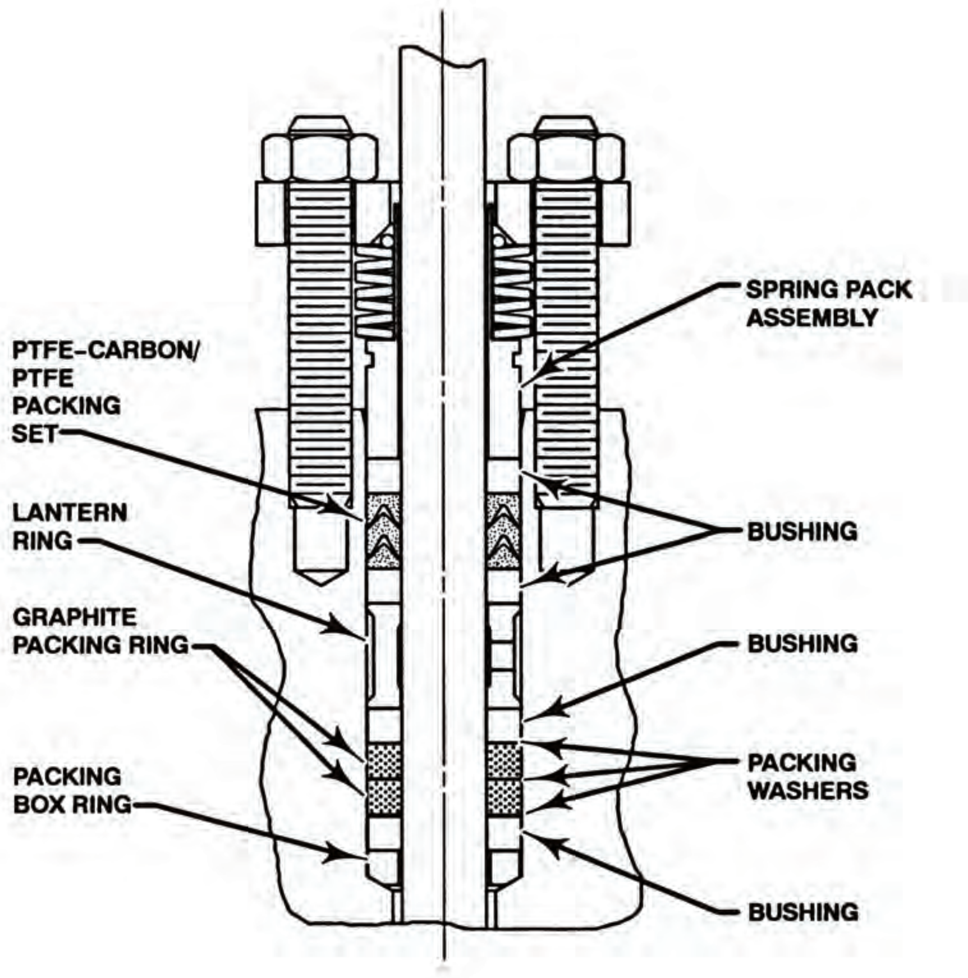


Figure 2—Typical Live-loaded Packing Arrangement

FFKM, perfluoroelastomer also has excellent inertness and good lubricating properties. It does not cold flow and therefore does not need live loading. It is available in V-rings. The temperature limit with standard packing box construction is 370 °C (700 °F).

Rotary valves, when suitable for the application, have a similar live load packing arrangement, and can provide excellent sealing for extended periods of time (300,000 cycles or more) with emissions remaining below 500 ppm. This is achievable because the shaft of a rotary valve does not move linearly across the seal, but rather rotates in place cross the seal.

4.2.5 Seat Leakage

As defined by ANSI B16.104 (FCI 70-2), seat leakage is the quantity of fluid passing through a valve when the valve is in its fully closed position at a specified process design pressure differential and temperature. Below are design guidelines to be aware of.

a) ANSI B16.104 (FCI 70-2) establishes a series of 6 seat leakage classes for control valves and defines their associated test procedures. Worst case process design conditions should be considered for control valve leakage class selection.

b) Metal-to-Metal seating with Class II leakage rating is expected for most process applications, especially for fluids containing abrasive particles or with design temperatures above 230 °C (450 °F). The control valve manufacturer should be consulted for guidance when better than Class II leakage is needed.

c) For tight shutoff applications, the leakage class should be at least Class V.

d) When better than Class V leakage is specified, composition (soft) seats may be considered as long as the valve seat materials can conform to the process design pressure and temperature, and the chemistry of the process. Composition seats are usually limited to process temperatures below 230 °C (450 °F) due to the fact that most elastomer materials begin to cold flow at this temperature. Steaming through a valve can damage or ruin a composition seat (see Figure 3) if the component pressure or temperature limitations are exceeded.

e) Double-ported valves and 3-way valves are limited to a Class II shutoff.

f) Single-seated unbalanced globe valves with metal-to-metal seating surfaces meet Class IV. Class V shutoff can be achieved by providing improved plug to seat ring concentricity or lapping seating surfaces and/or increasing actuator thrust. Resilient seats on single seated valves can provide Class VI shutoff.

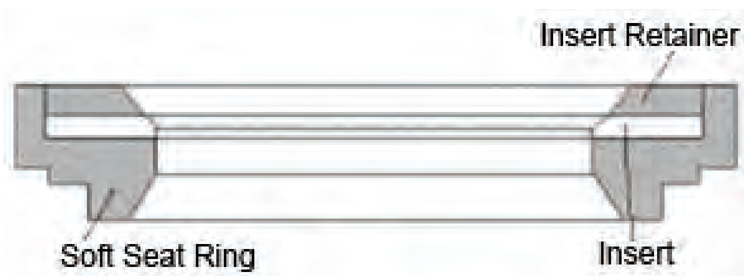


Figure 3—Resilient Seat

4.2.6 Control Valve Characteristics

A valve's trim is the heart of the valve and operates to give a specific relationship between flow capacity and the valve plug lift. This relationship is known as the valve flow characteristic and is achieved by different valve plug shape and/or cage designs.

a) Control valve flow characteristics are determined principally by the design of the valve trim. The three inherent characteristics available are quick opening, linear, and equal percentage, as shown in Figure 4 and Figure 5. A modified equal percentage characteristics generally falling between linear and equal percentage characteristics is sometimes available.

b) Positioners may use mechanical cams or be programmed to provide other desired characteristics.

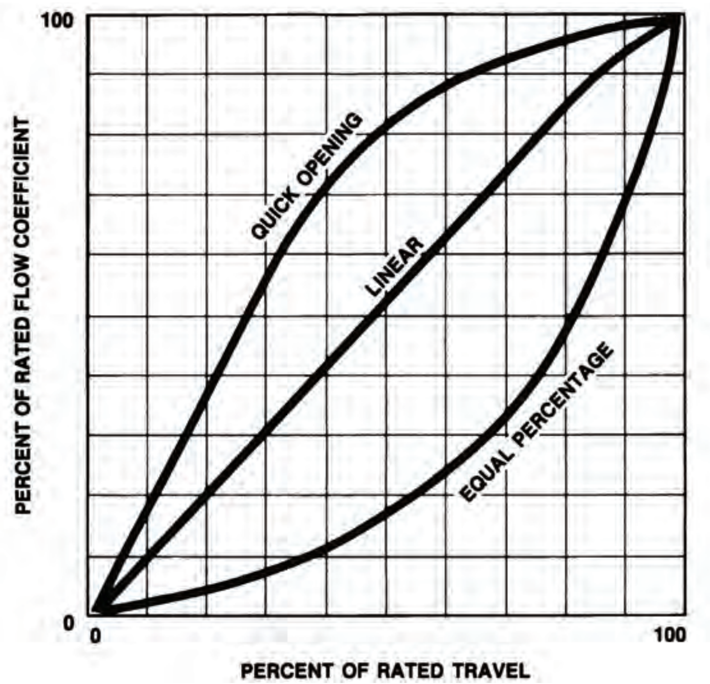


Figure 4—Inherent Valve Characteristics

Figure 5—Characterized Cages for Globe-style Valve Bodies

c) Installed characteristics often differ significantly from inherent characteristics if the pressure drop across the control valve varies with flow. As a result, equal percentage plugs are generally used for flow control applications because most of the “system pressure drop” is not across the control valve. Linear plugs are commonly used for applications where most of the “system pressure drop” occurs across the control valve.

d) Two-way control valves should be specified to have a equal percentage characteristic especially as noted below:

   1) gas compressor recycle control valves;

   2) valves in pressure-reducing service;

   3) valves in level control service.

An exception to the above, are two-way valves used in pairs as three-way valves. These should be specified with a linear characteristic.

4.2.7 Control Valve Types

Today's control valves operate by one of two primary motions: sliding stem motion (see Figure 6A) or rotary motion (see Figure 6B). The selection of a valve for a particular application is primarily a function of process requirements for control performance, pressure drop, temperature, and rangeability.

Loop dynamic performance should be considered when selecting control valves. Each type of control valve (sliding stem motion or rotary motion) has different performance characteristics. Theoretically, a loop has been tuned for optimum performance at some set point flow condition. As the flow varies about that set point, it is desirable to keep the installed process gain as constant as possible over the control valve operating range to maintain optimum performance. The ratio of the incremental change in valve flow (output) to the corresponding increment of valve travel (input) which caused the flow change is defined as the valve gain and impacts the process gain. If a valve is applied which results in the wrong valve gain for the application there is danger that the process gain might change enough to cause instability, limit cycling, or other dynamic difficulties.

To maintain acceptable dynamic process performance, the process gain should not vary more than a 4-to-1 ratio.

Process optimization requires a valve style and size be chosen that will keep the loop gain within acceptable limits over the operating range. Control range varies dramatically with valve style. The example case in Figure 7 shows different installed valve characteristics and valve gain behavior.

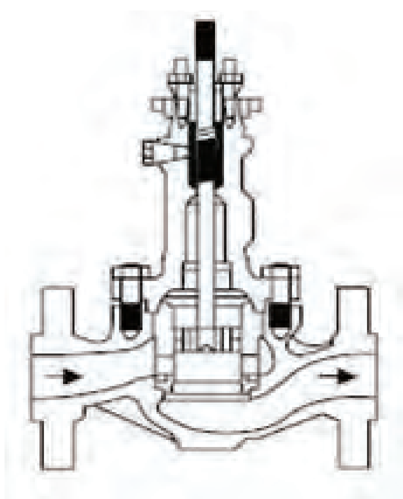


Figure 6A—Sliding Stem Motion Valve

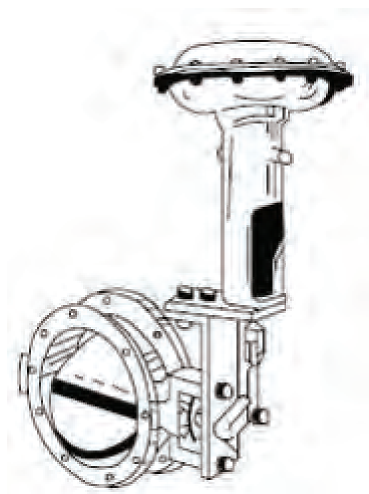


Figure 6B—Rotary Motion Valve

4.2.8 Sizing

This section discusses the methods for calculating flow through a control valve and for establishing the required capacity coefficient (C_V) for valve sizing purposes.

a) Control valve sizing and selection is the process of determining the correct valve size and style for a specific application. The fundamental flow equations used for this process are presented in the industry standards ISA 75.01.01, *Flow Equations for Sizing Control Valves*, and IEC 60534-2-1, *Flow Capacity – Sizing Equations for Fluid Flow Under Installed Conditions.* Per the associated test standards, ISA 75.02, *Control Valve Capacity Test*, the tolerance for control valve C_V testing is ±5 % at full opening; the tolerance for partial openings is not stated. Control valve data is typically based on water and air testing under ideal conditions for a limited set of sizes. The

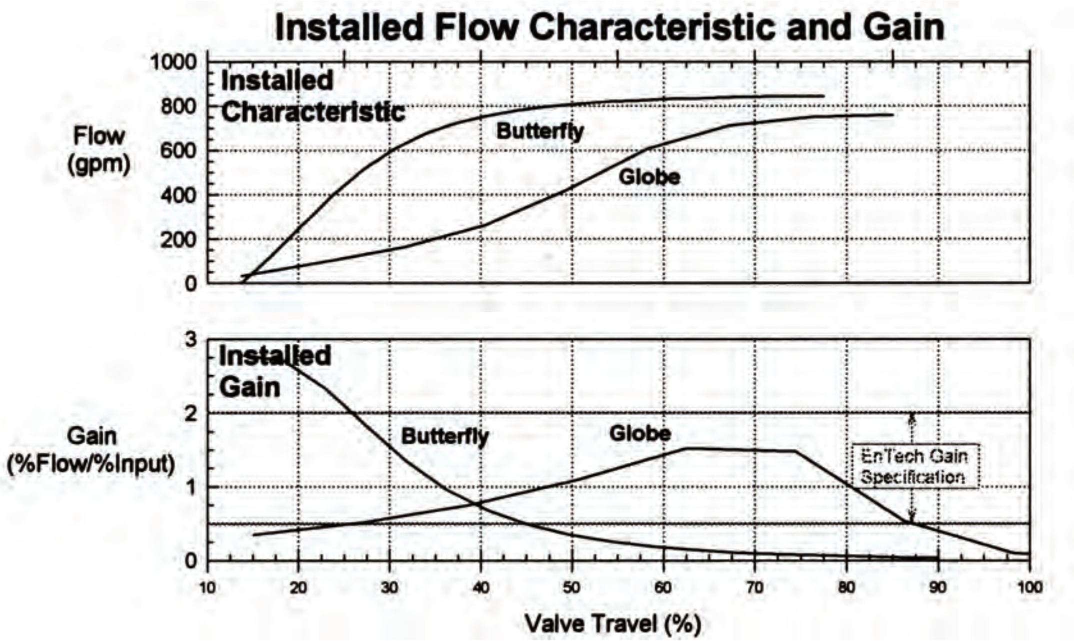


Figure 7—Effect of Valve Style on Control Range

calculations become less accurate for fluids and conditions significantly different from ideal, for very large or very small sizes, and for installed conditions significantly different from laboratory conditions.

b) The primary factors that should be known for accurate sizing are:

1) the fluid phase (gas, liquid, multiphase) and the density of the fluid (specific gravity, specific weight, molecular weight);

2) the valve inlet and outlet pressures at the flow rates being considered;

3) the temperature of the fluid;

4) cleanliness of fluid (entrained particule/catalyst);

5) the viscosity (liquids);

6) the vapor pressure and critical pressure (liquids);

7) specific heat ratio (gas);

8) the compressibility factor (gas);

9) flow rates required (maximum, normal, minimum);

10) pressure drop at shutoff;

11) maximum permissible noise level, if pertinent, and the measurement reference point;

12) inlet and outlet pipe size and schedule;

13) alternate process conditions including items like start-up, regeneration, or other modes of operation;

14) any significant temperature differentials the valve will see in case of an upset.

c) Control valve sizing should comply with the following criteria.

1) Control valve size should be selected so that at the maximum specified flow rate and corresponding pressure drop, the required travel should not be more than 90 % of full travel. In some cases travel up to 95 % may be desired, but this should be avoided, unless the process conditions present no alternatives.

2) Control valve size should be selected so that at the minimum specified flow rate and corresponding pressure drop, the required travel should not be less than 10 % to 20 % of full travel. Proposals to use control valves at lower travel should be reviewed and approved by Owner's engineer and the valve manufacturer.

3) Conventional butterfly valves should be sized for maximum angle opening of 60 degrees. Proposals to use angles greater than 60 degrees should be reviewed and approved by Owner's engineer and the valve manufacturer.

d) For heat exchanger service, conventional valves used in pairs (including rotary actuated valves such as ball or butterfly) are preferred over a single 3-way valve. Valves in heat exchanger service should be sized in accordance with the following:

1) For globe (and characterized type three-way) valves in three-way service, the exchanger valve (port) should be sized to pass the maximum design flow through the exchanger and zero flow through the bypass valve (port). The bypass valve (port) should be sized to pass the maximum design flow with zero flow through the exchanger valve (port) subject to the limitation that the bypass valve should be no smaller than one size below the exchanger valve.

2) Valves in heat exchanger service should be sized in accordance with the process design requirements. Although line size valves can generally be used, in some cases a more rigorous process/hydraulics study should be done to determine if a smaller bypass valve size is warranted due to pressure drop within the exchanger. The combination of valves will need to be able to handle the full process flow in all cases of full, partial and no bypass flow around the exchanger.

e) As part of valve selection, the overall system in which the valve is to be installed should be considered. A typical system (in addition to the control valves) includes a pump or compressor, that provides energy, and other types of refinery equipment, such as piping, exchangers, furnaces, and hand valves, that offer resistance to flow. Note that the differential pressure between the pump head curve and the system pressure drop curve is the amount of pressure available for the control valve. If no control valve was used, the flow would always be at the rate indicated by the intersection of the two curves (see Figure 8).

f) The presence of reducers upstream and/or downstream of the valve will usually result in a reduction in capacity because of the creation of an additional pressure drop in the system. Piping systems where both the inlet and outlet piping are larger than the valve will result in an increased valve C_V requirement. Capacity correction factors that can be applied to calculated C_V values are readily available from most manufacturers for the various styles of valves or estimated from the methods contained in ISA S75.01.01 or IEC 60534-2-1.

g) In any flow restriction, a portion of the pressure head of the incoming fluid is changed to velocity head, resulting in a reduction in static pressure at the vena contracta. Refer to Figure 9. As the fluid leaves the flow restriction and assumes downstream velocity, some portion of velocity head is recovered as pressure head. This process is termed pressure recovery. The degree of pressure recovery is dependent upon the internal geometry of the flow restriction. The vena contracta pressure may drop to the vapor pressure of the fluid. As the pressure recovers it may stay at the vapor pressure (flashing) or it may recover above the vapor pressure (cavitation). Flashing and cavitation are indications of partial or full choked flow, which may affect sizing (see following discussions).

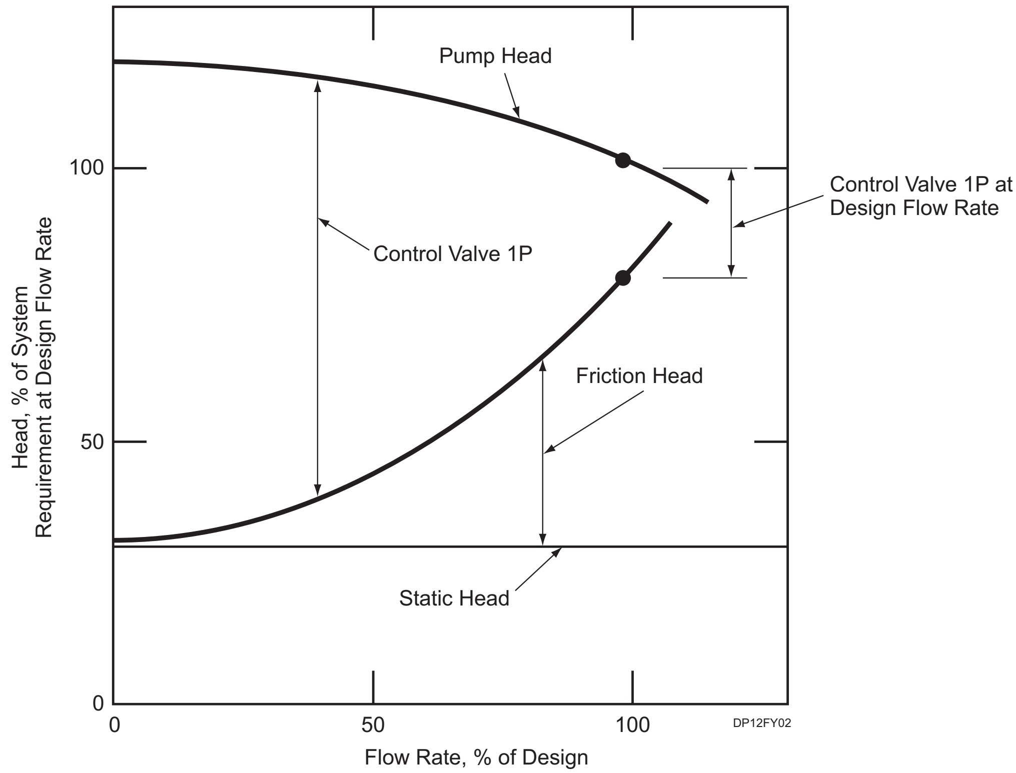


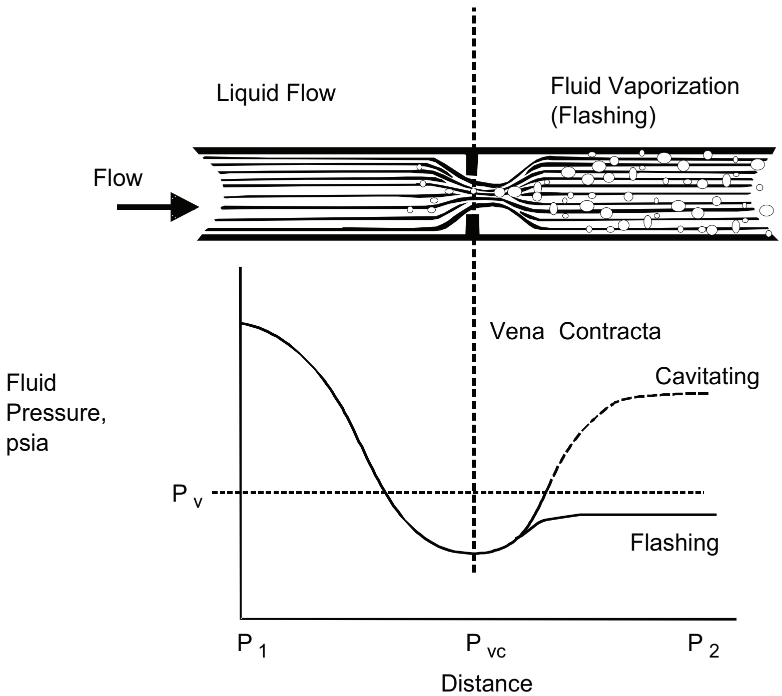
Figure 8—Typical System Head—Capacity Relationship

h) Choked volumetric flow occurs in gas or vapor service when the fluid velocity reaches the speed of sound at the vena contracta. Increasing the pressure drop (at constant inlet pressure) under a choked condition no longer increases the flow. This will affect the valve sizing by limiting the pressure drop available for sizing to the choked flow pressure drop value. Pressure recovery has the effect of achieving choked flow at a pressure drop that is less than would be predicted by the critical pressure ratio. This can become a problem for valves with high-pressure recovery, such as rotary valves. This necessitates the use of a larger valve or different valve style. Liquid flow can also experience choking when vaporization takes place and the resulting compressibility impacts the actual valve capacity.

i) Cavitation:

1) Cavitation is the generation of bubbles (vapor cavities) in the lowest pressure portion of the valve, and the subsequent collapse of these bubbles. See Figure 9. The bubble collapse (implosion) imparts a mechanical attack on the metal surfaces that can destroy a control valve in a short time. See Figure 10 and Figure 11. It is easily recognized by a characteristic sound described as “like rocks flowing through the valve.” High purity materials (single component) generally are the most likely to cause damage when cavitation takes place. Hydrocarbon mixtures with various vapor pressures for different components make it difficult to predict the onset or the severity of cavitation. Special cavitation control trims are offered by manufacturers that can reduce or prevent cavitation. Some of these trims are subject to plugging in dirty services and should be reviewed for suitability to each service.

2) Valves with low-pressure recovery should be used to minimize or prevent cavitation. In some cases it may be necessary to use special components, or stage the pressure reduction through specially design elements.



(Courtesy of Emerson Process Management)

Figure 9—Pressure-drop through a Restriction

(Courtesy of Flowserve)

Figure 10—Cavitation Damage to Valve Plug

(Courtesy of Flowserve)

Figure 11—Cavitation Damage to Seat Ring

j) Flashing:

1) Flashing occurs where the downstream pressure is at or below the vapor pressure of the fluid. See Figure 9 and Figure 12. Flashing, like cavitation, can cause physical damage and decreased flow capacity. Velocity is the major concern. The outlet flow increases velocity due to the fluid changing from a liquid to a gaseous state. A larger control valve body size with reduced trim and larger size outlet piping can be applied to prevent choking and excessive velocity problems. Other solutions to reduce or eliminate flashing damage are; hardened trim, flow down angle valves with sacrificial liner, and reverse flow rotary valve positioned for outlet to flow directly into a large volume (such as a tank), or sacrificial spool piece. Manufacturers should be consulted for recommendations.

2) Flashing damage is usually less severe than the damage from cavitation. However, restricted piping configurations at the valve outlet can cause the flashed vapor to cavitate and cause piping damage downstream of the control valve. Manufacturers should be consulted for recommendations.

k) Out-gassing:

1) Out-gassing appears to be identical to flashing from a macroscopic perspective; however, it is completely different in its composition and vapor generation process. Out-gassing flowing media consists of at least two separate, unique components of different molecular weights dissolved or entrained in a liquid continuum. The gas comes out of solution and becomes visible upon a reduction in static pressure. An everyday example of this is a carbonated beverage. The liquid in the sealed container has carbon dioxide gas that is entrained in it. Upon a slight depressurization, i.e. opening the container, the carbon dioxide will immediately come out of suspension, creating the familiar bubbles or fizz. Unlike flashing, out-gassing is not a thermal process in that absorption of heat is not required to generate the presence of the compressible component. In fact, out-gassing is a kinetic process like that of the carbonated beverage. A slight change in pressure is all that is needed to release the entrained gas.

Figure 12—Flashing Damage

2) Out-gassing cannot be sized in the same manner as you would size a flashing application. The potential existence of both a compressible (gas or vapor) element and non-compressible (liquid) element in the flowing media prior to the throttling orifice cannot be accurately modeled using the standard ANSI/ISA S75.01.01, or IEC 60534-2-1 methods. Specially developed methods and control valve sizing equations are required. The downstream flow rates and fluid properties for both the compressible component (gas/vapor) and the non-compressible (liquid) should be known. Misapplied outgassing applications can result in the application being undersized, extreme vibration, and increased trim and valve body wear. Manufacturers should be consulted to conduct proper sizing.

3) Typical control valve selections for outgassing service are multi-stage or sweep flow designed sliding stem “expanding area trim” or angle type control valves. The appropriate selection is based upon the pressure,

temperature, flow rate, and gas volume ratio of the application. Manufacturers should be consulted for recommendations.

l) Rangeability:

1) The rangeability of the control valve should be considered during valve selection. Control valves are available with published C_v rangeability of 50 to 1 and even greater, at constant pressure drop, a condition that rarely exists in actual practice. Typically, valves are sized with 10 % to 20 % excess capacity at the high end and 10 % to 20 % below the minimum required capacity at the low end.

2) A high rangeability is of little significance if the service conditions for the valves in question do not require it. The requirement for rangeability is to cover the maximum and minimum flow rates at the design flowing conditions.

m) Manufacturers should analyze all valve specifications for cavitation, noise, or other detrimental factors, using the data on the data sheets as a basis. Undesirable operating situations should be brought to purchaser's attention, including noise or cavitation severity. Manufacturers should propose possible solutions to these problems within the design limits of the type of valve covered by the specification or indicate that a special design is needed.

4.2.9 Noise

a) The predicted sound pressure level radiated from a control valve is a complex determination, and the allowable noise level in the installed location cannot be stated as one simple number to be specified in all circumstances. This is particularly true where there are other noise sources in close proximity, since they have an additive effect. The actual level depends on a number of factors, such as atmospheric discharge, physical location, proximity of other noise sources and their magnitude, piping system configuration and wall thickness, insulation on piping, presence of reflective sources, etc.

b) Prediction of noise generated by a control valve is an inexact science. Prediction levels for a valve operation at conditions specified on the specification sheet can vary widely using various manufacturers' methods. Refer to ISA Control Valve Standard 75.17

c) To provide a basis for allowable noise level analysis, control valves calculated to generate excessive noise levels should have alternate valves proposed that will not exceed the specified noise level within 1 m (3 ft) downstream and 1 m (3 ft) out from the pipe. For atmospheric discharge vent control valves (or system), the noise level should not exceed the specified noise level at a point three meters down from the vent exhaust and at a downward angle of 45 degrees.

d) Allowance may be taken for insulation and/or increased pipe wall thickness.

e) The calculated continuous noise level should not exceed 85 dBA, measured where personnel may be continuously working. This may not be within 1 m (3 ft) downstream and 1 m (3 ft) out from the pipe. The Occupational Safety and Health Administration decreases the allowable time of exposure as the sound level increases, and the user is referred to OSHA 1910.95 for specific guidelines. It is the user's responsibility to determine if the sound level will meet OSHA requirements or local site standards, whichever is more stringent.

f) Noise levels above 85 dBA may be allowable where personnel are not working continuously.

g) The maximum intermittent sound level should normally be limited to 110 dBA at one meter downstream and one meter out from the pipe.

h) In no case shall the calculated sound level exceed 115 dBA within 1 m (3 ft) downstream and 1 m (3 ft) out from the pipe due to possible mechanical failure within the system (pipe welds, small lines, etc.). In this case, no allowance shall be taken for insulation.

i) IEC and ISA industry standards exist for estimating noise levels of general service valves. However, noise prediction and mitigation is a specialized effort generally requiring the manufacturer recommendation for an effective design. It should be noted that the standards are being revised to allow for manufacturers' information to be available in a uniform format.

j) Noise can be treated in two ways: source treatment and path treatment. Source treatment means the noise is reduced using an inline device. These devices treat noise by breaking up high velocity jets. In a control valve, this is achieved by using a cage characterized with small passageways. Three types of technology exist for these cages: slotted windows (Figure 13A), drilled holes, or stacked disks (Figure 13B). Selection of trim type for noise reduction is based on the dP/P1 ratio, a suitable amount of noise attenuation, and process considerations such as plugging due to pipe scale, coke particles, or other debris. Another type of source treatment is the use of inline silencers. Path treatment utilizes thick wall piping or insulation to reduce noise. However, this treatment only masks the generated noise. If piping is reduced to the standard wall thickness or insulation is removed, the calculated noise will be generated.

k) Valves with noise abatement or cavitation control trim with small passages tend to plug with debris, particularly during startup, and should be protected with conical or T-type strainers. These devices should be used cautiously throughout refineries in applications where process streams are clean. On new construction where upstream piping is modified, special consideration should be taken to protect the control trim from being damaged during flushing activities.

4.2.10 Body Integrity

Hydrostatic testing of pressure-containing components is needed per ASME B16.34 and ISA S75.19. For special services, other non-destructive tests are sometimes specified.

Figure 13A—Slotted Noise Abatement Trim

Figure 13B—Stacked Disc Design Cage

4.2.11 Valve Assembly

The valve, actuator, and associated accessories, regardless of manufacturer(s), should be assembled, piped, aligned, tested, and shipped as a unit by the valve manufacturer. Tests may include hydrostatic, stroke test, leakage, or accessory calibration.

4.3 Valve Actuators

4.3.1 Pneumatic Valve Actuators

Pneumatic valve actuators, using air or gas, are preferred for most process control applications. Electric motor or electrohydraulic operators may be considered for special applications, particularly when pneumatic power is not available. Electrohydraulic actuators are commonly used where very high thrust forces are required or pneumatic supply is not available.

4.3.2 Direct Acting/Reverse Acting

Actuators are classified as direct acting (an increase in air loading extends the actuator stem) or reverse acting (an increase in air loading retracts the actuator stem). Some actuators are field reversible. They can be changed from direct to reverse acting with no additional parts. Most manufacturers publish tables that allow selection of actuator size based on valve size, flow direction, air action, pressure drop, packing friction, and available air pressure.

4.3.3 Diaphragm Actuators

Diaphragm actuators are one of the simplest and most common of control valve actuators.

a) A spring-opposed diaphragm actuator is a single-acting actuator where pressure is applied against a spring or springs. Upon loss of air, or control signal the spring will move the valve to the desired failure position. Construction of a typical spring diaphragm actuator is shown in Figure 14.

b) For installations where there is a limited supply of instrument air pressure available, the use of a higher spring range permits the use of positioners, and also helps to meet tight shutoff requirements.

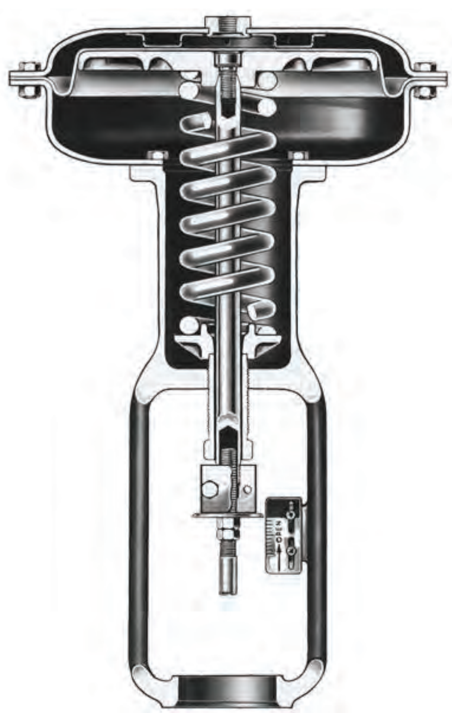


Figure 14—Diaphragm Actuator

4.3.4 Piston Actuators

The second most common control valve actuator is the piston type.

a) Piston (or cylinder) pneumatic actuators are commonly used for control valves where high thrust is needed. Single-acting piston actuators apply air pressure to one side of the piston against a spring or springs. Upon loss of air the spring will move the valve to the desired failure position. Double-acting piston actuators are considerably stiffer than single-acting designs and can therefore be used to control higher pressure drops. Double-acting piston actuators apply air to both sides of the cylinder. Double-acting piston actuators without springs require an external volume tank and trip system to achieve the desired failure position. Springs can be added to double-acting piston actuators to provide the air failure mode. See Figure 15.

b) Linear type piston actuators are used for globe style control valves. They are also used for rotary valves with adapter linkage. Scotch yoke or rack-and-pinion type piston actuators are normally used for on/off control, but may be used for regulatory control if control degradation is not critical.

4.3.5 Electrohydraulic Actuators

A variation of the piston actuator is the electrohydraulic, actuator which uses an electric motor to drive a pump and supply hydraulic pressure for the piston. For multiple valve installations, electrohydraulic actuators may be supplied by a common electric motor/pump skid. See Figure 16 and Figure 17.

4.3.6 Actuator Selection

4.3.6.1 Actuator selection guidelines are based on the assumption that the control valve will be required to operate against the maximum differential pressure specified. Generally, the worst case is to use the maximum upstream pressure with the downstream pressure vented to atmosphere. Utilizing this condition for selection of the actuator ensures adequate power for maximum service conditions but can dramatically affect operator size, particularly on larger valve sizes. Actuators should be sized to achieve all of the following:

a) minimum air supply pressure expected at the valve location;

b) force to overcome static unbalance of valve plug;

c) to account for the frictional effects of the stuffing box packing selected;

d) to ensure proper seat load to shutoff against the maximum differential pressure;

e) to prevent instability of the valve plug or disk over its full travel, based on a pressure drop equal to the maximum upstream design pressure.

4.3.6.2 Stroking speed and control accuracy requirements should be reviewed and specified for critical applications, such as compressor anti-surge control, or where closing speed should be controlled to prevent hydraulic water hammer and control accuracy enables proper system start-up.

4.3.6.3 Valve failure position should be carefully analyzed in the event that supply pressure or instrument signal is lost. Generally, the valve should fail in the safe direction on loss of power or signal.

4.3.6.4 The most reliable fail-safe action is achieved with an enclosed spring. If volume tanks are required to provide reserve operating power, they should be sized to stroke the valve twice. Volume tanks should be stamped and otherwise conform to ASME Code guidelines (see Part U-1, Section VIII, Division 1, *ASME Boiler and Pressure Vessel Code)*. Volume tanks should be designed with all necessary accessories to ensure the required valve action and failure position.

4.3.6.5 The actuator case should be rated for the maximum available pneumatic supply pressure. Filters or filter regulators, if required, should be supplied at the actuator inlet or the positioner inlet.

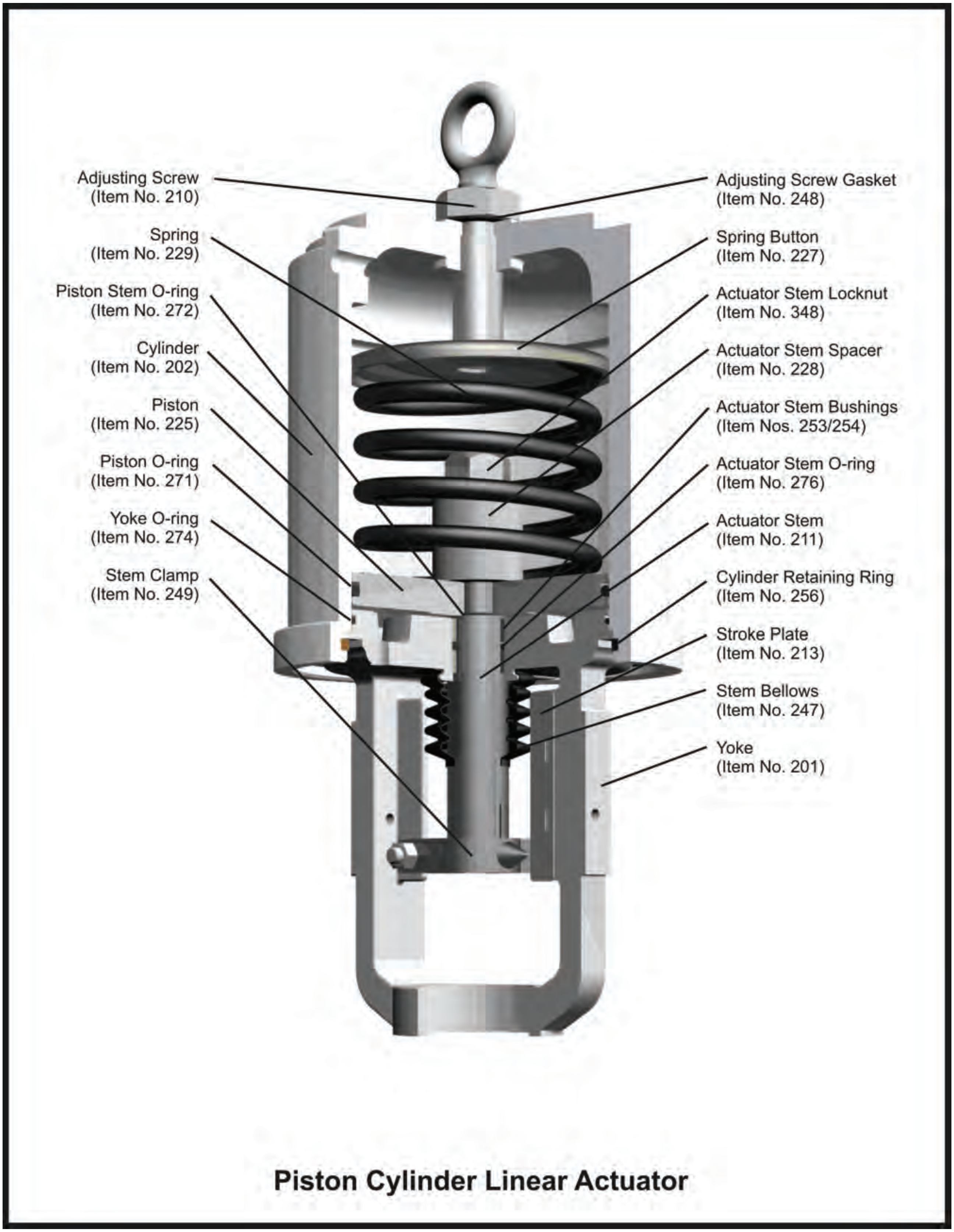


Figure 15—Double-Acting Spring Return Piston

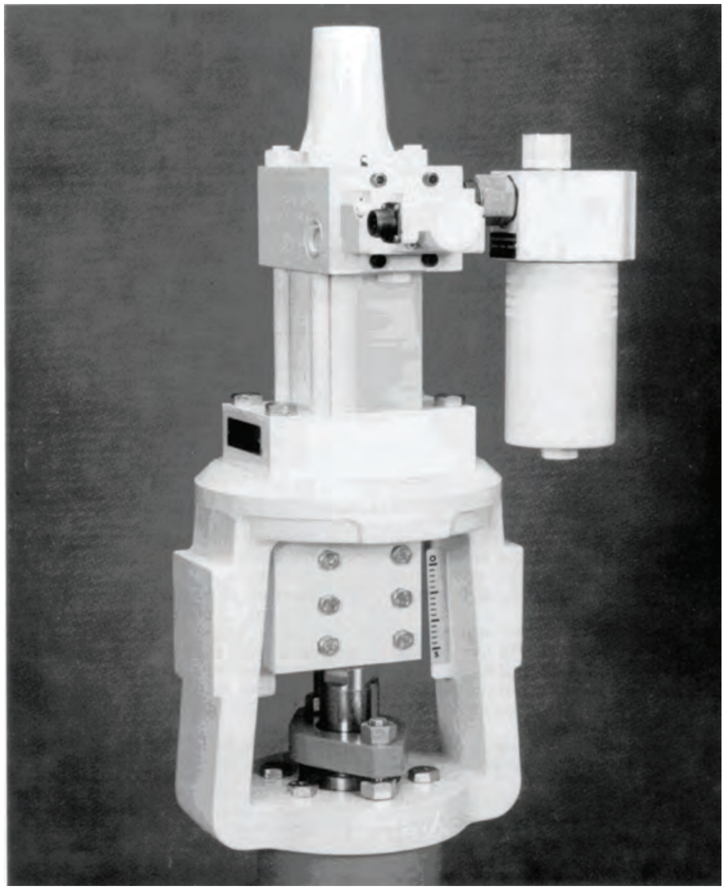


Figure 16—Electrohydraulic Actuator

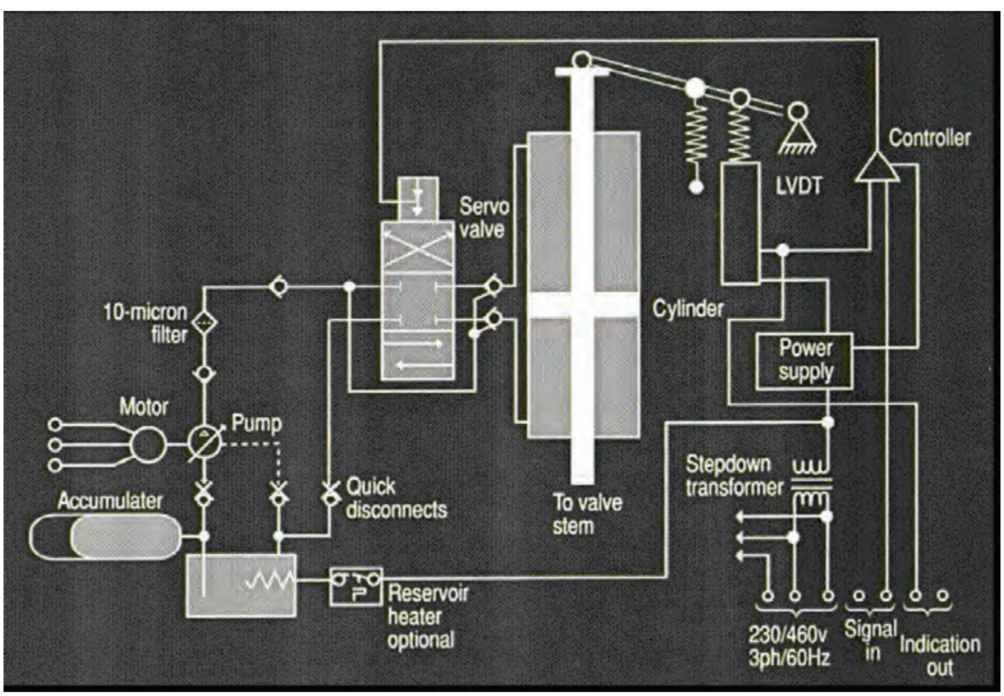


Figure 17—Electrohydraulic Actuator Schematic

4.3.6.6 The actuator should be sized to meet all control, shutoff, and valve leakage requirements. Shutoff capabilities should be investigated at conditions of maximum differential pressure.

4.3.6.7 To improve control valve performance, the effects of low frequency response and excessive deadband and hysteresis should be addressed. The valve, actuator, and positioner and accessories should be evaluated as part of the entire loop to determine loop performance.

4.3.6.8 In general, the actuator materials of construction should be the manufacturer’s standard.

4.3.6.9 Sliding stem actuators should be supplied with an indicator showing valve stem position. Rotary valve actuators should have a travel indicator attached at the actuator end of the shaft, graduated in percent or degrees open.

4.4 Valve Positioner

4.4.1 Positioners are used to provide pneumatic output to the actuator to move a control valve to a specified position so that a process meets specific parameters (flow, pressure, temperature). Positioners by design have an integrated feedback mechanism that corrects for variations and ensures the valve stays in the position requested by the control system. Positioners provide air or fluid to an actuator in proportion to the input signal received from the control system.

4.4.2 The following is a list of functions a positioner can accomplish.

a) Provide for split range operation.

b) Reverse the valve action without changing the “failsafe” action of the spring in the actuator. (Note that this may also be done with a reversing type relay.)

c) Increase the thrust in spring diaphragm actuators.

d) Modify the control valve flow characteristic.

e) Improve the resolution or sensitivity of the actuator where high precision valve control is needed. Precision is enhanced by the availability of positioners with adjustable gain.

f) Reduce hysteresis.

4.4.3 There are two categories of positioners.

a) Conventional mechanical or electro-pneumatic positioners (Figure 18) that receive their input setpoint from a pneumatic signal or from a DC analog signal. In older process units, it was standard practice for a mechanical positioner's pneumatic input set point to originate from an intermediate device between the Basic Process Control System (BPCS) and the positioner called a “current to pneumatic” transducer—commonly referred to as an I/P transducer. These are very rarely specified anymore with control valves. I/Ps were used to simply convert a DC analog signal (typically 4 mA to 20 mA) to a pneumatic signal (3 psig to 15 psig) that was the input to the conventional mechanical positioner.

b) Digital Valve Controllers (Figure 19) that receive their input setpoint as a DC analog signal or as a pure digital setpoint.

4.4.4 Conventional

a) Conventional positioners use a variety of mechanical parts to provide the position control function. Parts such as mechanical cams, springs, balance beams and bellows are commonly found in these assemblies.

Figure 18—Conventional Valve Positioner

Figure 19—Smart Valve Positioner

b) Electromechanical positioners are conventional positioners that have an integrated electro-pneumatic transducer. The transducer receives the input signal via a DC analog signal and converts it to a proportional pneumatic signal which is then sent to the conventional positioner that performs the position function.

4.4.5 Digital Valve Controllers

a) Digital valve controllers use microprocessors and have become the dominant positioner technology since the mid 1990's. Commonly referred to as "Smart" or "Digital" positioners, they integrate functionality far beyond the traditional analog or pneumatic positioner. The benefits of using a digital valve controller include availability of equipment alerts to notify the user of pending issues, and automated configuration, calibration and tuning. This provides the benefit of consistent and predictable performance regardless who performs the task.

b) Valve diagnostics have become an integral part of many digital valve controllers. Diagnostics are used to determine physical problems with the entire valve assembly. Most manufacturers offer some type of basic to advanced valve diagnostics functionality with their digital valve controller. The key difference between the level of diagnostics are the use of pressure sensors which monitor and record pneumatic signals from the instrument supply and actuator pressures.

Diagnostics on the control valve assembly can be performed while the valve is in control of the process and responding to the control system setpoint, or they may occur while the valve is shut down and blocked from the process. The information collected provides a direct indicator of the health of the control valve assembly. In many plants, valve diagnostic information is integrated with other equipment diagnostics as part of an overall preventive and predictive maintenance and reliability program. This allows longer running cycles and minimizing plant down time. Large operating units are now delegating this function to the "Reliability/Asset Engineers".

c) There are a variety of digital communications protocols in use today by digital valve controllers. The most commonly used protocols in the process control industry are HART (Highway Addressable Remote Transducer), Foundation Fieldbus, and Profibus.

4.5 Handwheels

4.5.1 Manual handwheel operators should be supplied only on specific request by the owner, or where bypass facilities are not installed. Side-mounted, top-mounted, lockable, screw or gear drive manual operators, continuously connected and operable through an integral declutching mechanism, are preferred. See Figure 20 and Figure 21.

4.5.2 Handwheels should be permanently marked to indicate valve open and closed directions

4.5.3 When a handwheel is used for a piston actuator, a cylinder bypass valve should be included.

4.5.4 When handwheels or hydraulic hand jacks are specified, they should be mounted and designed to operate in the following manner.

a) For globe valves, handwheels should be mounted on the actuator yoke or casing, arranged so that the valve stem can be jacked in either direction, if specified.

b) Neutral position should be clearly marked.

c) Handwheel operation should not add friction to the actuator.

d) Clutch/linkage mechanisms for handwheels on rotary valves should be designed such that valve position does not change when engaging the handwheel.

e) Handwheels should not be used as a travel limit stop.

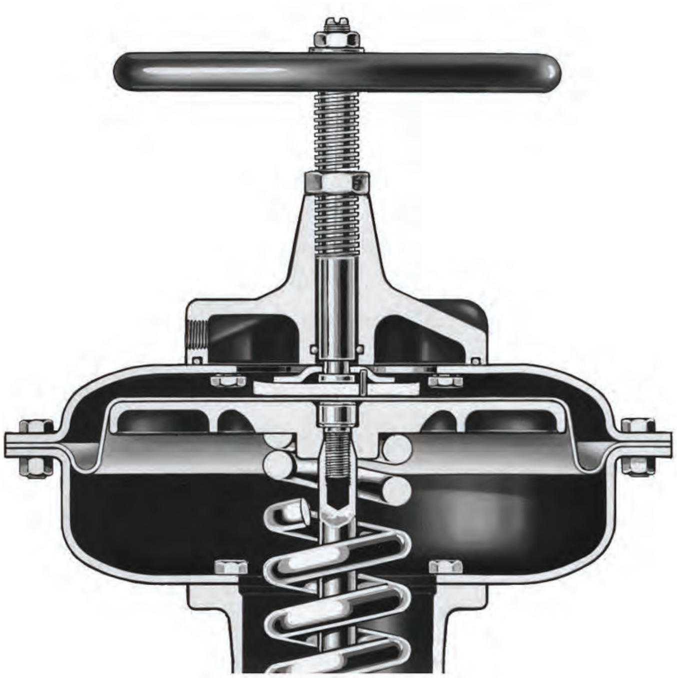


Figure 20—Top Mounted Handwheel

Figure 21—Side Mounted Handwheel

4.6 Switches and Solenoids

4.6.1 Digital valve controllers may be used to achieve the same functionality as that of independent limit switches and solenoids as discussed earlier under Valve Positioners. When the use of independent switches and solenoids are preferred over digital valve controllers, the following factors should be considered.

4.6.1.1 Hermetically-sealed Magnetic or Inductive proximity switches are preferred when independent “open” or “closed” indication of stem position is needed. See Figure 22, Figure 23, and Figure 24.

Figure 22—Cam-operated Limit Switch

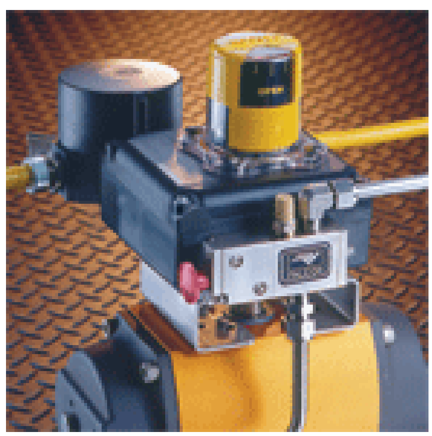


Figure 23—Beacon Type Limit Switch Housing

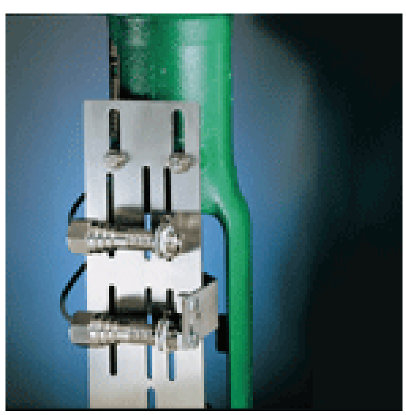


Figure 24—Proximity Switches

4.6.1.2 Limit switches and linkage devices used to detect valve stem position should not have a dead band exceeding the lesser of 10 % of valve travel or 3 mm (0.125 in.). Rotary valve limit switch dead band should not exceed 5.0 degrees rotation of the valve disk shaft.

4.6.1.3 Solenoid valves should be rated for continuous duty with Class H high temperature encapsulated coils and be satisfactory for both NEMA 4 and NEMA 7 installations. The valve vent port should be equipped with an insect screen oriented downward. Three-way solenoid valves are used with spring return actuators and double-acting actuators with positioners. Four-way solenoid valves are used with double-acting actuators with no spring and on/off double-acting spring return valves. Solenoid valves should be specified so that they do not require a minimum differential pressure across the valve to actuate.

4.6.1.4 Valve trip solenoids should be installed in the actuator inlet tubing. When exhaust rate is critical, the solenoid valve C_v should be selected accordingly. A quick exhaust valve, working in concert with a pilot solenoid valve, may be required if the trip solenoid does not have sufficient venting capacity. Quick exhaust valves have relatively large vent capacity with a C_v value at least ten times that of the typical DN 10 ($^1/_4$ in.) solenoid valve.

4.6.1.5 When SOVs are used, the air should be clean, and dry. If inert gas is used instead, it should be filtered to 40 microns or better. To prevent freezing, the dew point of the air or gas should be at least –8 °C (18 °F) below the minimum temperature to which any portion of the clean air or gas could be exposed

4.6.1.6 Solenoids and limit switches supplied with control valves should be specified with a minimum of 460 mm (18 in.) of connecting lead wires or be prewired to a junction box mounted on the valve. Low voltage and 120-volt wiring should not be used in the same junction box.

4.6.1.7 For transient protection, DC voltage solenoids should be installed with a transient voltage suppressor or diode mounted in parallel with the solenoid coil. AC voltage solenoids should have a metal oxide varistor mounted with the solenoid coil.

4.6.1.8 For process applications where there is both a control and a process safety trip function requirement, per IEC61511 (ANSI/ISA 84) these requirements may warrant a completely independent valve for control and for shutdown. For non-safety cases, this functional requirement could be met with the same process valve, if independent means of positioning are used. Even when using a positioner with digital valve controller capabilities, it may be necessary to install an independent solenoid system to trip the valve based on input from the logic system. Also refer to Section 9 for additional insight.

4.6.1.9 The process impact to a failure of a position switch or solenoid valve should be determined when considering the installation of switches and solenoids. Failure modes that should be considered include the position switch not indicating the proper valve position, and a solenoid coil being stuck. Single device installations should not be used when the impact of the valve going fully open or fully closed will cause a unit shutdown.

4.7 Volume Boosters/Quick Exhaust Vents/Air Locks

4.7.1 The air supply system (piping and air filters) to a control valve should be sized to provide a sufficient quantity of air for the desired stroking time.

4.7.2 Volume booster relays may be used to improve the dynamic response of a control valve, if its positioner does not have capacity to operate the valve fast enough to meet the process need. Volume boosters amplify the pneumatic signal to the actuator or from the positioner.

However, the addition of volume boosters, if not properly sized and selected, could result in excessive overshoot, causing the valve to move further than the intended position. Volume boosters should be selected such that the overall dynamic performance of the control valve assembly meets the dynamic performance requirements of the process.

4.7.3 Quick exhaust vents are used when it is desired to fully dump the volume of air in an actuator to cause the valve to move to a predetermined position in a specified time period. Typically this time period is 1 second to 2 seconds. Caution should be used when using quick exhaust vents in liquid applications as this can cause hydraulic shock (sometimes referred to as water hammer) to the line.

4.7.4 Air locks are used in applications where the desired failure position of a control valve is Fail Stationary or Hold Last Position on a loss of pneumatic supply. If air locks are required, they should be installed as close to the valve actuator as possible, unless the control valve is also used in trip/dump applications. In a trip/dump application, the air lock should be installed such that the trip/dump valve moves to its failure state regardless of the air lock state**.**

4.7.5 The air supply for the air lock should be the same as for the valve positioner. The setpoint for the air lock needs to be set at a value above the minimum pressure required by the actuator for the application.

4.7.6 Control valves with an air lock feature should have a pressure gauge indicating actual diaphragm or piston pressure after the air lock.

5 Specific Criteria

5.1 Globe-Style Valves

5.1.1 Globe-style valves (e.g. sliding stem) are preferred for high pressure drop applications, low flow applications, or where cavitation, flashing, noise are considerations. However, some rotary valve models having a characterized ball or eccentric rotary plug are suitable for these applications.

5.1.2 Globe-style valves can be single or double-ported.

a) Single-ported designs (Figure 25) are more common and can be used to meet tight shut off requirements with either a metal-to-metal seating surface or soft-seated design. Many modern single-seated valve bodies use cage or retainer-style construction to retain the seat ring cage, provide valve-plug guiding, and provide a means for establishing particular valve flow characteristics.

b) Double-ported designs (Figure 26) traditionally were used to provide a balanced plug design. They tend to provide more capacity than single-ported valves of the same size, but are not capable of tight shutoff, ANSI Class IV, or better.

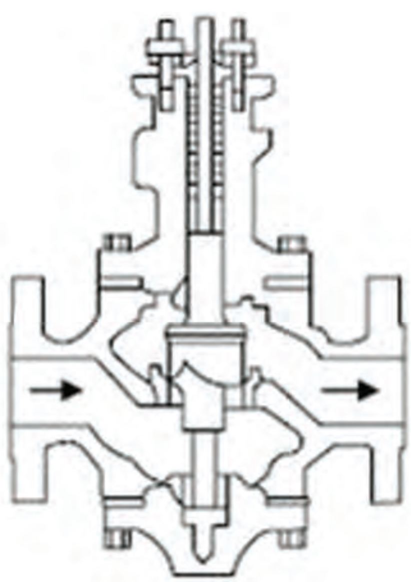


Figure 25—Single-ported Globe Valve

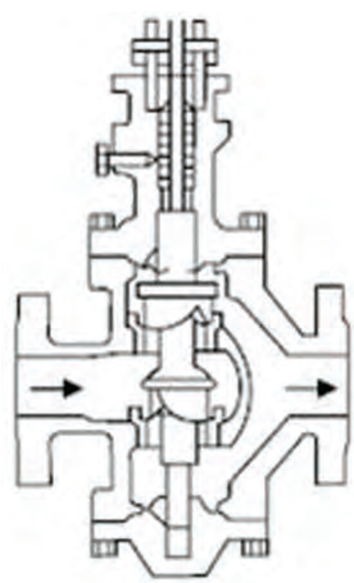


Figure 26—Double-ported Globe Valve

5.1.3 A globe-style valve that has a cast flanged body that can be serviced while in the line is preferred. Split body valves are not recommended because they are prone to leakage.

5.1.4 Three-way and angle body valves may be considered for special applications. Three-way valves can be used for proportioning control of converging or diverging flow. Angle body valves should be considered for outgassing service, coking service (where solids are carried in suspension), severe flashing service, and where the piping design can take advantage of the valve geometry.

5.1.5 The recommended minimum globe body size is 1 in. when installed in lines 1 in. and larger. Valves installed in lines smaller than 1 in. should be line sized. The following valve sizes are not recommended: DN 30 (NPS $1^{1}/_{4}$), DN 65 (NPS $2^{1}/_{2}$), DN 90 (NPS $3^{1}/_{2}$), and DN 125 (NPS 5).

5.1.6 Either integral or separable flange bodies are acceptable. Valves having integrally cast flanges are generally used, but separable flanged valves are available but require additional maintenance considerations.

5.1.7 Control valve bodies should have the flow direction permanently marked on the body.

5.1.8 Stem or post-guided, unbalanced trim is preferred for tight shutoff applications or for fluids containing suspended solids. Balanced, cage-guided trim is acceptable for applications in clean, non-slurry service.

5.2 Rotary Style Valves

5.2.1 Cost considerations and certain process conditions may favor the rotary style control valve. Eccentric disk valves are recommended in applications requiring tighter shutoff, and in high flow, low pressure drop services. Rotary-segmented ball valves should be considered for highly viscous services and where greater flow turndown ratios are required. Eccentric rotary disk valves can be considered for many applications where rising stem globe valves are currently specified, in accordance with the maximum pressure drop limitations of rotary style valves.

5.2.2 Butterfly valves with lug bodies (Figure 27) may have threaded or unthreaded bolt holes. Unthreaded bolt holes are preferred, as threaded bolt holes tend to gall over time requiring bolts to be cut to permit valve removal. In those applications where allowed, wafer (unflanged) valves (Figure 28) should have centering holes or clips to ensure proper valve and gasket alignment. Long pattern valves having longer stud bolts with greater exposure should be insulated for fire protection (Figure 29).

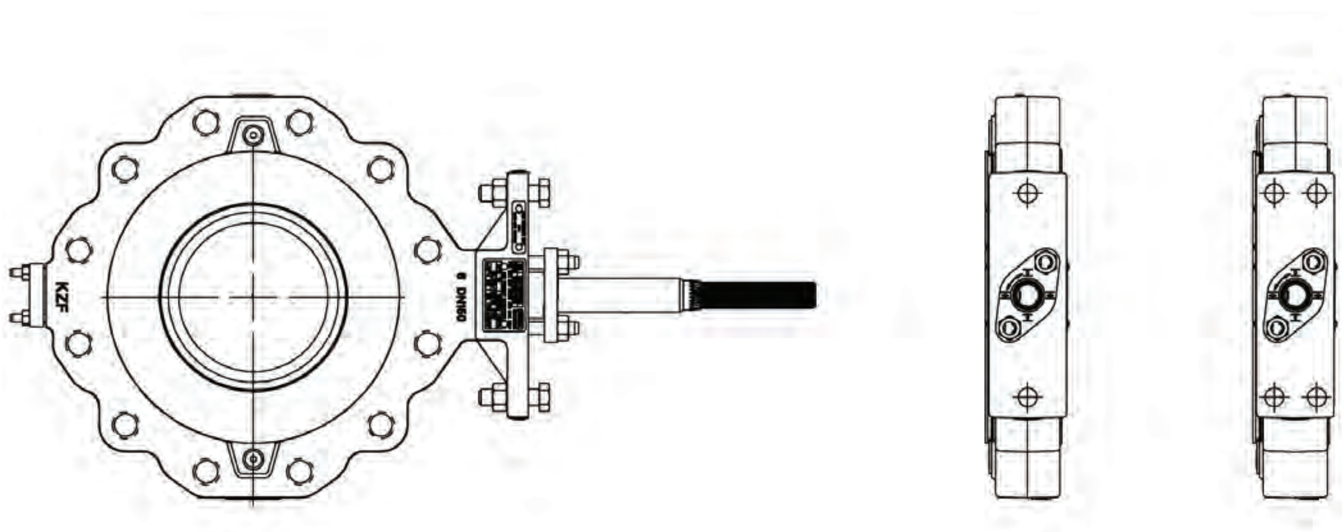


Figure 27—Lugged-style Butterfly Valve

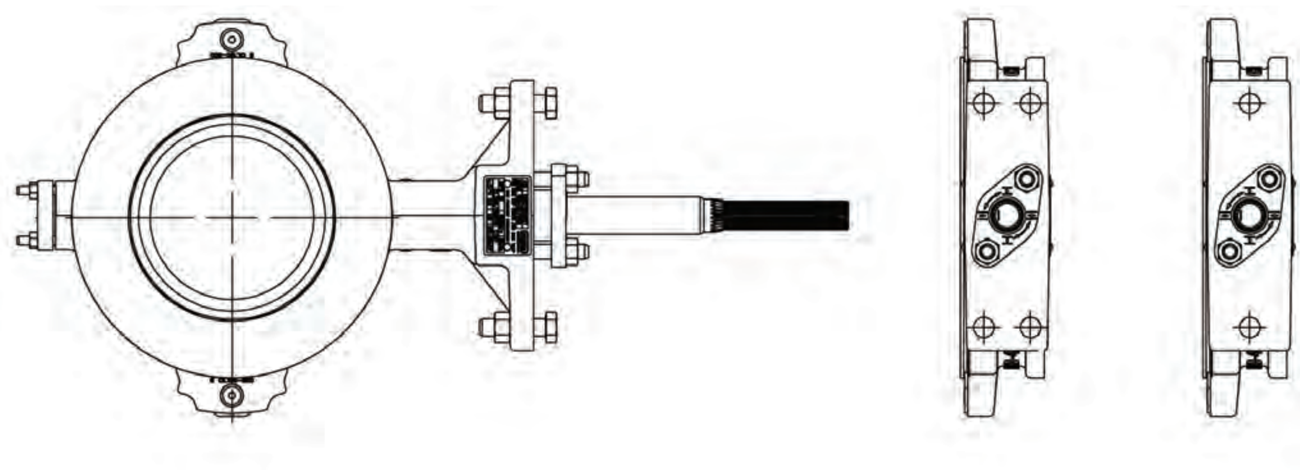


Figure 28—Wafer-style Butterfly Valve

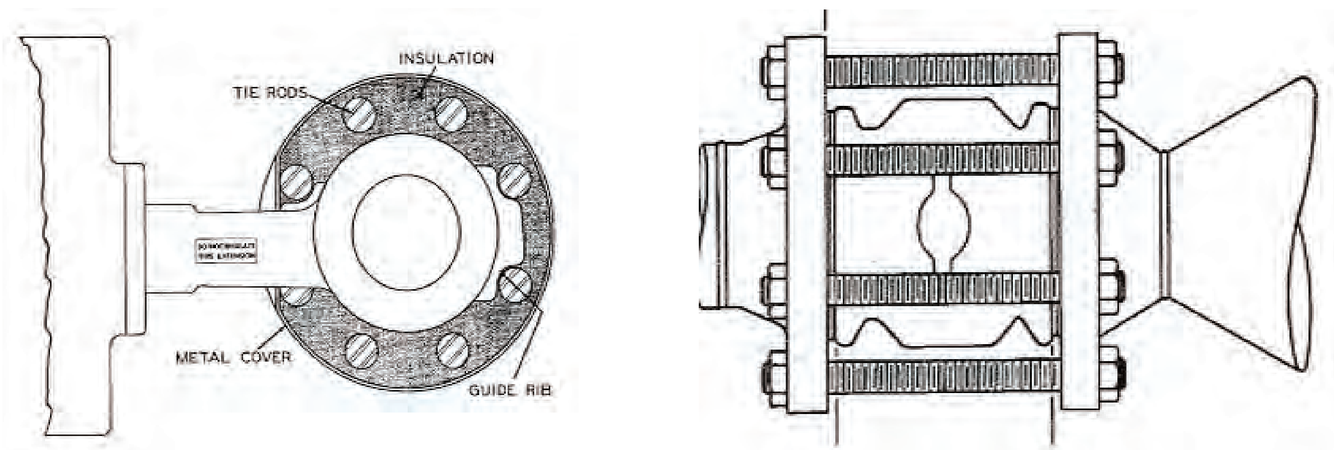


Figure 29—Typical Wafer-style (flangeless) Valve Installation

5.2.3 Particular attention should be given to clearance requirements of butterfly disks. The pipe wall thickness of heavy-wall pipe or lined pipe can interfere with disk rotation.

5.2.4 The valve shaft should normally be oriented in the horizontal plane. The valve disk or ball should be positively attached to the valve shaft. The use of pinning alone should be avoided as pins can vibrate out while the valve is in service resulting in the detachment of the disk or ball from the shaft.

5.2.5 The actuator end of the shaft should be designed to minimize hysteresis and deadband.

5.2.6 The shaft bearing should be designed to prevent the guide bushing from rotating in the body.

5.2.7 Shaft material should be stainless steel for carbon steel or stainless steel valves. Other trim parts at a minimum should be stainless steel. The bearing material should not cause galling of the bearing or the shaft.

5.2.8 A shaft retention device should be provided on both the drive and follower.

5.3 Specialty Valves—High Pressure Drop and Particle Applications

5.3.1 Non-standard valves should be considered for severe service applications in refineries. Severe service can be defined as high pressure drop [>14 barg (200 psig)] with entrained particulates. In these cases a control valve with large clearances capable of passing entrained particulates is preferred.

Consideration should be given in specifying control valves that will not only address high-pressure liquid or gas letdown, but also solve the “real world” problem of debris in the flow stream.

The solution is a set of control valve trim designs which break up high stream jets by spacing slots or holes accordingly. Figure 30 is a multistage, debris tolerant trim for liquid service. This design delivers a high level of cavitation prevention by safely staging the pressure drop, while also providing large flow passage areas that can pass entrained solids with less difficulty. These control valves also offer a high level of reliability because they eliminate clogging and damage by debris as a failure mechanism. An angle valve (Figure 31) is another type of valve for these applications. Some rotary valves with low noise/anti-cavitation trims are also available for this kind of application.

While most debris problems in valves are associated with control valves in liquid service, the same type of considerations also apply to control valves used in severe service gas applications. Figures 13A and Figure 13B are low noise trim (slotted cage and tortuous path type) for gas service. Similar to anti-cavitation liquid control valve trims for clean service applications, the technology uses small slotted holes or tortuous flow passages. The purpose is to minimize noise and vibration levels associated with the high-pressure reduction of a compressible gas.

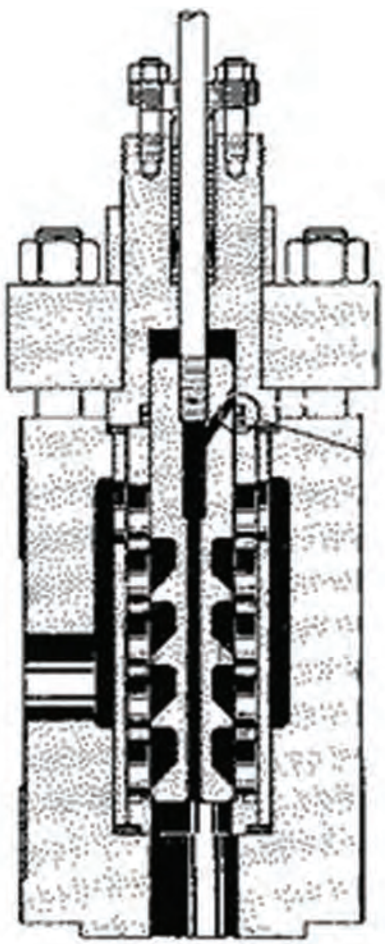


Figure 30—Multi-stage Valve

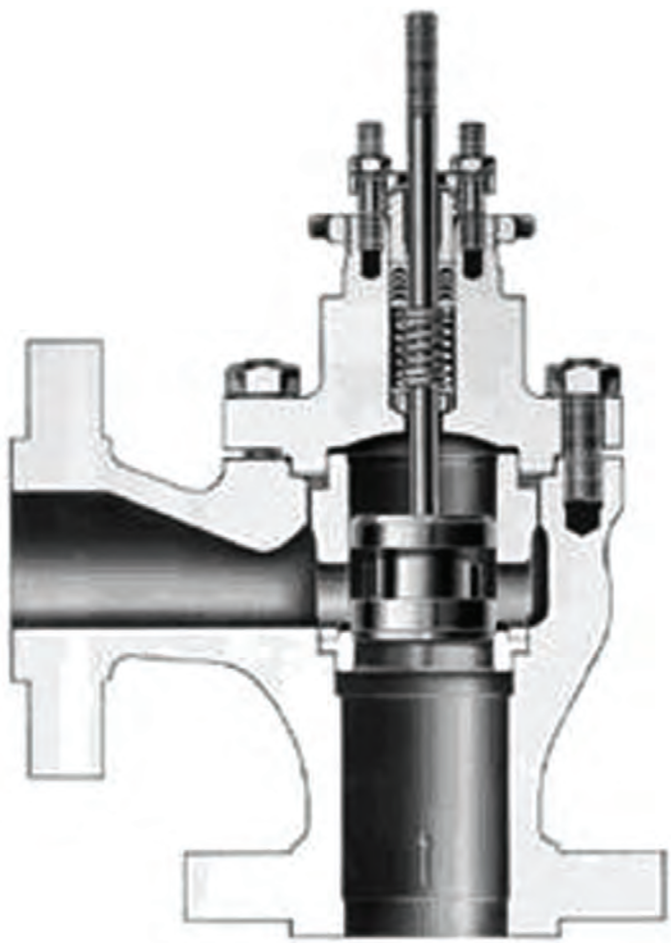


Figure 31—Angle Valve

While the risk of clogging and damage is less in gas service than in liquid service, the potential still exists for these issues to occur in some critical or severe service applications. Refinery blend/fuel gas, choke valves, and compressor anti-surge bypass or expander bypass valves are typical examples of severe service gas applications.

As with specialty liquid valves there are options to accommodate these situations. Among them are unique control valve trim designs that safely reduce the pressure on high-pressure gas applications while also passing entrained solids or liquids without clogging or damage. One major difference between this trim and those associated with dirty liquids is that each pressure drop stage has an expanded area. Because gases are compressible, each pressure drop has a reduction in density and an expansion in volume; thus these control valve technologies should have expanded flow areas to operate properly without choking the flow.

5.4 Control Valve Performance

The control valve assembly plays an extremely important role in producing the best possible performance from the control loop. Advanced process optimization can be achieved, if proper attention is given to the control valve design aspects described in 5.4.1, 5.4.2, 5.4.3, 5.4.4, and 5.4.5. Also refer to ANSI/ISA 75.25, *Test Procedure for Control Valve Response Measurement from Step Inputs*.

5.4.1 Process Variability

Any deviation from an established specification is process variability. Reducing process variability through better process control allows process optimization.

The non-uniformity inherent in the raw materials and processes of production are common causes of variation that produce a variation of the process variable both above and below the set point.

The ability of control valves to reduce process variability depends upon many factors. Control valves should be designed with consideration for dead band, actuator/positioner linkages, and response time. Control valve assemblies including the valve, actuator, and positioner designed as a unit result in the best overall dynamic performance.

5.4.2 Dead Band

Dead band is a major contributor to excess process variability. Primary sources of control valve dead band are friction, backlash (slack or looseness of a mechanical connection), shaft windup (twisting of the shaft), relay or spool valve dead zone, etc.

Dead band is a general phenomenon where a range or band of controller output values fails to produce a change in the measured process variable (PV) when the input signal reverses direction. When a load disturbance occurs the PV deviates from the set point. This deviation initiates a corrective action through the controller and back through the process. However, an initial change in controller output can produce no corresponding corrective change in the process variable. Only when the controller output has changed enough to progress through the dead band does a corresponding change in the process variable occur. Any time the controller output reverses direction, the controller signal should pass through the dead band before any corrective change in the process variable will occur. The presence of dead band in the process ensures the process variable deviation from the set point will have to increase until it is big enough to get through the dead band. Only then can a corrective action occur.

5.4.3 Valve Response Time

For optimum control of some processes, it is important that the valve reach a specific position quickly. A quick response to a small signal (around 1 %) is one of the most important factors in providing optimum process control. If a control valve can respond to these very small changes, process variability will be improved.

Valve response time is measured by T63, the dead time and dynamic time to reach 63 % of the corresponding change. On fast loops, it is important to minimize dead time by selecting equipment with as little dead time as possible. The dynamic time will be determined by the dynamic characteristics of the positioner and actuator combination. These components as well as any special speed accessories should be carefully matched to minimize the total valve response time. Selecting the proper valve, actuator, accessories, and positioner combination is not an easy task, and is critical to proper valve performance. It is not just a matter of finding a combination that is physically compatible. Good engineering judgment should go into the practice of valve assembly sizing and selection to achieve the best dynamic performance from the loop.

5.4.4 Valve Type and Characterization

The style of valve used and the sizing of the valve can have a large impact on the performance of the control valve assembly in the system. While a valve should be of sufficient size to pass the required flow under all possible contingencies, a valve that is too large for the application is a detriment to the system. Flow capacity of the valve is also related to the style of valve through the inherent characteristic of the valve.

Typical valve characteristics are named linear, equal percentage, and quick opening. The linear characteristic has a constant inherent valve gain throughout its range, and the quick-opening characteristic has an inherent valve gain that is the greatest at the lower end of the travel range. The greatest inherent valve gain for the equal percentage valve is at the largest opening.

Knowledge of the inherent valve characteristic is useful, but the more important characteristic for process optimization is the installed flow characteristic of the entire process, including the valve and all other equipment in the loop. The installed flow characteristic is defined as the relationship between the flow through the valve and the valve assembly input when the valve is installed in the system, and the pressure drop across the valve is allowed to change naturally, instead of being held constant.

Installed gain is a plot of the slope of the installed characteristic curve at each point. Installed flow characteristic curves can be obtained under laboratory conditions by placing the entire loop in operation at some nominal set point and with no load disturbances.

The control range of a valve varies dramatically with valve style. The V-port segment or control ball valves have a much wider control range than the butterfly valve. Other valve styles such as globe valves and eccentric plug designs fall somewhere in between.

The best process performance occurs when the required flow characteristic is obtained through changes in the valve trim rather than through use of cams or other methods. Proper selection of a control valve designed to produce a reasonably linear installed flow characteristic over the operating range of the system is a critical step in ensuring optimum process performance.

5.4.5 Valve Sizing

Oversizing of valves sometimes occurs when trying to optimize process performance through a reduction of process variability. Oversizing the valve hurts process variability in two ways.

a) The oversized valve puts too much gain in the valve, leaving less flexibility in adjusting the controller. Best performance results when most loop gain comes from the controller.

b) An oversized valve is likely to operate more frequently at lower openings where seal friction can be greater. Because an oversized valve produces a disproportionately large flow change for a given increment of valve travel, this phenomenon can greatly exaggerate the process variability associated with dead band due to friction.

When selecting a valve, it is important to consider the valve style, inherent characteristic, and valve size that will provide the broadest possible control range for the application.

5.5 High Performance Control Valves

5.5.1 High performance control valves are those valves whose performance directly and significantly impacts plant or unit operation. There are two criteria to be considered.

a) Reliability Performance—severe service conditions are those which impact the valve's reliability. Severe service conditions include the following:

   1) cavitation or flashing;

   2) high pressure drop, where the pressure drop exceeds the critical pressure;

   3) high piping vibration;

   4) erosion, such as solids in the fluid, liquid particles in gas stream, and steam;

   5) high valve outlet velocity (liquids > 5m/sec, gas/steam > 0.3 mach).

b) Process Performance—conditions that impact process performance include the following:

   1) high rangeability (>100:1);

   2) quick step response (> 4 in. travel/sec or full stroke in less than 2 seconds in either direction;

   3) very low or zero overshoot (<1 %);

   4) very low hysteresis (<1 %);

   5) resolution (< 0.5 % in both directions);

   6) high sound pressure level (>90 dBA);

   7) high duty cycle (> 10 cycles/hr).

Underperforming valves are avoidable in refineries. With the focus on improved performance available from valve vendors, the user is encouraged to perform regular maintenance to understand how valve performance is impacting unit operation. A focus on control loop performance improvements should be incorporated into the reliability and maintenance programs of the plant.

One measure is to review the number of control loops running in manual mode due to poor control loop performance. A focused effort to reduce the number of loops in manual may require a focus on control valve performance. The user is encouraged to review ISA75.25 for further guidance on this subject.

5.5.2 These high performance valves deserve special attention during the engineering, procurement, installation, and maintenance processes. These valves should be handled as separately engineered products, as opposed to off-the-shelf products. Special attention should be paid to the accuracy of the process data in the sizing and selection of the valve, actuator, and all accessories.

5.5.3 High performance valves should adhere to the requirements in ANSI/ISA 75.25 "Test Procedure for Control Valve Response Measurement from Step Inputs".

5.6 Material Considerations for Control Valves in Refining Processes

5.6.1 General

There are many processes in refining units that require special material selection. As refiners are processing more acidic and heavier crudes, special care has to be taken in material selection. To ensure proper material selection is performed, each refinery's materials specialist(s) should be consulted prior to final selection. Ultimately, the end user is responsible for all material selections with guidance from the control valve vendor. Many material selections are based on successful experience and full knowledge of process conditions and fluid components. Consult with the manufacturers to assure requirements are understood and can be met.

Table 1 gives a listing of the highly corrosion resistant alloys that will be discussed within the following subsections on material considerations. Table 1 depicts the generic material designations, their UNS equivalents, and their customary casting designations from ASTM DS56JOL.

Table 1—Material Designations for High Nickel Alloys

Casting Designations	Equivalent Wrought Tradenames	Generic Designations	UNS Number for Wrought Equivalents
CF3		304L	S30403
CF8		304	S30400
CF3M		316L	S31603
CF8M		316	S31600
CG8M		317	S31700
		321	S32100
CF8C		347	S34700
CK3MCuN	Avesta 254 SMO [a]	Alloy254	S31254
CN7M	Carpenter 20Cb3 [b]	Alloy 20	N08020
CU5MCuC	Incoloy 825 [c]	Alloy 825	N08825
CW12MW	Obsolete Hastelloy C [d]	Alloy C	N10002
CW2M	New Hastelloy C [d]	Alloy C276	N10276
CX2MW	Hastelloy C22 [d]	Alloy C22	N06022
CW6MC	Inconel 625 [c]	Alloy 625	N06625
CY40	Inconel 600 [c]	Alloy 600	N06600
	Inconel 718 [c]	Alloy 718	N07718
	Inconel X750 [c]	Alloy X750	N07750
	Nitronic 50		S20910
CZ100	Nickel 200	Alloy 200	N02200
LCB		LCB	J03003
LCC		LCC	J02505
	K-Monel [c]		N05500
M25S	S-Monel [c]	Alloy S	
M35-1	Monel 400 [c]	Alloy 400	N04400
N12MV	Obsolete Hastelloy B [d]	Alloy B	N10001
N7M	Hastelloy B2 [d]	Alloy B2	N10665
WCB		WCB	J03002
WCC		WCC	J02503
C12	Chromium Molybdenum		J82090
C12A	Chromium Molybdenum Vanadium		J84090

[a] Trademark of Avesta AB

[b] Tradenames of Carpenter Technology

[c] Tradenames of Inco Alloys International

[d] Tradename of Haynes International

5.6.2 Sulfidic Environments

5.6.2.1 Sulfide Stress Cracking (SSC)

Sulfide stress cracking can occur in environments containing an aqueous phase and hydrogen sulfide (H_2S). Environmental cracking can occur in some materials, particularly hardened steels. Cracking is a function of a number of parameters, but the primary factors for a given material are hardness, tensile stress level, and the hydrogen permeation flux. The hydrogen permeation flux is influenced by the concentration of H_2S, the concentration of free cyanide, and the pH of the aqueous phase. Typical applications where this may occur are desulfurizing, hydrocracking, hydrotreating, crude distillation, and fluid catalytic cracking units. In order to prevent this degradation, many refineries specify materials per NACE MR0103, *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*. This is essentially the refining industry's version of NACE MR0175 and is a refining-specific document for materials resistant to sulfide stress cracking. Before this document existed, application of NACE MR0175 in refining applications was inconsistent. Many catalytic processes within the refinery have chloride levels sufficient to induce chloride stress corrosion cracking (CSCC) therefore the recommendation of the process licensor should be followed to ensure proper operating procedures are consistent with the valve materials used. In 2003, NACE MR0175 was revised to include CSCC (resulting is what is now NACE MR0175/ISO 15156).

5.6.2.1.1 Although most materials and requirements are identical in MR0175 and MR0103, some material differences exist. The major differences between MR0103 and MR0175 are:

a) environmental restrictions on materials;

b) MR0103 does not include limits on H_2S concentrations, temperature, etc.;

c) materials and/or material conditions included;

d) welding controls in MR0103 are much stricter, especially with regard to carbon steels, alloy steels, and duplex stainless steels.

It is recommended that the applicable specification is reviewed prior to use.

5.6.2.1.2 Another major difference addressed in MR0103, is that for the first time, guidelines were included for determining whether an environment is deemed sour. Generally, in upstream sour applications, dissolved CO_2 causes low pH, and chlorides cause stress corrosion cracking (issues addressed by NACE MR0175). In downstream sour applications, dissolved ammonia and cyanides are present, and the fluid can have a resulting high pH (>7) which produces a high hydrogen charging potential even with low H_2S levels. NACE MR0103 defines a sour environment by one of the following credentials:

— free water in the liquid phase and:

a) >50 ppmw total sulfide content in the free water; or

b) ≥1 ppmw total sulfide content in the free water and pH <4; or

c) ≥1 ppmw total sulfide content and ≥20 ppmw free cyanide in the free water, and pH >7.6; or

d) >0.0003 MPa absolute (0.05 psia) partial pressure H_2S in the gas phase associated with the free water of a process.

NOTE Total sulfide content is defined as H_2Saq (dissolved hydrogen sulfide), HS- (bisulfide ion), and S_2- (soluble sulfide ion).

For more information see the latest revision of NACE MR0103. Note that the user is ultimately responsible for deciding whether the material requirements of the standard need to be applied for both MR0175 and MR0103. NACE

MR0103 allows that decision to be based upon the sour service definition guideline, plant experience, and risk-based analysis. Manufacturers are responsible for meeting and understanding metallurgical requirements when requested.

5.6.2.2 Sulfidic Corrosion

5.6.2.2.1 Some crude oils contain as much as 5 % sulfur by weight in a variety of different sulfur compounds. At high temperatures, the sulfur reacts with steels to corrode the surface. Typical applications where this may be an issue are desulfurizing, hydrocracking, hydrotreating, crude distillation, and fluid catalytic cracking units. A proven solution is to use steels with higher chromium content to increase corrosion resistance.

Material Progression:

a) $2^1/_4$ Cr-1 Mo (WC9);

b) 5 Cr-$^1/_2$ Mo (C5);

c) 9 Cr-1 Mo (C12);

d) Austenitic SST (CF8C) (Greatest resistance).

However, there still can be selection issues. C5 (5Cr-$^1/_2$ Mo) and C12 (9 Cr-1Mo) are more difficult to cast and weld than the other alloys, and these issues may create delays in the manufacturing process. Another selection issue is that C12A (9 Cr-1 Mo Vanadium modified) should not be substituted for C12. C12A should only be specified for applications above 538 °C (1000 °F), which rarely occur outside of steam applications in power or utilities plants.

It is not safe to assume that any austenitic stainless steel (such as S31600) will be acceptable. See 5.6.2.3 on polythionic acid stress corrosion cracking. When chromium-containing materials are nitrided, the corrosion resistance is compromised. Nitrided chromium-molybdenum or nitrided stainless steel trim parts should not be utilized in chromium-molybdenum or stainless steel bodies in refineries.

For more information, refer to NACE Technical Committee Report 34103, *Overview of Sulfidic Corrosion In Petroleum Refining*.

5.6.2.3 Polythionic Acid Stress Corrosion Cracking (PTA SCC)

5.6.2.3.1 In applications involving sulfur compounds and operating temperatures above 370 °C (700 °F), sulfur-containing corrosion products form on the interior surfaces of process equipment. During a shutdown, if air and moisture are allowed into the system, polythionic acids (H_2SnO_6 – where n can range from 3 to 80) can form, and can cause stress corrosion cracking of sensitized austenitic stainless steels. Typical applications where this scenario is present include desulfurizing, hydrocracking, hydrotreating, crude distillation, and fluid catalytic cracking units. A proven solution is to use stabilized stainless steel grades (S34700/CF8C and S32100), which are resistant to sensitization.

The reason a standard CF8M austenitic stainless steel is not used is because the non-stabilized 300-series stainless steels are susceptible to sensitization if exposed to temperatures above 370 °C (700 °F). Using S32100 or S34700 is successful because S32100 is stabilized with titanium and S34700 is stabilized with tantalum and columbium. Titanium and niobium are stronger carbide formers than chromium and prevent the formation of chromium carbides, thus avoiding sensitization. These will not sensitize, therefore are not susceptible to PTA stress corrosion cracking.

Also, if nickel alloys are being considered, stabilized or low-carbon grades should be specified. Grades which should not be used include N06600/CY40 and N07750. Although S20910 does not contain enough niobium to be fully stabilized, and is not fully a low-carbon grade (0.06 % max carbon), the fact that it does contain some niobium and has a reduced maximum carbon content has resulted in its acceptance by some customers as an acceptable stem or shaft material. If S20910 is not accepted, N07718, which is fully stabilized, can be used, but is significantly more expensive.

Some refiners continue to use S31600 in this service with special washing and shutdown procedures to prevent this type of attack.

For more information refer to NACE RP0170, *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During Shutdown of Refinery Equipment*.

5.6.3 Acidic Environments

5.6.3.1 Hydrofluoric Acid

Hydrofluoric acid, whether in the form of dry liquid, gas, or water solution, is a strong acid that rapidly attacks many substances—including ordinary glass and human flesh. This fluid is highly toxic and a primary concern in the hydrofluoric acid alkylation plant is employee safety.

Carbon steel is the most widely used material for most control valve bodies. A thin film of purplish-colored fluoride compound builds up on iron and steel surfaces exposed to hydrofluoric acid. This plating is fairly hard and durable. In the right circumstances, it protects the metal against further attack by the acid, so that the corrosion is self-limiting. The main concern with fluoride plating is that it takes up more space than the thin surface layer of metal which it replaced. For this reason, cage guided valves with their narrow clearances and tight fits are not allowed. For valve trims, N04400 and N05500 alloys are generally accepted as optimum for all exposed (wetted) parts. Some users also have success using N10276 and N06625. These applications are found in the hydrofluoric acid alkylation unit in a refinery.

5.6.3.2 Sulfuric Acid

Like Hydrofluoric acid, H_2SO_4 is a strong acid that can attack many substances and is toxic. N08020 has been proven to be a successful material to withstand this attack. Some refiners utilize a sulfuric acid alkylation plant instead of HF, which is where these applications will be found.

Sulfuric Acid is incompatible with many types of coatings including Electroless Nickel Coating (ENC), chrome plating, hard chrome, and chromium coating.

5.6.3.3 Napthenic Acid Corrosion

Napthenic acid corrosion occurs when any organic acids are present in crude oils. Napthenic acid corrosion is most common in crude oils from California, Venezuela, North Sea, Western Africa, China and Russia. This type of acidic corrosion is typically seen in hydrotreaters, crude distillation, and some coker applications. Successful prevention of this corrosion can be achieved by using an austenitic stainless steel valve body with a minimum molybdenum requirement (often specified as 2.5 % minimum). In order to meet this minimum with an austenitic stainless steel, users can either specify a special grade of S31600 or S31603 or they can use standard grade S31700. The molybdenum content in S31600 and S31603 can range from 2 % to 3 %, while S31700 has a minimum content of 3.0 % (range is 3.0 % to 4.0 %). CoCr-A is also a material option.

Basing the entire trim selection on the minimum molybdenum requirement can be quite challenging. One issue is shaft selection. S17400 (17-4 ph Stainless Steel) is not acceptable for resistance. S20910 has a range of 1.5 % to 3.0 % Molybdenum, typically around 2.2 %. Many users have no issue with this selection. One option is to upgrade to N07718. The other issue is coating and hardfacing. CoCr-A hard facing does not contain any molybdenum, nor does chromium or electroless nickel. If a conservative approach is used for this service, R31233 (Ultimet) is a coating used in refining applications that meets the molybdenum requirement.

5.6.4 Alkaline Environments

5.6.4.1 Alkaline Stress Corrosion Cracking (ASCC)

Alkaline environments can cause stress corrosion cracking in carbon steels. The common types of ASCC encountered in refineries are caustic cracking, amine cracking, and carbonate cracking. Severity of cracking is dependent on temperature, concentration, level of residual tensile stresses, and other factors. Controlling hardness does not prevent ASCC. Typical applications in refineries are any environment where caustic, amines, or carbonates are encountered. Successful methods of prevention are to stress relieve welds to reduce residual tensile stresses and help mitigate ASCC. The stress relieving practices for the various types of ASCC are described in NACE RP0472, *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments*. Manufacturers should have practices written to perform stress relieving of pressure retaining parts that meet these RP0472 requirements.

Other facts to note.

a) These instructions apply only to carbon steels.

b) Customers will typically not indicate on specification sheets that ASCC is a possibility, but will rather simply impose Post Weld Heat Treating (PWHT) of all welds.

c) Applications involving ASCC may or may not also be sour. Therefore, specification sheets may indicate post weld heat treatment (PWHT) requirements without imposing MR0103, or PWHT requirements plus MR0103 requirements.

6 Installation/Inspection/Testing

6.1 Accessibility

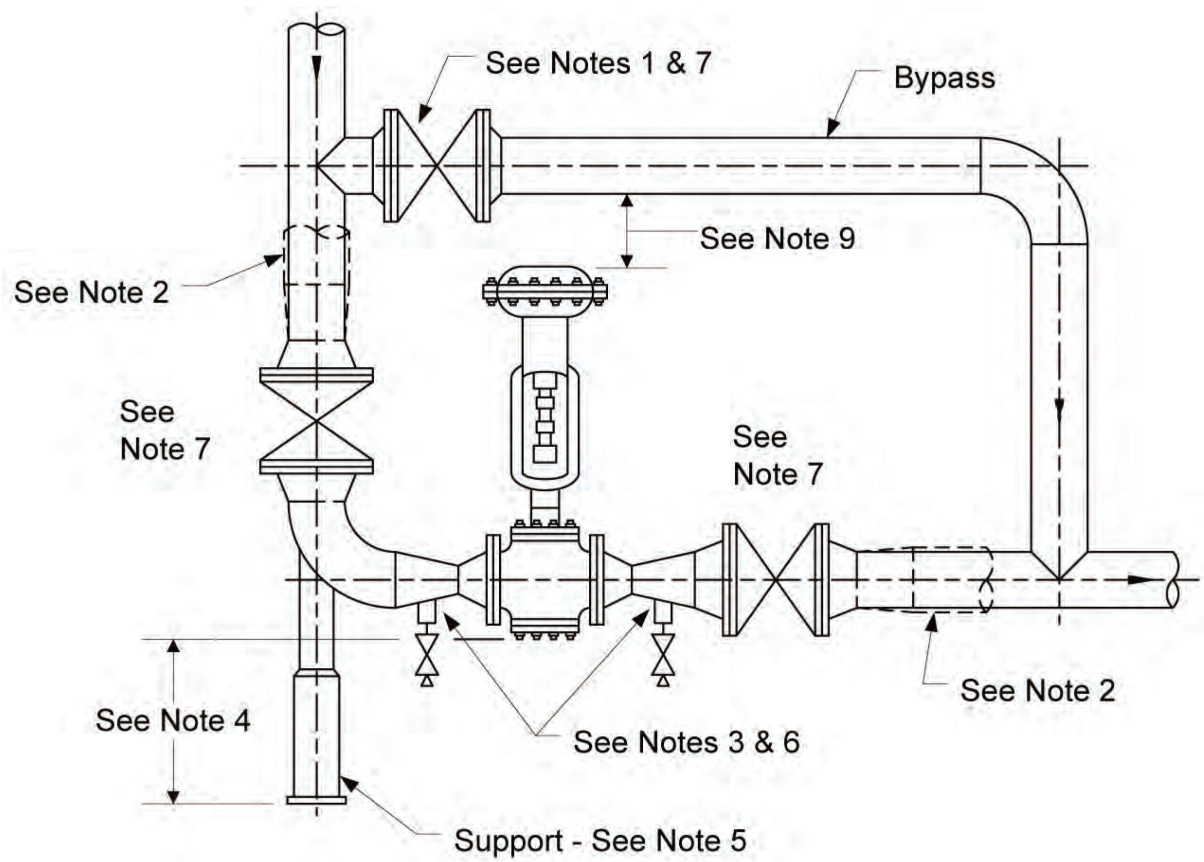
6.1.1 All control valves and associated accessories should be installed so that they are readily accessible for maintenance purposes and for operation of a handwheel, if one is provided. They should generally be located at grade unless pressure head or other design conditions make such an arrangement impractical. When located above grade, control valves should be installed so that they are readily accessible from a permanent platform or walkway with ample clearances for maintenance purposes. There should be sufficient clearance between the control valve actuator and the bypass line to allow removal of the actuator, bonnet, and plug. Consult the valve installation manual for preferred mounting and orientation. Figure 32 illustrates a typical control valve station.

6.2 Location

6.2.1 Where there is a choice of location, it is desirable to have the control valve installed near the piece of operating equipment that should be observed while on local manual control. In these cases, it is also desirable to have indication of the controlled variable readable from the control valve handwheel or the bypass valve.

6.2.2 Control valves used in process lines or fuel lines to fired heaters should be located on the sides of the heater away from the burners or at a sufficient distance from the heater, with blocks and bleed valves, so that the line can be drained and the control valves removed without danger of a flashback. An alternate method is to pipe the drain or bleed connection a safe distance from the heater.

6.2.3 High temperatures can cause premature failure of actuator or positioner soft goods and electrical or electronic components. Control valves should not be located adjacent to hot lines or equipment, or where temperature may be excessive. The actuator and accessories should have a minimum clearance of 600 mm (24 in.) from surfaces exceeding 260 °C (500 °F). Where this clearance is not available, thermal shielding should be used. Consult the manufacturer’s literature for maximum permissible ambient temperature.



NOTES:

(1) Bypass valve size should be equivalent to Control Valve size (i.e. as close to equivalent C_v as possible).

(2) Reduce line size ahead of the block valves so that the manifold pipe size and the control valve fall within the relationships.

(3) Where control valve is line size, provide minimum straight length of six inches or one pipe diameter, whichever is larger. For rotary control valve, allow sufficient length of straight pipe on one side of the valve to permit removal of line flange bolting.

(4) Install control valve close to grade or platform with a 30 mm (12 in.) minimum under clearance.

(5) Support control valve manifold.

(6) An NPS 3/4 (DIN 20) bleeder valve should be installed between the block valves and the control valve.

(7) Block and bypass valve sizes should be standard sizes.

(8) Expander and reducing flanges should not be used in control valve manifolds.

(9) Clearance should be provided to permit the removal of the actuator with the valve in the line. This dimension should not be less than 30 mm (12 in.).

Figure 32—Typical Control Valve Manifold

6.2.4 All electrical equipment and circuits for instrumentation and controls should be designed, furnished, and certified to meet the electrical area classification in which they are to be installed.

6.2.5 Control valves should be removed from the piping system during flushing and hydrotesting.

6.2.6 When a control valve is equipped with a handwheel, the handwheel should be easily operable from normal personnel access paths or platforms. For ergonomic reasons, handwheels should face the operator access area, and the shaft center should be 1 m to 1.5 m (3 ft to 5 ft) above the elevation of the access area.

6.3 Control Valve Manifolds

6.3.1 General

The design of control valve manifolds varies widely. In applications where a process shutdown for the servicing of control valves cannot be tolerated and the process can be safely operated manually, block and bypass valves should be provided.

6.3.2 Block and Bypass Valves

6.3.2.1 Where the greatest flexibility is to be provided for future expansion, the block valves upstream and downstream of the control valve should be line size. In situations where the control valve is two sizes smaller than line size, the block valves may be one size smaller than line size.

6.3.2.2 For controllability, the bypass valve capacity should not be significantly greater than the control valve capacity. It is not unusual to make bypass valves smaller than the line size in such cases.

6.3.2.3 For critical applications where the by-pass must be used to provide continuous operation while the main control valve is taken out of service for any reason, the by-pass valve size and the trim characteristic should be exactly the same as that used for the main control valve. Consideration should also be given to fully automating the by-pass valve (i.e. duplicate specification of the main control valve), when the potential exists to completely shut down the process if the main control valve becomes inoperable.

6.3.3 Manifold Piping Arrangements

6.3.3.1 The manifold piping should be arranged to provide flexibility for removing control valves, particularly where ring-type joints are used. Flexibility of piping is also necessary to keep excessive stresses from being induced in the body of the control valve. Vents and drains should be provided as required to service the control valve.

6.3.3.2 The piping around control valves should be self-supporting or should be permanently supported so that when the control valve or block valve is removed the piping integrity remains.

6.3.3.3 Severe services may require special valve manifold designs. Design should be reviewed by user and manufacturer.

6.3.4 Swages

6.3.4.1 Where a flanged or flangeless control valve smaller than line size is used, swages are placed adjacent to the control valve except where additional piping is needed to permit removal of the through bolts. Some users swage outside the valve manifold to use smaller block valves, but this reduces the flexibility of being able to change to a larger control valve on-line.

6.4 Inspection and Testing

6.4.1 Factory Acceptance Tests should be conducted for all high performance control valves.

6.4.2 All high performance control valves should be furnished with a valve signature that documents its baseline for future maintenance and troubleshooting.

6.4.3 Steel bodies should be pressure tested per ASME B16.34. For cast iron, brass, or bronze bodies, test pressure should be two times primary pressure rating.

6.4.4 Where valves are specified to meet FCI-70-2 leakage Class V or above, vendor should supply documentation demonstrating the valve meets the specified leakage class.

6.4.5 For operational testing, all valves should be completely assembled with the packing box fully packed and torqued to the appropriate value for the valve per the valve manufacturer's specifications. The valve stem may be lightly lubricated. The performance values noted below are considered to provide adequate performance for many process applications. If tighter control performance is required by the process application, or process license agreement, the end user may specify different values in the purchase requisition.

Testing should consist of applying increasing and decreasing control signals directly to the positioner and at the same time measuring valve stem position. For PTFE, the following performance criteria should be achievable with repeatable results.

a) For polytetrafluoroethylene (PTFE) packing, the stem position error should not exceed 2 % of rated travel.

b) For polytetrafluoroethylene (PTFE) packing, hysteresis plus dead band should not exceed 2 % of rated travel.

Graphite packing is often specified for high temperature applications. Since graphite packing tends to exhibit more system friction at cooler temperatures, the performance values noted below compensate for the increased friction at room temperature when the test is conducted. The following performance criteria for graphite packing should be achievable with repeatable results.

a) For graphite packing, the stem position error should not exceed 3 % of rated travel.

b) For graphite packing, hysteresis plus dead band should not exceed 3 % of rated travel.

The end user should consider witnessing these tests, particularly for valves that have specific performance requirements that must be achieved for either a unique process application or license agreement.

6.4.6 Valve body (and flanges where applicable) should be marked in accordance with MSS SP-25.

6.4.7 The fixed-open port for three-way valves should be steel-stamped COMMON on the flange.

6.4.8 Valves should have the following identifying information on a nameplate fastened to the valve:

1) equipment identification or tag number;

2) manufacturer name or trademark;

3) valve serial number;

4) maximum valve body pressure rating;

5) valve body material and body size;

6) plug/seat material;

7) packing material;

8) valve action and bench set;

9) C_V and characteristic.

6.4.9 Valves in safety critical service should be clearly marked or painted to insure they are not bypassed or put into maintenance without following the proper management procedures.

6.4.10 As a minimum**,** each valve should be furnished with a detailed assembly drawing or description of parts traceable to a serial number.

If the end user requires more specific vendor documentation, the following other technical documents are available from the valve manufacturer—if specifically requested in the purchase requisition:

a) valve signature curves;

b) Certified Material Test Reports (CMTRs);

c) Positive Material Identification (PMI) record;

d) Certificate of Conformance – NACE (either MR1075 or MR0103);

e) weld record certification/weld repair documentation;

f) X-ray examination;

g) magnetic particle or liquid penetrant testing.

7 Refinery Applications

7.1 Introduction

The simplified process flow diagrams in the following sections depict common Refinery Processing Units. Also shown are the most common locations of the major control valves for these Units.

7.1.1 For select streams within each of these Units, this section provides a general discussion as to which type of control valve would be best suited for these services with application notes and recommendations. The valves recommended represent the most economical solution to the given problem. These solutions have been proven in service.

7.1.2 Materials and packing suggested in these examples may be modified, based on material engineer's specification, vendor suggestions, and specific applications. Special environmental packing may be used where required by regulations.

7.1.3 The user is cautioned to understand the significance of the recommendations herein and the limitations. It is more likely that a given problem will resemble an example than actually match it. Thus, the user should use caution.

NOTE The process conditions depicted in these examples are shown as a reference only.

7.2 Atmospheric Distillation—(Typical)

See the atmospheric distillation simplified flow diagram in Figure 33.

7.2.1 Atmospheric Distillation—Unit Feed (Valve #1)

7.2.1.1 Operating Conditions

See Table 2 for valve sizing data for unit feed valves.

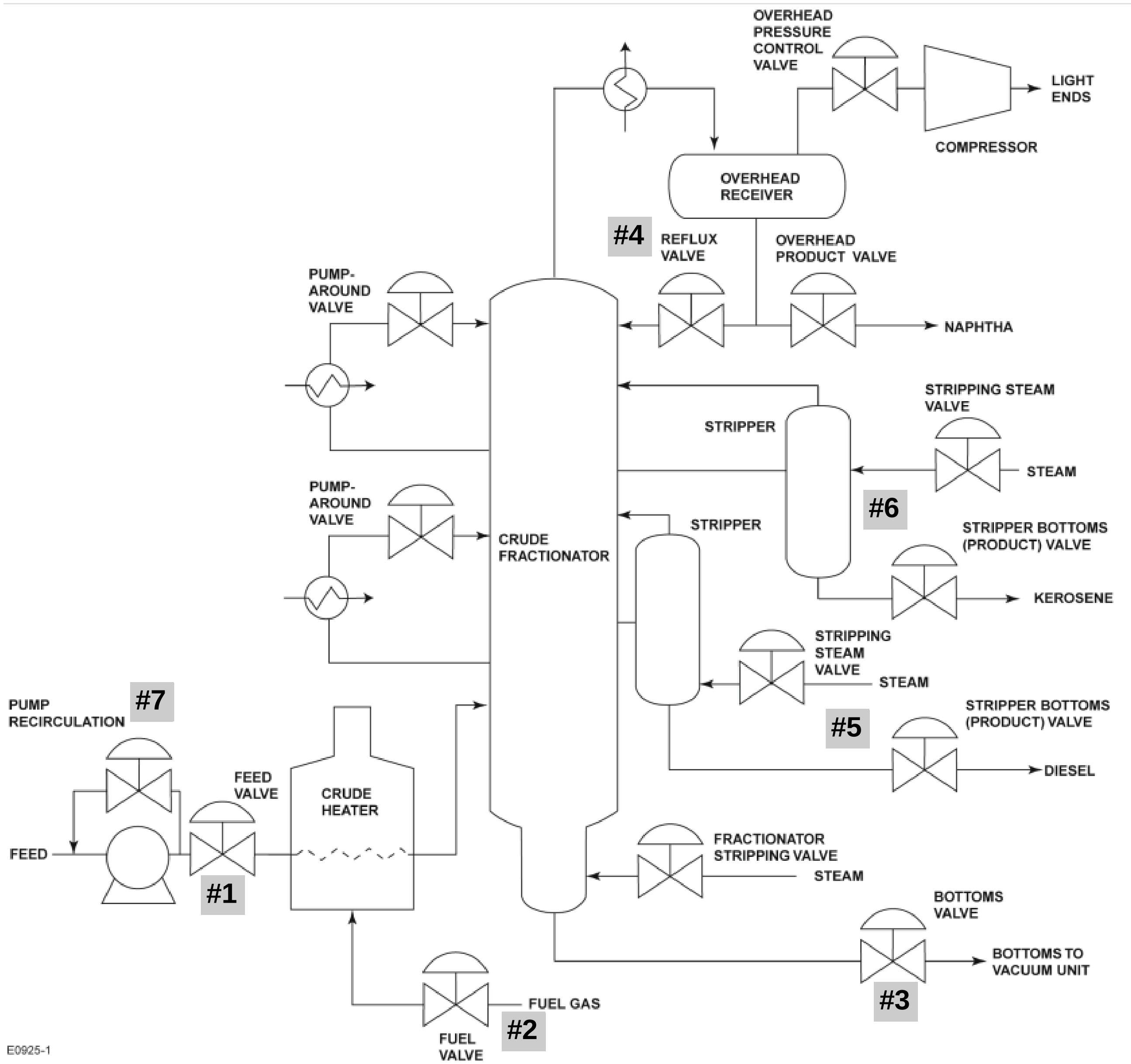


Figure 33—Atmospheric Distillation Simplified Flow Diagram

7.2.1.2 Valve Specification

Either an **eccentric rotary plug style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a chrome-molybdenum body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The chrome-moly body provides enhanced hardness characteristics over carbon steel at higher ANSI pressure/temperature ratings. If an eccentric rotary plug valve is selected a reverse flow (flow passes plug, then seal) valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is typically ANSI Class IV shutoff.

7.2.1.3 Trim

Reverse flow full port trim configuration consisting of S17400 stainless steel seat ring retainer, CoCr-A seal, and CoCr-A valve plug with equal percentage characteristic. Reverse flow configurations will minimize high velocity flow

Table 2—Valve Sizing Data for Unit Feed Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid – Crude Oil	Liquid – Crude Oil
Flow m^3/h (gpm)	545 (2400)	681 (3000)
P_1 barg (psig)	22.4 (325)	20.7 (300)
ΔP bar (psi)	6.9 (101)	4.3 (63)
T °C (°F)	232 (450)	315 (600)
Specific Gravity	0.72	0.72
Molecular Weight		
Vapor Pressure bara (psia)	5.3 (7.7)	5.3 (7.7)

across the rotary plug, seal, and inner valve body surfaces, helping maintain shutoff specified and optimal body life. S17400 shaft and CoCr-A bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The CoCr-A/S17400 shaft/bearing combination will minimize valve friction which would be caused by excessive fluid particle buildup in the bearing areas.

For Globe style valves, valve guiding should be post guided or double top stem guided to prevent galling and sticking of valve trim.

Also, refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.2.1.4 Sizing

Conventional valve sizing equations for liquid.

7.2.2 Atmospheric Distillation—Fuel Gas To Furnace (Valve #2)

7.2.2.1 Operating Conditions

See Table 3 for valve sizing data for fuel gas to furnaces.

Table 3—Valve Sizing Data for Fuel Gas to Furnace

Process Data	Design Conditions	
	Normal	Normal
Fluid	Gas	Gas
Flow sm^3/h (scfh)	3681 (130,000)	5890 (208,000)
P_1 barg (psig)	3.45 (50)	3.45 (50)
ΔP bar (psi)	1.4 (20)	1.2 (17)
T °C (°F)	32 (90)	37 (100)
Specific Gravity	0.59	0.59
Molecular Weight	11	11

7.2.2.2 Valve Specification

Either an **eccentric rotary style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL150 or CL300, with a carbon steel body, polytetrafluoroethylene (PTFE) fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.2.2.3 Trim

Refer to 5.6 for material selection based on valve vendor's standard trim materials (use caution with low-noise trim in these services if fuel gas is dirty).

7.2.2.4 Sizing

Conventional valve sizing equations for gases.

7.2.3 Atmospheric Distillation—Heavy Bottoms (Valve #3)

7.2.3.1 Operating Conditions

See Table 4 for valve sizing data for heavy bottoms valves.

Table 4—Valve Sizing Data for Heavy Bottoms Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	430 (1896)	477 (2100)
P_1 barg (psig)	17.7 (257)	16.2 (235)
ΔP bar (psi)	4.13 (60)	1.03 (15)
T °C (°F)	332 (630)	399 (750)
Specific Gravity	0.71	0.71
Vapor Pressure bara (psia)	5.3 (7.7)	5.3 (7.7)

7.2.3.2 Valve Specification

Either an **eccentric rotary plug style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a chrome-molybdenum body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The chrome-moly body provides enhanced hardness characteristics over carbon steel at higher ANSI pressure/temperature ratings. If an eccentric rotary plug valve is selected a reverse flow (flow passes plug, then seal) valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is typically ANSI Class IV shutoff.

7.2.3.3 Trim

Reverse flow full port trim configuration consisting of S17400 stainless steel seat ring retainer, CoCr-A seal, and CoCr-A valve plug with equal percentage characteristic. Reverse flow configurations will minimize high velocity flow across the rotary plug, seal, and inner valve body surfaces, helping maintain shutoff specified and optimal body life. S17400 shaft and CoCr-A bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The S17400/CoCr-A shaft/bearing combination will minimize valve friction which would be caused by excessive fluid particle buildup in the bearing areas.

For Globe style valves, valve guiding should be post guided or double top stem guided to prevent galling and sticking of valve trim.

Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.2.3.4 Sizing

Conventional valve sizing equations for liquids.

7.2.4 Atmospheric Distillation—Reflux (Valve #4)

7.2.4.1 Operating Conditions

See Table 5 for valve sizing data for reflux valves.

Table 5—Valve Sizing Data for Reflux Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	152 (670)	172 (758)
P_1 barg (psig)	5.93 (86)	5.65 (82)
ΔP bar (psi)	1.9 (28)	1.3 (19)
T °C (°F)	212 (415)	249 (480)
Specific Gravity	0.73	0.73
Vapor Pressure bara (psia)	1.3 (20)	1.3 (20)

7.2.4.2 Valve Specification

Either an **eccentric rotary style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a carbon steel body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service.

7.2.4.3 Trim

Standard 300 or 400 series stainless steel trims. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.2.4.4 Sizing

Conventional valve sizing equations for liquids.

7.2.5 Atmospheric Distillation—Stripping Steam (Valves #5 and #6)

7.2.5.1 Operating Conditions

See Table 6 for valve sizing data for stripping steam valves.

Table 6—Valve Sizing Data for Stripping Steam Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Steam	Steam
Flow kg/h (lb/h)	907 (2000)	1814 (4000)
P_1 barg (psig)	2.76 (40)	2.76 (40)
ΔP bar (psi)	0.96 (14)	0.96 (14)
T °C (°F)	371 (700)	374 (705)
Molecular Weight	18	18

7.2.5.2 Valve Specifications

These valves are usually an **eccentric rotary plug style** or **general service sliding stem globe style** control valve with ANSI CL300, a carbon steel body, graphite packing and a Fail Close actuator and positioner for throttling control.

7.2.5.3 Trim

Use S41600 or hard faced S31600 base trim with hardened S17400 steel seat ring retainer and S17400 steel guide bushing. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.2.5.4 Sizing

Conventional valve sizing equations for vapor/steam.

7.2.6 Atmospheric Distillation—Feed Pump Recirculation (Valve #7)

7.2.6.1 Operating Conditions

See Table 7 for valve sizing data for feed pump recirculation valve.

Table 7—Valve Sizing Data for Feed Pump Recirculation Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	727 (3200)	1590 (7000)
P_1 barg (psig)	28 (400)	29 (422)
ΔP bar (psi)	24 (350)	17 (256)
T °C (°F)	212 (415)	249 (480)
Specific Gravity	0.87	0.87
Vapor Pressure barga (psia)	0.2 (3.0)	0.2 (3.0)

7.2.6.2 Valve Specifications

Either an **eccentric rotary plug style** or **general service sliding stem globe style** control valve with ANSI CL300 carbon steel body, graphite packing, Fail Closed actuator, and positioner for throttling service.

7.2.6.3 Trim

For globe style valve stem-guided, unbalanced construction, S41600 valve plug, and S41000 seat ring are selections with high hardness to combat erosive flow; precipitation hardened S17400 cage. If an eccentric rotary plug style is selected a reverse flow (flow passes plug, then seal) valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. ANSI Class IV shutoff is typical.

Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.2.6.4 Sizing

Standard liquid sizing is adequate for an initial evaluation. However, special procedures may be required to account for solids present in flow stream; beware of underestimating flow coefficient with standard liquid sizing equations. Sizing should consider the erosive nature of the solids present in the flow stream; the equal percentage characteristic is preferred to position the operating conditions at an intermediate travel to avoid the high velocity flow of low travel conditions. The equal percentage characteristic will also provide relatively uniform control loop stability over the expected range of operating conditions, compensating for the installed gain effects of the pump curve.

7.3 Vacuum Distillation—(Typical)

See the vacuum distillation simplified flow diagram in Figure 34.

7.3.1 Vacuum Distillation—Charge Heater Pass Feed (Valve #1)

7.3.1.1 Operating Conditions

See Table 8 for valve sizing data for charge heater pass feed valves.

Table 8—Valve Sizing Data for Charge Heater Pass Feed Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	37 (164)	50 (219)
P_1 barg (psig)	10 (150)	21 (300)
ΔP bar (psi)	0.2 (3)	0.13 (2)
T °C (°F)	332 (630)	360 (680)
Specific Gravity	0.76	0.76
Vapor Pressure bara (psia)	0.14 (2.1)	0.14 (2.1)

7.3.1.2 Valve Specification

Either an **eccentric rotary plug style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a chrome-molybdenum body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The chrome-moly body provides enhanced hardness characteristics over carbon steel at higher ANSI pressure/temperature ratings. If an eccentric rotary plug valve is selected a reverse flow (flow passes plug, then seal) valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is typically ANSI Class IV shutoff.

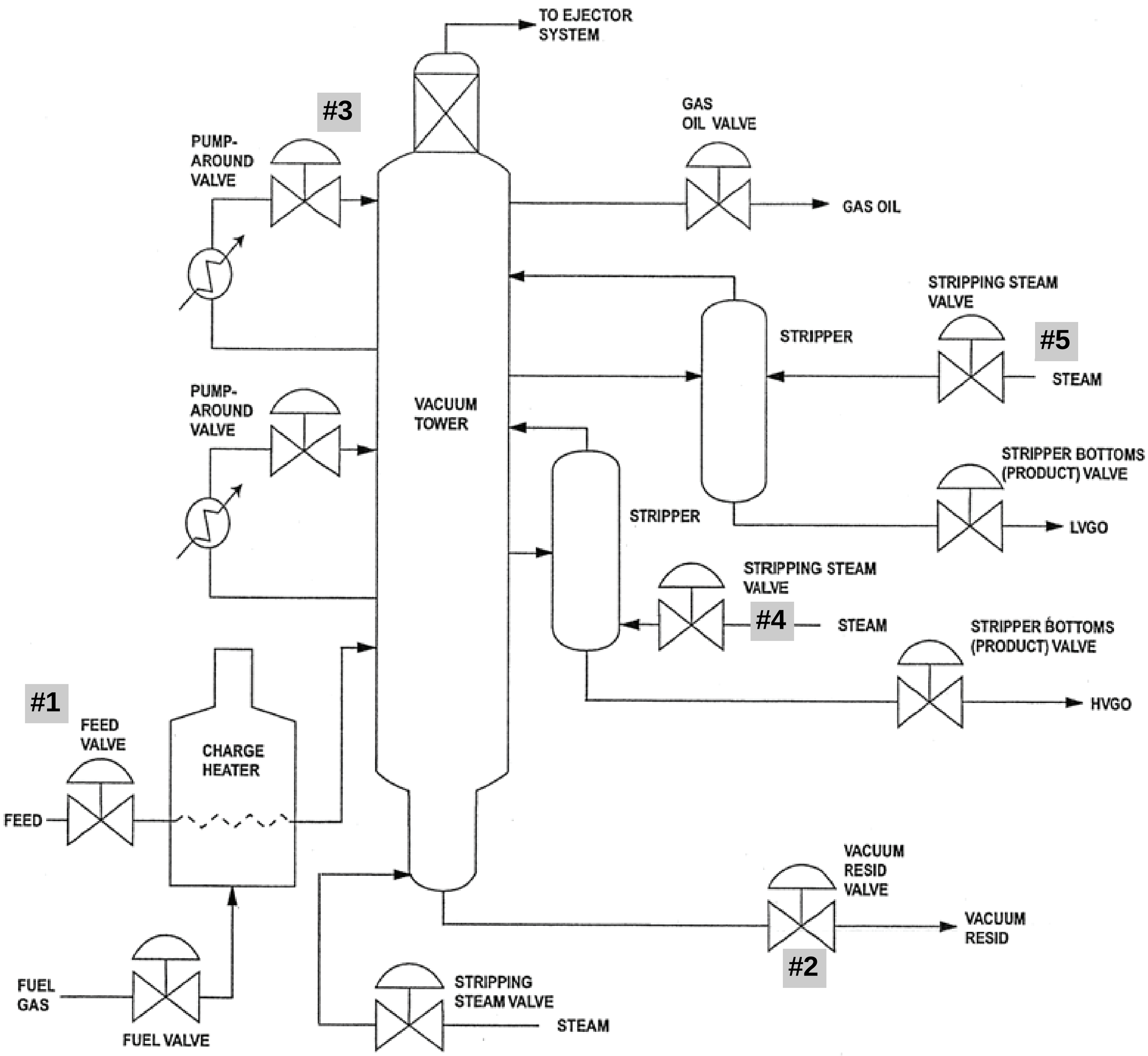


Figure 34—Vacuum Distillation Simplified Flow Diagram

7.3.1.3 Trim

Reverse flow full port trim configuration consisting of S17400 seat ring retainer, CoCr-A seal, and CoCr-A plug with equal percentage characteristic. Reverse flow configurations will minimize high velocity flow across the rotary plug, seal, and inner valve body surfaces, helping maintain shutoff specified and optimal body life. S17400 shaft and CoCr-A bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The S17400/CoCr-A shaft/bearing combination will minimize valve friction which would be caused by excessive fluid particle buildup in the bearing areas.

For Globe style valves, valve guiding should be post guided or double top stem guided to prevent galling and sticking of valve trim.

Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.3.1.4 Sizing

Conventional valve sizing equation for liquids.

7.3.2 Vacuum Distillation—Resid (Valve #2)

7.3.2.1 Operating Conditions

See Table 9 for valve sizing data for resid bottoms valves.

Table 9—Valve Sizing Data for Resid Bottoms Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	273 (1200)	307 (1350)
P_1 barg (psig)	13 (190)	21 (300)
ΔP bar (psi)	2.8 (40)	0.3 (5)
T °C (°F)	332 (630)	399 (750)
Specific Gravity	0.92	0.92
Vapor Pressure bara (psia)	0.14 (2.1)	0.14 (2.1)

7.3.2.2 Valve Specification

Either an **eccentric rotary plug style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a chrome-molybdenum body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The chrome-moly body provides enhanced hardness characteristics over carbon steel at higher ANSI pressure/temperature ratings. If an eccentric rotary plug is selected a reverse flow (flow passes plug, then seal) valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is typically ANSI Class IV shutoff.

7.3.2.3 Trim

Reverse flow full port trim configuration consisting of S17400 seat ring retainer, CoCr-A seal, and CoCr-A valve plug with equal percentage characteristic. Reverse flow configurations will minimize high velocity flow across the rotary plug, seal, and inner valve body surfaces, helping maintain shutoff specified and optimal body life. S17400 shaft and CoCr-A bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The S17400/CoCr-A shaft/bearing combination will minimize valve friction which would be caused by excessive fluid particle buildup in the bearing areas.

For Globe style valves, valve guiding should be post guided or double top stem guided to prevent galling and sticking of valve trim.

Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.3.2.4 Sizing

Conventional valve sizing equations for liquids.

7.3.3 Vacuum Distillation—Top Pumparound (Valve #3)

7.3.3.1 Operating Conditions

See Table 10 for valve sizing data for top pumparound valves.

Table 10—Valve Sizing Data for Top Pumparound Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	265 (1166)	371 (1633)
P_1 barg (psig)	6 (87)	21 (300)
ΔP bar (psi)	1.4 (20)	1.4 (20)
T °C (°F)	66 (150)	149 (300)
Specific Gravity	0.83	0.83
Vapor Pressure bara (psia)	0.14 (2.1)	0.14 (2.1)

7.3.3.2 Valve Specification

Either an **eccentric rotary plug style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a carbon steel body, PTFE fugitive emission packing, and a Fail Open actuator and positioner for throttling service.

7.3.3.3 Trim

Standard 300 or 400 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.3.3.4 Sizing

Conventional valve sizing equations for liquids.

7.3.4 Vacuum Distillation—Stripping Steam (Valves #4 and #5)

7.3.4.1 Operating Conditions

See Table 11 for valve sizing data for stripping steam valves.

Table 11—Valve Sizing Data for Stripping Steam Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Steam	Steam
Flow kg/h (lb/h)	454 (1000)	907 (2000)
P_1 barg (psig)	1.9 (28)	17.2 (250)
ΔP bar (psi)	1.8 (27)	1.8 (27)
T °C (°F)	338 (640)	338 (640)
Molecular Weight	18	18

7.3.4.2 Valve Specifications

These valves are usually a **general service sliding stem globe style** control valve with ANSI CL300, a carbon steel body, graphite packing and a Fail Close actuator and positioner for throttling control.

7.3.4.3 Trim

S41600 and hardened S17400 seat ring retainer and S17400 guide bushing. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.3.4.4 Sizing

Conventional valve sizing equations for vapor/steam.

7.4 Fluid Catalytic Cracking (FCCU)—(Typical)

See the fluid catalytic cracking (FCCU) simplified flow diagrams for:

— Reactor section, see Figure 35A;

— Fractionator section, see Figure 35B;

— Vapor recovery section, see Figure 35C.

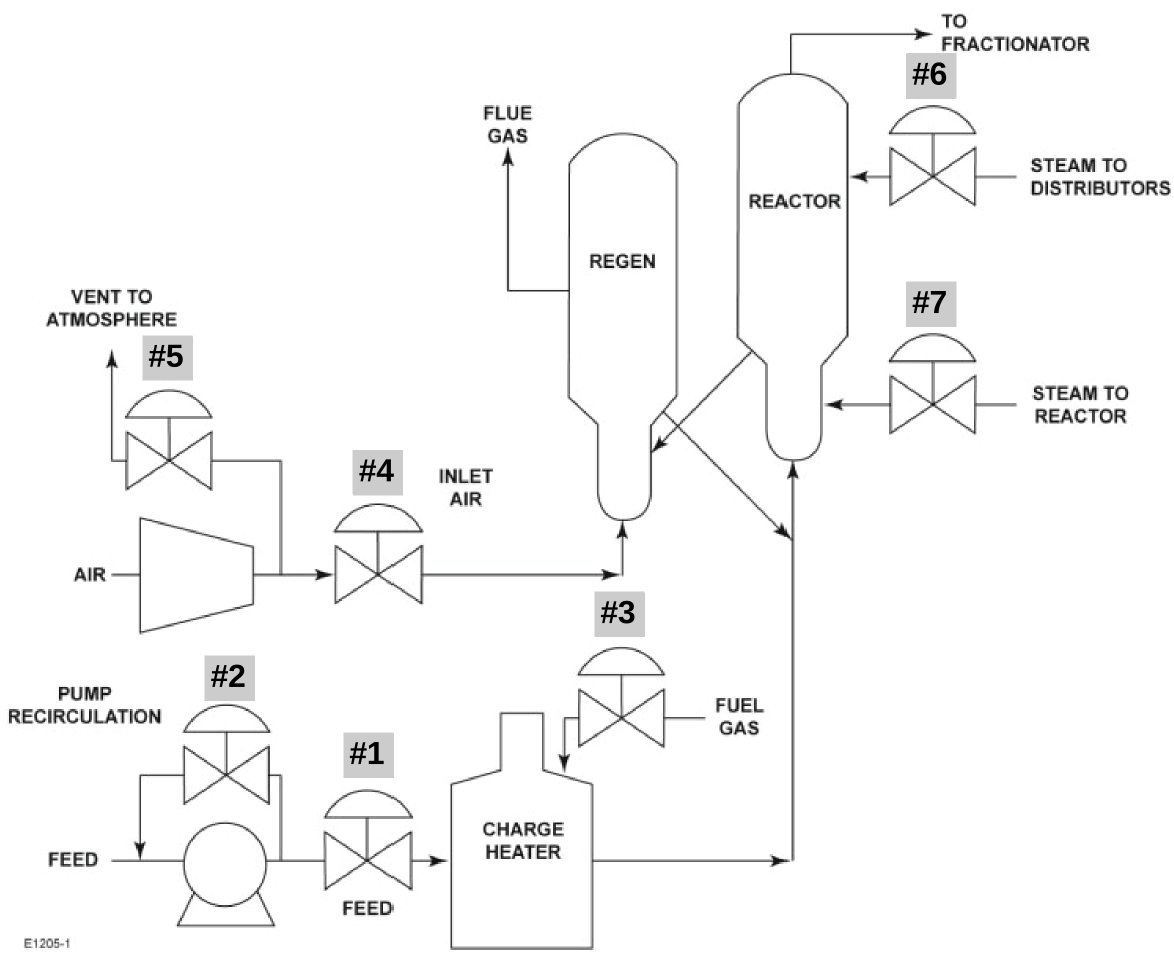


Figure 35A—Fluid Catalytic Cracking (FCCU)—Reactor Section Simplified Flow Diagram

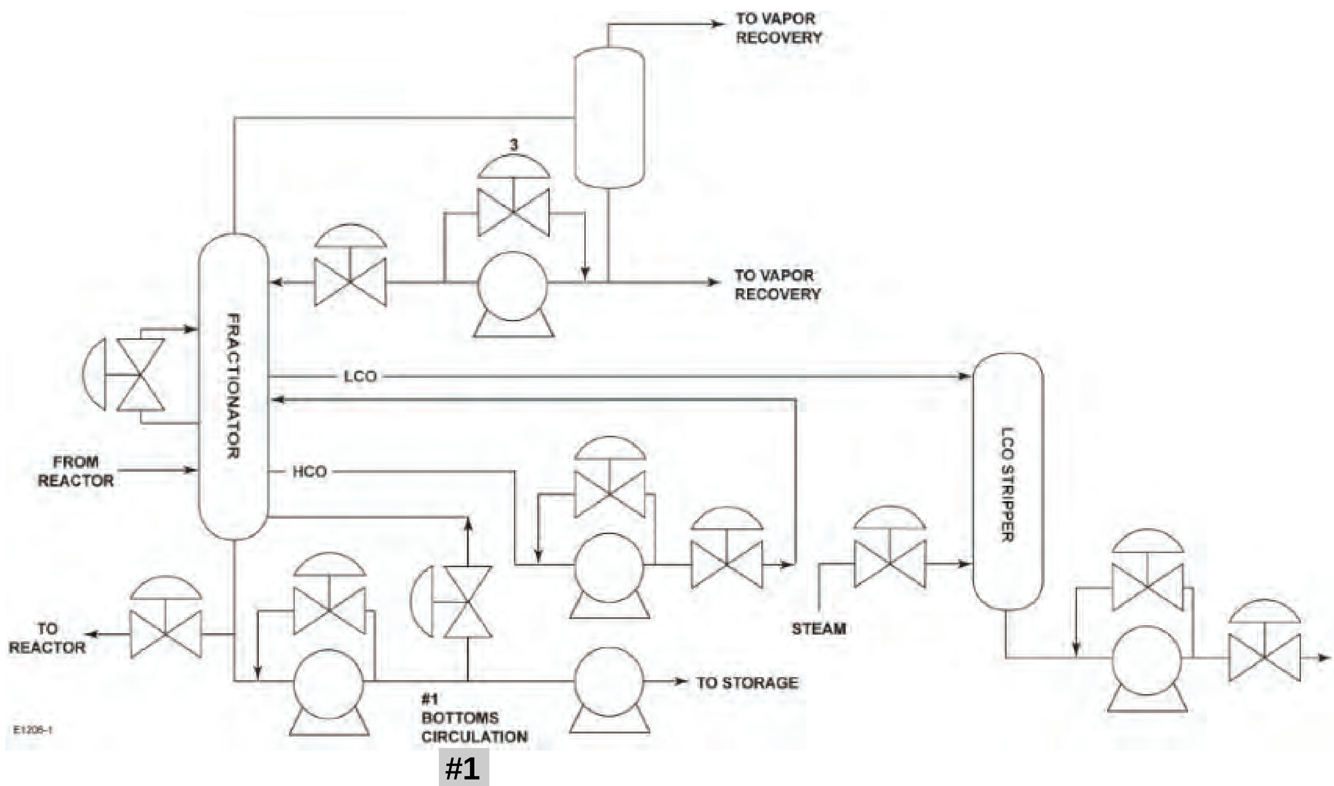


Figure 35B—Fluid Catalytic Cracking (FCCU)—Fractionator Section Simplified Flow Diagram

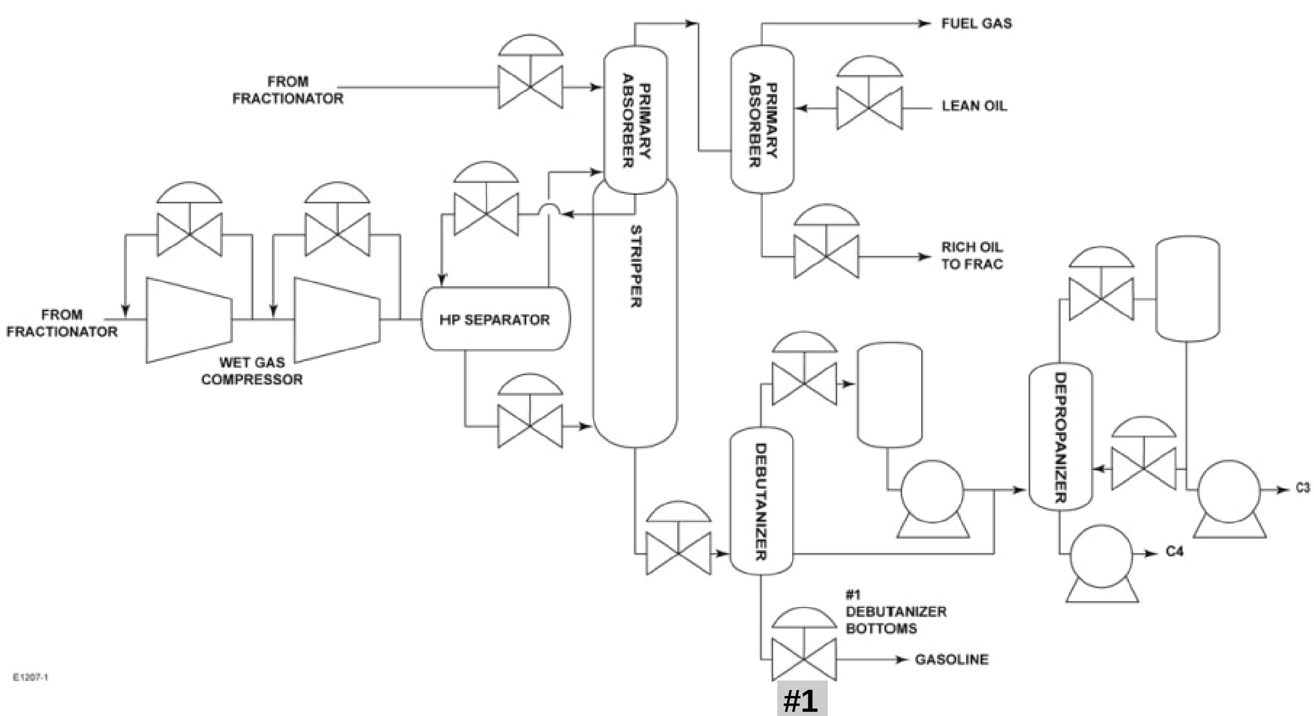


Figure 35C—Fluid Catalytic Cracking (FCCU)—Vapor Recovery Section Simplified Flow Diagram

7.4.1 FCCU—Charge Oil (Valve #1)

This valve controls the flow of feedstock into the charge heater and then to the reactor. Proper flow control is important for maintaining outlet temperature from the charge heater, which, as a result, can affect the reaction performance. Poor control can result in excessive buildup on the tubes in the charge heater thus reducing its efficiency.

7.4.1.1 Operating Conditions

See Table 12 for valve sizing data for charge oil valves.

Table 12—Valve Sizing Data for Charge Oil Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	227 (1000)	454 (2000)
P_1 barg (psig)	18 (261)	24 (348)
ΔP bar (psi)	12 (174)	9 (130)
T °C (°F)	70 (158)	80 (176)
Specific Gravity	0.83	0.83
Vapor Pressure bara (psia)	0.14 (2.1)	0.14 (2.1)

7.4.1.2 Valve Specification

Either an **eccentric rotary style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with carbon steel or chrome-molybdenum body, PTFE fugitive emission packing, and a Fail Open actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.4.1.3 Trim

Use standard 300, 300 hard faced, or 400 series hardened stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.4.1.4 Sizing

Conventional valve sizing equations for liquids.

7.4.2 FCCU—Charge Pump Spillback (Valve #2)

This recirculation valve is used to prevent cavitation in the charge pump. The pressure drop can be high enough to warrant the use of anti-cavitation trims, but some facilities utilize a rotary valve with hardened trim to resist the cavitation damage. A rotary or globe valve with hardened trim or a globe valve with anti-cavitation trim are commonly used solutions in this application.

7.4.2.1 Operating Conditions

See Table 13 for valve sizing data for spill back valves.

Table 13—Valve Sizing Data for Spill Back Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	75 (330)	225 (991)
P_1 barg (psig)	18 (261)	24 (348)
ΔP bar (psi)	16 (232)	22 (319)
T °C (°F)	70 (158)	80 (176)
Specific Gravity	0.83	0.83
Vapor Pressure bara (psia)	0.14 (2.1)	0.14 (2.1)

7.4.2.2 Valve Specification

Either an **eccentric rotary plug style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with carbon steel or chrome-molybdenum body, PTFE fugitive emission packing, and a Fail Open actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.4.2.3 Trim

Standard or anti-cavitation 300, 300 hard faced, or 400 series stainless steel hardened trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.4.2.4 Sizing

Conventional valve sizing equations for liquids.

7.4.3 FCCU—Charge Oil Heater Fuel Gas (Valve #3)

This valve controls the flow of fuel to the furnace to heat the charge oil before injection into the reactor. Proper flow control is important for maintaining discharge temperature of the charge oil. A small globe or ball valve is generally used in this application. It should be noted that not all units will utilize a separate charge heater.

7.4.3.1 Operating Conditions

See Table 14 for valve sizing data for heater fuel gas valves.

Table 14—Valve Sizing Data for Heater Fuel Gas Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Fuel Gas	Fuel Gas
Flow sm^3/h (scfh)	250 (8800)	300 (10,600)
P_1 barg (psig)	3.0 (43)	13 (188)
ΔP bar (psi)	0.50 (7)	6 (87)
T °C (°F)	30 (86)	40 (104)
Specific Gravity	0.59	0.59
Molecular Weight	11	11

7.4.3.2 Valve Specification

Either a **segmented ball** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with carbon steel or chrome-molybdenum body, PTFE fugitive emission packing, and a Fail Close actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.4.3.3 Trim

Standard 300 or 400 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.4.3.4 Sizing

Conventional valve sizing equations for gases.

7.4.4 FCCU—Inlet Air To Regenerator (Valve #4)

This valve controls the flow of air to the regenerator to burn the coke off the catalyst. Poor performance can lead to pressure swings, which, as a result, can affect the pressure balance between the reactor and regenerator. This can potentially result in reactor products flowing into the regenerator, which could lead to an explosion. A large butterfly valve is commonly used in this application.

7.4.4.1 Operating Conditions

See Table 15 for valve sizing data for inlet air to regenerator valves.

Table 15—Valve Sizing Data for Inlet Air to Regenerator Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Air	Air
Flow sm^3/h (scfh)	300,000 (10,594,400)	600,000 (21,188,800)
P_1 barg (psig)	3.0 (44)	5.0 (73)
ΔP bar (psi)	0.5 (7)	0.5 (7)
T °C (°F)	150 (302)	220 (428)
Molecular Weight	28	28

7.4.4.2 Valve Specification

Usually a **high performance butterfly style** control valve will perform in this service. This valve is usually ANSI CL 150 or CL300, with a carbon steel body, polytetrafluoroethylene (PTFE) packing, and a Fail Open actuator and positioner for throttling service.

7.4.4.3 Trim

Standard 300 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials

7.4.4.4 Sizing

Conventional valve sizing equations for gases.

7.4.5 FCCU—Inlet Air Vent To Atmosphere (Valve #5)

This valve, potentially referred to as the “snort valve”, is utilized to protect the inlet air compressor from surge during startup, shutdown, and normal operation. A number of configurations can be used in this application ranging from globe, angle, and rotary valves. Globe and angle valves are most commonly used, but a butterfly valve or segmented ball rotary control valve may be used in isolated situations. In the event of a process upset, this valve should provide fast, accurate control to maintain the pressure balance between the reactor and regenerator.

7.4.5.1 Operating Conditions

See Table 16 for valve sizing data for inlet air to atmosphere valves.

Table 16—Valve Sizing Data for Inlet Air to Atmosphere Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Air	Air
Flow sm^3/h (scfh)	80,000 (2,825,173)	220,000 (7,769,226)
P_1 barg (psig)	3.0 (44)	5.0 (73)
ΔP bar (psi)	1.0 (14.5)	1.0 (14.5)
T °C (°F)	30 (86)	40 (104)
Molecular Weight	28	28

7.4.5.2 Valve Specification

Usually a **high performance butterfly style, globe,** a**ngle or segmented ball** control valve will perform in this service. This valve is usually ANSI CL150 or CL300, with a carbon steel body, polytetrafluoroethylene (PTFE) packing, and a Fail Close actuator and positioner for throttling service. For noise attenuation in a globe or angle style valve a slotted, drill hole, or stacked disk noise trim, is sometimes required.

7.4.5.3 Trim

Standard 300 or 400 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials

7.4.5.4 Sizing

Conventional valve sizing equations for gases.

7.4.6 FCCU—Stripping Steam To Distributors (Valve #6)

There will typically be separate valves that control steam flow to the upper, middle, and lower distributors. These valves control the flow of stripping steam to the reactor to remove the hydrocarbons from the catalyst prior to regeneration. A small to medium sized globe valve will be used in all three cases.

7.4.6.1 Operating Conditions

See Table 17 for valve sizing data for stripping steam valves.

Table 17—Valve Sizing Data for Stripping Steam Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Steam	Steam
Flow kg/h (lb/h)	680 (1500)	5000 (11,000)
P_1 barg (psig)	5.0 (73)	7.0 (102)
ΔP bar (psi)	2.8 (41)	2.0 (29)
T °C (°F)	200 (392)	220 (428)
Molecular Weight	18	18

7.4.6.2 Valve Specification

These valves are usually an **eccentric rotary plug** or **general service sliding stem globe style** control valve with ANSI CL300, a carbon steel body, PTFE packing and a Fail Close actuator and positioner for throttling control. When specifying a globe valve a characterized cage or slotted noise attenuation trim may be utilized. This valve is typically ANSI Class IV or V shutoff.

7.4.6.3 Trim

Standard 300 or 400 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.4.6.4 Sizing

Conventional valve sizing equations for vapors/steam.

7.4.7 FCCU—Steam To Reactor (Valve #7)

This valve controls the flow of steam to the lower portion of the reactor. A small globe valve is typically used in this application.

7.4.7.1 Operating Conditions

See Table 18 for valve sizing data for steam to reactor valves.

Table 18—Valve Sizing Data for Steam to Reactor Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Steam	Steam
Flow kg/h (lb/h)	1996 (4400)	35,834 (79,000)
P_1 barg (psig)	6.0 (87)	9.0 (131)
ΔP bar (psi)	4.0 (58)	5.0 (73)
T °C (°F)	200 (392)	220 (428)
Molecular Weight	18	18

7.4.7.2 Valve Specification

These valves are usually an **eccentric rotary plug style** or **general service sliding stem globe style** control valve with ANSI CL300, a carbon steel body, PTFE packing and a Fail Close actuator and positioner for throttling control. When specifying a globe valve a characterized cage or slotted noise attenuation trim may be utilized. This valve is typically ANSI Class IV or V shutoff

7.4.7.3 Trim

Standard 300 or 400 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials

7.4.7.4 Sizing

Conventional valve sizing equations for vapors/steam.

7.4.8 FCCU—Bottoms Circulation (Valve #1)

This valve circulates flow from the bottom of the column to the reboiler and back to the column to facilitate separation. Accurate control is needed in this application to ensure the proper product specification. Because of the high-viscosity slurry, a rotary valve is commonly used. Entrained catalyst may be present in the flow stream and can damage the valve.

7.4.8.1 Operating Conditions

See Table 19 for valve sizing data for bottoms circulation valves.

Table 19—Valve Sizing Data for Bottoms Circulation Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Slurry Liquid with Solids	Slurry Liquid with Solids
Flow m^3/h (gpm)	150 (660)	300 (1320)
P_1 barg (psig)	6.0 (87)	8.0 (116)
ΔP bar (psi)	2.0 (29)	3.0 (43)
T °C (°F)	270 (518)	360 (680)
Specific Gravity	0.82	0.82

7.4.8.2 Valve Selection

Because of high viscosity slurry, a **segmented ball style** or **eccentric rotary plug style** control valve is used in this service. This valve is usually ANSI CL300, with a chrome-molybdenum or S31600 body, graphite fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. Sometimes these valves are provided with a Slurry liner or downstream sacrificial spool to minimize effects of erosion. This valve is typically ANSI Class IV shutoff. Trim

Use 300 hard faced or 400 hardened series stainless steel trim. Special slurry trim package may be considered. Also refer to 5.6 for material selection based on valve vendor's standard trim materials

7.4.8.3 Sizing

Conventional valve sizing equations for liquids.

7.4.9 FCCU—Debutanizer Bottoms (Valve #1)

This valve controls the liquid level in the debutanizer ensuring proper separation of the lighter components from the heavier components. A rotary valve is commonly used in this application.

7.4.9.1 Operating Conditions

See Table 20 for valve sizing data for debutanizer bottoms valves.

Table 20—Valve Sizing Data for Debutanizer Bottoms Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	70 (308)	350 (1540)
P_1 barg (psig)	12.0 (174)	14.0 (203)
ΔP bar (psi)	4.0 (58)	4.0 (58)
T °C (°F)	100 (212)	110 (230)
Specific Gravity	0.76	0.76

7.4.9.2 Valve Specification

Either an **eccentric rotary plug style** or **segmented ball style** control valve is used in this service. This valve is usually ANSI CL300, with carbon steel, polytetrafluoroethylene (PTFE) fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.4.9.3 Trim

Standard 300 series hard faced stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials

7.4.9.4 Sizing

Conventional valve sizing equations for liquids.

7.5 Catalytic Reformer—(Typical)

Figure 36 provides a simplified flow diagram for the catalytic reformer.

7.5.1 Catalytic Reformer—Reactor Feed (Valve #1)

This valve controls feedstock from a hydrotreater coming into the heater section of the catalytic reformer. This valve is usually set up in a flow-control loop.

7.5.1.1 Operating Conditions

See Table 21 for valve sizing data for reactor feed valves.

Table 21—Valve Sizing Data for Reactor Feed Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	Not Available	Not Available
P_1 barg (psig)	3.0 (44)	72 (1044)
ΔP bar (psi)	Not Available	Not Available
T °C (°F)	70 (158)	210 (410)
Specific Gravity	Not Available	Not Available

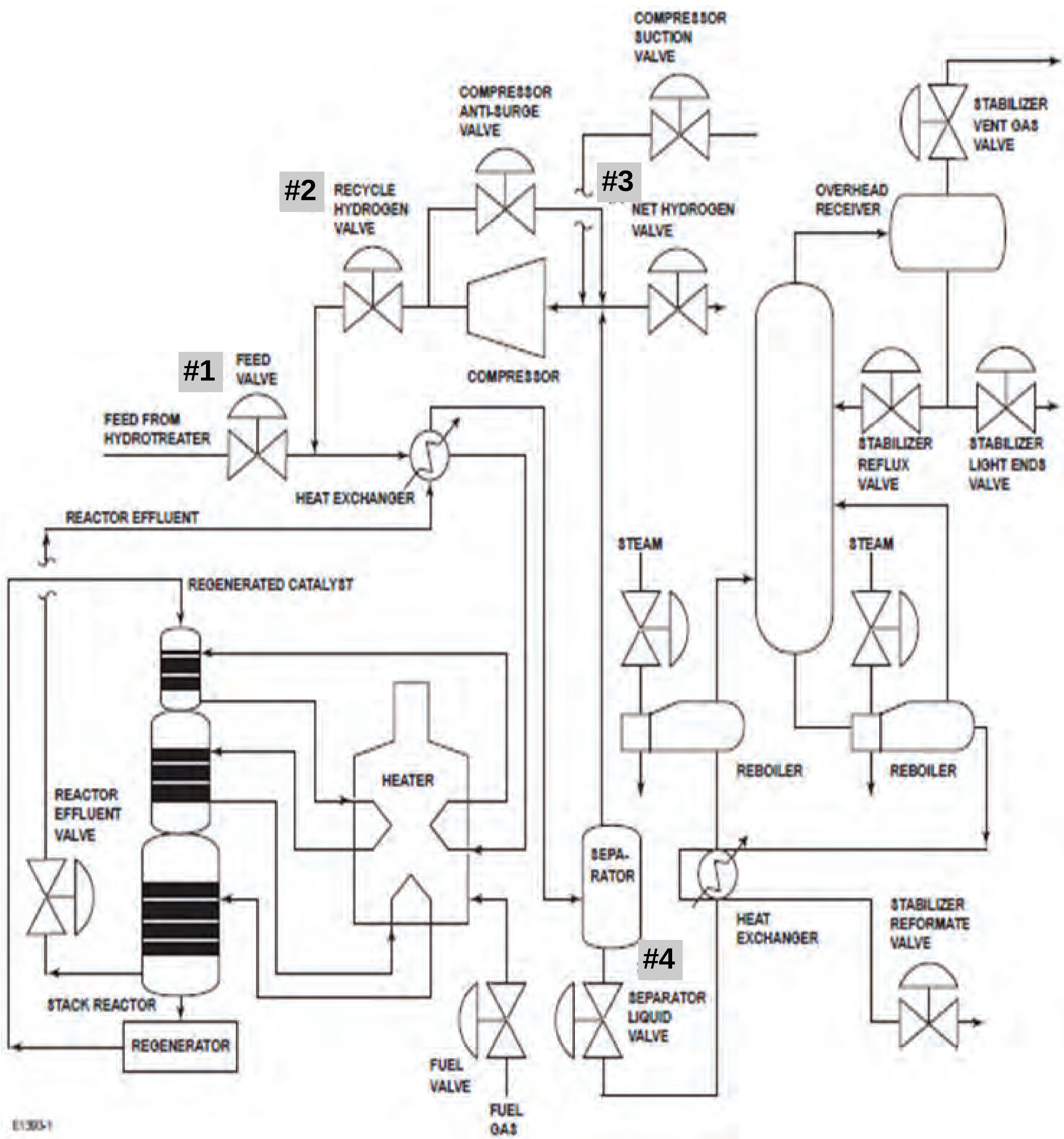


Figure 36—Catalytic Reformer Simplified Flow Diagram

7.5.1.2 Valve Specification

These valves are usually **eccentric rotary style or general service sliding stem globe style** control valve. This valve is usually ANSI CL300, or CL600, with a carbon steel cast body, PTFE fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.5.1.3 Trim

Standard 300 hard faced or 400 hardened series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials

7.5.1.4 Sizing

Conventional valve sizing equations for liquids.

7.5.2 Catalytic Reformer—Recycle Hydrogen (Valve #2)

This valve controls the hydrogen produced by the catalytic reformer by adding it back to the inlet feed. The amount of hydrogen delivered to the reformer helps to control conversion and catalyst degradation caused by coking. Precise control of this feed is essential in extending catalyst and reactor life

7.5.2.1 Operating Conditions

See Table 22 for valve sizing data for recycle hydrogen valves.

Table 22—Valve Sizing Data for Recycle Hydrogen Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Gas	Gas
Flow sm^3/h (scfh)	Not Available	Not Available
P_1 barg (psig)	8.0 (116)	17.0 (247)
ΔP bar (psi)	Not Available	Not Available
T °C (°F)	65 (149)	135 (275)
Specific Gravity	Not Available	Not Available

7.5.2.2 Valve Specification

These valves are usually **high performance butterfly style** control valve. This valve is usually ANSI CL300 with a carbon steel cast body, PTFE fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.5.2.3 Trim

Manufacturer's standard trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials

7.5.2.4 Sizing

Conventional valve sizing equations for gases.

7.5.3 Catalytic Reformer—Net Hydrogen (Valve #3)

This valve controls the net hydrogen that reformer unit produces. Although it should not affect the performance of the unit, if the valve is sticking badly it can produce back pressure or cause extra hydrogen to be recycled back into the compressor or reactors.

7.5.3.1 Operating Conditions

See Table 23 for valve sizing data for net hydrogen valves.

Table 23—Valve Sizing Data for Net Hydrogen Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Gas	Gas
Flow sm^3/h (scfh)	Not Available	Not Available
P_1 barg (psig)	14.0 (203)	88 (1276)
ΔP bar (psi)	Not Available	Not Available
T °C (°F)	65 (149)	135 (275)
Specific Gravity	Not Available	Not Available

7.5.3.2 Valve Specification

These valves are usually **segmented ball or general service sliding stem globe style** control valve. This valve is usually ANSI CL300 or CL600 with a carbon steel cast body, PTFE fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.5.3.3 Trim

Manufacturer's standard trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.5.3.4 Sizing

Conventional valve sizing equations for gases.

7.5.4 Catalytic Reformer—Separator Liquid (Valve #4)

This valve controls the level of liquid in the separator and is also the feed valve to the stabilizer section. It may be set up as either a flow or level loop, depending on the process licenser.

7.5.4.1 Operating Conditions

See Table 24 for valve sizing data for separator valves.

7.5.4.2 Valve Specification

These valves are usually **eccentric rotary plug style** or **general service sliding stem globe style** control valve. This valve is usually ANSI CL300 or CL600 with a carbon steel cast body, PTFE fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

Table 24—Valve Sizing Data for Separator Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	Not Available	Not Available
P_1 barg (psig)	40.0 (580)	63.0 (914)
ΔP bar (psi)	Not Available	Not Available
T °C (°F)	60 (140)	85 (185)
Specific Gravity	Not Available	Not Available

7.5.4.3 Trim

Manufacturer’s standard trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.5.4.4 Sizing

Conventional valve sizing equations for liquids.

7.6 Hydrocracker—(Typical)

Figure 37 provides a simplified flow diagram for the hydrocracker.

7.6.1 Hydrocracker—Feed To Hydrocracker (Valve #1)

This valve controls feed to the hydrocracker unit. To maintain consistent flow and outlet temperature, accurate control is necessary. Temperature is the primary means of controlling conversion in this unit.

7.6.1.1 Operating Conditions

See Table 25 for valve sizing data for hydrocracker feed valves.

Table 25—Valve Sizing Data for Hydrocracker Feed Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	94 (415)	229 (1006)
P_1 barg (psig)	135 (1950)	200 (2900)
ΔP bar (psi)	12 (167)	4.0 (62)
T °C (°F)	290 (554)	345 (653)
Specific Gravity	0.85	0.85

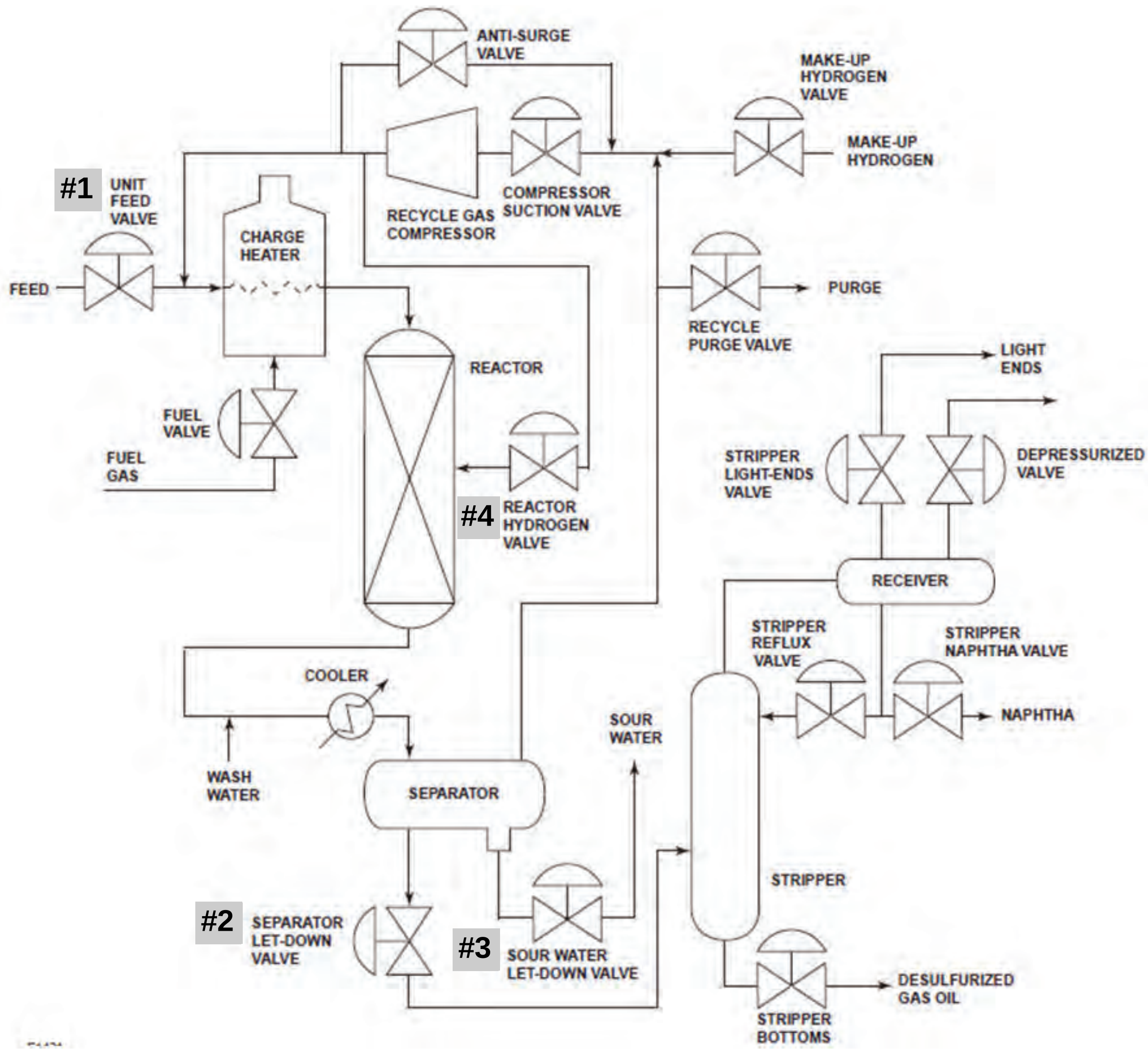


Figure 37—Hydrocracker Simplified Flow Diagram

7.6.1.2 Valve Specification

These valves are usually **high pressure severe service sliding stem globe style** control valve with ANSI CL900, CL1500, or CL2500, carbon or stainless steel cast body, Graphite packing and a Fail Close actuator and positioner for throttling control. This valve is typically ANSI Class IV shutoff.

7.6.1.3 Trim

Use of S31600, S34700 or S32100 trim with CoCr-A facing may be required. This is very process condition/license driven material selection. NACE may be required. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.6.1.4 Sizing

Conventional valve sizing equations for liquids.

7.6.2 Hydrocracker—Reactor Letdown With Erosive Solids (Not Shown)

7.6.2.1 Operating Conditions

See Table 26 for valve sizing data for reactor letdown valves.

Table 26—Valve Sizing Data for Reactor Letdown Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	315 (1386)	373 (1642)
Flow Out - Liquid / Vapor Split		
m^3/h / sm^3/h (gpm/scfh)	296/493 (1305 /17,400)	359/588 (1580/20,760)
P_1 barg (psig)	108.0 (1571)	108.0 (1571)
ΔP bar (psi)	81 (1176)	81 (1176)
T °C (°F)	438 (820)	435 (814)
Specific Gravity	0.75	0.75
Vapor Pressure bara (psia)	27.2 (395)	27.2 (395)
Critical Pressure bara (psia)	49.0 (711)	49 (711)

7.6.2.2 Valve Specification

High pressure severe service multi-stage, drilled hole, or sweep flow **angle valve,** capable of handling outgassing dirty service, per manufacturer's recommendation. Stainless steel or chrome-molybdenum blend cast or forged body. Fail Closed piston actuator with high performance positioner and valve position switch or transmitter.

May require stabilized stainless steel body to prevent polythionic acid stress corrosion cracking during shutdown procedures.

Quality Control recommendations: 100 percent radiography of body and bonnet; liquid dye penetrant inspection; mill test reports; hydrostatic test report; final visual inspection; and NACE materials.

7.6.2.3 Trim

Use a minimum S31600 hard faced trim with NACE compatibility. Trim material is sometimes upgraded to S32100, S34700, N07718 or tungsten carbide based on user's experience. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.6.2.4 Sizing

Very special application. Consult with valve manufacturer.

7.6.2.5 Application Notes

This application will experience outgassing, solids, flashing and cavitation.

7.6.3 Hydrocracker—Hot Separator Liquid To Hot Flash Drum (Valve # 2)

These level valves maintain pressure of the high pressure separator off gas and the makeup gas compressor. Loss of separator level will force vapor through these liquid valves and will require flaring.

7.6.3.1 Operating Conditions

See Table 27 for valve sizing data for hot separator valves.

Table 27—Valve Sizing Data for Hot Separator Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	456 (2008)	495 (2179)
Flow Out - Liquid / Vapor Split		
m^3/h / sm^3/h (gpm/scfh)	374/10,619 (1645/375,000)	422/11,327 (1860/400,000)
P_1 barg (psig)	168.0 (2435)	177.0 (2571)
ΔP bar (psi)	143 (2075)	81 (1176)
T °C (°F)	288 (550)	435 (814)
Specific Gravity	0.54	0.54
Vapor Pressure bara (psia)	169 (2449.7)	169 (2449.7)
Critical Pressure bara (psia)	19.7 (286.0)	19.7 (286.0)

7.6.3.2 Valve Specification

These valves are usually a **multi-stage or sweep flow angle-style** control valve with ANSI CL1500, a chrome-molybdenum body, NACE conformance body and trim, graphite packing and a Fail Close actuator and positioner for throttling control. This valve is typical Class V shutoff required.

7.6.3.3 Trim

Use a minimum S31600 hard faced trim with NACE compatibility. Trim material is sometimes upgraded to S32100, S34700, N07718, or tungsten carbide based on user's experience. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.6.3.4 Sizing

Very special application. Consult with valve manufacturer.

7.6.3.5 Application Notes

Inlet piping should be sized to minimize potential of flashing at the valve inlet. Outlet piping should be sized to avoid potential for cavitation occurring downstream of valve. Valve installation with the body and actuator in the horizontal plane simplifies piping and equipment layout. Trim style should be trash tolerant.

7.6.4 Hydrocracker—Cold Separator Sour Water (#3)

This level valve removes the sour water removed from solution in the cold separators. The water is sent to a flash drum to remove residual H_2S and NH_3.

7.6.4.1 Operating Conditions

See Table 28 for valve sizing data for cold separator valves.

Table 28—Valve Sizing Data for Cold Separator Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	20 (86)	35 (154)
Flow Out - Liquid / Vapor Split		
m^3/h / sm^3/h (gpm/scfh)	19/544 (81.5/19,200)	26/630 (114/22,248)
P_1 barg (psig)	166.0 (2404)	180 (2610)
ΔP bar (psi)	141 (2050)	141 (2050)
T °C (°F)	50 (122)	50 (122)
Specific Gravity	0.96	0.96
Vapor Pressure bara (psia)	35 (512)	35 (512)
Critical Pressure bara (psia)	90 (1300)	90 (1300)

7.6.4.2 Valve Specification

These valves are usually a **multi-stage or sweep flow angle style** control valve in ANSI CL900 or CL1500. Carbon steel body with NACE conformance body and trim, graphite packing and a Fail Close actuator and positioner for throttling control. This valve is typically Class V shutoff required.

7.6.4.3 Trim

Use a minimum S31600 hard faced trim with NACE compatibility. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.6.4.4 Sizing

Special application. Consult with valve manufacturer.

7.6.4.5 Application Notes

Outlet piping should be sized to avoid potential for cavitation occurring downstream of valve. Trim style should be trash tolerant.

7.6.5 Hydrocracker—Hydrogen Quench (Valve #4)

7.6.5.1 Operating Conditions

See Table 29 for valve sizing data for hydrogen quench valves.

7.6.5.2 Valve Specification

These valves are usually a **high pressure severe service globe style** control valve with ANSI CL1500 or CL2500 stainless steel cast body, graphite packing and a Fail Open actuator and positioner for throttling control. This valve is typically Class V shutoff.

Table 29—Valve Sizing Data for Hydrogen Quench Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Gas	Gas
Flow m^3/h (gpm)	Not Available	Not Available
P_1 barg (psig)	69.0 (1000)	207 (3000)
ΔP bar (psi)	Not Available	Not Available
T °C (°F)	290 (554)	345 (653)
Molecular Weight	2.0	2.0

7.6.5.3 Trim

NACE compliant hard faced trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.6.5.4 Sizing

Conventional valve sizing equations for gases.

7.7 Hydrotreater—(Typical)

Figure 38 provides a simplified flow diagram for the hydrotreater.

7.7.1 Hydrotreater—Hot High Pressure Separation Letdown (Valve #1)

This critical valve is used in the process to efficiently remove sulfur from various hydrocarbon streams. Hydrogen is introduced to the hydrocarbon stream upstream of the separator. The high pressure separator separates the hot liquids and hot gases. Hot liquid enters the valve at high pressure and as pressure is let down through the valve, a combination of flashing of the hydrocarbon Liquid and outgassing of the hydrogen occurs through the valve. At the valve outlet, the flow stream consists of two phase flow having hydrocarbon liquid, hydrocarbon vapor, and hydrogen gas.

7.7.1.1 Operating Conditions

See Table 30 for valve sizing data for hot high pressure separator valves.

Table 30—Valve Sizing Data for Hot High Pressure Separator Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	456 (2008)	505 (2223)
Flow Out - Liquid / Vapor Split		
m^3/h / sm^3/h (gpm/scfh)	374/10,619 (1645/375,000)	405/12,500 (1783/441,433)
P_1 barg (psig)	168.0 (2435)	180 (2610)
ΔP bar (psi)	143 (2075)	141 (2050)
T °C (°F)	288 (550)	343 (650)
Specific Gravity	0.538	0.538
Vapor Pressure bara (psia)	169 (2449.7)	169 (2449.7)
Critical Pressure bara (psia)	19.7 (286)	19.7 (286)

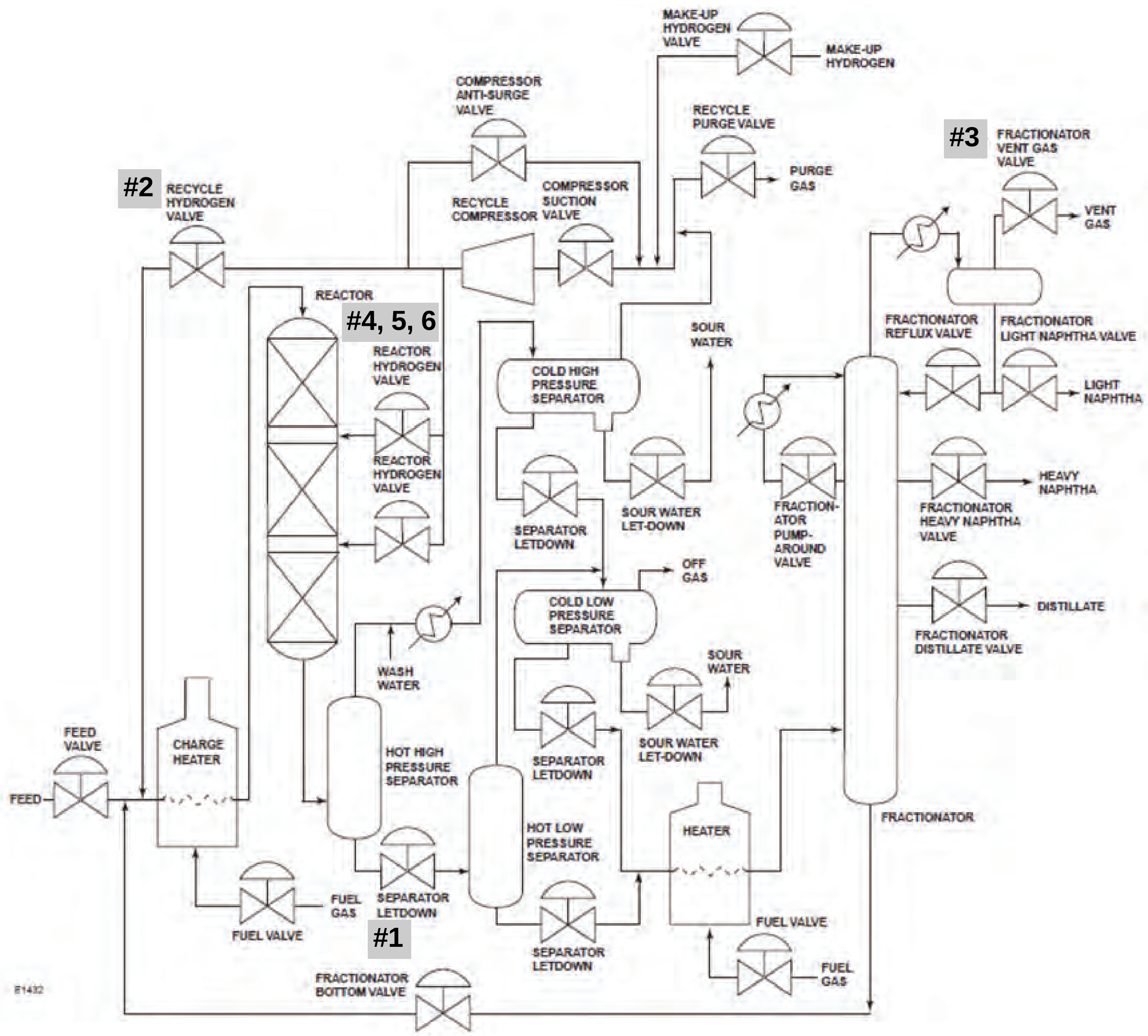


Figure 38—Hydrotreater Simplified Flow Diagram

7.7.1.2 Valve Specification

These valves are usually a high pressure severe service multi-stage, drilled hole, or sweep flow angle valve capable of handling outgassing dirty service, per manufacturer's recommendations. Stainless steel or chrome-molybdenum blend cast or forged body, Fail Close actuator and positioner for throttling control. Class V shutoff required.

7.7.1.3 Trim

Use a minimum S31600 hard faced trim with NACE compatibility. Trim material is sometimes upgraded to S32100, S34700, N07718, or tungsten carbide based on user's experience. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.7.1.4 Sizing

Very special application. Consult with valve manufacturer.

7.7.1.5 Application Notes

Inlet piping should be sized to minimize potential of flashing at the valve inlet. Outlet piping should be sized to avoid potential for cavitation occurring downstream of valve. Valve installation with the body and actuator in the horizontal plane simplifies piping and equipment layout. Trim style should be trash tolerant.

7.7.2 Hydrotreater—Compressor Recycle (Valve # 2)

7.7.2.1 Operating Conditions

See Table 31 for valve sizing data for compressor recycle valves.

Table 31—Valve Sizing Data for Compressor Recycle Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Gas	Gas
Flow sm^3/h (scfh)	127,425 (4,500,000)	253,152 (8,940,000)
P_1 barg (psig)	95.0 (1380)	97 (1400)
ΔP bar (psi)	17.0 (250)	24.0 (350)
T °C (°F)	93.0 (200)	93.0 (200)
Molecular Weight	4.9	4.9

7.7.2.2 Valve Specification

These valves are usually a **general purpose sliding stem globe style** control valve with soft seating. ANSI CL900, carbon steel body, polytetrafluoroethylene (PTFE) packing, and a Fail Open actuator and positioner for throttling control. This valve is typically Class VI shutoff.

7.7.2.3 Trim

Manufacturer's standard trim selection. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.7.2.4 Sizing

Conventional valve sizing equations for gases.

7.7.2.5 Application Notes

To ensure the valve opens in 1 to 2 seconds during periods when the Compressor is in Surge, a quick exhaust or volume booster is usually required, in conjunction with a high performance actuator/positioner system.

7.7.3 Hydrotreater—Drum Vent (Depressurizing) To Hydrotreater Flare (Valve #3)

7.7.3.1 Operating Conditions

See Table 32 for valve sizing data for depressurizing valves.

Table 32—Valve Sizing Data for Depressurizing Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Gas	Gas
Flow sm^3/h (scfh)	673 (23,760)	710 (25,073)
P_1 barg (psig)	75.8 (1100)	80 (1160)
ΔP bar (psi)	73 (1060)	78 (1131)
T °C (°F)	121 (250)	121 (250)
Molecular Weight	Not Available	Not Available

7.7.3.2 Valve Specification

These valves are usually an **eccentric rotary plug** or **general purpose sliding stem globe style** control valve with soft seating. ANSI CL600, NACE materials with carbon steel body stress relieved, polytetrafluoroethylene (PTFE) packing, and a Fail Hold Drift Open actuator and positioner for throttling control. This valve is typically Class VI shutoff.

7.7.3.3 Trim

Standard 300 series stainless steel trim with soft seal. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.7.3.4 Sizing

Conventional valve sizing equations for gases.

7.7.3.5 Application Notes

Materials should conform to NACE requirements (per specification), due to acid gas service.

7.7.4 Hydrotreater—Quench Gas To Reactor (Valves # 4, 5, 6)

7.7.4.1 Operating Conditions

See Table 33 for valve sizing data for quench gas valves.

Table 33—Valve Sizing Data for Quench Gas Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Gas	Gas
Flow sm^3/h (scfh)	1699 (60,000)	71,358 (2,520,000)
P_1 barg (psig)	90 (1310)	87 (1261)
ΔP bar (psi)	7 (101)	2.6 (38)
T °C (°F)	79.0 (175)	79.0 (175)
Molecular Weight	3.9	3.9

7.7.4.2 Valve Specification

These valves are usually a **rotary style** or **general purpose sliding stem globe style** control valve, ANSI CL900, carbon steel body, polytetrafluoroethylene (PTFE) packing and a Fail Open actuator and positioner for throttling control. This valve is typically Class IV shutoff.

7.7.4.3 Trim

Manufacturer's standard trim selection. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.7.4.4 Sizing

Conventional valve sizing equations for gases.

7.8 Delayed Coker—(Typical)

Figure 39 provides a simplified flow diagram for the delayed coker.

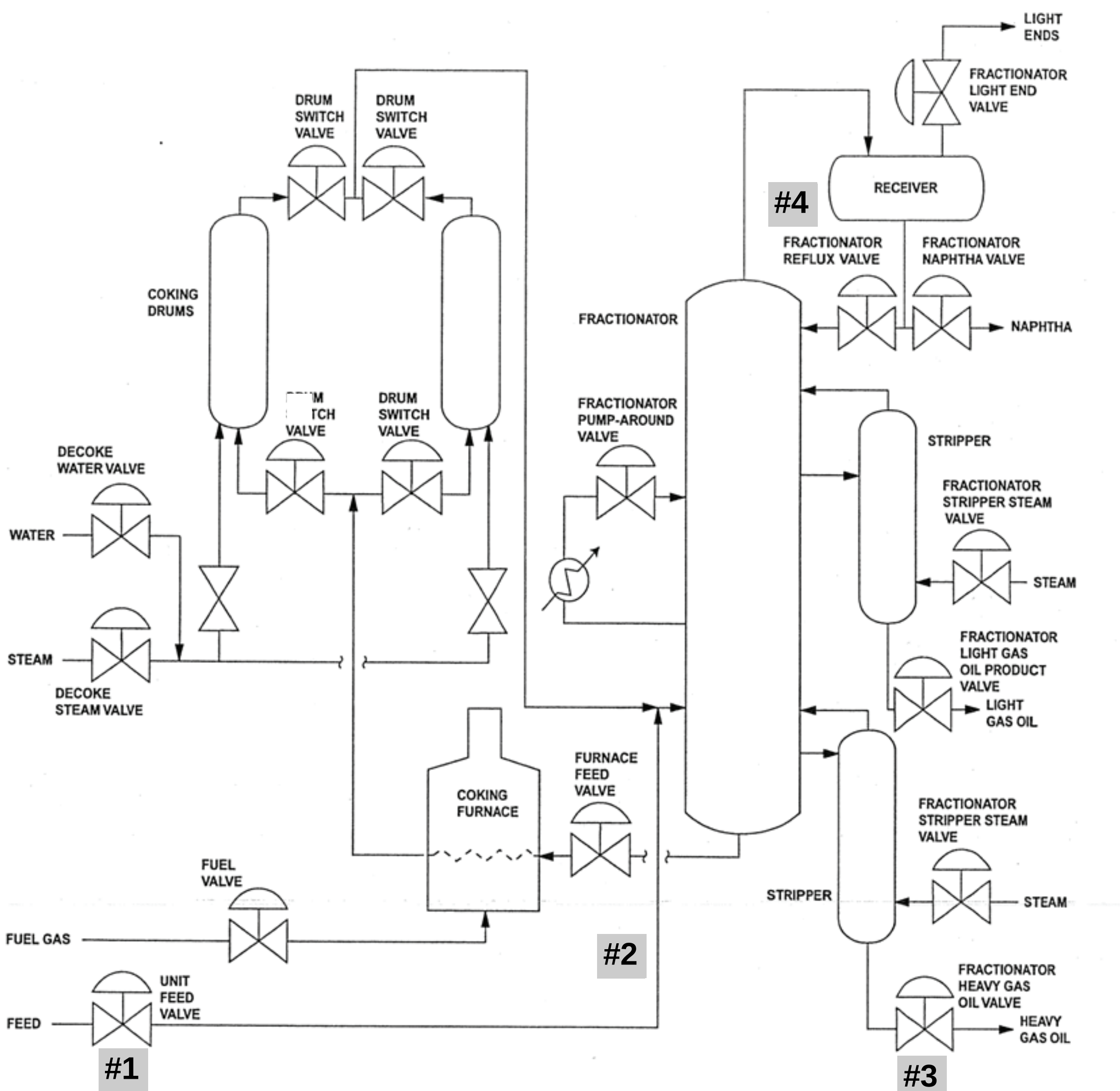


Figure 39—Delayed Coker Simplified Flow Diagram

7.8.1 Delayed Coker—Unit Feed (Valve #1)

This valve controls the feed directly from the bottom of the vacuum distillation column to the coker fractionator. Temperature swings in this valve can cause coke build up.

7.8.1.1 Operating Conditions

See Table 34 for valve sizing data for unit feed valves.

Table 34—Valve Sizing Data for Unit Feed Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	299 (1312)	340 (1500)
P_1 barg (psig)	8.9 (130)	8.9 (130)
ΔP bar (psi)	0.34 (5)	0.34 (5)
T °C (°F)	232 (450)	399 (750)
Specific Gravity	0.93	0.93
Vapor Pressure bara (psia)	1.77 (25.7)	1.77 (25.7)

7.8.1.2 Valve Specification

Either an **eccentric rotary style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a chrome molybdenum body, graphite fugitive emission packing, and a Fail Close actuator and positioner for throttling service. The chrome-moly body provides enhanced hardness characteristics over carbon steel at higher ANSI pressure/temperature ratings. If an eccentric rotary style is selected a reverse flow (flow passes plug, then seal) valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is typically ANSI Class IV shutoff.

7.8.1.3 Trim

Reverse flow full port trim configuration consisting of S17400 seat ring retainer, CoCr-A seal, and valve plug with equal percentage characteristic. Reverse flow configurations will minimize high velocity flow across the rotary plug, seal, and inner valve body surfaces, helping maintain shutoff specified and optimal body life. S17400 shaft and CoCr-A bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The S17400/CoCr-A shaft/bearing combination will minimize valve friction which would be caused by excessive fluid particle buildup in the bearing areas.

Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

For Globe style valves, valve guiding should be post guided or double top stem guided to prevent galling and sticking of valve trim.

7.8.1.4 Sizing

Conventional valve sizing equation for liquids.

7.8.2 Delayed Coker—Furnace Feed (Valve #2)

This valve controls the feed directly from the bottom of the vacuum distillation column to the coker fractionator. Temperature swings in this valve can cause coke build up.

7.8.2.1 Operating Conditions

See Table 35 for valve sizing data for furnace feed valves.

Table 35—Valve Sizing Data for Furnace Feed Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	36 (159)	39 (175)
P_1 barg (psig)	31 (453)	29 (420)
ΔP bar (psi)	10.0 (150)	3.5 (50)
T °C (°F)	306 (583)	343 (650)
Specific Gravity	0.91	0.91
Vapor Pressure bara (psia)	1.77 (25.7)	1.77 (25.7)

7.8.2.2 Valve Specification

This valve is usually an **eccentric rotary plug style** control valve (due to the presence of coke fines) with ANSI CL300, a chrome-molybdenum blend or S31600 body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The chrome-moly body provides enhanced hardness characteristics when compared to carbon steel at higher ANSI pressure/temperature ratings.

7.8.2.3 Trim

Due to the presence of entrained solids, typical trim types used in this severe service include CoCr-A, tungsten carbide, or ceramic. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.8.2.4 Sizing

Conventional valve sizing equations for liquids.

7.8.3 Delayed Coker—Heavy Coker Gas Oil (Valve #3)

This valve is used to provide reflux in the lower portions of the product fractionator. Poor control can cause temperature variations, which can impact separation and overall performance of the unit.

7.8.3.1 Operating Conditions

See Table 36 for sizing data for heavy coker gas oil valves.

7.8.3.2 Valve Specification

Either an **eccentric rotary style** or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300 with a chrome-molybdenum blend or S31700 body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

Table 36—Valve Sizing Data for Heavy Coker Gas Oil Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	149 (656)	179 (788)
P_1 barg (psig)	10.3 (150)	8.9 (130)
ΔP bar (psi)	7.0 (100)	6.0 (85)
T °C (°F)	216 (420)	316 (600)
Specific Gravity	0.88	0.88
Vapor Pressure bara (psia)	Not Available	Not Available

7.8.3.3 Trim

Standard 300 hard faced or 400 hardened series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.8.3.4 Sizing

Conventional valve sizing equations for liquids.

7.8.4 Delayed Coker—Reflux (Valve #4)

This valve is used to control separation between the top product and the highest side-draw products. Good control is needed in this valve to provide quality specifications in the overhead product and the top-side draw.

7.8.4.1 Operating Conditions

See Table 37 for valve sizing data for reflux valves.

Table 37—Valve Sizing Data for Reflux Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	75 (328)	89 (394)
P_1 barg (psig)	6.6 (95)	6.0 (87)
ΔP bar (psi)	2.7 (40)	2.3 (34)
T °C (°F)	38 (100)	232 (450)
Specific Gravity	0.73	0.73
Vapor Pressure bara (psia)	1.3 (20)	1.3 (20)

7.8.4.2 Valve Specification

Either a **eccentric rotary plug, segmented ball, or high performance butterfly style** control valve will perform in this service. This valve is usually ANSI CL300 with a carbon steel body, PTFE fugitive emission packing, and a Fail Open actuator and positioner for throttling service.

7.8.4.3 Trim

Manufacturer's standard trim selection. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.8.4.4 Sizing

Conventional valve sizing equations for liquids.

7.9 Gas Plant—(Typical)

Figure 40 provides a simplified flow diagram for a gas plant.

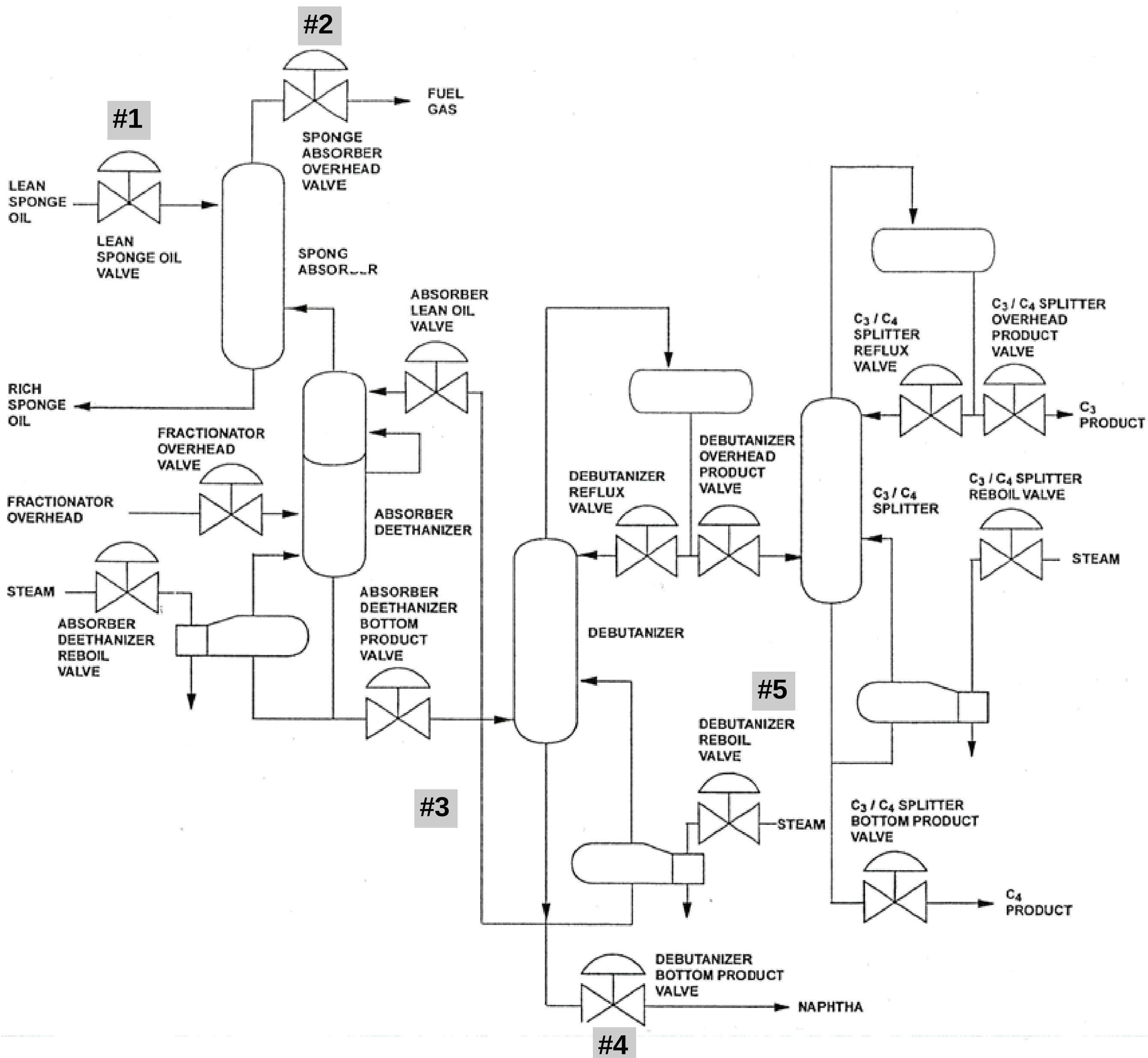


Figure 40—Gas Plant Simplified Flow Diagram

7.9.1 Gas Plant – Lean Sponge Oil (Valve #1)

7.9.1.1 Operating Conditions

See Table 38 for valve sizing data for lean sponge oil valves.

Table 38—Valve Sizing Data for Lean Sponge Oil Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	23 (103)	26 (114)
P_1 barg (psig)	13 (192)	12 (180)
ΔP bar (psi)	1.7 (25)	0.69 (10)
T °C (°F)	57 (135)	199 (390)
Specific Gravity	0.86	0.86
Vapor Pressure bara (psia)	1.6 (24)	1.6 (24)

7.9.1.2 Valve Specification

An **eccentric rotary plug** style or **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300 with carbon steel or S31600 body, PTFE fugitive emission packing, and a Fail Close actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.9.1.3 Trim

Manufacturer's standard trim selection. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.9.1.4 Sizing

Conventional valve sizing equations for liquids.

7.9.2 Gas Plant—Sponge Absorber Overhead (Valve #2)

7.9.2.1 Operating Conditions

See Table 39 for valve sizing data for **sponge absorber overhead valves.**

Table 39—Valve Sizing Data for Sponge Absorber Overhead Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Gas	Gas
Flow sm^3/h (scfh)	21,407 (756,000)	23,786 (840,000)
P_1 barg (psig)	9.0 (127)	8.0 (122)
ΔP bar (psi)	0.40 (6)	0.20 (3.0)
T °C (°F)	38 (100)	82 (180)
Molecular Weight	23.7	23.7

7.9.2.2 Valve Specification

This valve is usually a **butterfly style** control valve with ANSI CL150 or CL300, a carbon steel body, PTFE fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.9.2.3 Trim

Manufacturer's standard trim selection. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.9.2.4 Sizing

Conventional valve sizing equations for gases.

7.9.3 Gas Plant—Absorber Deethanizer Bottoms (Valve #3)

7.9.3.1 Operating Conditions

See Table 40 for valve sizing data for absorber deethanizer bottoms valves.

Table 40—Valve Sizing Data for Absorber Deethanizer Bottoms Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	84 (372)	100 (438)
P_1 barg (psig)	12.4 (180)	12 (170)
ΔP bar (psi)	0.70 (10)	0.60 (8)
T °C (°F)	132 (270)	177 (350)
Specific Gravity	0.60	0.60
Vapor Pressure bara (psia)	Not Available	Not Available

7.9.3.2 Valve Specification

An **eccentric rotary plug style, segmented ball,** or **general service sliding stem** control valve will perform in this service. This valve is usually ANSI CL300, with a carbon steel body, polytetrafluoroethylene (PTFE) fugitive emission packing, and a Fail Close actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.9.3.3 Trim

Standard 300 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.9.3.4 Sizing

Conventional valve sizing equations for liquids.

7.9.4 Gas Plant Debutanizer Bottoms (Valve #4)

7.9.4.1 Operating Conditions

See Table 41 for valve sizing for debutanizer bottoms valves.

Table 41—Valve Sizing Data for Debutanizer Bottoms Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	50 (219)	60 (263)
P_1 barg (psig)	11 (160)	11 (160)
ΔP bar (psi)	7.6 (110)	7.7 (112)
T °C (°F)	49 (121)	204 (400)
Specific Gravity	0.69	0.69
Vapor Pressure bara (psia)	10 (152)	10 (152)

7.9.4.2 Valve Specification

Either an **eccentric rotary plug style** or **sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a carbon steel body, PTFE fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.9.4.3 Trim

Standard 300 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.9.4.4 Sizing

Conventional valve sizing equations for liquids.

7.9.5 Gas Plant—Debutanizer Reboiler Steam (Valve #5)

7.9.5.1 Operating Conditions

See Table 42 for valve sizing data for debutanizer reboiler steam valves.

Table 42—Valve Sizing Data for Debutanizer Reboiler Steam Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Steam	Steam
Flow kg/h (lb/h)	6803 (15,000)	9072 (20,000)
P_1 barg (psig)	17 (250)	17 (250)
ΔP bar (psi)	1 (15)	1 (15)
T °C (°F)	216 (420)	399 (750)
Molecular Weight	18	18

7.9.5.2 Valve Selection

These valves are usually an **eccentric rotary plug style** or **general service sliding stem globe style** control valve with ANSI CL600, a carbon steel body, graphite packing and a Fail Close actuator and positioner for throttling control. The valve is usually supplied with characterized cage. The valve is typically ANSI Class IV or V shutoff.

7.9.5.3 Trim

Manufacturer's standard trim selection. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.9.5.4 Sizing

Conventional valve sizing equations for steam.

7.10 Alkylation Unit—(Typical)

Figure 41 provides a simplified flow diagram for sulfuric acid alkylation units.

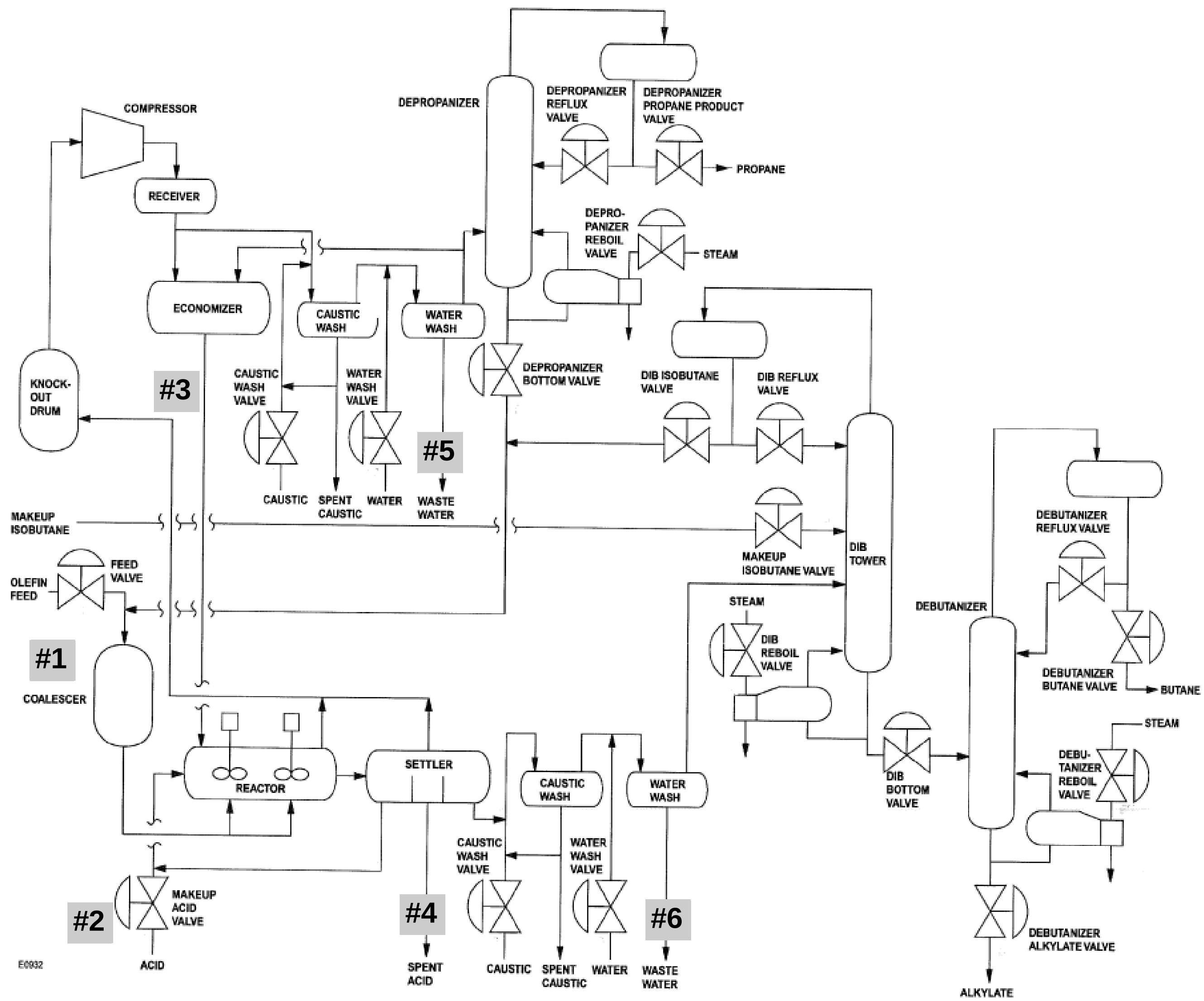


Figure 41—Sulfuric Acid Alkylation Unit Simplified Flow Diagram

7.10.1 Alkylation Unit—Olefin Feed (Valve #1)

7.10.1.1 Operating Conditions

See Table 43 for valve sizing data for alky feed valves.

Table 43—Valve Sizing Data for Alky Feed Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	75 (328)	104 (459)
P_1 barg (psig)	11 (160)	11 (160)
ΔP bar (psi)	1.3 (19)	0.83 (12)
T °C (°F)	32 (90)	66 (150)
Specific Gravity	0.58	0.58
Vapor Pressure bara (psia)	3.3 (48)	3.3 (48)

7.10.1.2 Valve Specification

A **general service sliding stem globe style** control valve will perform in this service. This valve is usually ANSI CL300, with a carbon steel body, PTFE fugitive emission packing, and a Fail Close actuator and positioner for throttling service. This valve is typically ANSI Class IV shutoff.

7.10.1.3 Trim

Standard 300 or 400 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.10.1.4 Sizing

Conventional valve sizing equations for liquids.

7.10.2 Alkylation Unit—Makeup Acid (Valve #2)

7.10.2.1 Operating Conditions

See Table 44 for valve sizing data for makeup acid feed valves.

Table 44—Valve Sizing Data for Makeup Acid Feed Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	1.5 (3.2)	2.0 (4.5)
P_1 barg (psig)	11 (160)	11 (160)
ΔP bar (psi)	3.4 (50)	3.4 (50)
T °C (°F)	29 (85)	38 (100)
Specific Gravity	1.82	1.82
Vapor Pressure bara (psia)	Not Available	Not Available

7.10.2.2 Valve Specification

An **eccentric rotary plug style, segmented ball** or **general service globe style** control valve will perform in this service. If the sulfuric acid is concentrated a carbon steel body may be used. Alternately, a PTFE lined carbon steel valve may be used. For dilute service, an alloy such as N10665, N10276, or N08020 may be used. This valve is usually ANSI CL300, with a 316SS body, polytetrafluoroethylene (PTFE) fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.10.2.3 Trim

Alloys such as N10665, N10276, or N08020 may be used. Alternately, PTFE encapsulated trim may be substituted. Also refer to Section 5.6 for material selection based on valve vendor's standard trim materials

7.10.2.4 Sizing

Conventional valve sizing equations for liquids.

7.10.3 Alkylation Unit—Caustic Wash (Valve #3, 4)

7.10.3.1 Operating Conditions

See Table 45 for valve sizing data for caustic wash valves.

Table 45—Valve Sizing Data for Caustic Wash Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	2.8 (12.5)	3.1 (14)
P_1 barg (psig)	3.4 (50)	3.4 (50)
ΔP bar (psi)	1.70 (25)	1.70 (25)
T °C (°F)	27 (80)	66 (150)
Specific Gravity	1.05	1.05
Vapor Pressure bara (psia)	Not Available	Not Available

7.10.3.2 Valve Specification

An **eccentric rotary plug style, segmented ball** or **general service globe style** control valve will perform in this service. This valve is usually ANSI CL300 or CL600, with a carbon steel body, polytetrafluoroethylene (PTFE) fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.10.3.3 Trim

Standard 300 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.10.3.4 Sizing

Conventional valve sizing equations for liquids.

7.10.4 Alkylation Unit—Water Wash (Valve #5, 6)

7.10.4.1 Operating Conditions

See Table 46 for valve sizing data for wash water valves.

Table 46—Valve Sizing Data for Wash Water Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	1.1 (5)	1.6 (7)
P_1 barg (psig)	3.4 (50)	3.4 (50)
ΔP bar (psi)	2.1 (30)	2.1 (30)
T °C (°F)	27 (80)	38 (100)
Specific Gravity	1.0	1.0
Vapor Pressure bara (psia)	0.04 (0.6)	0.04 (0.6)

7.10.4.2 Valve Specification

An **eccentric rotary plug style, segmented ball** or **general service globe style** control valve will perform in this service. This valve is usually ANSI CL300 or CL 600, with a carbon steel body, polytetrafluoroethylene (PTFE) fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.10.4.3 Trim

Standard 300 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials

7.10.4.4 Sizing

Conventional valve sizing equations for liquids.

7.10.5 Alkylation Unit—Hydrofluoric Acid Service

7.10.5.1 Operating Conditions

— Various flows, pressures, and temperatures.

— Hydrofluoric acid (HF), toxic, and corrosive.

7.10.5.2 Valve Specification

Carbon steel bodies (WCB) are designated for moderate temperature services, 66 °C (150 °F). This temperature should not be considered a limit. Initial corrosion of the surface creates an iron fluoride protective scale to limit further corrosion. Abrasion or water can remove this barrier. Use N04400 body for high temperature services above 150 °C (300 °F) hot acid. Use N04400 trim. N04400 develops a protective coating in service. It is necessary to allow adequate clearances at critical metal interfaces at the plug to guides, and seat to body, to allow for this buildup.

Virgin PTFE gaskets and packing should be specified (no glass fill).

7.10.5.3 Quality Control

Due to varying manufacturing techniques of castings, stringent inspection and quality control efforts should be specified. There have been cases of undetected sand hole or shrinkage defects causing through-wall leaks on castings. Verification of materials is needed.

It is important to eliminate any water from the valve; thus, pressure testing with kerosene is often specified. Kerosene is less viscous than water and will be more sensitive in finding casting defects and seat leakage. Leak detecting paint may be specified for flanges; the orange paint turns green on exposure to HF. Refer to process licensers for detailed valve requirements.

7.11 Sulfur Recovery Unit—(Typical)

Figure 42 provides a simplified flow diagram for sulfur recovery units.

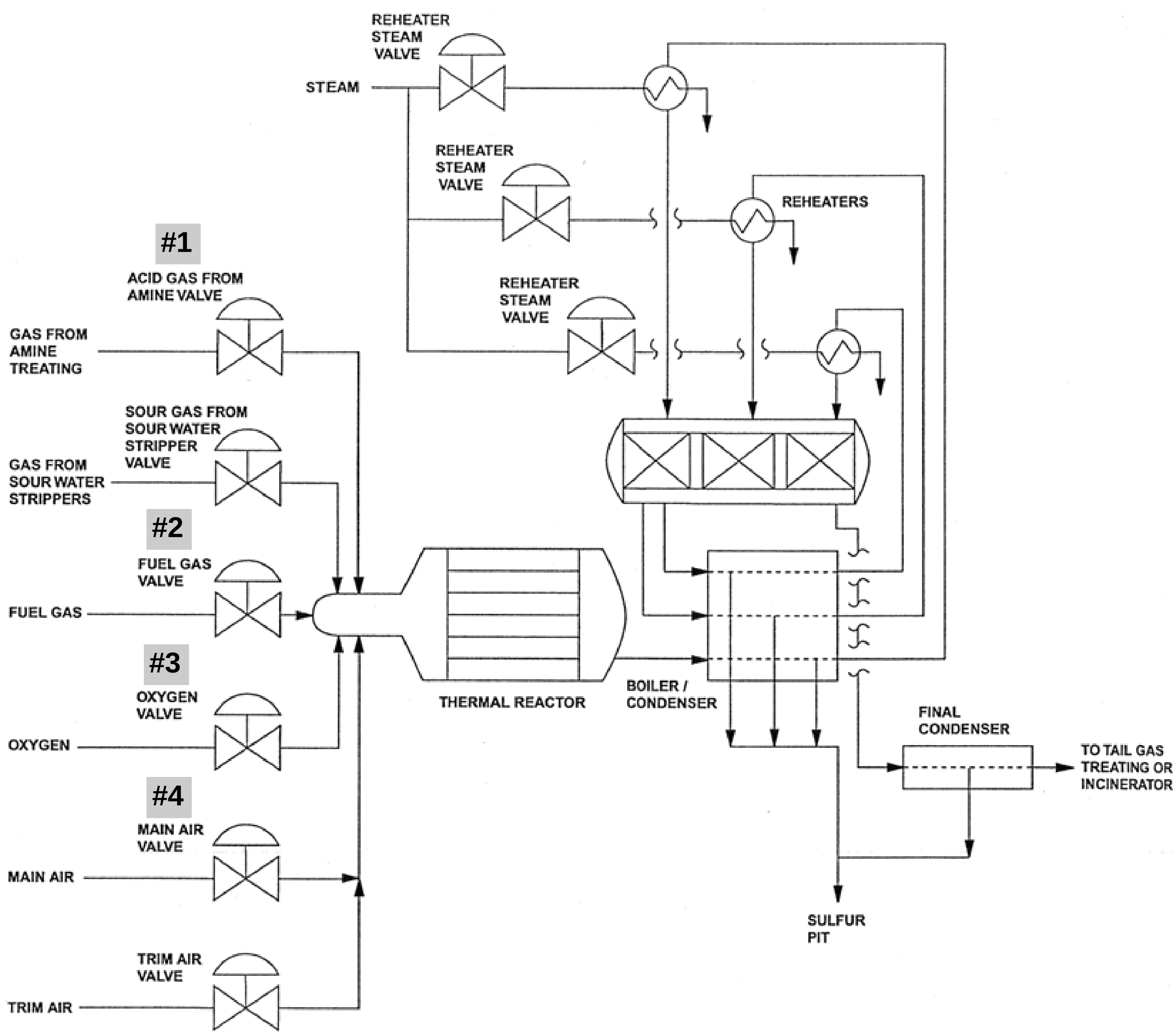


Figure 42—Sulfur Recovery Unit Simplified Flow Diagram

7.11.1 Sulfur Recovery Unit – Acid Gas (Valve #1)

7.11.1.1 Operating Conditions

See Table 47 for valve sizing data for acid gas valves.

Table 47—Valve Sizing Data for Acid Gas Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Gas	Gas
Flow sm^3/h (scfh)	18,972 (670,000)	33,980 (1,200,000)
P_1 barg (psig)	0.60 (9)	0.70 (10)
ΔP bar (psi)	0.070 (1)	0.140 (2)
T °C (°F)	49 (120)	177 (350)
Molecular Weight	37.1	37.1

7.11.1.2 Valve Specification

A **high performance butterfly style or segmented ball** control valve will perform in this service. Carbon steel body, NACE certified materials, PTFE fugitive emissions packing required. Use all stainless steel tubing and fittings. No copper or brass components should be used.

7.11.1.3 Trim

Standard 300 series stainless steel disk and NACE shaft. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.11.1.4 Sizing

Conventional valve sizing equations for gases.

7.11.1.5 Application Notes

This application requires NACE materials (per specification) and high reliability components.

7.11.2 Sulfur Recovery Unit—Fuel Gas (Valve #2)

7.11.2.1 Operating Conditions

See Table 48 for valve sizing data for fuel gas valves.

Table 48—Valve Sizing Data for Fuel Gas Valve

Process Data	Design Conditions	
	Normal	**Maximum**
Fluid	Gas	Gas
Flow sm^3/h (scfh)	1133 (40,000)	1868 (66,000)
P_1 barg (psig)	2.8 (40)	2.6 (38)
ΔP bar (psi)	0.70 (10)	0.70 (10)
T °C (°F)	38 (100)	82 (180)
Molecular Weight	11.9	11.9

7.11.2.2 Valve Specification

These valves are usually a **eccentric rotary plug style** or **general service sliding stem globe style** control valve with ANSI CL300, a carbon steel body, polytetrafluoroethylene (PTFE) packing and a Fail Close actuator and positioner for throttling control.

7.11.2.3 Trim

Manufacturer's standard trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.11.2.4 Sizing

Conventional valve sizing equations for gases.

7.11.3 Sulfur Recovery Unit—Oxygen (Valve #3)

7.11.3.1 Operating Conditions

See Table 49 for valve sizing data for oxygen valves.

Table 49—Valve Sizing Data for Oxygen Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Gas	Gas
Flow sm^3/h (scfh)	4813 (170,000)	5946 (210,000)
P_1 barg (psig)	2.6 (38)	2.3 (34)
ΔP bar (psi)	1.70 (25)	1.1 (16)
T °C (°F)	38 (100)	66 (150)
Molecular Weight	32	32

7.11.3.2 Valve Specification

This valve is usually a **eccentric rotary plug style** or **general service sliding stem globe style** control valve with ANSI CL300, 316SS body, polytetrafluoroethylene (PTFE) packing and a Fail Close actuator and positioner for throttling control. This valve is typically ANSI Class VI shutoff. **Special cleaning is required for oxygen service.**

7.11.3.3 Trim

N04400 or N05500 trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.11.3.4 Sizing

Conventional valve sizing equations for gases.

7.11.4 Sulfur Recovery Unit—Combustion Air (Valve #4)

7.11.4.1 Operating Conditions

See Table 50 for valve sizing data for combustion air valves.

Table 50—Valve Sizing Data for Combustion Air Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Gas	Gas
Flow sm^3/h (scfh)	36,872 (1,300,000)	45,307 (1,600,000)
P_1 barg (psig)	0.60 (9)	0.70 (10)
ΔP bar (psi)	0.06 (0.8)	0.05 (0.7)
T °C (°F)	93 (200)	149 (300)
Molecular Weight	28.1	28.1

7.11.4.2 Valve Specification

These valves are usually a **butterfly style** control valve with ANSI CL300, a carbon steel body, polytetrafluoroethylene (PTFE) packing and a Fail Open actuator and positioner for throttling control.

7.11.4.3 Trim

Standard 300 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.11.4.4 Sizing

Conventional valve sizing equations for gases.

7.11.5 Sulfur Recovery Unit—Liquid Sulfur To Storage (Not Shown)

7.11.5.1 Operating Conditions

See Table 51 for valve sizing data for sulfur valves.

Table 51—Valve Sizing Data for Sulfur Valve

Process Data	Design Conditions	
	Normal	Maximum
Fluid	Liquid	Liquid
Flow m^3/h (gpm)	1.1 (5)	2.0 (11)
P_1 barg (psig)	2.1 (30)	2.6 (38)
ΔP bar (psi)	0.70 (10)	0.70 (10)
T °C (°F)	138 (280)	150 (180)
Specific Gravity		

7.11.5.2 Valve Specification

These valves are usually either an **eccentric rotary style or general service sliding stem globe style** control valve with ANSI CL300, a carbon steel body, polytetrafluoroethylene (PTFE) packing and a Fail Close actuator and positioner for throttling control.

7.11.5.3 Trim

Standard 300 series stainless steel trim. Also refer to 5.6 for material selection based on valve vendor's standard trim materials.

7.11.5.4 Sizing

Conventional valve sizing equations for liquids.

7.11.5.5 Application Notes

Body and flanges are usually steam jacketed 3.5 barg (50 psig) steam.

8 Emergency Block Valves

An emergency block valve (EBV) is used as a means of isolating flammable or toxic substances in the event of a leak or fire. The EBV valve type is dependent upon the distance from the leak source. There are generally four types of EBVs: Type A, Type B, Type C, and Type D. Refer to Section 3, Terms and Definitions for their individual meanings.

Any valve in the fire zone handling flammable liquid should be fire-safe. Generally, metal-seated isolation valves (such as gate, ball, high-performance butterfly, etc.) are tested to API 608, *Metal Ball Valves—Flanged, Threaded, and Welding Ends*. It is not sufficient for the valve to have an inherent design to be fire safe such as fitted graphite packing and seal. Additionally, this “inherent design” does not ensure that the other metallurgical parts of the valve will survive a fire. Soft-seated valves require testing to API 607 or equivalent standard.

Check valves should not be used as an EBV. Likewise, control valves used to operate continuously in response to process demands usually are not considered EBVs. The end user should approve the use of a control valve as an EBV. In addition, the control valve should meet the following criteria.

a) The valve failure position should be considered carefully if in EBV service. Normally, the fail-safe action would be fail-closed. There are many instances, however, when it would be safer to de-inventory the vessel through the control valve. The installation should be designed to allow for such conditions.

b) The control valve should have a minimum Class IV shutoff classification per ANSI/FCI 70-2.

8.1 EBV General Installation Guidelines

8.1.1 Compressors

8.1.1.1 EBVs are typically required for all compressors 200 HP or larger handling flammable or toxic materials.

8.1.1.2 An EBV is needed in all suction and discharge lines.

8.1.1.3 An EBV is needed between stages and inter-stage equipment if the inter-stage equipment holds greater than 3.8 m^3 (1000 gallons) of liquid.

8.1.2 Pumps

8.1.2.1 An EBV is typically required for pumps having seals where the upstream vessel contains greater than 7.6 m^3 (2000 gallons) of light ends or hydrocarbons above the auto ignition point or above 316 °C (600 °F).

8.1.2.2 An EBV is needed where the upstream vessel contains greater than 15 m^3 (4000 gallons) of liquid hydrocarbons.

8.1.2.3 Pumps with high discharge pressures shall have an EBV at its discharge (i.e. downstream of pump spillback) for reverse flow overpressure protection.

8.1.3 Vessels

8.1.3.1 An EBV is needed for vessels containing light ends or toxic material. The flow from these vessels should be isolated from potential leak sources such as pumps, compressors, and heat exchangers and fired equipment. Any branch connection between the vessel and the EBV should have its own EBV.

8.1.3.2 An EBV is needed for vessels containing liquids heavier than light ends, but above the flash point.

8.1.4 Heaters

8.1.4.1 An EBV is needed for each fuel gas or oil line to fired heaters and boilers. At least one manual isolation valve outside battery limits for each fuel gas or oil line is typically specified.

8.1.4.2 A manual EBV valve(s) is often used in conjunction with automated SIS valves [see 9.6 b)]. Re-opening the SIS valves after a trip requires a manual reset after all safety interlock parameters have been satisfied. Also, refer to API 556, *Instrumentation, Control, and Protective Systems for Gas Fired Heaters*, 2nd Edition.

8.1.4.3 An EBV is needed for each Process side feed line to a fired heater that contains flammable fluid. The EBV should be located outside the firewall or fire zone, which contains the heater.

8.2 Actuator Selection

8.2.1 General

Actuator selection should be dependent upon torque requirements, available power supply, and fail-safe requirements. Fail-safe, single-action piston actuators are preferred. Double-acting piston and electric motor actuators may be used. Automatic shutoff through thermal (fire) actuation should be considered.

The speed of operation is application specific yet should be as fast as practical without damaging the valve or subjecting the system to excessive hydraulic shock (i.e. water hammer). Programmed closing may be required.

EBV actuators equipped with handwheels should be geared such that the breakaway force applied to the handwheel rim does not exceed 100 lbs (45 kgs). If necessary, access should be provided to the valve operator with platforms, chain wheels, etc. The valve operator and handwheel on the piping should be oriented away from the fire hazardous location.

As a minimum, full open and full closed positions should be indicated in a manned location. For sliding stem valves, if position switches are required, the proximity type is preferred. For rotary valves, integral, direct stem mounted proximity type hermetically sealed micro-switches are preferred. Alternately, the use of analog valve position transmitters in lieu of limit switches may be a consideration.

8.2.2 Electric Motor Actuator

8.2.2.1 This is the first choice for a gate valve. Because the electric motor will fail stationary upon power loss, any valve of this type which is in the fire zone should have its actuator fireproofed. Also, that portion of the control cable which is in the fire zone should be fireproofed. Fire/rated cable is an option.

8.2.2.2 For EBV service, it is more important to close the valve than to protect the actuator motor. Therefore, the following wiring precautions should be observed.

a) The closing torque switch should be bypassed and the valve should close to make closed position limit switch.

b) The control circuit fuse should be bypassed.

c) The thermal overloads should be bypassed.

d) Any thermistor in the motor windings should be bypassed.

8.2.2.3 For motor actuated valves, the actuator-to-valve adapter should be able to withstand the stall torque of the motor operator.

8.2.2.4 For motor actuated valves, alternate sources of power should be considered. Alternate sources of power may be from batteries, an Uninterruptable Power Supply (UPS), or separate independent circuits. Consideration should be given to increasing the electric motor torque requirements to compensate for anticipated service loading, insulating effects of intumescent coating (i.e. fireproofing), temperature, and type of valve.

8.2.3 Pneumatic Actuator

8.2.3.1 This is the first choice for quarter-turn valves. Fail-safe here refers to fail closed in the event of instrument air failure.

8.2.3.2 Fail-to-Safety in a Fire—This valve is remotely operable under normal circumstances, but the actuator is sacrificed in the event of a fire. A spring-return piston actuator on top of a metal-seated ball valve is recommended. The pneumatic tubing connected to the open port of the actuator should be sunlight-resistant polyethylene tubing and be wrapped around the actuator. Alternately, a fusable plug can be used. When the valve is involved in a fire, the tubing will melt and the valve will close. The valve will remain closed despite involvement in the fire. No fireproofing is necessary.

8.2.3.3 Operable During a Fire—This actuator should be hard-piped (no soft tubing) and should be fireproofed. A spring-closed actuator or a double-acting piston actuator with a fail-safe trip valve with two check valves in series and air bottle may be used.

8.2.3.4 Actuator to Valve Adaptation—For pneumatic actuated valves, the adapter should be able to withstand the maximum torque generated by the actuator with the maximum design air pressure applied to the piston. The adapter should also be made of materials that will withstand a fire until the valve can be closed.

8.2.4 Electro-Hydraulic Actuator

8.2.4.1 Electro-Hydraulic actuators with spring-return for fail-safe EBV service may be considered when instrument air is not available.

8.3 Fireproofing

8.3.1 EBV air supply, critical electrical wiring, local control panel, and actuator should be able to withstand a 1093 °C (2000 °F) petroleum fire while keeping all internal electrical controls and wiring below 93 °C (200 °F) for a period of at least thirty minutes. Critical wiring is defined as control circuit transformers, primary or secondary wiring (NEC 430-72-C or any other external control wiring) that may hinder the EBV actuator from operating to the desired safe position. The fireproofing should be able to withstand a sustained water stream from a fire hose. The fireproofing should be weatherproof and sunlight resistant. Refer to API 2218, *Fireproofing Practices in Petroleum and Petrochemical Processing Plants*.

8.3.2 Fire protection is not required in the following cases:

a) fusible link actuators that are designed to close under the fire conditions listed above;

b) fail-safe type valve and actuators that are designed to close even with the loss of the actuator.

8.4 Control Stations

8.4.1 Control stations should be located in the vicinity of the EBV location (outside the fire zone), and in a remote manned location.

8.4.2 When multiple control stations are engineered for a single EBV, each station should be independently wired in parallel from the EBV operator. In the event one of the stations is damaged or disabled, the other control stations should be designed to remain operable.

8.4.3 The following criteria should be considered when locating field mounted EBV control stations:

a) accessibility from ground level;

b) accessibility along the most likely escape route;

c) upwind from potential fire sources, taking into account the direction of the prevailing seasonal winds;

d) away from surface drains;

e) relative to the potential fire zone, maintaining a minimum distance of 15 m (50 ft) to 30 m (100 ft) from the EBV.

8.4.4 EBV control stations should be constructed to prevent accidental operation by human or environmental factors.

8.4.5 EBV control stations should be painted a unique color to easily identify them as emergency controls in the event of a fire. Permanent signage identifying the EBV tag number, purpose, and location of the EBV valve should also be considered.

9 Safety Instrumented System (SIS) Valves

9.1 As corrective action to safe state, a SIS valve is typically used to isolate or vent a process stream when unsafe process conditions exist. When an unsafe condition is detected by the SIS logic, the SIS valve is commanded to its fail-safe position (e.g. open or closed), typically via spring return. While an SIS valve is frequently specified as an on/off block valve independent of process control, the SIS may also act on a control valve commanding it to a fail-safe position typically via an independent SIS solenoid. SIS valves can also be manually activated via an ESD Pushbutton.

Safety Advisory—Especially where SIS solenoids are added to existing control valves to act as isolation valves, the bench set should be confirmed to shutoff against the maximum shutoff pressure. This may exceed the original design specification. For example, a control valve spring that is properly sized for the forward flow direction may not be capable of shutting off against reverse flow (e.g. high pressure to low pressure reverse flow scenario) if the reverse flow assists the valve to open.

9.2 SIS block valves independent of process control (e.g. dedicated on/off valve) shall not have hand wheels which could prevent their fail action to safe state. However, where hand wheels are installed on modulating control valves used as SIS valves, they shall be governed by a formal policy and permitting procedure requiring signed authorization before use.

9.3 SIS valves shall be fail-safe (e.g. spring return) and shall remain in their safe state position until safe conditions are present. Resetting the SIS valves after a trip typically requires manual intervention by the operator after all permissives are satisfied; usually called a Manual Reset. A "manual reset" may be interpreted as operator intervention at a HMI panel (e.g. local pushbutton or switches) or the SIS solenoids (e.g. integral reset handles or pushbuttons).

9.4 SIS valves should be specified with a minimum shutoff requirement of Class IV per ANSI/FCI70-2. Applications requiring tight shutoff should be specified as Class V or VI or rated as bubble tight per API 598.

9.5 SIS valves in hydrocarbon service should either be fire safe per API 607 (soft-seated valves), API 608 (metal seated valves), API 6FA or be located in a fire safe area.

9.6 SIS valves should be provided with position indication for shutdown verification and startup sequencing. See the following for example.

a) A proof of closure valve diagnostic alarm is recommended if a safety shutoff valve fails to close within the prescribed time requirements (e.g. 5 to 10 seconds or twice the valve stroke time).

b) If a safety shutoff valve fails to close, the operator should assume there is a process hazard, clear the area of personnel, and isolate the process from outside of battery limits (e.g. a manual EBV per 8.1.3.1) prior to approaching equipment that may not be at safe state.

9.7 Permissible stroke times of SIS valves requires an understanding of the time to safe state and the available process safety time. Unless otherwise specified in the Safety Requirement Specification of the SIS, safety shutoff valves should have a maximum travel time as noted in Table 52.

Table 52—Typical SIS Valve Response Times versus Body Size (from API RP 556 Second Edition)

Valve Size (in.)	Time (seconds)
Up to 4 in.	< 3
6 in. to 8 in.	< 4
8 in. to 12 in.	< 5

As an example, suppose that a safe state must be achieved within a process safety time of 5 to 10 seconds. Since this can be difficult to achieve for larger valves, this may require large actuator connections [greater than DN15 (1/2 in. NPT)] and quick exhaust valves [greater than DN15 (1/2 in.) orifice] to expedite the desired valve closure time.

As a design consideration for liquid applications, be sure to mitigate pipe hammering. Liquid hammer is the destructive force, pounding noises and vibration in a piping system, when liquid flowing through a pipeline is stopped abruptly by closing a valve too quickly.

9.8 SIS solenoids to SIS valves are typically operated by a 24 Vdc digital output signal from the SIS.

Recommended practice is to de-energize to trip. For these systems, solenoid operated valves shall not allow forcing or reset to the normal position when de-energized (e.g. a "free handle" or pushbutton manual reset).

Where an energize-to-trip philosophy is implemented, line monitoring of the signal path to the SIS solenoid is recommended. Otherwise, high frequency testing may be required to achieve the desired target availability.

Depending on the assigned availability and reliability targets of the Safety Instrumented Function (SIF) that includes the SIS valve, the use of more than one SOV or in some cases SIS valve (i.e. 2 SIS valves in series) could be needed. This concept is called voting. Below are examples of the three commonly used SOV arrangements. Other voting arrangements and pre-packaged SOV cabinets also exist.

The pros and cons of the typical solenoid arrangements are briefly described below.

9.8.1 While a 1oo1 or 1ooX solenoid configuration has the highest safety availability, it also has the highest spurious trip rate (see Figure 43). Thus, redundant solenoids are a frequent design consideration.

To improve the safety availability, redundant solenoids may be configured in a series 1oo2 voting arrangement (see Figure 44). While this may extend the test interval for the solenoids, (i.e. reduce the testing requirements), it increases the spurious trip rate.

To improve reliability, redundant solenoids may be configured in a parallel 2oo2 voting arrangement. While this may shorten the test interval for the solenoids, (i.e. increase the testing requirements), it reduces the spurious trip rate.

9.8.2 The 2oo2 arrangement is commonly used for applications requiring higher reliability.

Reducing the spurious trip rate. In this arrangement, a spurious trip of one SOV would have no impact on the SIS valve. Both SOVs must trip to move the SIS valve to its fail-safe position.

Achieving availability requirements. It is important to note that 2oo2 voting without increased solenoid testing will reduce the safety availability of the solenoids by one-half. Thus high frequency, automated testing is frequently implemented to achieve the availability requirements and to diagnose solenoid failures. For example, automated testing of redundant solenoids is frequently performed weekly or monthly to exceed the minimum availability requirements.

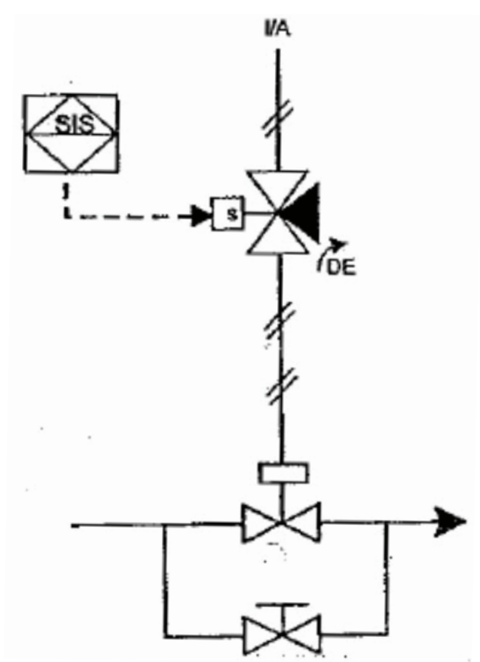


Figure 43—1 out-of 1 SOV Arrangement (1oo1)

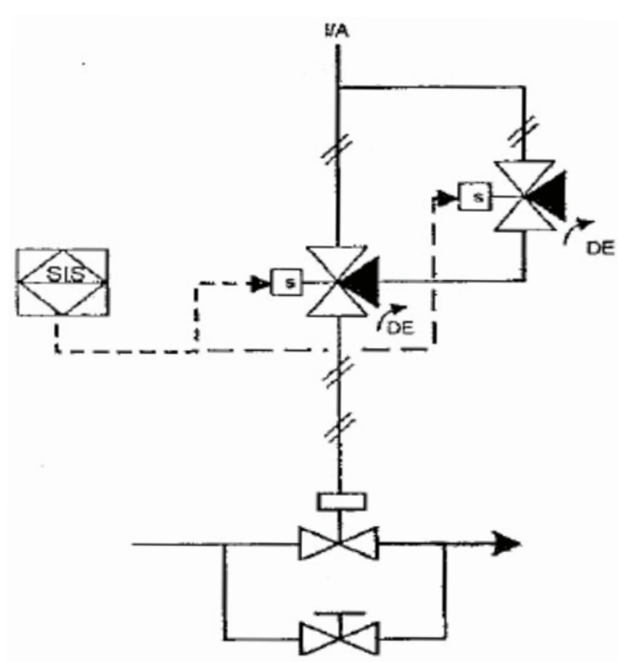


Figure 44—2 out-of 2 SOV Arrangement (2oo2)

9.8.3 In the 2oo3 configuration, it requires two of the three solenoids to trip in order to shift the SIS valve to its safe state. The 2oo3 configuration is used for high reliability and high availability applications reducing the higher testing requirements of the 2oo2 configuration. See Figure 45.

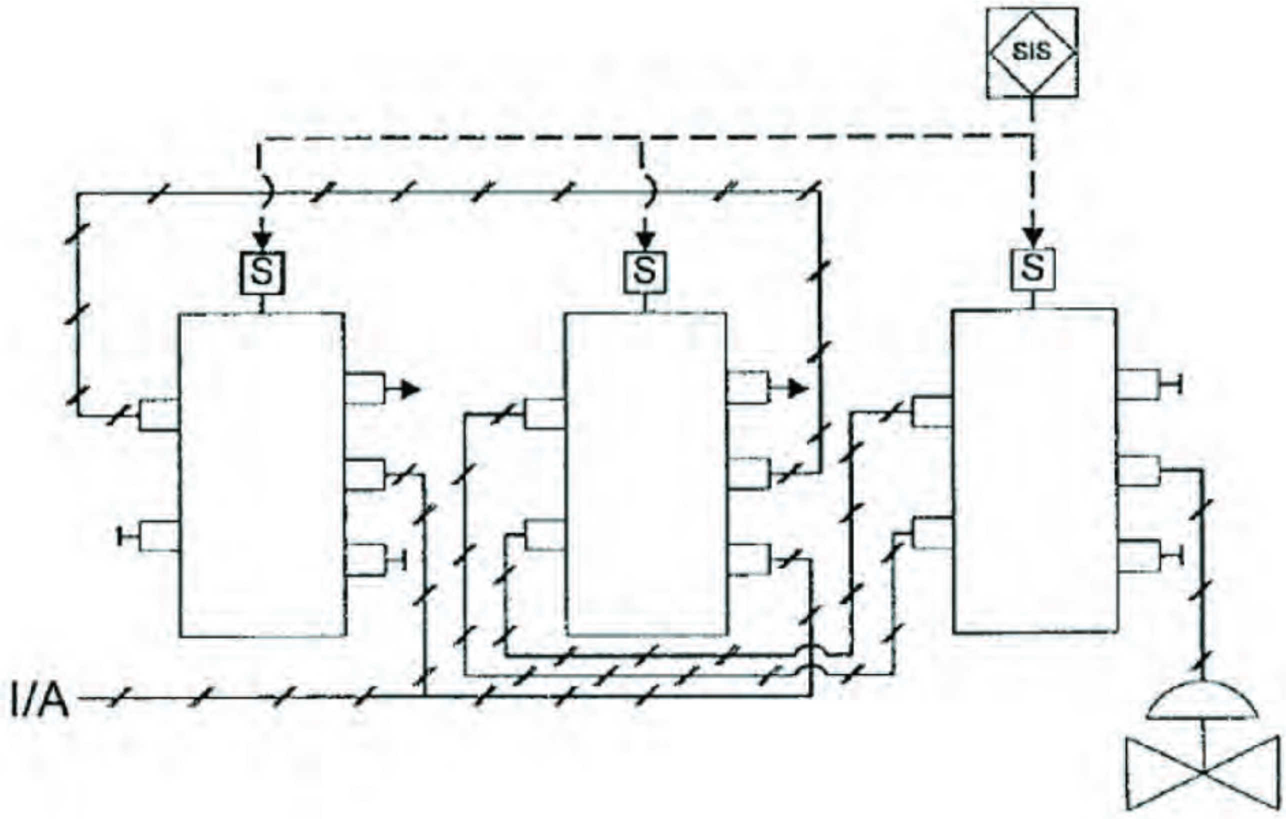


Figure 45—Generic 2 out-of 3 SOV Arrangement (2003)

9.9 When selecting the spring range for an SIS valve actuator, a valve manufacturer may apply a standard safety factor (e.g. 10 % to 15 %) to the valve torque requirements. Design considerations to consider here typically include the minimum available air pressure, the maximum differential pressure across the valve, and process conditions which could cause the valve to stick.

For safety critical applications, SIS valves should be designed with an additional safety factor of 25 % to 40 % to valve torque requirements to account for unknown variability in these parameters.

9.10 SIS valve diagnostics with digital valve controllers as follows.

9.10.1 When a control valve is used as an isolation valve, its digital valve controller can also be used to provide on/off functionality where dependency on the BPCS action and SIS action is considered sufficiently low. For control valves that have little change in controller output in normal operating mode, a digital valve controller can provide Partial Stroke Testing (PST) which provides a degree of assurance that the control valve will mechanically respond to a trip. Digital valve controllers with PST can also be used on conventional on/off SIS block valves.

9.10.2 There are two types of SIS interfaces to a digital valve controller. While the traditional interface is a 24 Vdc signal output, an alternate interface is a 4 mA to 20 mA signal output. A potential benefit of the analog interface is that the instrument remains powered during a 24Vdc trip which permits the digital valve controller to capture a "Valve Trip

Signature". By uploading this stored information to a historical database, a plant engineer may evaluate the full stroke diagnostic data to:

a) benchmark the current diagnostic data against the original commissioning data to ensure that the valve is performing within specified limits;

b) reset the Proof Test Interval upon a spurious trip or unscheduled shutdown, if the valve is performing within specified limits;

c) schedule necessary maintenance or overhaul interval.

9.11 Provisions for online testing of SIS valves are found in 9.11.1 through 9.11.6.

9.11.1 Manual double blocks and a bypass, (Figure 32) or a double block and blind arrangement, may be installed around a SIS valve to facilitate periodic on-line full stroke testing and maintenance.

9.11.2 SIS bypass valves shall be provided with either a proof-of-closure status alarm in a manned location or be car sealed closed (or locked) when not in use. As a design consideration, the SIS bypass valve may also be provided with appropriate color-coding, signage, locks and chains to prevent someone from inadvertently using it.

A formal policy, permitting procedure, and signed authorization shall be required prior to opening the SIS bypass valve. For facilities that have reservations with administrative control of bypass valves, an automated partial stroke test of the SIS valve may be considered to meet proof test requirements without SIS bypass valves.

9.11.3 SIS bypass valves in hydrocarbon service should either be fire safe per API 607 (soft-seated valves), API 608 (metal seated valves), API 6FA, or be located in a fire safe area.

9.11.4 SIS bypass valves should have the same or better leakage class than the main SIS valve.

9.11.5 SIS bypass valves shall not be used to bypass unsafe process conditions.

9.11.6 SIS bypass valves shall not be used as a startup bypass. The SIF logic should be designed to allow sequencing through startup overrides. For example, an internally configured start-up bypass timer which automatically re-activates the SIF logic once a trip initiator passes through its trip set point.

10 Vapor Depressurizing Valves

10.1 General

10.1.1 Vapor depressurizing systems are often installed on large volume hydrocarbon systems, especially those operating at higher pressures. They are used to prevent upset conditions from actuating safety relief valves or to de-pressure the equipment in emergency conditions, especially in case of fire. In the fire case, for a vessel containing both liquid and vapor, the un-wetted portion of the vessel will probably reach a temperature at which the strength of the material will be reduced. In this case, the relief valve would not protect against vessel rupture, whereas a vapor depressurizing system could reduce the pressure to a safe level.

10.1.2 Emergency vapor depressurizing facilities should consist of local and/or remote operated controls. These controls may be executed through either a manual or automatic action resulting in the depressurizing valve's discharge into a closed system. The system should be designed to comply with the availability and reliability targets established for the associated process unit and/or individual vapor depressurizing system, through an approved quantitative hazard analysis method. Redundant actuating devices and appropriate device voting logic should be selected to assure compliance with the availability and reliability targets. Air-to-open systems, (if considered to reduce the spurious trip rate) should draw air and any backup media from a reliable source, and be fireproofed as outlined in above Section 8, Emergency Block Valves.

10.1.3 Depressurizing valves should be sized in accordance with API RP 521 for conditions of fire exposure, density change, and liquid flash, assuming that depressurizing starts at the normal operating pressure. The valves should be sized to de-pressure the system within 15 minutes to 7 barg (100 psig) or 50 % of design pressure, whichever is lower, unless this depressurizing rate would subject equipment to unacceptably low temperatures. Low temperature materials may be required for the depressurizing valve and its outlet piping. Alternately, a conventional valve and associated flow restriction device, such as orifice plate of adequate thickness for the high pressure drop or choke tube, may be used in lieu of the depressurizing valve.

10.2 Depressuring Valves and Actuator Requirements

10.2.1 Control valves may be used for depressurizing service. Some users specify two-position on/off valves only, while others use throttling valves with volume boosters and a positioner.

10.2.2 Depressurizing valves should be equipped with spring return pneumatic actuators for positive action on air failure. Actuators should be designed to open the valve with any process pressure from 0.0 psig to 110 percent of the relief valve set pressure, and should hold the valve closed at up to 110 percent of the relief valve set pressure. Quick exhaust valves or volume boosters for rapid depressurizing of the actuator may be required and specified for depressurizing valves. Conversely, the large forces imposed in the downstream piping systems after rapid opening of a depressurizing valve should be considered, so that appropriate pneumatic speed control devices or retuning of valve positioners may be incorporated to slow the valve opening speed, if required.

10.2.3 For mechanical integrity, the minimum body size and rating should be DN 50 (2 in.) ANSI CL300 flanged, with reduced trim as required.

10.2.4 Throttling control valve plugs should be a single seated, metal seat with quick opening or linear trim characteristic, with process pressure tending to open the valve. Other control valve designs may be considered, such as ball valves or choke valves, particularly in high pressure process units. Soft-seated trim and seals should not be used.

10.2.5 The depressurizing valve and actuator combination should achieve at least an ANSI B16.104 (FCI 70-2) Class V shutoff.

11 Hydraulic Slide Valve Actuators

11.1 General

11.1.1 This section details requirements for hydraulic type slide valve actuators with a dedicated hydraulic unit for each valve where the hydraulic unit is separate from the valve actuator. Central hydraulic units that are used to power multiple valves are sometimes used. Some newer designs have an integral hydraulic unit, which is mounted right on each slide valve actuator. Other large continuous duty valves may use these actuators.

11.1.2 Each slide valve (Figure 46) can have a totally independent hydraulic and control system. The following minimum components should be included at or near each valve.

a) A slide valve actuator consisting of high pressure hydraulic cylinders, manual operator, adapter plates to mount the actuator to the valve bonnets, a position feedback sensor, and any locally required manifolding, tubing, or valving.

b) A hydraulics skid containing all required hydraulic supply system components and positioning controls. This includes the hydraulic oil reservoir, hydraulic pumps and drivers, filters, manifolding, valving, and interconnecting tubing, servo valves, high pressure accumulators, pump controls, positioner electronics, pressure gauges, and miscellaneous other instrumentation.

Figure 46—Typical Slide Valve Installation

11.2 Hydraulic Power Unit (HPU)

11.2.1 The hydraulic fluid should be non-flammable synthetic or natural type hydraulic oil suitable for use in high pressure, high performance hydraulic systems and ambient temperature range.

11.2.2 The entire hydraulic system (Figure 47) should be constructed of 300 series stainless steel. The reservoir should be equipped with vent and vacuum breaker valves set at no more than 0.1 barg (2 psig) positive and 0.02 barg (0.3 psig) negative pressure, or as required by the reservoir design. The reservoir should be provided with additional inlets and outlets as required for filling and venting operations. Vents should be provided with filters to prevent oil contamination. Some users blanket the reservoir with nitrogen or provide a desiccant type drier on the vent to prevent moisture and dirt contamination of the hydraulic oil.

11.2.3 Each hydraulic power unit (Figure 47) should be equipped with dual pumps and drivers. Pumps should be variable stroke or pressure-compensated, positive displacement types and be equipped with internal relief valves. Each pump on each HPU should be of identical construction. One pump should be driven by a constant speed electric motor. The second pump is usually specified to be driven by an air motor, or can be powered by an isolated electrical feeder. Drivers should be sized to provide design hydraulic oil flow at the hydraulic oil relief pressure. The motor starter for the electric motor driven pump is usually supplied as part of the hydraulic unit.

11.2.4 The hydraulic power unit should include a pump control system which will automatically start the spare pump, designated by a switch on the HPU front panel, if the hydraulic supply pressure drops below a pre-set pressure. Alarm contacts indicating that the spare pump is running are required.

11.2.5 If coolers are required, dual coolers with a dual 3-way switching valve should be provided. Coolers should be installed on the hydraulic oil return stream. If air coolers are used, they should not require any type of forced air cooling.

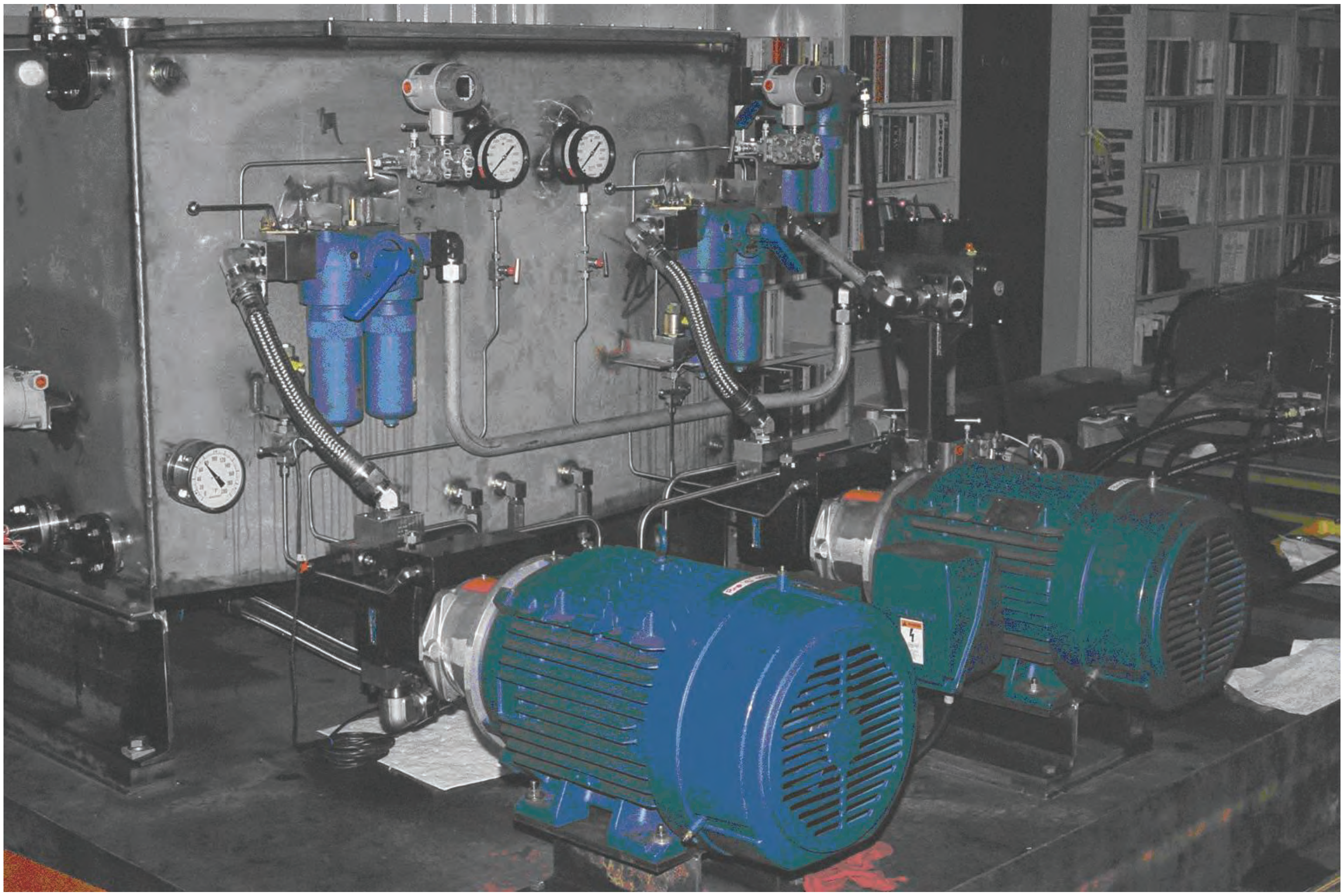


Figure 47—Typical HPU Unit

11.2.6 The HPU should include high pressure oil accumulators with sufficient capacity to provide for two complete valve strokes (full open to full closed, or vice versa, is one stroke). Accumulators should be designed such that they can be recharged and maintained/removed online without shutdown.

11.2.7 The HPU should include all required interconnecting manifolding, tubing, valving, etc. Dual high pressure hydraulic oil filters with valving necessary to allow switching of filters and change-out of filter elements should be provided. All tubing fittings should be O-ring seal SAE hydraulic type fittings. Compression fittings are not recommended.

11.3 Slide Valve Positioner Systems

11.3.1 Each slide valve actuator should be provided with a positioning system complete with a local field panel.

11.3.2 Each system should have dual inlet filters for hydraulic fluid. These filters should be switchable so that filter elements may be changed while on-stream.

11.3.3 For manual operation of the slide valves, each actuator system should include a mechanical handwheel and the capability to readily bypass the hydraulic system. The design should permit removal of the hydraulic cylinder while the valve remains on handwheel control. A local hydraulic manual "Open-Stop-Close" control is also required. In addition, a local manual hydraulic hand pump or standby hydraulic accumulator backup hydraulic system is needed. Any manual operation should actuate dry contacts for remote alarm indication.

11.3.4 All systems should be self-contained. Single block manifolds with a minimum of interconnecting tubing are preferred. Connections to the valve actuator cylinders should be flexible braided hose.

11.3.5 The positioner system should lock the slide valve in place and activate an alarm contact upon any of the following conditions:

a) loss of feedback;

b) loss of control signal;

c) loss of power;

d) electronics failure;

e) excessive servo position deviation error.

11.3.6 The positioner should be electronic type and accept a 4 mA to 20 mA DC control signal. The slide valve will be closed at 4 mA and open at 20 mA. All wiring should be run with appropriate high temperature wiring, or routed to avoid high temperature areas.

11.3.7 Electronic valve stem position feedback should be provided to the positioner. Magneto-restrictive or LVDT technology is preferred over slidewire or potentiometer techniques. The positioner system should also transmit a 4 mA to 20 mA signal proportional to the valve stem position to the refinery control system.

11.3.8 It is desirable to be able to calibrate the position feedback system without stroking the slide valve.

11.3.9 The hydraulic supply and positioner systems should include outputs for remote indication of diagnostic alarms (see 11.4.13 for complete list).

11.4 Instrumentation Required

11.4.1 Pump discharge pressure gauge on HPU gauge board.

11.4.2 Pump discharge pressure switch with circuit to automatically start the standby pump.

11.4.3 Pump suction pressure gauge on the HPU gauge board.

11.4.4 Vacuum breaker on oil reservoir.

11.4.5 Rotameter for nitrogen purge to oil reservoir.

11.4.6 Oil reservoir instruments:

a) level sight gauge;

b) temperature indicator;

c) high temperature switch;

d) low level switch;

e) low-low level switch to stop pumps.

11.4.7 Pressure gauge on HPU gauge board for filtered high pressure hydraulic fluid for distribution.

11.4.8 Accumulator(s) pressure gauge.

11.4.9 Temperature indicator on cooling water return from hydraulic fluid heat exchangers.

11.4.10 Accumulator low pressure switch.

11.4.11 Purge instruments (rotameter and pressure switch) for electrical boxes as required.

11.4.12 Selector switch for determining primary hydraulic pump. The non-selected pump automatically becomes the "stand-by."

11.4.13 For diagnostic and troubleshooting purposes, the following equipment and process alarms should be provided.

11.4.13.1 The package should include all required process switches and an alarm indication system to advise the operator of abnormal conditions. Alarms may be indicated at the positioner field panels and hydraulic unit (if these are separated) using LEDs, pilot lights, or alarm annunciators. Alarms should be included for each slide valve actuator for:

a) low reservoir level*;

b) high reservoir temperature*;

c) spare pump running*;

d) low-low reservoir level*;

e) low-low hydraulic pressure*;

f) low accumulator pressure;

g) positioner in local mode;

h) loss of control signal;

i) loss of feedback signal;

j) excessive servo error;

k) loss of power;

l) electronics purge failure (if used).

* Only one set of alarms required if a common HPU is used. Locate at HPU skid.

11.4.13.2 Provide dry Form C contacts to indicate positioner common trouble and positioner failure alarms to the refinery control system.

11.4.13.3 The following alarm groups should be provided for each slide valve.

a) Positioner common trouble alarm:

1) low reservoir level*;

2) high reservoir temperature*;

3) spare hydraulic pump running*;

4) low accumulator pressure*;

5) positioner purge failure (if used).

b) Positioner common failure alarm:

1) Positioner in local mode;

2) Loss of control signal;

3) Loss of feedback signal;

4) Loss of power;

5) Excessive servo error;

6) Loss of positioner power;

7) Low-low reservoir level*;

8) Low-low hydraulic supply pressure*.

* Only one set of alarms if a common HPU is used. If dedicated HPUs are used, alarms are required for each HPU.

11.5 Performance Characteristics

11.5.1 Linearity of stroke and the transmitted position signal versus the input control signal should be within ±0.25 % full stroke.

11.5.2 Tracking error (setpoint deviation) should be ± 2 % maximum.

11.5.3 Adjustable stroking speeds should be provided.

11.5.4 Stability of movement at constant position control signal input should not exceed 0.1 % of full stroke (cyclical, peak to peak).

11.6 Electrical Requirements

Area Classification: Minimum Class 1, Division 2, Group D. The electrical equipment should be suitable for the area electrical classification.

11.7 Testing and Inspection

A factory functional acceptance test, demonstrating that the entire system performs properly, is highly recommended.

11.8 Slide Valve Actuator Service

Table 53 is an example of a typical slide valve/actuator data sheet:

Table 53—Example of a Slide Valve Data Sheet

Location:	Regenerator
Valve Size:	DN900 (36 in.)
Stroke Including Overlap:	584 mm (23 in.)
Controlling Stroke:	486 mm (19 1/8 in.)
Welded or Flanged:	Welded
Hot or Cold Wall Valve:	Hot
Jacking Conn. on Body:	Yes
Lip Seals Provided:	Yes
Purges:	Bonnet
Orifice Opening:	1884 cm^2 (292 $in.^2$)
Orifice Shape:	Bonnet
Actuator Type:	Hydraulic
Operating Modes:	Auto/Manual
Input Control Signal:	4 mA to 20 mA
Local Control:	Yes
Cylinder ID:	356 mm (14 in.)
Stroke Travel Time:	30 seconds
Handwheel:	Yes
Air Motor:	No
Positioner Type:	Electronic
Position Indicator:	Yes
Limit Switches:	No
Hydraulic System Pressure:	17 barg (250 psig) or 138 barg (2000 psig) in high pressure service
Hydraulic Fluid:	Hydraulic Synthetics
Multiple or Local System:	Multiple
Filter Location:	Hydraulic Skid
Filter Elements:	Supply: 3 micron, high beta. Return: 50 micron
Accumulator Capacity:	As required by the Application
Backup # of Strokes:	As required by the Application

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