Refinery Valves and Accessories for Control and Safety Instrumented Systems

API RECOMMENDED PRACTICE 553
SECOND EDITION, NOVEMBER 2010 - (***FOR REVIEW & BALLOT ONLY***)

Refinery Valves and Accessories for Control and Safety Instrumented Systems

Manufacturing, Distribution and Marketing Department
API RECOMMENDED PRACTICE 553
SECOND EDITION, NOVEMBER 2010

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Refinery Valves and Accessories for Control and Safety Instrumented Systems

1 Scope

1.1 This Recommended Practice addresses the special needs of valves and their accessories in control and safety instrumented system (SIS) applications for 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 & spring) 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 FCCU slide valves and vapor depressurizing systems, are also included in this Recommended Practice.

2 References

All references should be the latest edition.

API - American Petroleum Institute

Publ 2218	*Fireproofing Practices in Petroleum and Petrochemical Processing Plants*
RP 521	*Guide for Pressure-Relieving and Depressurizing Systems*
Std 556	*Manual on Installation of Instrumentation, Control and Protective Systems for Fired Heaters*
Std 589	*Fire Test for Evaluation of Stem Packing*
Spec 6FA	*Specification for Fire Test for Valves*
Std 607	*Fire Test for Soft-Seated Quarter-Turn Valves*
Std 609	*Butterfly Valves: Double Flanged, Lug-and Wafer-Type*

ASME - American Society of Mechanical Engineers

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

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

ANSI - American National Standards Institute

B16.5	*Pipe Flanges and Flanged Fittings*
B16.34	*Valves—Flanges, Threaded, and Welded End*
70	*National Electrical Code*

ANSI/FCI - American National Standards Institute/ Fluid Controls Institute, Inc.

70-2	*Quality Control Standard for Control Valve Seat Leakage*

ISA - Instrumentation, Systems, and Automation Society - Control Valve Standards (75 Series)

75.01.01	*Flow equations for Sizing Control Valves*
75.02	*Control Valve Capacity Test*
75.17	*Control Valve Aerodynamic Noise Prediction*
75.08.01	*Face to Face Dimensions for Integral Flanged Globe Style Control Valve Bodies (Classes 125, 150, 250, 300 and 600)*
75.08.02	*Face to Face Dimensions for Flangeless Control Valves (Classes 150, 300, and 600)*

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75.08.06 *Face to Face Dimensions for Flanged Globe Style Control Valve Bodies (Classes 900, 1500, and 2500)*
75.08.07 *Face to Face Dimensions for Separable Flanged Globe Style Control Valves (Classes 150, 300, and 600)*

IEC - International Electro-technical Commission
60534-2-1 Flow Capacity - Sizing Equations for Fluid Flow Under Installed Conditions

MSS - Manufacturers Standardization Society of Valve and Fittings Industry
MSS SP-25 *Standard Marking System for Valves, Fittings, Flanges and Unions*

NACE - National Association of Corrosion Engineers
Std MR0103 *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*
Publication 34103 *Overview of Sulfidic Corrosion in Petroleum Refining*
Std RP0170 *Protection of Austenitic Stainless Steels and Other Austenitic Alloys from Polythionic Acid Stress Corrosion Cracking During Shutdown of Refinery Equipment*
Std MR0175
RP0472 *Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Enviroments*

OSHA - Occupational Safety and Health Association
1910.95 *Occupational Noise Exposure*

PIP - Process Industry Practices
PCECV001 *Guidelines for Application of Control Valves*

U.S. EPA
40 *CFR* Pt. 60 *Appendix A, Attachment 1: Reference Method 21. Determination of Volatile Organic Compound Leaks*
40 CFR 61-V National Emission Standard for Equipment Leaks (Fugitive Emission Sources)

Clean Air Act of 1990
National Emission Standard for Hazardous Air Pollutants (NESHAP)

3 Terms and Definitions

Actuator — A pneumatic, hydraulic, or electrically powered device that supplies force and motion to open or close a valve.

Bonnet — That portion of the valve that contains the packing box and stem seal and can guide the stem.

Dead Band — The range through which an input signal can be varied, upon reversal of direction, 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.

Dead Time — The time interval in which no response of the system is detected following a small (usually 0.25% - 5%) step input.

Dynamic Time — A measure of how long the actuator takes to get to the T63 (63%) point once it starts moving.

Emergency Block Valve (EBV) — 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 types A,

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B, C, and D.

Equal Percentage — An inherent flow characteristic that, for equal increments of rated travel, will ideally give equal percentage changes of the flow coefficient (Cv).

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.

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.

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

Fire Zone — This is an area which is unsafe to enter during an emergency situation. The area is considered to be within a 25-foot radius minimum surrounding the leak source.

Flow Characteristic — Relationship between flow through the valve and percent rated travel as the latter is varied from 0 to 100 percent.

Flow Coefficient (Cv) — A constant (Cv) related to the geometry of a valve, for a given travel, that can be used to establish flow capacity. It is the number of U.S. gallons per minute of 60 degree F water that will flow through a valve with a one pound per square inch pressure drop.

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

Globe Valve — A valve with a linear 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.

Hysteresis — The maximum difference in output value for any single input value during a calibration cycle, excluding errors due to dead band.

Inherent Characteristic — The relationship between the flow coefficient and the closure member (plug or disk) travel 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 Cv). 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.

Linear Characteristic — An inherent flow characteristic that can be represented by a straight line on a rectangular plot of flow coefficient (Cv) versus rated travel.

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).

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Packing	A part of the valve assembly used to seal against leakage around the valve disk or stem.
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.
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 (2σ/m), where σ is the standard deviation of the process variable, and m is the set point or mean value of the measured process variable.
Quick Opening Characteristic	An inherent flow characteristic in which a maximum flow coefficient (Cv) is achieved with minimal valve travel.
Rangeability	The ratio of the largest flow coefficient (Cv) to the smallest flow coefficient (Cv) for a given valve type.
Rotary Control Valve	A valve style in which the flow closure member (full ball, partial ball, disk or plug) is rotated in the flow stream to control the capacity of the valve.
Seat	The area of contact between the closure member and its mating surface that establishes valve shut-off.
Seat Leakage	The quantity of fluid passing through a valve when the valve is in the fully closed position with pressure differential and temperature.
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.
Trim	The internal components of a valve that modulate the flow of the controlled fluid.

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

Type B EBV — This fire-safe block valve should be installed at a minimum of 25 feet from the leak source when ignition is expected. The Type B valve is manually operated and is limited to sizes up to and including 8 inches, and pressure classes through 300#. 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 15 feet above grade.

Type C EBV — The Type C valve is a power-operated Type B valve. The valve must be power-operated if larger than 8 inches or because a pressure class higher than 300# is required. The valve should be installed a minimum of 25 feet (outside of the fire zone) from the leak source and no higher than 15 feet above grade. The controls should be at the valve in an accessible location.

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 40 feet from the leak source and should be out of the fire zone. An EBV installed at an elevation greater than 15 feet 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**.**

Valve Response Time — Usually measured by a parameter that includes both dead time and time constant. (See T63, Dead Time, and Time Constant.) When applied to the valve, it includes the entire valve assembly.

Volume Booster — A stand-alone relay is often referred to as a volume booster or simply booster because it boosts or amplifies, the volume of air supplied to the actuator.

4 Control Valves

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 must meet all of the applicable pressure, temperature, and corrosion requirements of the connecting piping.

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 must 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.

4.1 VALVE BODY

4.1.1 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 conditions.

4.1.2 Nickel alloy or stainless steel valve metallurgy should be specified for temperatures below -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 200 psi may require harder, chrome-molybdenum alloys. Sour service valve

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materials must meet the requirements of NACE MR0103. Corrosive and erosive components even in trace quantities may affect the metallurgical choice of the valve.

4.1.3 Inner valve parts should be the manufacturer's standard where acceptable. Hardened trim may be required for corrosive, erosive, cavitating, or flashing service, and where valve differential pressure exceeds 200 psi.

4.1.4 Flanges are the preferred end connection for globe-style valves; with butt-weld end connections acceptable for ASME classes 900 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.

4.1.5 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).

4.1.6 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, as 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 600 degree F (315 degree C).

b) Flangeless valves should not be used where the process design temperature is below 600 degree F (315 degree C) 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 light hydrocarbons lighter than 68 degrees API)

4) Boiler feed water and steam, in systems requiring ANSI Class 300 and higher flange ratings

5) Oxygen in concentrations greater than 35 percent

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

4.1.7 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 required for gaskets, it should be specified with the valve. The typical standard is 125–250 RMS, which provides a good sealing surface for the gasket.

4.1.8 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 to install flangeless valves so that they will not leak in hydrocarbon service under fire conditions.

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

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4.1.10 Final valve sizing should be reviewed by the valve manufacturer.

4.1.11 Threaded seat rings should be avoided where possible because corrosion often makes removal difficult.

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

4.1.13 Bonnets

Bonnets should be bolted. Bolting material should comply with ASTM A193/194/320 and should be compatible with the valve body and bonnet. For the temperature range between -50ºF and 1000ºF, bolts and studs should meet ASTM A193, Grade B7 specifications. For temperatures between 1000ºF and 1100ºF, bolts should be ASTM A193, Grade B16. For low temperature applications from -50ºF to -150ºF, bolts should be ASTM A320, Grade B7. Nuts should be ASTM A194, Grade 2H for the above applications. Stainless steel bodies require stainless steel bolting. Higher grade valve metallurgy requires 316 SST as the minimum bolting material.

Extended bonnets should be considered for process temperatures below 32°F or above the temperature limits of the packing materials shown below in section 3.1.13.

Bonnet gaskets should be fully retained spiral wound, with polytetrafloroethelene or graphite filler. Flat gaskets made from PTFE sheet stock are acceptable where conditions permit. Insert reinforcements should be 316 SST or other appropriate alloy, as required.

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

4.1.14 Packing

a. Packing boxes should be easily accessible for periodic adjustment. The packing material should (1) be elastic and easily deformable, (2) be chemically inert, (3) be able to withstand applicable process conditions, (4) provide a degree of fire resistance, (5) minimize friction, and (6) reduce fugitive emissions to meet regulatory requirements. Valve manufacturer's packing temperature limits refer to the temperature at the packing box.

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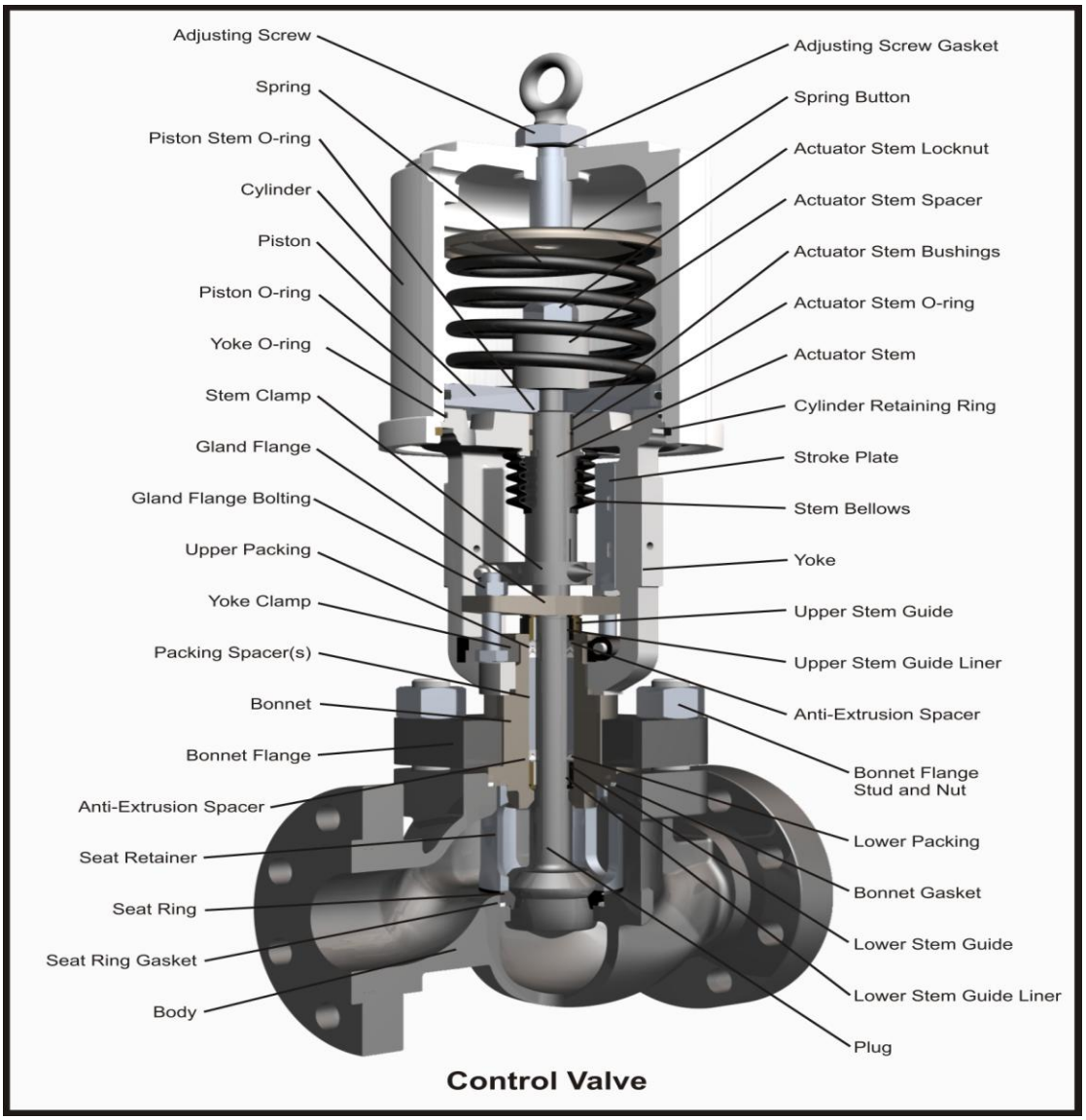


Figure 1 - Typical Control Valve Components
(Courtesy of Flowserve)

b. PTFE has excellent inertness, good lubricating properties, and is one of the most popular 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 450°F (230 degree C) . 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 2000ºF. The biggest difficulty caused by this type of packing is very high packing friction, which often requires an oversized actuator. Performance is often compromised, because of significant increases in hysteresis and deadband. This additional friction needs to be compensated for when sizing the actuator for the control valve.

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d. Asbestos should not be used.

e. Valve stuffing 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 so as to not put undue load on the packing.

4.1.15 Fugitive Emissions

The Clean Air Act of 1990 or 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 manufacturers are offering increasingly effective designs, and vendors should be consulted for specific applications. See Figure 2.

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 700ºF.

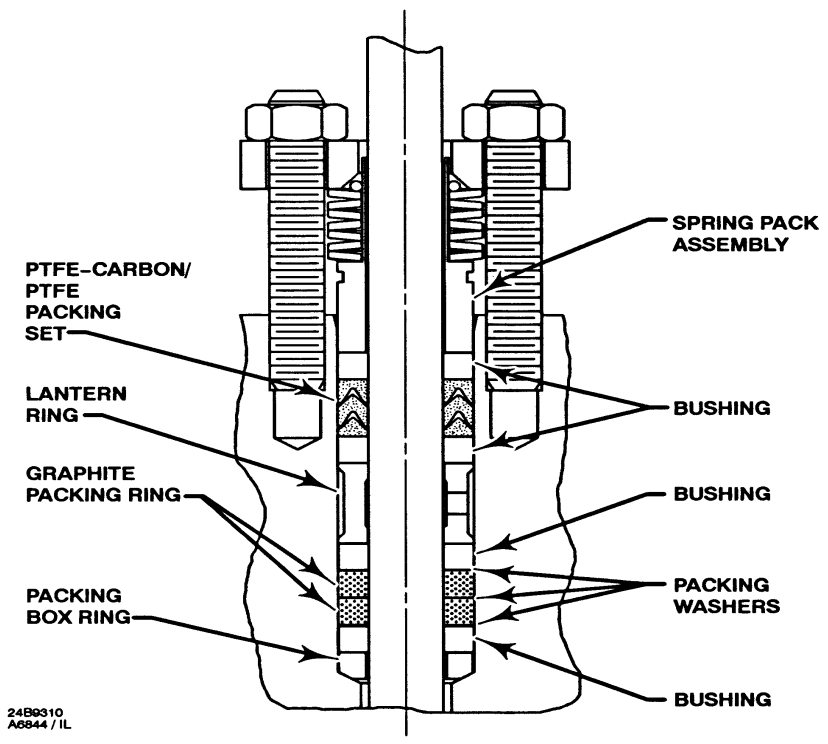


Figure 2 - Typical Live-loaded Packing Arrangement. (Courtesy of Emerson Process Management)

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4.1.16 Seat Leakage

a. ANSI/FCI 70-2 establishes a series of seat leakage classes for control valves and defines the test procedures. Worst case process conditions should be considered for control valve leakage class selection.

b. Metal-to-Metal seating with Class IV leakage rating is expected for most process applications, especially for fluids containing abrasive particles or with design temperatures above 450 degrees F (230 degree C).

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

d. Composition (soft) seats for shutoff valves may be used when better than Class V shutoff is desired, and when the seats conform to the pressure, temperature, and chemicals limitations of the process. Composition seats are usually limited to process temperatures below 450 degrees F (230 degree C) due to the fact that most elastomer materials begin to cold flow at this temperature.

e. Double-ported valves are limited to a Class II shutoff.

f. Single-seated 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.

g. However, before an insert material is selected, it should be determined that the insert is compatible with the process fluid, pressure, and temperature. In addition to normal process conditions, shutdown conditions should be considered in selecting resilient seats. Steaming through a valve can damage or ruin a resilient seat. (See Figure 3.)

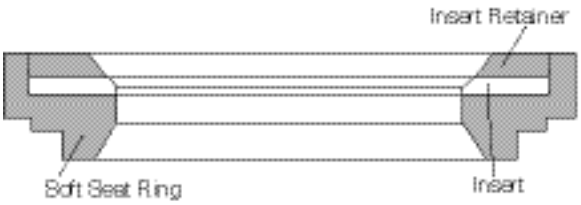


Figure 3 - Resilient Seat
(Courtesy of Emerson Process Management)

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4.1.17 Control Valve Characteristics

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 Figures 4 and 5. A modified equal percentage characteristics generally falling between linear and equal percentage characteristics is sometimes available.

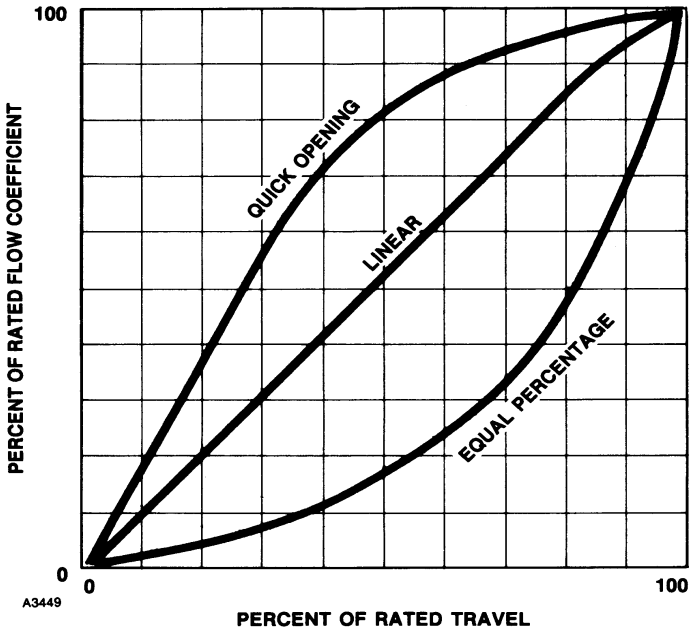


Figure 4 - Inherent Valve Characteristics.
(Courtesy of Emerson Process Management)



Figure 5 - Characterized cages for globe-style valve bodies.
(Courtesy of Emerson Process Management)

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

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

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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, except as indicated below:
   1) Valves used in pairs, as three-way valves, including rotary actuated valves such as ball or butterfly types should have linear characteristics.
   2) Gas compressor recycle control valves should have linear characteristics.
   3) Valves in pressure-reducing service should have linear characteristics.
   4) Valves in level control service should have linear characteristics.

4.1.18 Control Valve Types

Today's control valves operate by one of two primary motions: reciprocating motion (see Figure 6A) or rotary motion (see Figures 6B and 16). The selection of a valve for a particular application is primarily a function of process requirements for control performance, pressure drop, temperature, and rangeability.

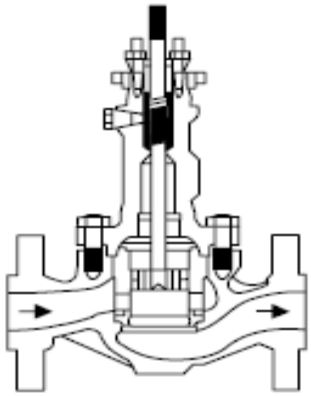


FIGURE 6A - Reciprocating Motion Valve
(Courstesy of Dresser-Masonelian)

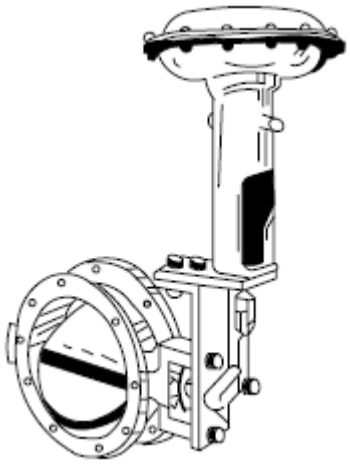


FIGURE 6B - Rotary Motion Valve
(Courtesy of Dresser-Masonelian)

Loop dynamic performance should be considered when selecting control valves. Each type of control valve (reciprocating 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, Figure 7 (line sized valves) shows the effect of valve style on control range.

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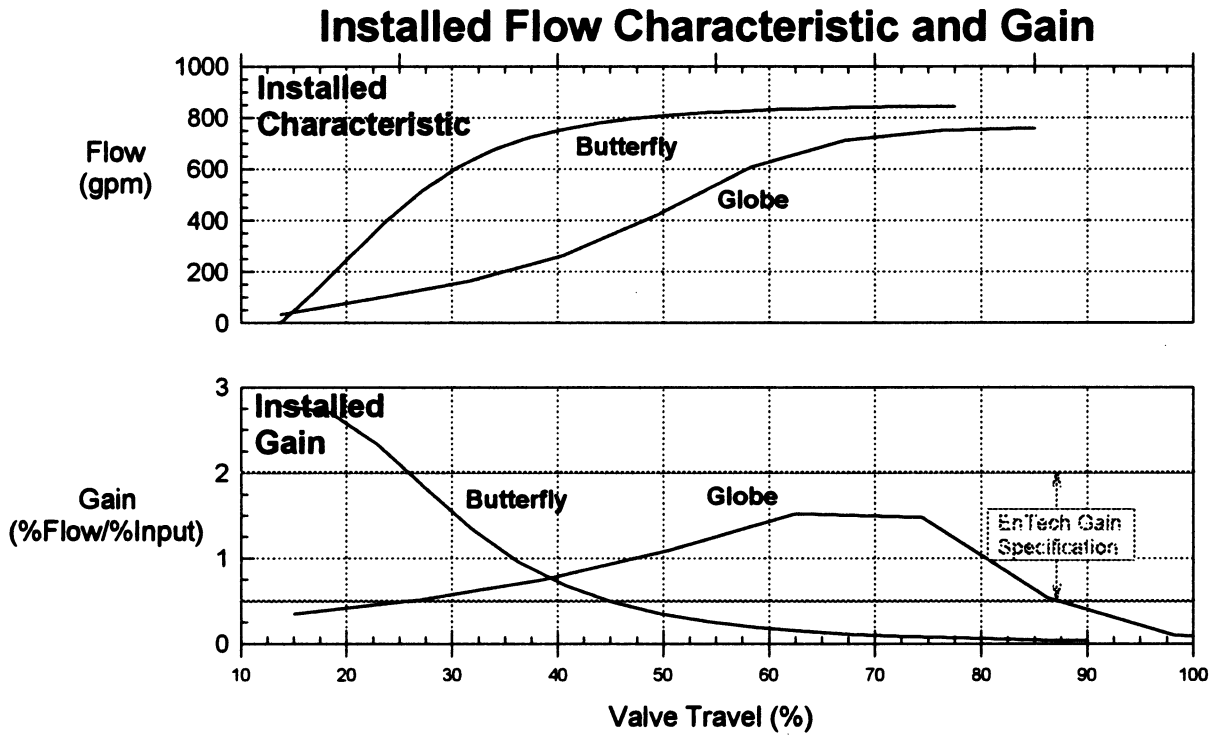


Figure 7 - Effect of Valve Style on Control Range.
(Courtesy of Emerson Process Management)

4.1.19 Sizing

a. Control valve sizing is the process of determining the correct valve size and style for a specific application. The fundmental 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 Cv 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 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.

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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. Start-up conditions, if different than minimum

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 to 95 percent of full travel.
   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 percent 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 v-port skirt design type three-way valves, the exchanger port should be sized to pass the maximum design flow through the exchanger and zero flow through the bypass port.
   2. For conventional valves in three-way service, the exchanger valve should be sized to pass the maximum design flow through the exchanger and zero flow through the bypass valve. The bypass valve should be sized to pass the maximum design flow with zero flow through the exchanger valve subject to the limitation that the bypass valve should be no smaller than one size below the exchanger valve.

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).

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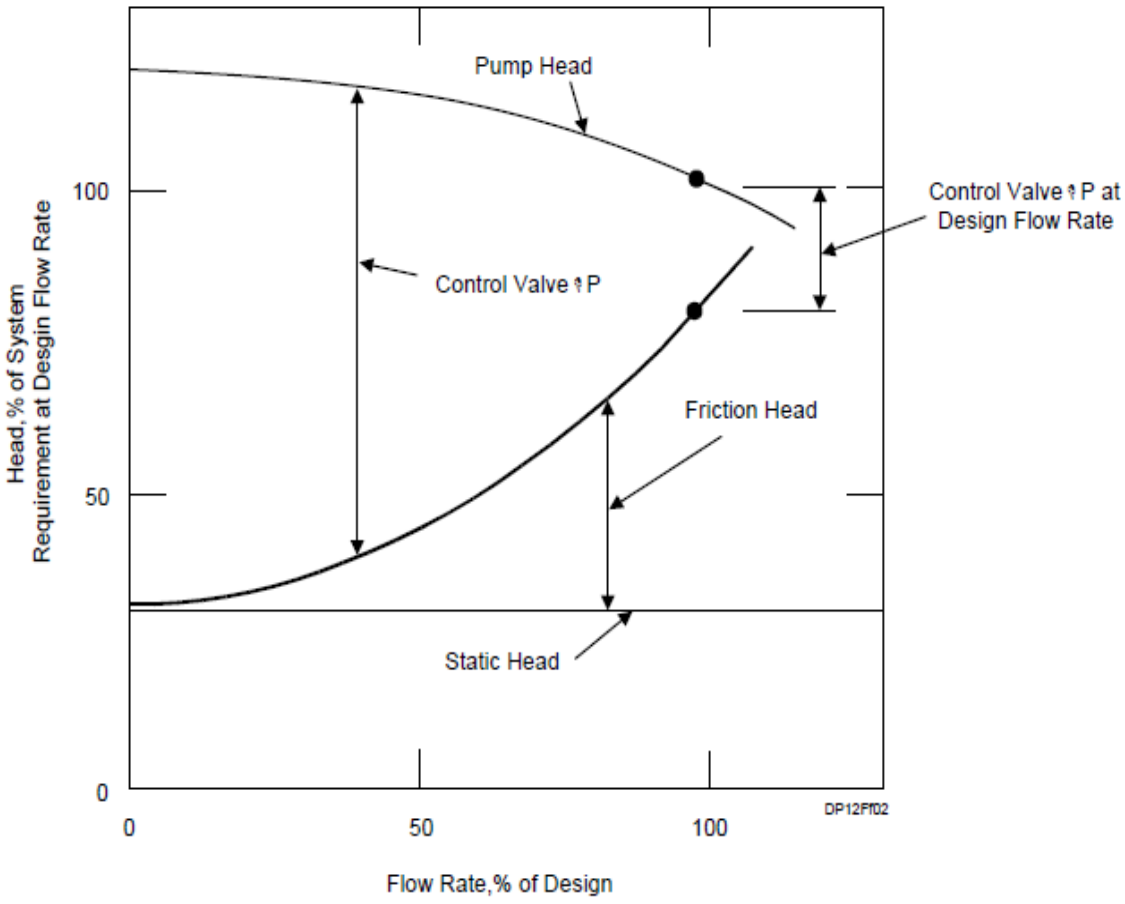


FIGURE 8 - Typical System Head - Capacity Relationship

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 Cv requirement. Capacity correction factors that can be applied to calculated Cv 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).

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

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recovery, such as rotary valves. This necessitates the use of a larger valve or different valve style. Similar choking effect occurs for liquid flows due to the introduction of compressibility resulting from vaporization of a portion of the liquid.

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 Figures 10 and 11. It is easily recognized by a characteristic sound described as "like rocks flowing through the valve." A single compound such as water is one of the most damaging fluids. Hydrocarbon mixtures can have various vapor pressures for different components in the mixture, making it very 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.

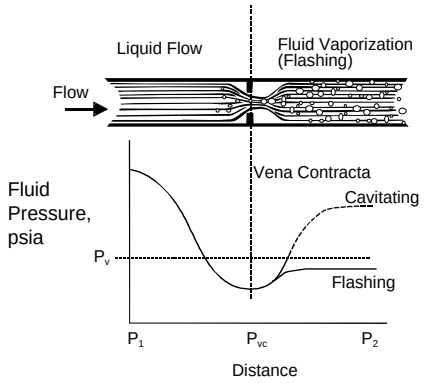


Figure 9 - Pressure-Drop through a Restriction (Courtesy of Emerson Process Management)





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FIGURE 10 - Cavitation Damage to Valve Plug (Courtesy of Flowserve)

Figure 11 - Cavitation Damage to Seat Ring (Courtesy of Flowserve)

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 the use of two or more valves, or specially design elements in series.

j. Flashing

1. Flashing occurs where the downstream pressure at the vapor pressure of the fluid. See Figures 9 and 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, angle valves with sacrificial liner, and reverse flow rotary valve positioned for outlet to flow directly into a large volume such as a tank. 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.



Figure 12 - Flashing Damage (Courtesy of Emerson Process Management)

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 required to release the entrained gas.

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

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flowing media prior to the throttling orifice can not 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 for both the compressible component (gas/vapor) and the non-compressible (liquid) must 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 pressure-drop sliding stem type control valves or single stage swept flow designed sliding stem type control valves based on the outlet vapor ratio. 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 Cv 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 real 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 required.

4.1.20 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.

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 at one meter downstream and one meter 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 one meter downstream and one meter 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

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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 should the calculated sound level exceed 115 dBA at one meter downstream and one meter out from the pipe due to possible mechanical failure within the system (pipe welds, small lines, etc.). No allowance should 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. 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. See Figures 13A and 13B. On new construction where upstream piping is modified, special consideration should be taken to protect the control trim from being damaged during flushing activities.



Figure 13A - Slotted noise abatement trim. (Courtesy of Emerson Process Management)



Figure 13B - Stacked disc design cage (Courtesy of Emerson Process Management)

4.1.21 Body Integrity

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

4.1.22 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.

4.1.23 Nameplate

The valve should be supplied with a permanently attached stainless steel tag, stamped with the manufacturer's standard data, and the tag or item number.

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4.2 VALVE ACTUATORS

4.2.1 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 used where very high thrust forces are required.

4.2.2 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.

4.2.3 Diaphragm Actuators

a. A spring 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.

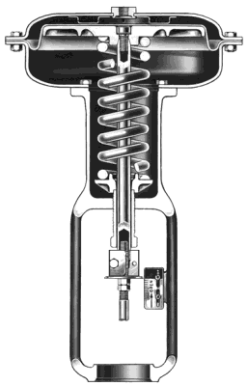


Figure 14 - Diaphragm Actuator.
(Courtesy of Emersom Process Management)

b. The frequent use of positioners and the requirements for tight shutoff have led to widespread use of higher spring ranges and pressures, utilizing the available air supply.

4.2.4 Piston Actuators

a. Piston (or cylinder) pneumatic actuators are used for control valves where high thrust is required. 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.

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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

4.2.5 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.

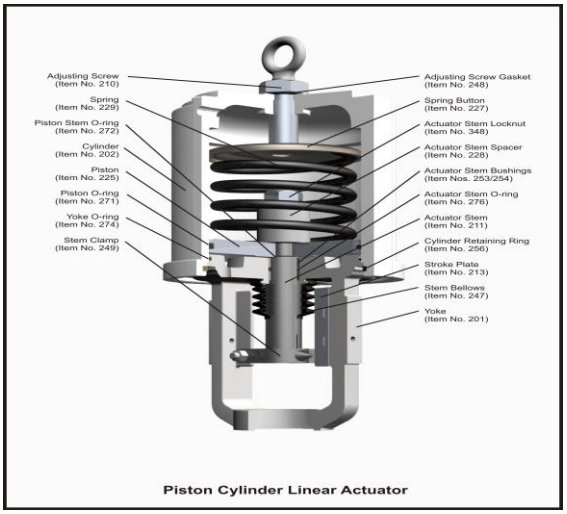


Figure 15 - Double-Acting Spring Return Piston. (Courtesy of Flowserve)

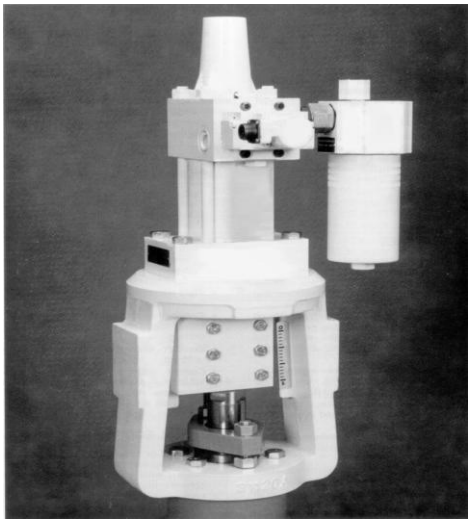


Figure 16 - Electrohydraulic Actuator (Courtesy of Flowserve)

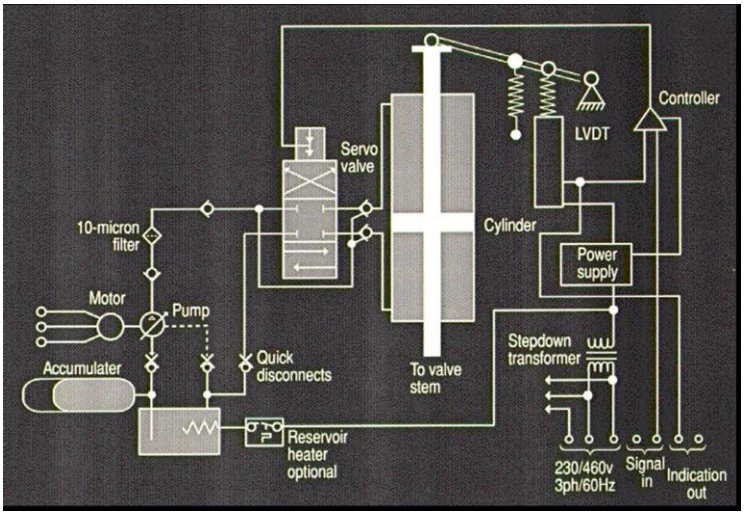


Figure 17 - Electrohydraulic Actuator Schematic

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(Courtesy of Flowserve)

4.2.6 Actuator Selection

4.2.6.1 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 vane over its full travel, based on a pressure drop equal to the maximum upstream design pressure.

4.2.6.2 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.

4.2.6.3 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.

4.2.6.4 The most reliable fail-safe action is achieved with an enclosed spring. If capacity tanks are required to provide reserve operating power, they should be sized to stroke the valve twice. Capacity 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)*. Capacity tanks should be designed with all necessary accessories to ensure the required valve action and failure position.

4.2.6.5 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.

4.2.6.6 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.

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

4.2.6.8 In general, the actuator materials of construction should be the manufacturer's standard.

4.2.6.9 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.

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4.3 VALVE POSITIONER

4.3.1 Positioners are generally used 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.

4.3.2 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 required. Precision is enhanced by the availability of positioners with adjustable gain.
f. Reduce hysteresis.

4.3.3 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 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 4-20mA) to a pneumatic signal (3-15 psi) 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.



Figure 18 - Conventional Valve Positioner (Courtesy of Dresser-Masonelian)



Figure 19 - SMART Valve Positioner (Courtesy of Dresser-Masonelian)

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4.3.4 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. It takes experience to quickly and effectively calibrate and tune these instruments. This technology has been used in plants for decades with few advances in the last 30 years.

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.

4.3.5 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. Diagnostics are becoming part of standard plant "Preventive" and "Predictive" maintenance toolset. 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.

4.4 HANDWHEELS

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

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

4.4.3 When a handwheel is used for a piston actuator, a cylinder bypass valve must be included.

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4.4.4 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 yoke, arranged so that the valve stem can be jacked in either direction.
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.

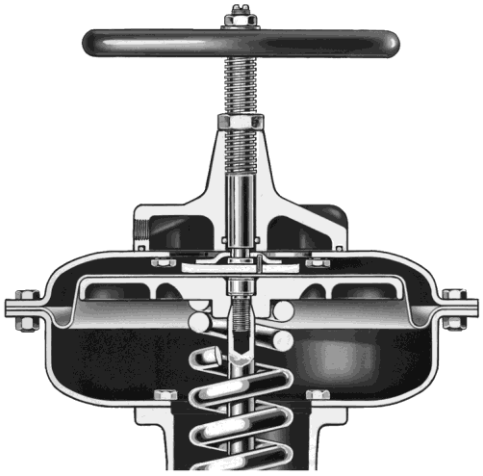


Figure 20 - Top Mounted Handwheel.
(Courtesy of Emerson Process Management)

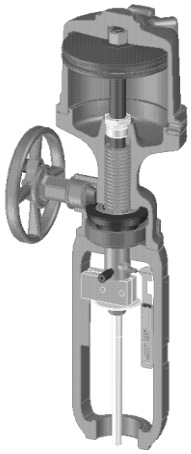


Figure 21 - Side Mounted Handwheel
(Courtesy of Emerson Process Management)

4.5 SWITCHES AND SOLENOIDS

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:

4.5.1 Hermetically-sealed Magnetic or Inductive proximity switches are preferred when independent "open" or "closed" indication of stem position is required. See Figure 22 - 24.

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

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Figure 22 - Cam-Operated Limit Switch.
(Courtesy of Emerson Process Management)



Figure 23 - Beacon Type Limit Switch Housing
(Courtesy of Westlock Controls Corp.)



Figure 24 - Proximity Switches
(Courtesy of Westlock Corporation)

4.5.3 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.

4.5.4 Valve trip solenoids should be installed in the actuator inlet tubing. When exhaust rate is critical, the solenoid valve Cv 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 Cv value at least ten times that of the typical $^{1}/_{4}$" solenoid valve.

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4.5.5 Solenoids and limit switches supplied with control valves should be specified with a minimum of 18" 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.

4.5.6 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 VOLUME BOOSTERS / QUICK EXHAUST VENTS / AIR LOCKS

4.6.1 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.

4.6.2 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 positioner.

4.6.3 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 in the order of 1 to 2 seconds.

4.6.4 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**.**

4.6.5 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.

4.6.6 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 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 for 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.

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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 II or III is possible.

5.1.3 A globe-style valve that has a cast flanged body and that can be serviced while in the line is preferred. Split body valves are not recommended except in special service.

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 coking service, where solids are carried in suspension, for severe flashing service, and where the piping design can take advantage of the valve geometry.

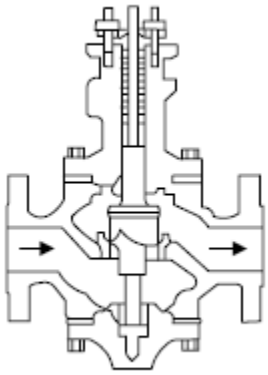


Figure 25 - Single-ported Globe Valve

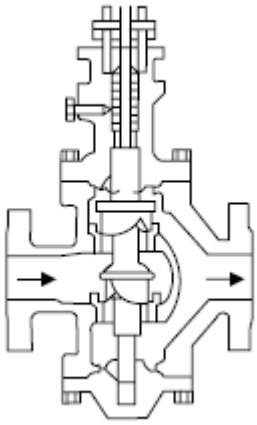


Figure 26 - Double-ported Globe Valve

5.1.5 The recommended minimum globe body size is one inch when installed in lines one inch and larger. Valves installed in lines smaller than one inch should be line sized. Valve sizes $1^1/_4$"NPS, $2^1/_2$"NPS, $3^1/_2$"NPS, and 5"NPS are not recommended.

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 drops services. Rotary-

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segmented ball valves should be considered for highly viscous services and where greater flow turndown ratios are required.

5.2.2 Butterfly valves with lug bodies may have threaded or unthreaded bolt holes. Unthreaded bolt holes are preferred, as threaded bolt holes tend to gall up over time requiring bolts to be cut to permit valve removal. Wafer (unflanged) valves should have centering holes 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).

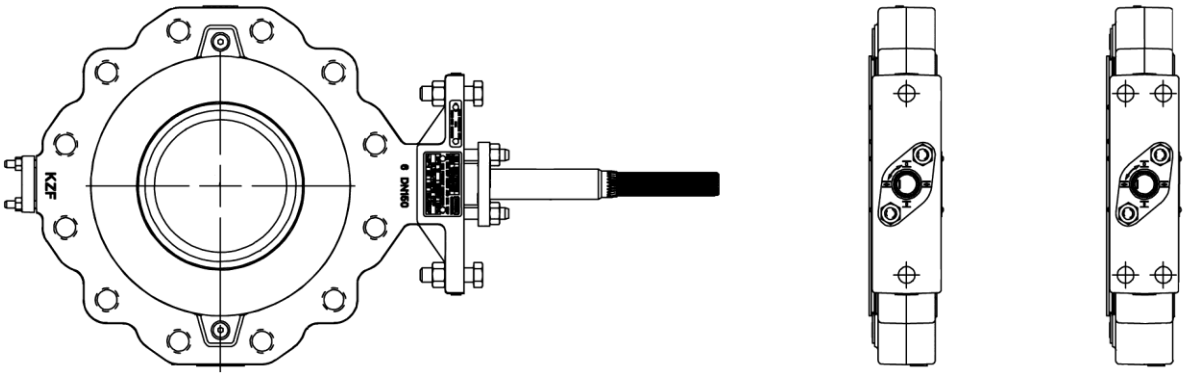


Figure 27 - Lugged-style butterfly valve.
(Courtesy of Emerson Process Management)

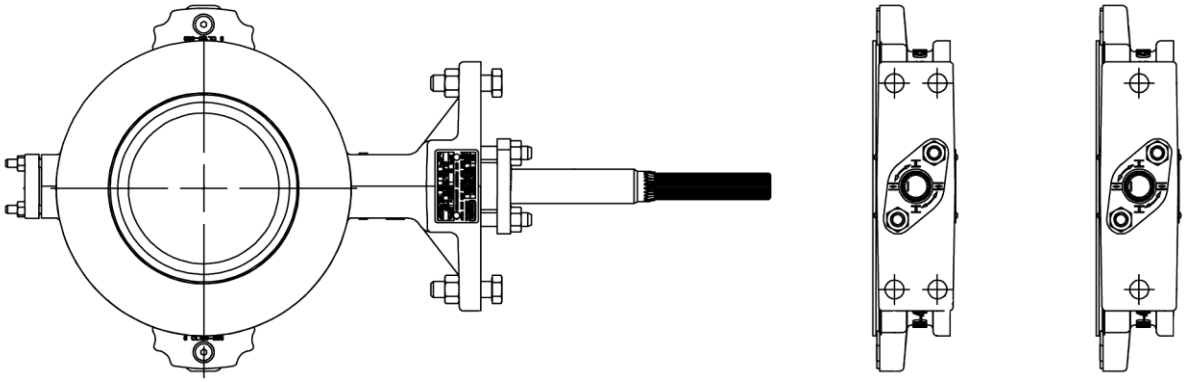


Figure 28 - Wafer-style butterfly valve.
(Courtesy of Emerson Process Management)

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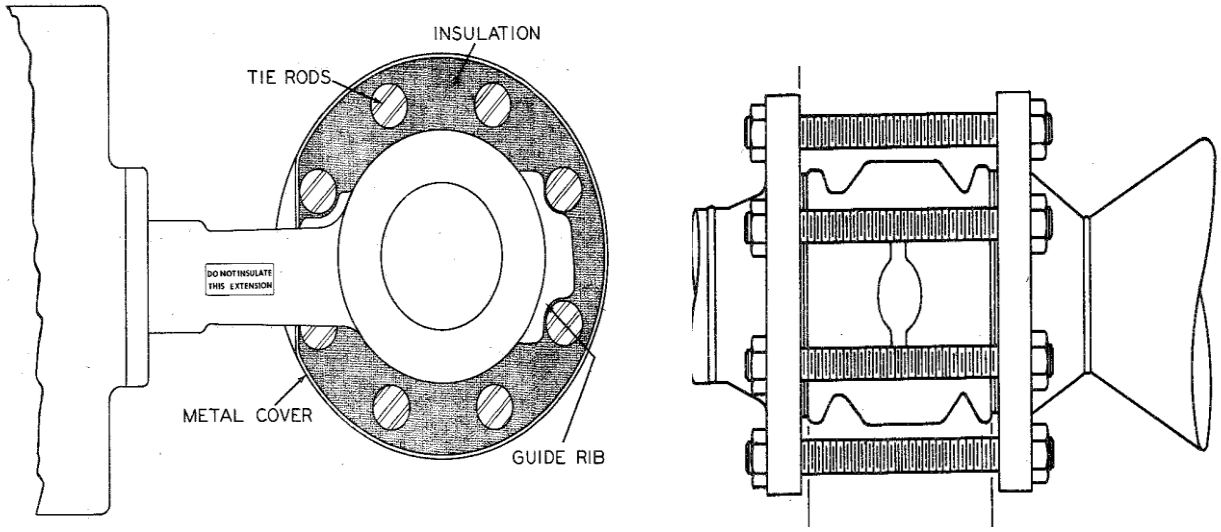


Figure 29 - Typical Wafer-style (flangeless) valve installation (Courtesy of Emerson Process Management)

5.2.3 Particular attention should be given to clearance requirements of butterfly disks. 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. Avoid the use of pinning 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 should be stainless steel or better. 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

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5.3.1 High pressure drop (> 200 psi) with particulates is considered a severe service application requiring a control valve with a debris-tolerant solution. A control valve with low noise or anti-cavitation trim with small passages will clog and result in valve and/or equipment failure.

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 in which small passages are replaced by a series of specially engineered large area expansion and contraction regions. Figure 30 is a multistage, debris tolerant trim for liquid service. This design delivers a high level of cavitation protection 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.

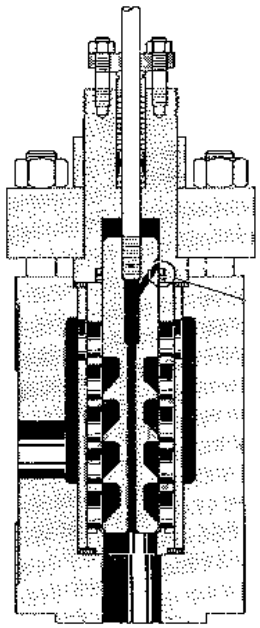


Figure 30 - Multi-Stage Valve (Courtesy of Dresser Masonelian)

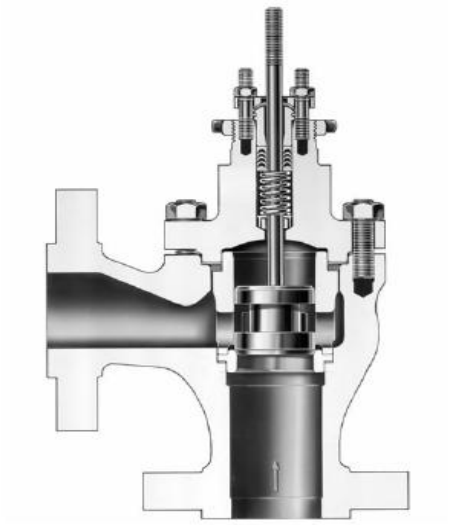


Figure 31 - Angle Valve (Courtesy of Dresser Masonelian)

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 (drilled hole and tortuous path type) for gas service. Similar to anti-cavitation liquid control valve trims for clean service applications, the technology uses small drilled holes or tortuous flow passages. The purpose is to minimize noise and vibration levels associated with the high-pressure reduction of a compressible gas.

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 Hot High Pressure Letdown valves are typical examples of severe service gas applications.

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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 must 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 such as:

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 must 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 process variable (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 must 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

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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 must 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 must 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 must 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 upper 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 globe valve has a much wider control range than the butterfly valve. Other valve styles such as V-notch ball 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 product 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 wasy

1. 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.

2. An oversized valve is likely to operate more frequently at lower openings where seal friction can be greater, especially in rotary valves. 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.

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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 whose performance directly and significantly impacts plant or unit operation. It is expected that less than 3 percent of all control valves will fall into this category. 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 inches 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) Controllability (< 0.5% in both directions)
6) High sound pressure level (>90 dBA)
7) High duty cycle (> 10 cycles/hr)

5.5.2 These high performance valves deserve special attention during the engineering, procurement, installation, and maintenance process. 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.

5.6 Material Considerations for Control Valves in Refining Processes

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. Please consult the manufacturers to assure requirements are understood and can be met.

5.6.1 Sulfidic Environments

5.6.1.1 Sulfide Stress Cracking (SSC)

Sulfide stress cracking can occur in environments containing an aqueous phase and hydrogen sulfide (H2S), 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, which is influenced by the concentration of H2S, the concentration of free cyanide, and the pH of the aqueous phase. Typical refining units where this may occur are atmospheric and vacuum distillation units, catalytic cracking units, hydrocracking & hydrotreating units, coker units, sour water recovery

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units, amine regenerator systems, gas recovery plants, and sulfur recovery 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. There is no need to address chloride stress corrosion cracking (CSCC) in refineries, because the first step in a refinery is to desalt crude to remove chlorides. MR0175 has been revised to include chloride SCC (resulting is what is now NACE MR0175/ISO 15156).

5.6.1.1.1 The major differences between MR0103 and MR0175 are:

- Environmental restrictions on materials
- MR0103 does not include limits on H2S concentrations, temperature, etc.
- Materials and/or material conditions included
- Welding controls in MR0103 are much stricter, especially with regard to carbon steels, alloy steels, and duplex stainless steels.

Although most materials and requirements are identical in MR0175 and MR0103, some materials included in MR0175 are not listed in MR0103, and vice versa. It is recommended that the applicable specification is reviewed prior to use.

5.6.1.1.2 **A**nother 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 CO2 causes low pH, and chlorides cause stress corrosion cracking (issues addressed by NACE MR0175). In downstream sour applications, dissolved ammonia & cyanides are present, and the fluid can have a resulting high pH (>7) which produces a high hydrogen charging potential even with low H2S 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 H2S in the gas phase associated with the free water of a process.

Note: total sulfide content is defined as H2Saq (dissolved hydrogen sulfide), HS- (bisulfide ion), and S2- 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.

5.6.1.2 Sulfidic Corrosion

5.6.1.2.1 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:

- 2-1/4 Cr - 1 Mo (WC9)
- 5 Cr - 1/2 Mo (C5)

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- 9 Cr - 1 Mo (C12)
- Austentic SST (CF8C) (Greatest resistance)

However, there still can be selection issues. C5 and C12 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 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 the section 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".

5.6.1.3 Polythionic Acid Stress Corrosion Cracking (PTA SCC)

5.6.1.3.1 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 (347/CF8C and 321), 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 700°F. Using S32100 (321SS) or S34700 (347SS) is successful because S32100 is stabilized with titanium and S34700 is stabilized with niobium. Titanium and niobium are stronger carbide formers than chromium, and prevent the formation of chromium carbides, thus avoiding sensitization. These will not sensitize, so 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 (Inconel 600) and N07750 (Inconel X750). Although S20910 (Nitronic 50) 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 (Inconel 718), which is fully stabilized, can be used, but is significantly more expensive.

Some refiners continue to use S31600 (316SS) 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".

5.6.2 Acidic Environments

5.6.2.1 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.

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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 HF 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 (Monel) and N05500 (K-Monel) alloys are generally accepted as optimum for all exposed (wetted) parts. Some users also have success using Hastelloy C and Inconel 625. These applications are found in the hydrofluoric acid alkylation unit in a refinery.

5.6.2.2 Sulfuric Acid

Like Hydrofluoric acid, H2S04 is a strong acid that can attack many substances and is toxic. N08020 (Alloy 20) 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.

5.6.2.3 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, vacuum and 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 (316L) or they can use standard grade S31700. The molybdenum content in S31600 and S31603 can range from 2-3%, while S31700 has a minimum content of 3.0% (range is 3.0-4.0%).

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 1.5-3.0% 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 (Alloy 6) 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.

5.6.3 Alkaline Environments

5.6.3.1 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. Note that hardness is not a factor in preventing ASCC.

Other facts to note:

- These instructions apply only to carbon steels.

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- Customers will typically not indicate on specification sheets that ASCC is a possibility, but will rather simply impose PWHT of all welds.
- 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. Preferred mounting is vertical.

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 24 inches (600mm) from surfaces exceeding 500 degrees Fahrenheit (260 degrees Celsius). Where this clearance is not available, thermal shielding should be used. Consult the manufacturer's literature for maximum permissible ambient temperature.

6.2.4 All electrical equipment and circuits for instrumentation and controls must 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 after initial installation.

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 3 to 5 ft (1 to 1.5 m) above the elevation of the access area.

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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.

6.3.3 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 required 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.

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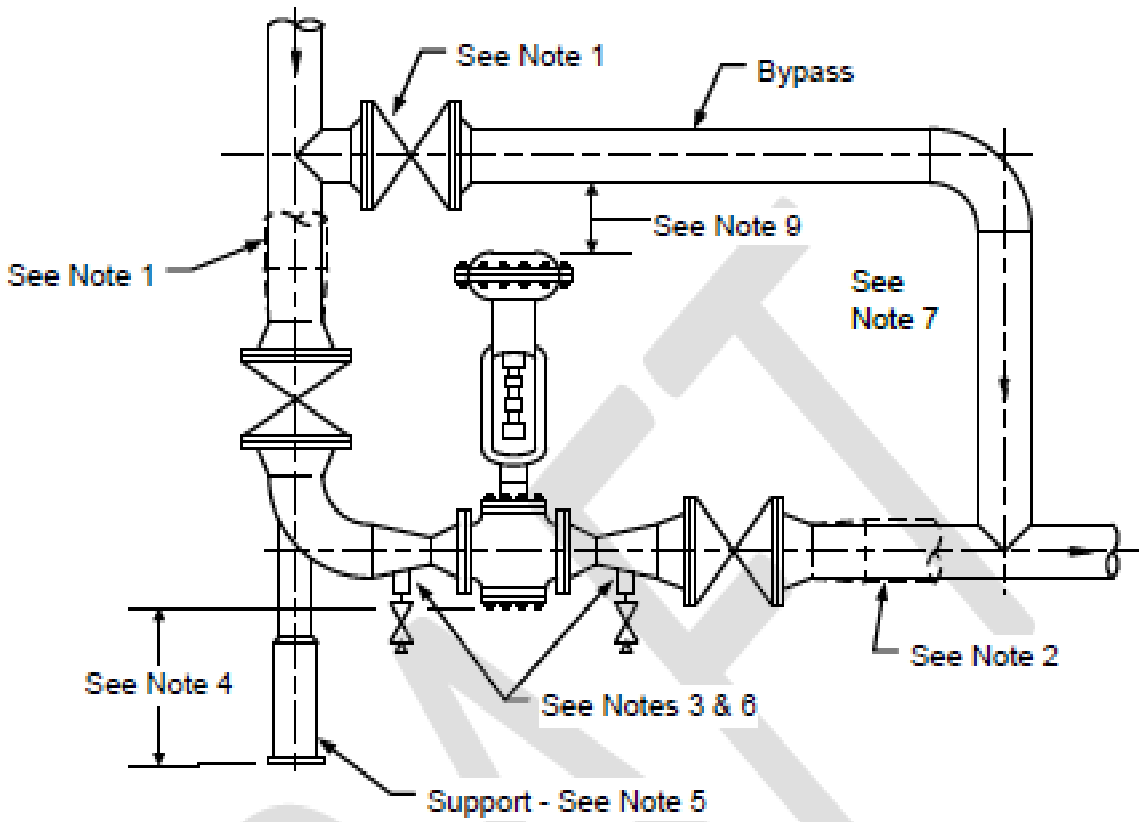


Figure 32 - Typical Control Valve Manifold

NOTES:

(1) Bypass valve size should be equivalent to Control Valve size.

(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 12-inch minimum under clearance.

(5) Support control valve manifold.

(6) An NPS 3/4 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 12 inches.

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6.4 Inspection and Testing

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

6.4.2 All critical and high performance control valves should be furnished with a valve profile 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. The valve stem may be lightly lubricated. The end user should consider witnessing the tests if the valve is judged to be critical. The following tests should be performed once the valves have been stroked sufficiently to produce repeatable results:

a. Valve stem position should be measured while applying increasing and decreasing air signals directly to the actuator without the positioner in service. Air signal should be consistent with the spring range of the actuator. Performance should meet the following requirements:

1) Stem position error should not exceed 3 percent of rated travel.

2) Hysteresis plus deadband should not exceed 3 percent of rated travel for PTFE packing. For graphite packing, this performance should not exceed 5 percent of rated travel.

b. Valve stem position should be measured while applying increasing and decreasing control signals directly to the positioner. Performance should meet the following requirements:

1) Stem position error should not exceed 1 percent of rated travel.

2) Hysteresis plus deadband should not exceed 1 percent of rated travel for all packing types.

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, model, serial number, operating range, materials of parts exposed to process fluid, size, type of valve characteristic, spring range, and failure position.

3) Packing materials.

6**.4.9** Valves should be furnished with the following documentation:

1) A detailed "assembly" drawing or description of parts traceable to a serial number.

2) A Positive Material Identification (PMI) record, as required.

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7 Refinery Applications

7.1 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.

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.

7.2 Materials and packing suggested in these examples may be modified, based on vendors, suggestions and specific applications. Special environmental packing may be used where required by regulations.

7.3 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 must use caution.

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7.4 ATMOSPHERIC DISTILLATION

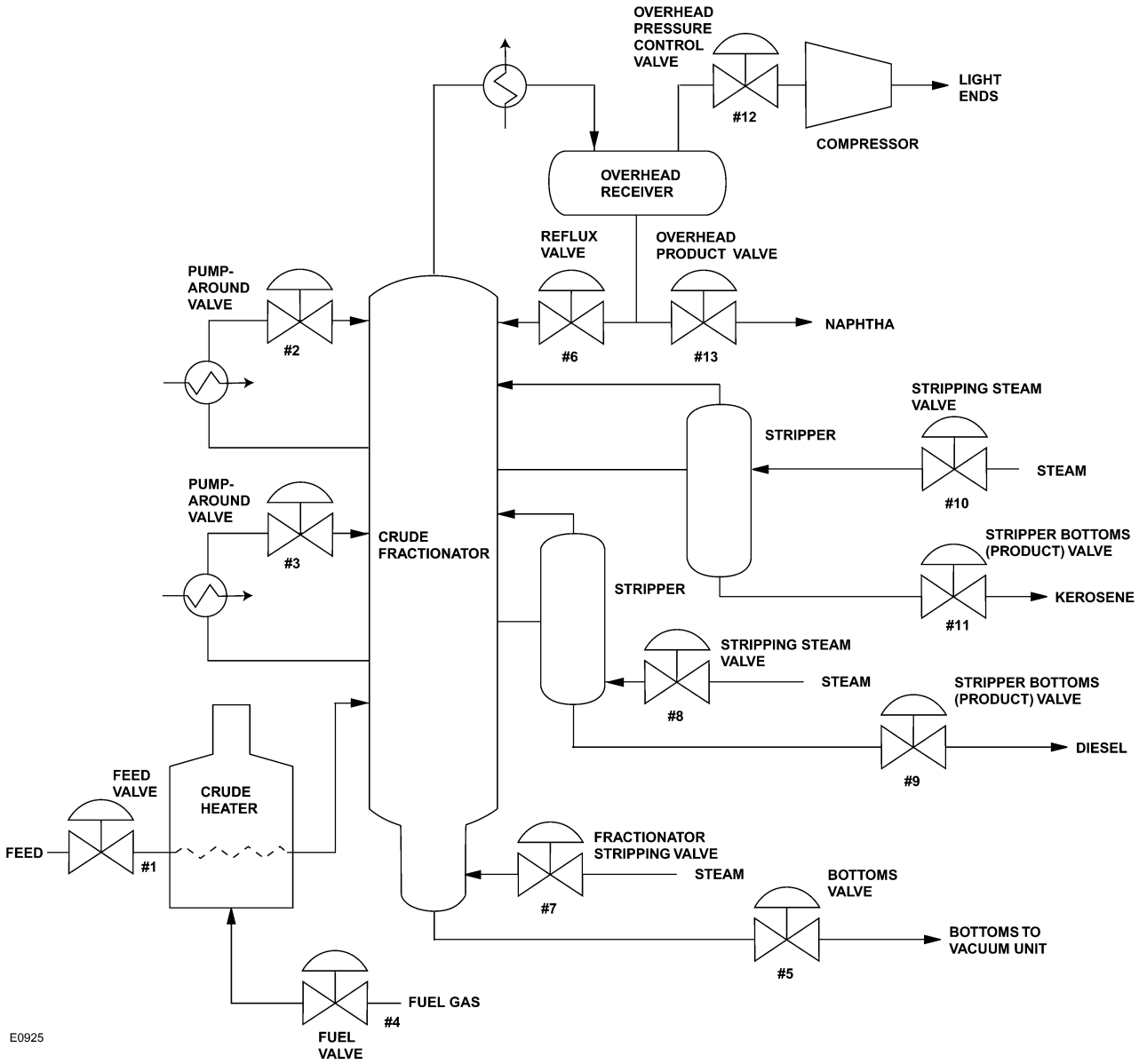


FIGURE 33 - ATMOSPHERIC DISTILLATION

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(Courtesy of Emerson Process Management)

7.4.1 ATMOSPHERIC DISTILLATION - UNIT FEED (VALVE #1)

7.4.1.1 Operating Conditions

Fluid: Liquid. Crude Oil.

	Normal	Maximum
Q m3/h (gpm)	545 (2400)	681 (3000)
P1 barg (psig)	22.4 (325)	20.7 (300)
dP bar (psid)	6.9 (101)	4.3 (63)
T °C (°F)	232 (450)	315 (600)
SG	0.72	0.72
Pv bara (psia)	5.3 (77)	5.3 (77)

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 Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The C5 chrome-moly body provides enhanced hardness characteristics with higher ANSI pressure/temperature ratings. A Reverse flow (flow passes plug, then seal) ball valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is normally ANSI Class IV shutoff.

7.4.1.3 Trim

Reverse flow full port trim configuration consisting of 17-4PH stainless steel seat ring retainer, Alloy 6 (Stellite 6) seal, and Stellite 6 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. 17-4PH shaft and Stellite 6 bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The 17-4PH/Alloy 6 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, double top stem guided to prevent galling and sticking of valve trim.

7.4.1.4 Sizing

Conventional.

7.4.2 ATMOSPHERIC DISTILLATION - FUEL GAS TO FURNACE (VALVE #4)

7.4.2.1 Operating Conditions

Fluid: Gas.

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	Normal	Maximum
Q km3/h (kscf/h)	3.6 (130)	5.9 (208)
P1 barg (psig)	3.54 (50)	3.54 (50)
dP bar (psid)	0.50 (20)	1.2 (17)
T °C (°F)	32 (90)	37 (100)
SG (MW)	0.59 (11)	0.59 (11)

7.4.2.2 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 Class 150# or 300#, with a Carbon Steel body, Teflon fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.4.2.3 Trim

Standard 316SS (use caution with low-noise trim in these services, if fuel gas is dirty)

7.4.2.4 Sizing

Conventional.

7.4.3 ATMOSPHERIC DISTILLATION - HEAVY BOTTOMS (VALVE #5)

7.4.3.1 Operating Conditions

Fluid: Liquid with "sticky" particulates.

	Normal	Maximum
Q km3/h (gpm)	430 (1896)	477 (2100)
P1 barg (psig)	17.7 (257)	16.2 (235)
dP bar (psid)	4.13 (60)	1.03 (15)
T °C (°F)	332 (630)	371 (700)
SG	0.71	0.71

7.4.3.2 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 Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The C5 chrome-moly body provides enhanced hardness characteristics with higher ANSI pressure/temperature ratings. A Reverse flow (flow passes plug, then seal) ball valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is normally ANSI Class IV shutoff.

7.4.3.3 Trim

Reverse flow full port trim configuration consisting of 17-4PH stainless steel seat ring retainer, Alloy 6 (Stellite 6) seal, and Stellite 6 valve plug with equal percentage characteristic. Reverse flow configurations will minimize high velocity

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flow across the rotary plug, seal, and inner valve body surfaces, helping maintain shutoff specified and optimal body life. 17-4PH shaft and Stellite 6 bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The 17-4PH/Alloy 6 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, double top stem guided to prevent galling and sticking of valve trim.

7.4.3.4 Sizing

Conventional.

7.4.4 ATMOSPHERIC DISTILLATION - REFLUX (VALVE #6)

7.4.4.1 Operating Conditions

Fluid: Liquid. Distillate

	Normal	Maximum
Q m3/h (gpm)	154 (670)	172 (758)
P1 barg (psig)	5.93 (86)	5.65 (82)
dP bar (psid)	1.9 (28)	1.3 (19)
T °C (°F)	212 (415)	249 (480)
SG	0.73	0.73
Pv bara (psia)	1.3 (20)	1.3 (20)

7.4.4.2 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 Class 300#, with a Carbon Steel body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service.

7.4.4.3 Trim

Standard 316SS

7.4.4.4 Sizing

Conventional.

7.4.5 ATMOSPHERIC DISTILLATION - STRIPPING STEAM (VALVES #8, #10)

7.4.5.1 Operating Conditions

Fluid: Steam

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	Normal	Maximum
Q MT/h (lb/h)	21.7 (2000)	43.5 (4000)
P1 barg (psig)	2.76 (40)	2.76 (40)
dP bar (psid)	0.96 (14)	0.96 (14)
T °C (°F)	371 (700)	374 (705)
SG (MW)	(18)	(18)

7.4.5.2 Valve Specifications

These valves are usually a **sliding stem globe style** control valve with ANSI Class 300#, a Carbon steel body, graphite packing and a Fail Close actuator and positioner for throttling control.

7.4.5.3 Trim

416 stainless steel and hardened 17-4PH stainless steel seat ring retainer and 17-4PH stainless steel guide bushing.

7.4.5.4 Sizing

Conventional.

7.4.6 ATMOSPHERIC DISTILLATION - FEED PUMP RECIRCULATION (NOT SHOWN)

7.4.6.1 Operating Conditions

Fluid: Liquid. Crude Oil with 10-12% solids

	Minimum	Normal	Maximum
Q m3/h (gpm)	227 (1000)	727 (3200)	1590 (7000)
P1 bar (psig)	29 (422)	28 (400)	21 (306)
dP bar (psid)	26 (372)	24 (350)	17 (256)
SG	0.8	0.87	0.87
Pv bara (psia)	0.2 (3.00)	0.2 (3.00)	0.2 (3.00)
Vis (cp)	3.00	3.00	3.00

7.4.6.2 Valve Specifications

Sliding stem Globe-style control valve with ANSI Class 300# Carbon steel body, Teflon packing, Fail Closed actuator, and positioner for throttling service.

7.4.6.3 Trim

Stem-guided, unbalanced construction, 416 stainless steel valve plug, and 410 stainless steel seat ring are selections with high hardness to combat erosive flow; precipitation hardened 17-4PH cage. ANSI Class IV shutoff.

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7.4.6.4 Sizing

Standard liquid sizing is adequate here 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.

7.5 Vacuum Distillation

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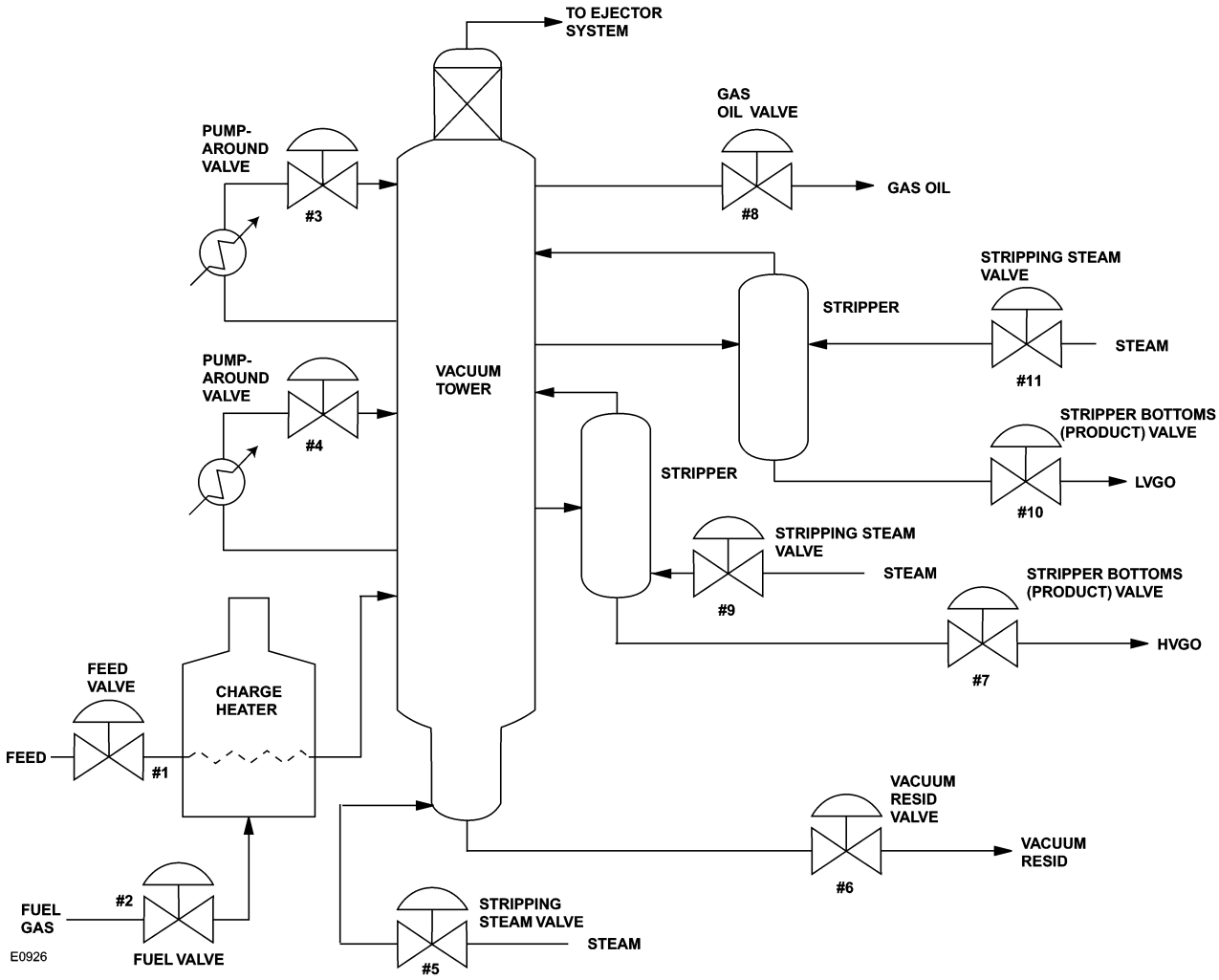


FIGURE 34 - VACUUM DISTILLATION

(Courtesy of Emerson Process Management)

7.5.1 VACUUM DISTILLATION - CHARGE HEATER PASS FEED (VALVE #1)

7.5.1.1 Operating Conditions

Fluid: Liquid. Crude Oil.

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	Normal	Maximum
Q m3/h (gpm)	37 (164)	50 (219)
P1 barg (psig)	10 (150)	10 (150)
dP bar (psid)	0.2 (3)	0.13 (2)
T °C (°F)	332 (630)	360 (680)
SG	0.76	0.76
Pv bara (psia)	0.14 (2.1)	0.14 (2.1)

7.5.1.2 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 Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The C5 chrome-moly body provides enhanced hardness characteristics with higher ANSI pressure/temperature ratings. A Reverse flow (flow passes plug, then seal) ball valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is normally ANSI Class IV shutoff.

7.5.1.3 Trim

Reverse flow full port trim configuration consisting of 17-4PH stainless steel seat ring retainer, Alloy 6 (Stellite 6) seal, and Stellite 6 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. 17-4PH shaft and Stellite 6 bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The 17-4PH/Alloy 6 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, double top stem guided to prevent galling and sticking of valve trim.

7.5.1.4 Sizing

Conventional.

7.5.2 VACUUM DISTILLATION - RESID (VALVE #6)

7.5.2.1 Operating Conditions

Fluid: Liquid with “sticky/ waxy” particulates.

	Normal	Maximum
Q km3/h (gpm)	273 (1200)	307 (1350)
P1 barg (psig)	13 (190)	12.5 (182)
dP bar (psid)	2.8 (40)	0.3 (5)
T °C (°F)	332 (630)	399 (750)
SG	0.90	0.90

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7.5.2.2 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 Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The C5 chrome-moly body provides enhanced hardness characteristics with higher ANSI pressure/temperature ratings. A Reverse flow (flow passes plug, then seal) ball valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is normally ANSI Class IV shutoff.

7.5.2.3 Trim

Reverse flow full port trim configuration consisting of 17-4PH stainless steel seat ring retainer, Alloy 6 (Stellite 6) seal, and Stellite 6 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. 17-4PH shaft and Stellite 6 bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The 17-4PH/Alloy 6 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, double top stem guided to prevent galling and sticking of valve trim.

7.5.2.4 Sizing

Conventional.

7.5.3 VACUUM DISTILLATION - TOP PUMPAROUND (VALVE #3)

7.5.3.1 Operating Conditions

Fluid: Liquid. Gas Oil

	Normal	Maximum
Q m3/h (gpm)	265 (1166)	371 (1633)
P1 barg (psig)	6 (87)	6 (87)
dP bar (psid)	1.4 (20)	1.4 (20)
T °C (°F)	66 (150)	149 (300)
SG	0.83	0.83

7.5.3.2 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 Class 300#, with a Carbon Steel body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service.

7.5.3.3 Trim

Standard 316SS

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7.5.3.4 Sizing

Conventional.

7.5.4 VACUUM DISTILLATION - STRIPPING STEAM (VALVES #9, #11)

7.5.4.1 Operating Conditions

Fluid: Steam

	Normal	Maximum
Q MT/h (lb/h)	0.5 (1000)	0.9 (2000)
P1 barg (psig)	1.9 (28)	1.9 (28)
dP bar (psid)	1.8 (27)	1.8 (27)
T °C (°F)	338 (640)	338 (640)
SG (MW)	(18)	(18)

7.5.4.2 Valve Specifications

These valves are usually a **sliding stem globe style** control valve with ANSI Class 300#, a Carbon steel body, graphite packing and a Fail Close actuator and positioner for throttling control.

7.5.4.3 Trim

416 stainless steel and hardened 17-4PH stainless steel seat ring retainer and 17-4PH stainless steel guide bushing.

7.5.4.4 Sizing

Conventional.

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7.6 Fluid Catalytic Cracking (FCCU)

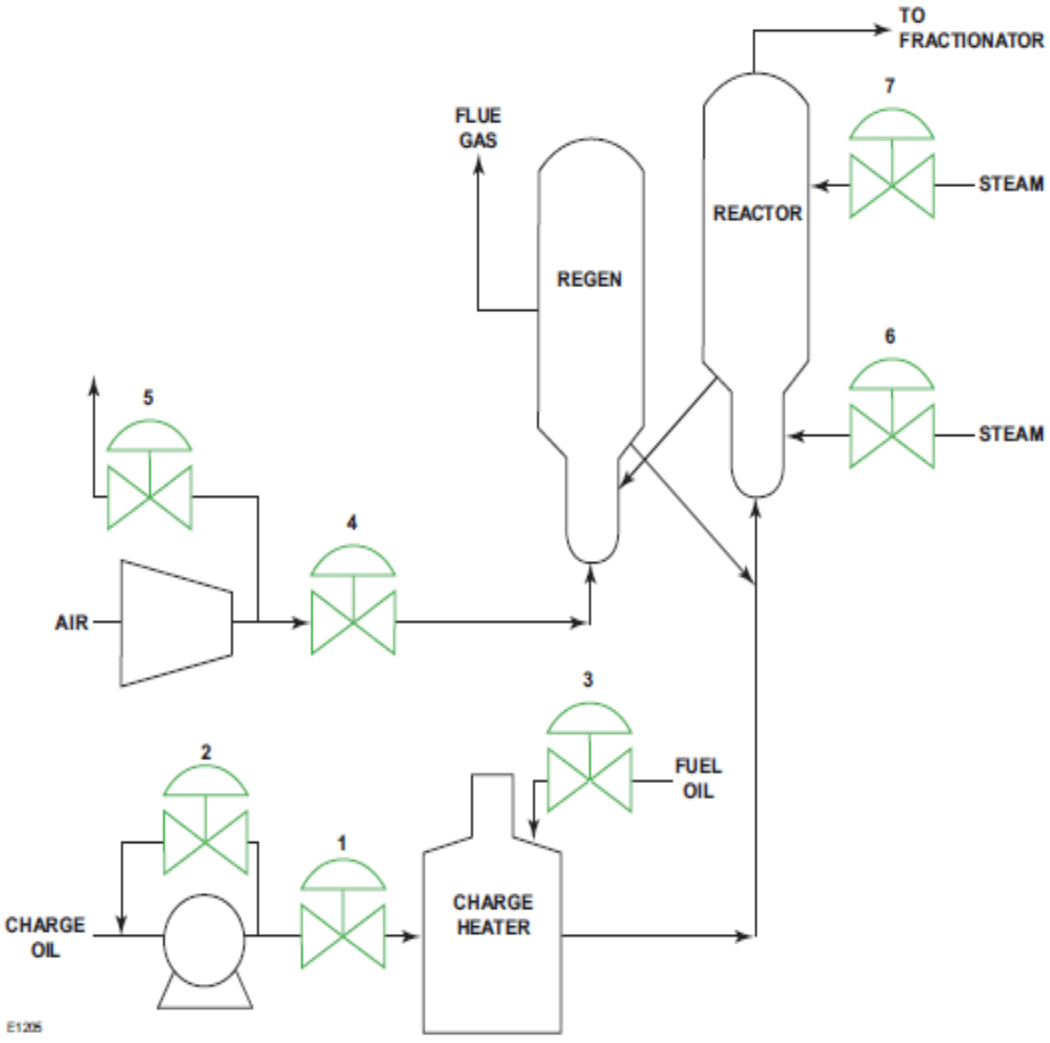


FIGURE 35A - FLUID CATALYTIC CRACKING (FCCU) - REACTOR SECTION

(Courtesy of Emerson Process Management)

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7.6.1 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. A medium sized ball valve is generally used in this application.

7.6.1.1 Operating Conditions

Fluid: Liquid. Charge Oil

	Normal	Maximum
Q m3/h (gpm)	150 (1000)	1500 (2000)
P1 barg (psig)	18 (261)	24 (348)
dP bar (psid)	12 (174)	9 (130)
T °C (°F)	70 (158)	80 (176)
SG		

7.6.1.2 Valve Selection

Either an **Eccentric rotary style** or **general service sliding stem Globe style** control valve will perform in this service. This valve is usually ANSI Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.6.1.3 Trim

S31600 hardfaced trim.

7.6.1.4 Sizing

Conventional.

7.6.2 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.

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7.6.2.1 Operating Conditions

Fluid: Liquid. Charge Oil

	Normal	Maximum
Q m3/h (gpm)	75 (330)	225 (991)
P1 barg (psig)	18 (261)	24 (348)
dP bar (psid)	16 (232)	22 (319)
T °C (°F)	70 (158)	80 (176)
SG		

7.6.2.2 Valve Selection

Either an **Eccentric rotary style** or **general service sliding stem Globe style** control valve will perform in this service. This valve is usually ANSI Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.6.2.3 Trim

S31600 hardfaced trim.

7.6.2.4 Sizing

Conventional.

7.6.3 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.

7.6.3.1 Operating Conditions

Fluid: Fuel Gas

	Normal	Maximum
Q m3/h (kscf/h)	250 (8.8)	300 (10.6)
P1 barg (psig)	3.0 (43)	13 (188)
dP bar (psid)	0.50 (7)	6 (87)
T °C (°F)	30 (86)	40 (104)
SG (MW)	0.59 (11)	0.59 (11)

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7.6.3.2 Valve Selection

Either an **Eccentric rotary style** or **general service sliding stem Globe style** control valve will perform in this service. This valve is usually ANSI Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Close actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.6.3.3 Trim

316SS trim.

7.6.3.4 Sizing

Conventional.

7.6.4 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.

7.6.4.1 Operating Conditions

Fluid: Air

	Normal	Maximum
Q km3/h (kscf/h)	300 (8.8)	600 (10.6)
P1 barg (psig)	3.0 (44)	5.0 (73)
dP bar (psid)	0.50 (7)	0.5 (7)
T °C (°F)	150 (302)	220 (428)
SG (MW)	(28)	(28)

7.6.4.2 Valve Selection

Usually a **High Performance Butterfly style** control valve will perform in this service. This valve is usually ANSI Class 150# or 300#, with a Carbon Steel body, Teflon packing, and a Fail Open actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.6.4.3 Trim

316SS trim.

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7.6.4.4 Sizing

Conventional.

7.6.5 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 must provide fast, accurate control to maintain the pressure balance between the reactor and regenerator.

7.6.5.1 Operating Conditions

Fluid: Air

	Normal	Maximum
Q km3/h (kscf/h)	80 (2.8)	220 (7.8)
P1 barg (psig)	3.0 (44)	5.0 (73)
dP bar (psid)	1.0 (14.5)	1.0 (14.5)
T °C (°F)	30 (86)	40 (104)
SG (MW)	(28)	(28)

7.6.5.2 Valve Selection

Usually a **High Performance Butterfly style** or **Angle** control valve will perform in this service. This valve is usually ANSI Class 150# or 300#, with a Carbon Steel body, teflon packing, and a Fail Close actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff. For noise attenuation a drilled hole, or stacked disk noise trim is sometimes required.

7.6.5.3 Trim

316SS trim.

7.6.5.4 Sizing

Conventional.

7.6.6 FCCU - STRIPPING STEAM TO DISTRIBUTORS (VALVE #7)

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.

7.6.6.1 Operating Conditions

Fluid: Steam

	Normal	Maximum

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Q MT/h	(klb/h)	0.7 (1.5)	5.0 (11)
P1 barg	(psig)	5 (73)	7 (102)
dP bar	(psid)	2.8 (41)	2 (29)
T °C	(°F)	200 (392)	220 (428)
SG (MW)		(18)	(18)

7.6.6.2 Valve Selection

These valves are usually a **sliding stem globe style** control valve with ANSI Class 300#, a Carbon steel body, graphite packing and a Fail Close actuator and positioner for throttling control. Cast cage or drilled hole noise attenuation trim. ANSI Class IV or V shutoff

7.6.6.3 Trim

416 stainless steel and hardened 17-4PH stainless steel seat ring retainer and 17-4PH stainless steel guide bushing.

7.6.6.4 Sizing

Conventional.

7.6.7 FCCU - STEAM TO REACTOR (VALVE #6)

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

7.6.7.1 Operating Conditions

Fluid: Steam

		Normal	Maximum
Q MT/h	(klb/h)	2 (4.4)	36 (79)
P1 barg	(psig)	6 (87)	9 (131)
dP bar	(psid)	4 (58)	5 (73)
T °C	(°F)	200 (392)	220 (428)
SG (MW)		(18)	(18)

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7.6.7.2 Valve Selection

These valves are usually a **sliding stem globe style** control valve with ANSI Class 300#, a Carbon steel body, graphite packing and a Fail Close actuator and positioner for throttling control. Cast cage or drilled hole noise attenuation trim. ANSI Class IV or V shutoff

7.6.7.3 Trim

416 stainless steel and hardened 17-4PH stainless steel seat ring retainer and 17-4PH stainless steel guide bushing.

7.6.7.4 Sizing

Conventional.

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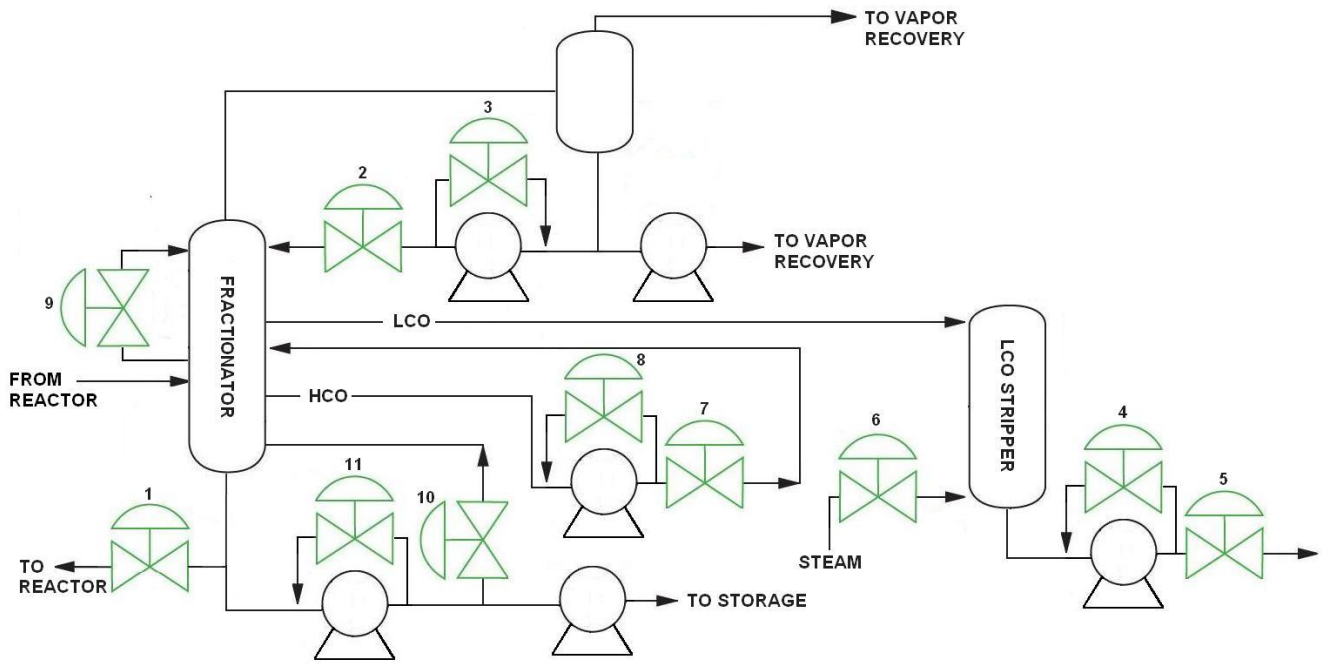


FIGURE 35B - FLUID CATALYTIC CRACKING (FCCU) - FRACTIONATOR SECTION

(Courtesy of Emerson Process Management)

7.6.8 FCCU - BOTTOMS CIRCULATION (VALVE #10)

This valve circulates flow from the bottom of the column to the reboiler and back to the column to facilitate separation. Accurate control is required 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.

7.6.8.1 Operating Conditions

Fluid: Liquid. Slurry bottoms with solids

	Normal	Maximum
Q m3/h (gpm)	150 (660)	300 (1320)
P1 barg (psig)	6 (87)	8 (116)
dP bar (psid)	2 (29)	3 (43)
T °C (°F)	270 (518)	360 (680)
SG	.82	.82

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7.6.8.2 Valve Selection

Because of high viscosity slurry, an **Eccentric rotary style** control valve is used in this service. This valve is usually ANSI Class 300#, with a C5 Chrome Moly or S316 body, graphite fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. Sometimes these valves are provided with a Slurry liner to minimize erosion. This valve is normally ANSI Class IV shutoff.

7.6.8.3 Trim

S31600 hardfaced trim. Special slurry trim package may be considered.

7.6.8.4 Sizing

Conventional.

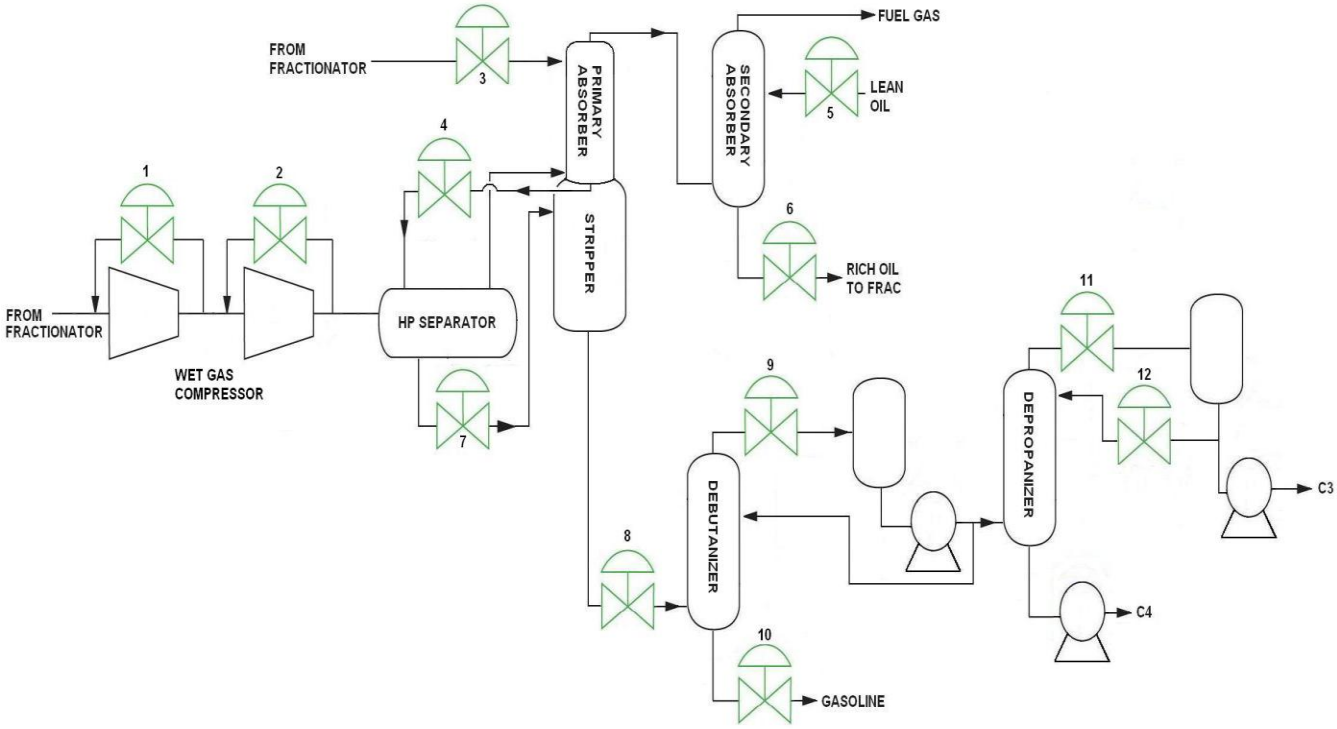


FIGURE 35C - FLUID CATALYTIC CRACKING (FCCU) - VAPOR RECOVERY SECTION

(Courtesy of Emerson Process Management)

7.6.9 FCCU - DEBUTANIZER BOTTOMS (VALVE #10)

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.

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7.6.9.1 Operating Conditions

Fluid: Liquid. Gasoline

	Normal	Maximum
Q m3/h (gpm)	70 (308)	350 (1540)
P1 barg (psig)	12 (174)	14 (203)
dP bar (psid)	4 (58)	4 (58)
T °C (°F)	100 (212)	110 (230)
SG	.76	.76

7.6.9.2 Valve Selection

Either a **Eccentric rotary style** or **general service sliding stem Globe style** control valve is used in this service. This valve is usually ANSI Class 300#, with a Carbon Steel, Teflon fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.6.9.3 Trim

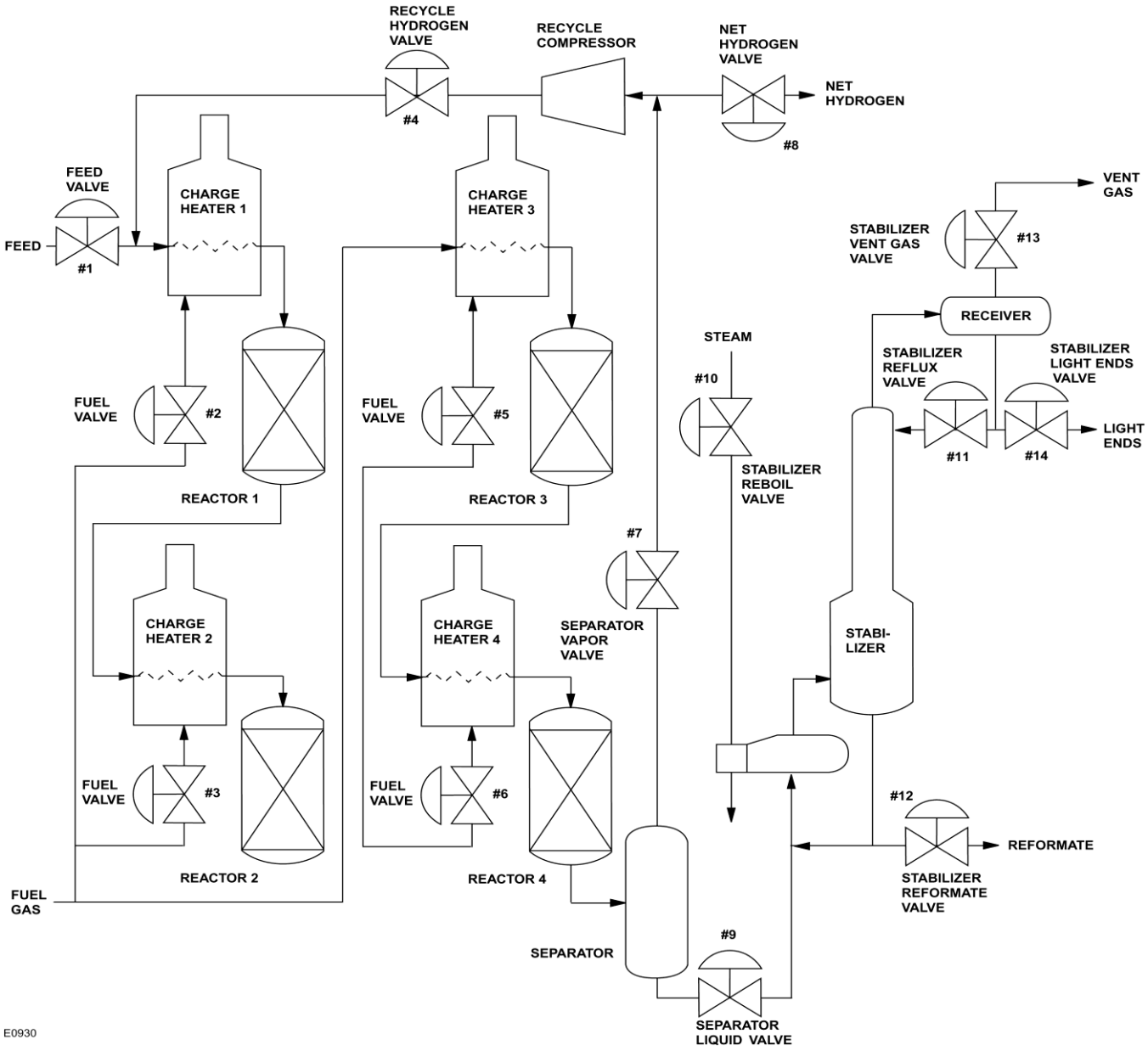
S31600 hardfaced trim.

7.6.9.4 Sizing

Conventional.

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7.7 Catalytic Reformer



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FIGURE 36 - CATALYTIC REFORMER

(Courtesy of Emerson Process Management)

7.7.1 CCR 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.

7.7.1.1 Operating Conditions

Fluid: Liquid. Heavy Gas Oil

	Minimum	Maximum
P1 bar (psig)	7 (101)	72 (1044)
T ºC (ºF)	70 (158)	210 (410)

7.7.1.2 Valve Specification

These valves are usually **Eccentric Rotary style or general service globe style** control valve. This valve is usually ANSI Class 300#, or 600#, with a Carbon Steel cast body, Graphite fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.7.1.3 Trim

416SS hardened trim. If feed is untreated, NACE material may be required.

7.7.1.4 Sizing

Conventional.

7.7.2 CCR REFORMER - RECYCLE HYDROGEN (VALVE #2)

This valve controls the hydrogen produced by the cataylitic 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

7.7.2.1 Operating Conditions

Fluid: Gas. Hydrogen, Hydrogen Sulfide

	Minimum	Maximum
P1 bar (psig)	8 (116)	17 (247)
T ºC (ºF)	65 (149)	135 (275)

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7.7.2.2 Valve Specification

These valves are usually **high performance Butterfly style** control valve. This valve is usually ANSI Class 300#, with a Carbon Steel cast body, Graphite fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.7.2.3 Trim

416SS hardened trim. NACE may be required.

7.7.2.4 Sizing

Conventional.

7.7.3 CCR REFORMER - HOT GAS BLOCK/BYPASS (THREE-WAY BUTTERFLY) (NOT SHOWN)

7.7.3.1 Operating Conditions

Fluid: Gas High Temperature Hydrogen

	Minimum	Maximum
Flow Mm3/h (MSCFH)	23 (800)	45 (1600)
P1 bar (psig)	20 (285)	20 (285)
P2 bar (psig)	19 (282) (block)	0 (bypass)
T ºC (ºF)	849 (1560)	849 (1560)

7.7.3.2 Valve Specification

These valves are usually a **Butterfly style** control valve with an Inconel 800 liner with refractory lining. Piston actuator with high performance positioner. 347 SS body.

7.7.3.3 Trim

Special two-piece bearing for high temperature service, with tap for steam purge.

7.7.3.4 Sizing

Conventional.

7.7.3.5 Application Notes

Very special application. Consult with vendor.

7.7.4 CCR REFORMER - NET HYDROGEN (VALVE #8)

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.

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7.7.4.1 Operating Conditions

Fluid: Gas. Hydrogen,

	Minimum	Maximum
P1 bar (psig)	14 (203)	88 (1276)
T ºC (ºF)	65 (149)	135 (275)

7.7.4.2 Valve Specification

These valves are usually **segemented ball or general service Globe style** control valve. This valve is usually ANSI Class 300# or 600#, with a Carbon Steel cast body, Graphite fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.7.4.3 Trim

416SS hardened trim. NACE may be required.

7.7.5 CCR REFORMER - SEPARATOR LIQUID (VALVE #9)

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 process license.

7.7.5.1 Operating Conditions

Fluid: Gas. Hydrocarbon with aromatics.

	Minimum	Maximum
P1 bar (psig)	40 (580)	63 (914)
T ºC (ºF)	60 (140)	85 (185)

7.7.5.2 Valve Specification

These valves are usually **general service Globe style** control valve. This valve is usually ANSI Class 300# or 600#, with a Carbon Steel cast body, Graphite fugitive emission packing, and a Fail Closed actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.7.5.3 Trim

416SS hardened trim. NACE may be required, if feed is untreated.

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7.8 Hydrocracker

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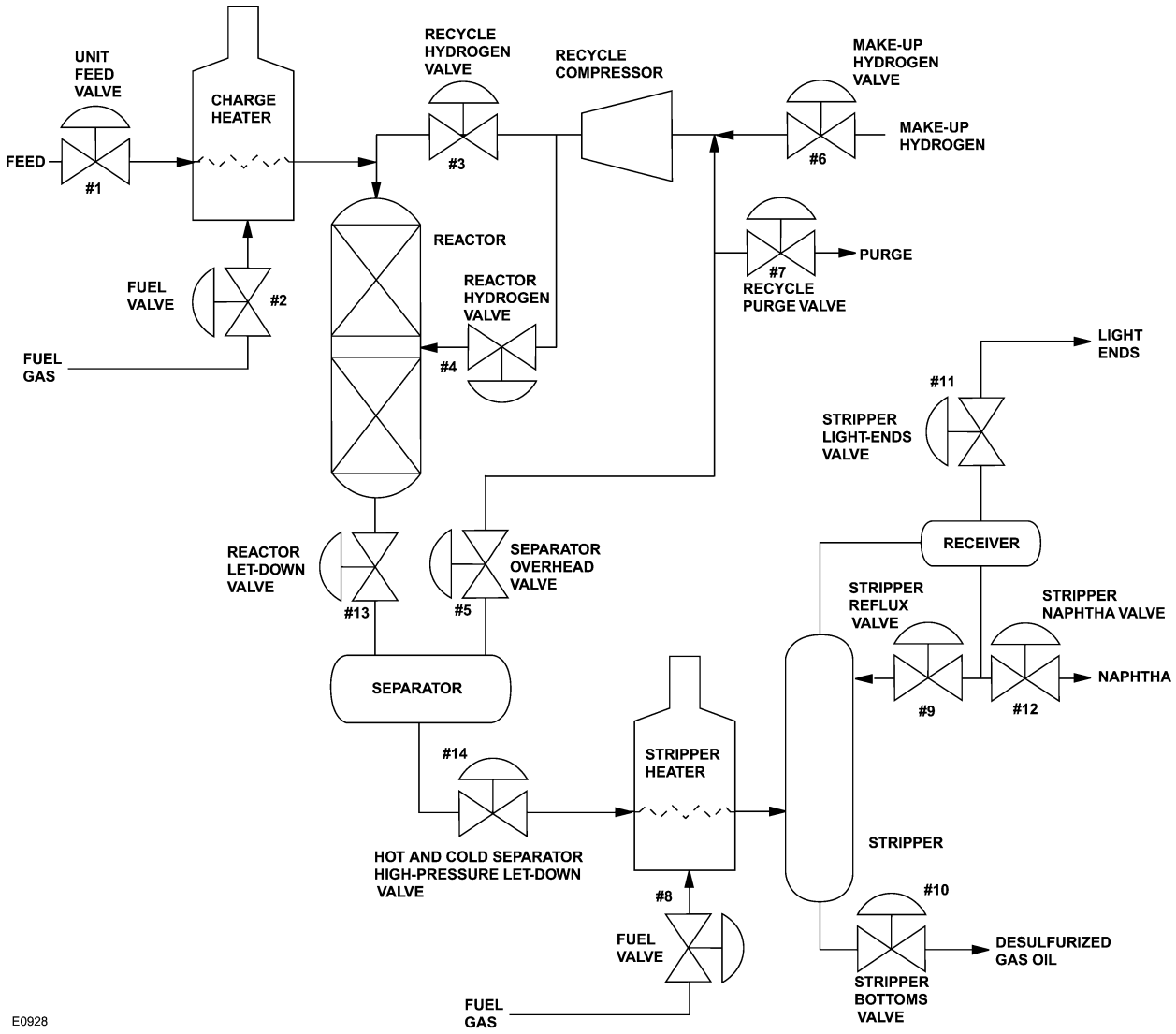


FIGURE 37 - HYDROCRACKER

(Courtesy of Emerson Process Management)

7.8.1 HYDROCRACKER - FEED TO HYDROCRACKER (VALVE #1)

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7.8.1.1 Operating Conditions

Fluid: Liquid Heavy Gas Oil

	Normal	Maximum
Flow m3/h (gpm)	94 (415)	229 (1006)
P1 bar (psig)	135 (1950)	205 (2900)
dP bar (psig)	12 (167)	4 (62)
T ºC (ºF)	290 (554)	345 (653)

7.8.1.2 Valve Specification

These valves are usually **high pressure severe service sliding stem globe style** control valve with ANSI Class 900#, 1500#, or 2500# Stainless Steel cast body, Graphite packing and a Fail Close actuator and positioner for throttling control. ANSI Class IV shutoff.

7.8.1.3 Trim

316 stainless steel hardened. NACE may be required.

7.8.1.4 Sizing

Conventional.

7.8.2 HYDROCRACKER - REACTOR LETDOWN WITH EROSIVE SOLIDS (VALVE #13)

7.8.2.1 Operating Conditions

Fluid: Liquid outgassing, solids, flashing, cavitation

	Normal	Maximum
Flow m3/h (gpm)	315 (1386)	373 (1642)
Liquid / Vapor Split m3/h / m3/h (gpm/scfm)	296 / 493 (1305/290)	359 / 588 (1580/346)
P1 bar (psig)	108 (1571)	108 (1571)
dP bar (psig)	81 (1176)	81 (1176)
T ºC (ºF)	438 (820)	435 (814)
Viscosity	0.24 cp	
Vapor Press bar (psia)	395 psig	
Crit Press bar (psia)	711 psig	
Solids	3% consisting of clay, catalyst, silica, 90% < 10 microns	
H_2S	3000 ppm	

7.8.2.2 Valve Specification

"**Anti-coking" angle valve,** 1500# ANSI, 347 SS, sweep angle body, expanding venturi outlet, with extended bonnet, plug/guide purging system, Fail Closed piston actuator with high performance positioner and valve position switch or transmitter. Heat treatment is required for the valve body.

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

7.8.2.3 Trim

At least $1^1/_2$" port, modified parabolic plug, massive plug guiding, outlet liner. Plug, seat ring, seat ring retainer are mixture of Inconel 718, TC Grade 701, Inconel 625 with cobalt chrome hard facing.

7.8.2.4 Sizing

Very special application. Consult with vendor.

7.8.3 HYDROCRACKER - HOT SEPARATOR LIQUID TO HOT FLASH DRUM (VALVE # 14)

7.8.3.1 Operating Conditions

Fluid: Liquid. Hydrogen Liquid

	Normal
Flow m3/h (gpm)	456 (2008)
Flow Out - Liquid/Vapor Split m3/h / m3/h (gpm / scfm)	374 / 10619 (1645 / 6250)
P1 bar (psig)	168 (2435)
dP bar (psig)	143 (2075)
T °C (°F)	288 (550)
Pv bar (psia)	169 (2449.7)
Pc bar (psia)-(pseudo)	19.7 (286.0)
SG (liquid Inlet)	0.538
SG (liquid Outlet)	0.627
Mol Wt (Vapor)	23.580

7.8.3.2 Valve Specification

These valves are usually a **angle-style axial flow multi-step globe style** control valve with ANSI Class 1500#, a $2^1/_4$ percent Cr, 1 percent Mo body, NACE conformance body and trim, graphite packing and a Fail Close actuator and positioner for throttling control. Class V shutoff required.

7.8.3.3 Trim

Expanding labyrinth plug with top and bottom balanced piston guide. Hardened trim

7.8.3.4 Sizing

Consult with vendor. The calculated Cv for this flashing service is determined by adding the calculated Cv for liquid and the vapor at the outlet conditions of the valve. Process simulation is required to calculate the amount of vapor flashed. The ISA sizing equations are inaccurate for this flashing application. Manufacturers' control valve sizing programs which calculate flashing only on the basis of single compound streams cannot be used for this sizing calculation.

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7.8.3.5 Application Notes

Inlet piping must 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 must be trash tolerant.

7.8.4 HYDROCRACKER - COLD SEPARATOR SOUR WATER (NOT SHOWN)

7.8.4.1 Operating Conditions

Fluid: Liquid Water with 2.36 mole % H_2S and trace hydrocarbon

	Normal
Flow m3/h (gpm)	20 (86.0)
Flow- Outlet Liquid/Vapor Split m3/h / m3/h (gpm / scfm)	19 / 544 (81.5 / 320)
P1 bar (psig)	166 (2404)
dP bar (psig)	141 (2050)
T °C (°F)	50 (122)
Pv bara (psia)	35 (512)
Pc bara (psia)-(pseudo)	90 (1300)
SG (liquid Inlet)	0.960
SG (liquid Outlet)	0.973
Mol Wt (Vapor)	34.020

7.8.4.2 Valve Specification

These valves are usually a **angle-style axial flow multi-step globe style** control valve with ANSI Class 1500#, a Carbon Steel body with NACE conformance body and trim, graphite packing and a Fail Close actuator and positioner for throttling control. Class V shutoff required.

7.8.4.3 Trim

Series of equal capacity stages with last stage expansion. Relatively large flow passages and trim shearing action allow long service life and reduced potential for clogging which can occur with other multistage trim styles. Hardened trim.

7.8.4.4 Sizing

Consult with vendor. The calculated Cv for this flashing service is determined by adding the calculated Cv for liquid and the vapor at the outlet conditions of the valve. Process simulation is required to calculate the amount of H_2S flashed. Manufacturers' control valve sizing programs which calculate flashing only on the basis of single compound streams cannot be used for this sizing calculation.

7.8.4.5 Application Notes

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 must be trash tolerant.

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7.8.5 HYDROCRACKER - HYDROGEN QUENCH (VALVE #4)

7.8.5.1 Operating Conditions

Fluid: Gas. Hydrogen with Hydrogen Sulfide

	Minimum	Maximum
P1 bar (psig)	69 (1000)	205 (3000)
T ºC (ºF)	290 (554)	345 (653)

7.8.4.2 Valve Specification

These valves are usually a **high pressure severe service globe style** control valve with ANSI Class 1500# or 2500#, a Stainless Steel cast body, graphite packing and a Fail Open actuator and positioner for throttling control. Class IV shutoff required.

7.8.4.3 Trim

416SS trim.

7.8.4.4 Sizing

Conventional.

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7.9 Hydrotreater

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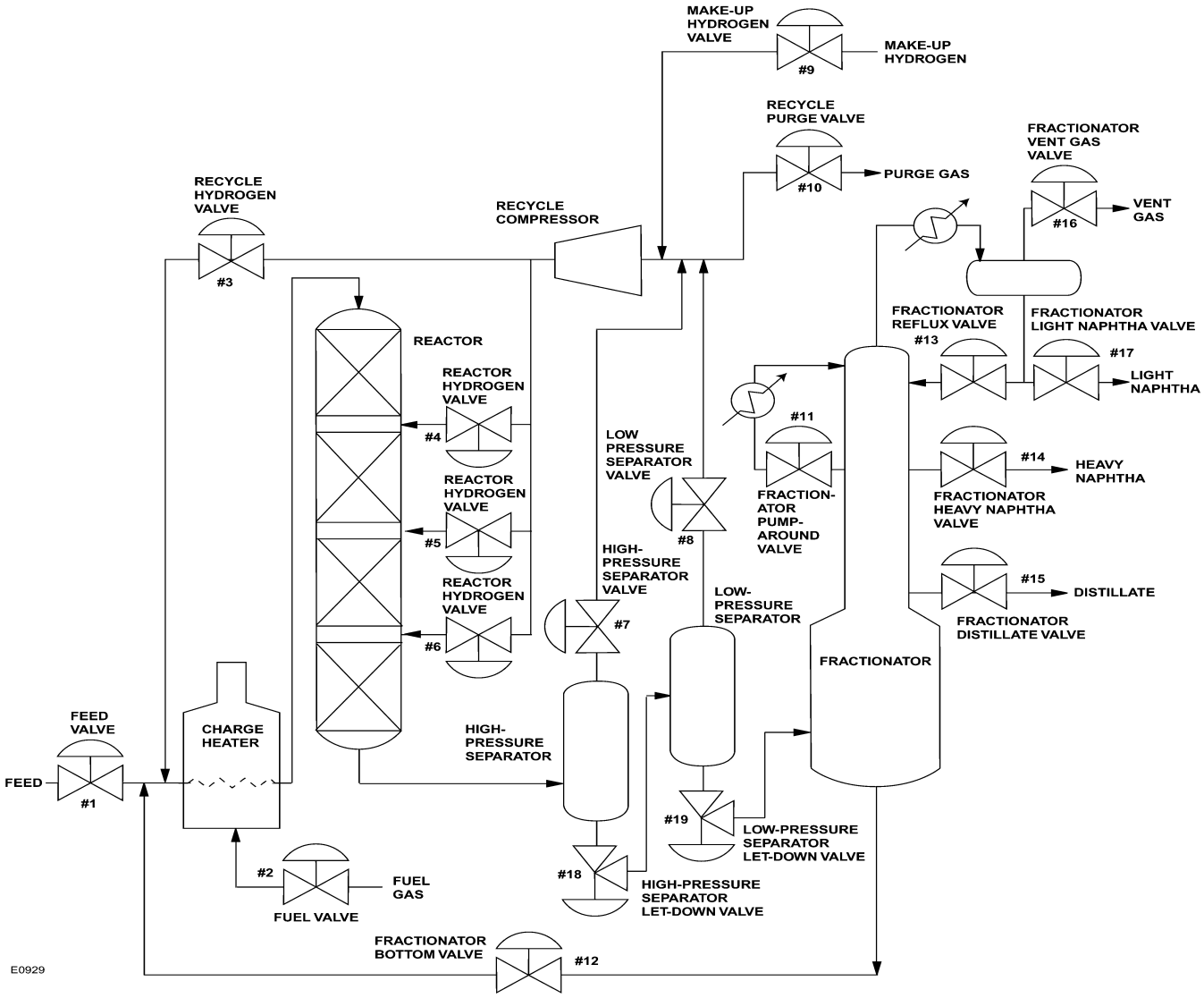


FIGURE 38 - HYDROTREATER

(Courtesy of Emerson Process Management)

7.9.1 HYDROTREATER - HOT HIGH PRESSURE SEPARATION LETDOWN (VALVE #18)

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This Critical Valve is used in the process to efficiently remove sulfur from various HC streams. Hydrogen is introduced to the HC 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 HC Liquid and outgassing of the Hydrogen occurs through the valve. At the valve Outlet, the Flow stream consists of Two phase flow having HC liquid, HC Vapor and Hydrogen gas.

7.9.1.1 Operating Conditions

Fluid: Liquid. Hydrogen Liquid

	Normal
Flow m3/h (gpm)	456 (2008)
Flow Out - Liquid/Vapor Split m3/h / m3/h (gpm / scfm)	374 / 10619 (1645 / 6250)
P1 bar (psig)	168 (2435)
dP bar (psig)	143 (2075)
T °C (°F)	288 (550)
Pv bar (psia)	169 (2449.7)
Pc bar (psia)-(pseudo)	19.7 (286.0)
SG (liquid Inlet)	0.538
SG (liquid Outlet)	0.627
Mol Wt (Vapor)	23.580

7.9.1.2 Valve Specification

These valves are usually a **angle-style axial flow multi-step globe style** control valve with ANSI Class 1500#, a $2^1/_4$ percent Cr, 1 percent Mo body, NACE conformance body and trim, graphite packing and a Fail Close actuator and positioner for throttling control. Class V shutoff required.

7.9.1.3 Trim

Expanding labyrinth plug with top and bottom balanced piston guide. Hardened trim

7.9.1.4 Sizing

Conventional sizing equations can not be directly applied to the sizing of this application. The combination of the Flashing of the Hydrocarbon liquid along with the outgassing of Hydrogen as the pressure is letdown through the valve does not permit for precise Cv calculation. The outgassing of Hydrogen is not predictable and when it occurs the vapor bubble accelerates the process fluid through conventional trim configurations many times resulting in Choked flow. The Expanding Labyrinth trim provides for an increase in flow area as the process fluid moves from inlet to outlet. This expansion of trim area provides the additional space required to prevent Choked flow. The Control Valve manufacturer should be contacted for the proper sizing of this application.

7.9.1.5 Application Notes

Inlet piping must 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 must be trash tolerant.

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7.9.2 HYDROTREATER - COMPRESSOR RECYCLE (VALVE # 3)

7.9.2.1 Operating Conditions

Fluid: Gas Hydrogen

	Normal	Maximum
Q km3/h (kscfm)	127 (75)	253 (149)
P1 bar (psig)	95 (1380)	97 (1400)
dP bar (psid)	17 (250)	24(350)
T °C (°F)	93 (200)	93 (200)
SG (MW)	(4.9)	(4.9)

7.9.2.2 Valve Specification

These valves are usually a **general purpose Globe style** control valve with soft seating. ANSI Class 900#, Carbon Steel body, Teflon packing and a Fail Open actuator and positioner for throttling control. Class VI shutoff required.

7.9.2.3 Trim

17-4PH cage, 416 SST seat ring, 316 SST stem.

7.9.2.4 Sizing

Conventional.

7.9.2.5 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.

7.9.3 HYDROTREATER - DRUM VENT (DEPRESSURIZING) TO HYDROTREATER FLARE (VALVE #16)

7.9.3.1 Operating Conditions

Fluid: Gas Acid Gas

	Normal
Flow m3/h (SCFH)	673 (23,760)
P1 bar (psig)	0.76 (1100)
dP bar (psig)	0.04 (1060)
T ºC (ºF)	46 (250)

7.9.3.2 Valve Specification

These valves are usually a **general purpose Globe style** control valve with soft seating. ANSI Class 600#, NACE materials with carbon steel body stress relieved, Teflon packing and a Fail Hold Drift Open actuator and positioner for throttling control. Class VI shutoff required.

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7.9.3.3 Trim

317 SS, PTFE seal,

7.9.3.4 Sizing

Conventional.

7.9.3.5 Application Notes

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

7.9.4 HYDROTREATER - QUENCH GAS TO REACTOR (VALVES # 4, 5, 6)

7.9.4.1 Operating Conditions

Fluid: Gas Hydrogen

	Normal	Maximum
Q km3/h (kscfm)	1.7 (1)	71 (42)
P1 bar (psig)	90 (1310)	87 (1261)
dP bar (psid)	7 (101)	2.6 (38)
T °C (°F)	79 (175)	79 (175)
SG (MW)	(3.9)	(3.9)

7.9.4.2 Valve Specification

These valves are usually a **general purpose Globe style** control valve, ANSI Class 900#, Carbon Steel body, Teflon packing and a Fail Open actuator and positioner for throttling control. Class IV shutoff required.

7.9.4.3 Trim

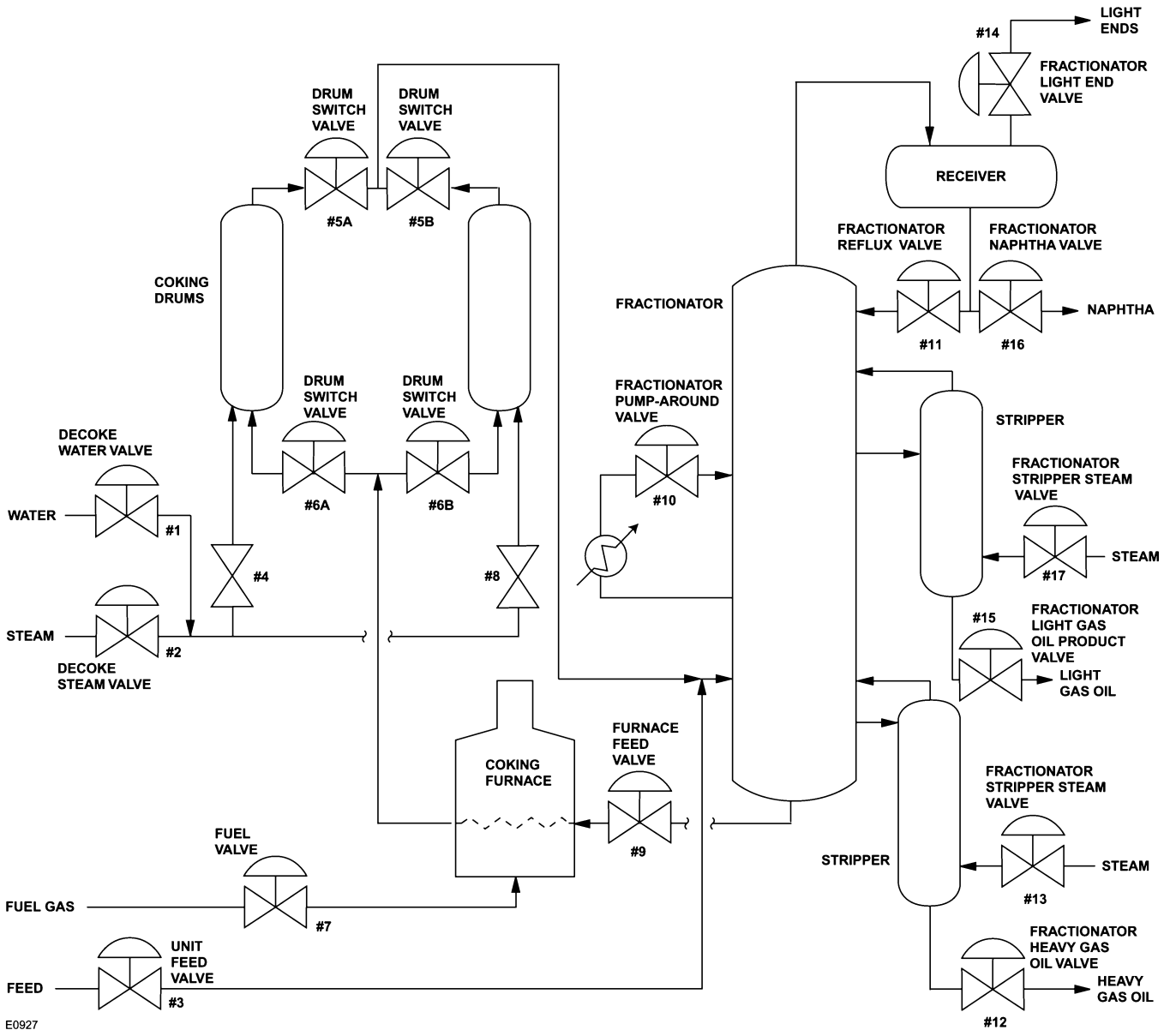
17-4PH cage, 416 SST seat ring, 316 SST stem.

7.9.4.4 Sizing

Conventional.

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7.10 Delayed Coker



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FIGURE 39 - DELAYED COKER

(Courtesy of Emerson Process Management)

7.10.1 DELAYED COKER - UNIT FEED (VALVE #3)

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.

7.10.1.1 Operating Conditions

Fluid: Liquid. Vacuum Resid with entrained solids.

	Normal	Maximum
Q m3/h (gpm)	299 (1312)	340 (1500)
P1 barg (psig)	8.9 (130)	8.9 (130)
dP bar (psid)	0.34 (5)	0.34 (5)
T °C (°F)	232 (450)	399 (750)
SG	0.93	0.93
Pv bara (psia)	0.07 (.99)	0.07 (.99)

7.10.1.2 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 Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Close actuator and positioner for throttling service. The C5 chrome-moly body provides enhanced hardness characteristics with higher ANSI pressure/temperature ratings. A Reverse flow (flow passes plug, then seal) ball valve is preferred to maximize valve body life and divert high velocity erosive flow downstream. This valve is normally ANSI Class IV shutoff.

7.10.1.3 Trim

Reverse flow full port trim configuration consisting of 17-4PH stainless steel seat ring retainer, Alloy 6 (Stellite 6) seal, and Stellite 6 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. 17-4PH shaft and Stellite 6 bearing will provide high temperature strength, as well as desirable corrosion and galling resistance. The 17-4PH/Alloy 6 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, double top stem guided to prevent galling and sticking of valve trim.

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7.10.1.4 Sizing

Conventional.

7.10.2 DELAYED COKER - FURNACE FEED (VALVE #9)

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.

7.10.2.1 Operating Conditions

Fluid: Liquid. Entrained Coke particles.

	Normal	Maximum
Q m3/h (gpm)	36 (159)	39 (175)
P1 barg (psig)	31 (453)	29 (420)
dP bar (psid)	10 (150)	3.5 (50)
T °C (°F)	306 (583)	343 (650)
S.G.	0.91	0.91
Pv bara (psia)	25.7	25.7

7.10.2.2 Valve Specification

This valve is usually an **Eccentric rotary style** control valve (due to the presence of coke fines) with ANSI Class 300#, a C5 body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. The C5 chrome-moly body provides enhanced hardness characteristics with higher ANSI pressure/temperature ratings.

7.10.2.3 Trim

Solid Stellite.

7.10.2.4 Sizing

Conventional.

7.10.3 DELAYED COKER - HEAVY COKER GAS OIL PUMPAROUND (VALVE #12)

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

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7.10.3.1 Operating Conditions

Fluid: Liquid with "sticky" particulates.

		Normal	Maximum
Q km3/h	(gpm)	149 (656)	179 (788)
P1 barg	(psig)	10.3 (150)	8.9 (130)
dP bar	(psid)	7 (100)	6 (85)
T °C	(°F)	216 (420)	316 (600)
SG		0.88	0.88

7.10.3.2 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 Class 300#, with a Chrome Moly of Stainless Steel cast body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.10.3.3 Trim

316 SST Hardened Face.

7.10.3.4 Sizing

Conventional.

7.10.4 DELAYED COKER - REFLUX (VALVE #11)

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

7.10.4.1 Operating Conditions

Fluid: Liquid. Distillate

		Normal	Maximum
Q m3/h	(gpm)	75 (328)	89 (394)
P1 barg	(psig)	6.6 (95)	6 (87)
dP bar	(psid)	2.7 (40)	2.3 (34)
T °C	(°F)	38 (100)	232 (450)
SG		0.73	0.73

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Pv bara	(psia)	1.3 (20)	1.3 (20)

7.10.4.2 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 Class 300#, with a Carbon Steel body, graphite fugitive emission packing, and a Fail Open actuator and positioner for throttling service.

7.10.4.3 Trim

Standard 316SS

7.10.4.4 Sizing

Conventional.

7.11 Gas Plant

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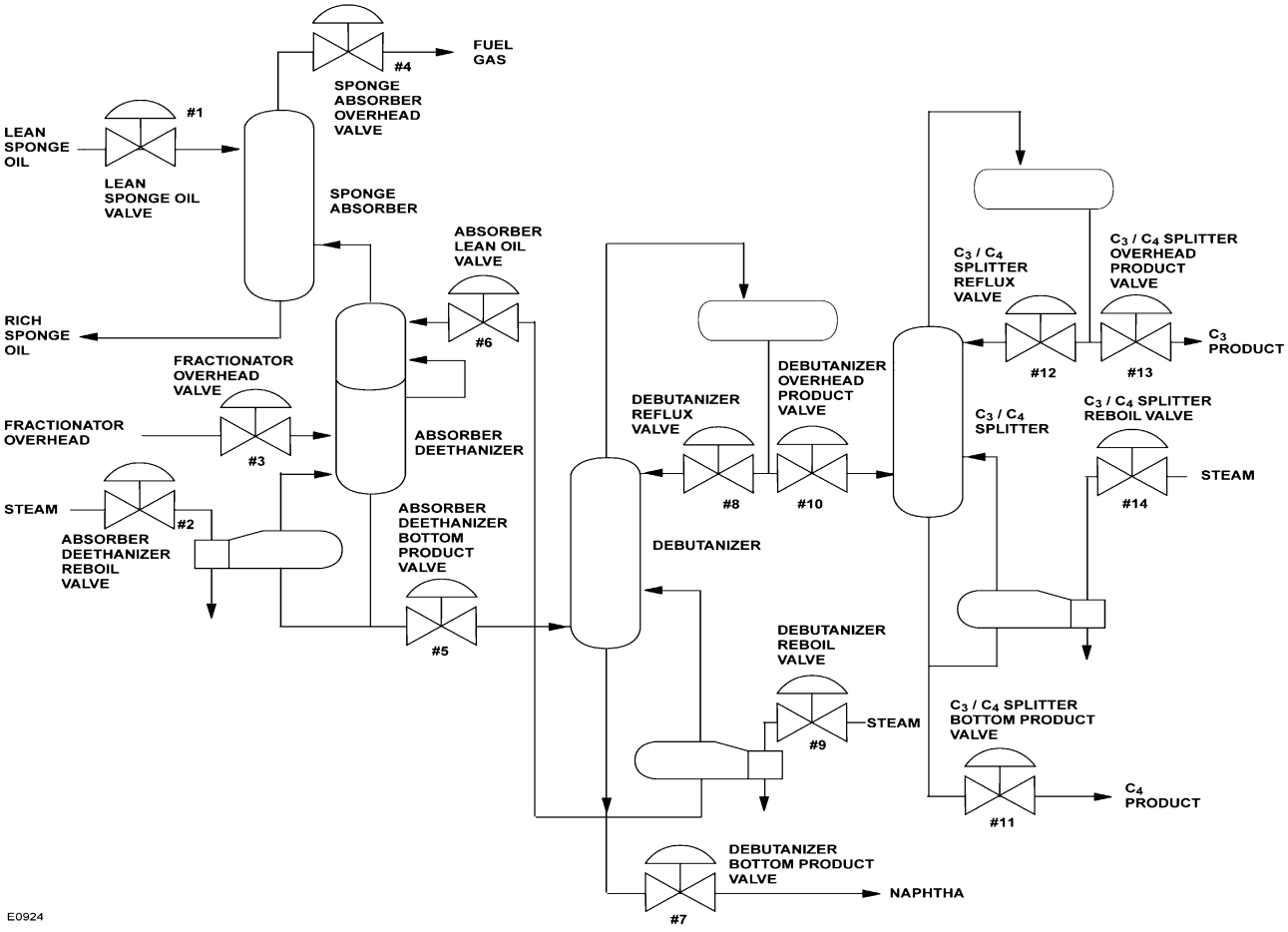


FIGURE 40 - GAS PLANT

(Courtesy of Emerson Process Management)

7.11.1 GAS PLANT - LEAN SPONGE OIL (VALVE #1)

7.11.1.1 Operating Conditions

Fluid: Liquid. Light Gas Oil.

	Normal	Maximum

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Q m3/h (gpm)	23 (103)	26 (114)
P1 barg (psig)	13 (192)	12 (180)
dP bar (psid)	1.7 (25)	0.69 (10)
T °C (°F)	57 (135)	199 (390)
SG	0.86	0.86
Pv bara (psia)	1.6 (24)	1.6 (24)

7.11.1.2 Valve Specification

A **general service sliding stem Globe style** control valve will perform in this service. This valve is usually ANSI Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Close actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.11.1.3 Trim

Standard 316SS

7.11.1.4 Sizing

Conventional.

7.11.2 GAS PLANT - SPONGE ABSORBER OVERHEAD (VALVE #4)

7.11.2.1 Operating Conditions

Fluid: Gas. Sour Gas

	Normal	Maximum
Q km3/h (kscfm)	21.5 (12.6)	23.8 (14)
P1 barg (psig)	9 (127)	8 (122)
dP bar (psid)	0.4 (6)	0.2 (3)
T °C (°F)	38 (100)	82 (180)
SG (MW)	(23.7)	(23.7)

7.11.2.2 Valve Specification

This valve is usually a **Butterfly style** control valve with ANSI Class 150# or 300#, a C5 body, graphite fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

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7.11.2.3 Trim

Standard 316SS.

7.11.2.4 Sizing

Conventional.

7.11.3 GAS PLANT - ABSORBER DETHANIZER BOTTOMS (VALVE #5)

7.11.3.1 Operating Conditions

Fluid: Liquid. Hydrocarbon.

		Normal	Maximum
Q km3/h	(gpm)	84 (372)	100 (438)
P1 barg	(psig)	12.4 (180)	12 (170)
dP bar	(psid)	0.7 (10)	0.6 (8)
T °C	(°F)	132 (270)	177 (350)
SG		0.6	0..6

7.11.3.2 Valve Specification

A **Eccentric rotary style** control valve will perform in this service. This valve is usually ANSI Class 300#, with a C5 body, Teflon fugitive emission packing, and a Fail Close actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.11.3.3 Trim

316 SST Hardened Face.

7.11.3.4 Sizing

Conventional.

7.11.4 GAS PLANT DEBUTANIZER BOTTOMS (VALVE #7)

7.11.4.1 Operating Conditions

Fluid: Liquid. Distillate

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	Normal	Maximum
Q m3/h (gpm)	50 (219)	60 (263)
P1 barg (psig)	11 (160)	11 (160)
dP bar (psid)	7.6 (110)	7.7 (112)
T °C (°F)	49 (121)	204 (400)
S.G.	0..69	0.69
Pv bara (psia)	10 (152)	10 (152)

7.11.4.2 Valve Specification

Either an **Eccentric rotary style** control valve will perform in this service. This valve is usually ANSI Class 300#, with a Carbon Steel body, graphite fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.11.4.3 Trim

Stellite Trim.

7.11.4.4 Sizing

Conventional.

7.11.5 GAS PLANT - DEBUTANIZER REBOILER STEAM (VALVE #9)

7.11.5.1 Operating Conditions

Fluid: Steam

	Normal	Maximum
Q MT/h (klb/h)	7 (15)	9 (20)
P1 barg (psig)	17 (250)	17 (250)
dP bar (psid)	1 (15)	1 (15)
T °C (°F)	216 (420)	399 (750)
SG (MW)	(18)	(18)

7.11.5.2 Valve Selection

These valves are usually a **sliding stem globe style** control valve with ANSI Class 600#, a Carbon steel body, graphite packing and a Fail Close actuator and positioner for throttling control. Cast cage or drilled hole noise attenuation trim. ANSI Class IV or V shutoff.

7.11.5.3 Trim

416 stainless steel and hardened 17-4PH stainless steel seat ring retainer and 17-4PH stainless steel guide bushing.

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7.11.5.4 Sizing

Conventional.

7.12 Alkylation

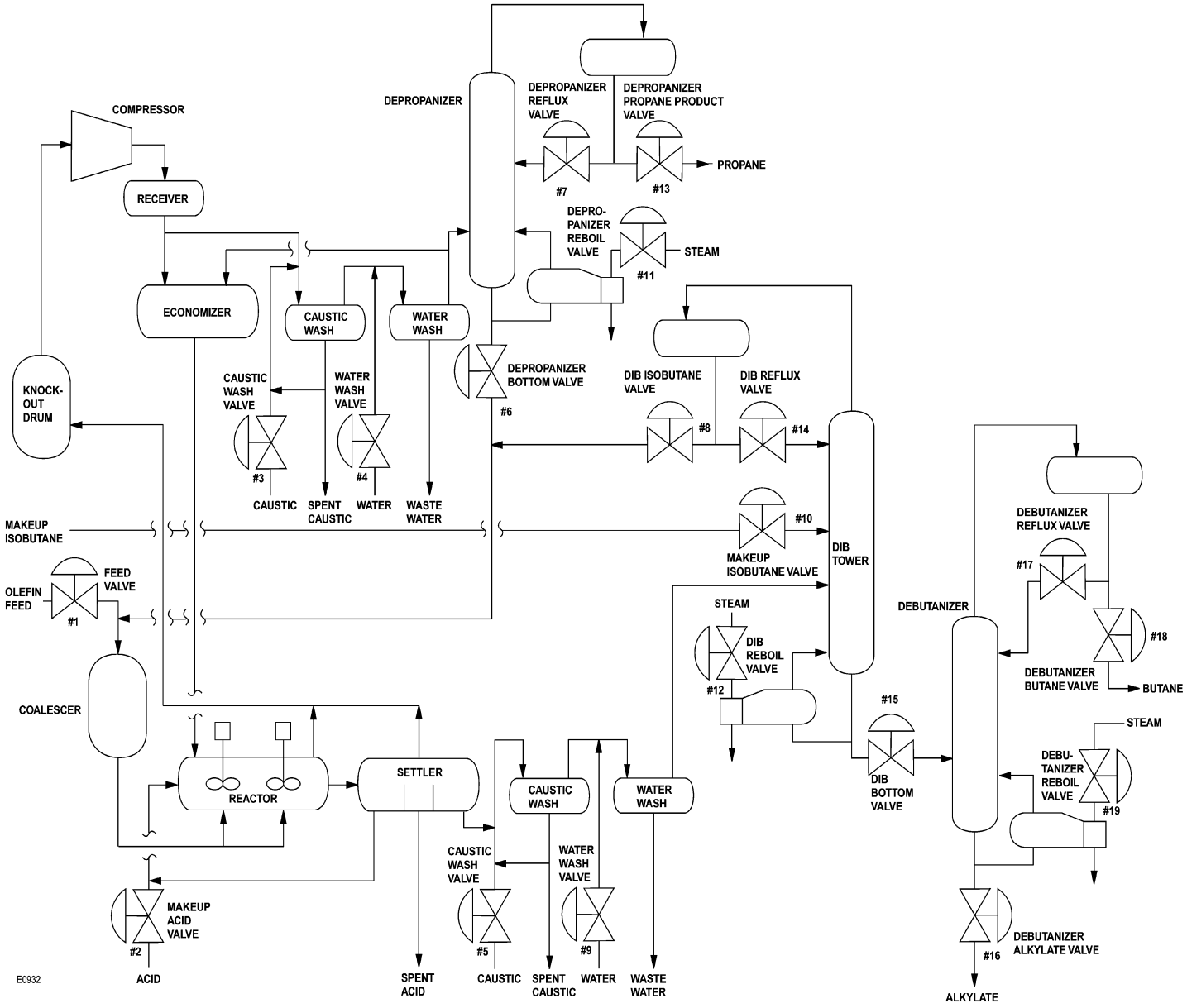


FIGURE 41 - SULFURIC ACID ALKYLATION UNIT

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(Courtesy of Emerson Process Management)

7.11.1 ALKY PLANT - OLEFIN FEED (VALVE #1)

7.11.1.1 Operating Conditions

Fluid: Liquid. Olefinsl.

	Normal	Maximum
Q m3/h (gpm)	75 (328)	459 (114)
P1 barg (psig)	11 (160)	11 (160)
dP bar (psid)	1.3 (19)	0.83 (12)
T °C (°F)	32 (90)	66 (150)
SG	0.576	0.576
Pv bara (psia)	3.3 (48)	3.3 (48)

7.11.1.2 Valve Specification

A **general service sliding stem Globe style** control valve will perform in this service. This valve is usually ANSI Class 300#, with a C5 body, graphite fugitive emission packing, and a Fail Close actuator and positioner for throttling service. This valve is normally ANSI Class IV shutoff.

7.11.1.3 Trim

416SS

7.11.1.4 Sizing

Conventional.

7.11.2 ALKY PLANT - MAKEUP ACID (VALVE #2)

7.11.2.1 Operating Conditions

Fluid: Liquid. Sulfuric Acid.

	Normal	Maximum
Q kg/d (lb/d)	35 (77)	50 (110)
P1 barg (psig)	11 (160)	11 (160)
dP bar (psid)	3.4 (50)	3.4 (50)

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T °C	(°F)	29 (85)	38 (100)
SG		1.82	1.82
Pv bara	(psia)	3.3 (0.1)	3.3 (0.1)

7.11.2.2 Valve Specification

A **Eccentric rotary style** control valve will perform in this service. This valve is usually ANSI Class 300#, with a 316SS body, Teflon fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.11.2.3 Trim

416SS

7.11.2.4 Sizing

Conventional

7.11.3 ALKY PLANT - CAUSTIC WASH (VALVE #3, 5)

7.11.3.1 Operating Conditions

Fluid: Liquid. Caustic.

		Normal	Maximum
Q m3/h	(gpm)	2.8 (12.5)	3.1 (14)
P1 barg	(psig)	3.4 (50)	3.4 (50)
dP bar	(psid)	1.7 (25)	1.7 (25)
T °C	(°F)	27 (80)	66 (150)
SG		1.05	1.05

7.11.3.2 Valve Specification

A **general service Globe style** control valve will perform in this service. This valve is usually ANSI Class 300# or 600#, with a Carbon steel body, Teflon fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.11.3.3 Trim

316SS

7.11.3.4 Sizing

Conventional.

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7.11.4 ALKY PLANT - WATER WASH (VALVE #4, 9)

7.11.4.1 Operating Conditions

Fluid: Liquid. Water.

	Normal	Maximum
Q m3/h (gpm)	1.1 (5)	1.6 (7)
P1 barg (psig)	3.4 (50)	3.4 (50)
dP bar (psid)	2.1 (30)	2.1 (30)
T °C (°F)	27 (80)	38 (100)
SG	1.0	1.0

7.11.4.2 Valve Specification

A **general service Globe style** control valve will perform in this service. This valve is usually ANSI Class 300# or 600#, with a Carbon steel body, Teflon fugitive emission packing, and a Fail Close actuator and positioner for throttling service.

7.11.4.3 Trim

316SS

7.11.4.4 Sizing

Conventional.

7.11.5 ALKY PLANT - HYDROFLUORIC ACID SERVICE (ALTERNATE ACID CASE)

7.11.5.1 Operating Conditions

Various flows, pressures and temperatures.
Hydrofluoric acid (HF), toxic and corrosive.

7.11.5.2 Valve Specification

Carbon steel body (WCB) for moderate temperature services. Initial corrosion of the surface creates a protective barrier to limit further corrosion. Abrasion or water can remove this barrier. Use Monel body for high temperature services above 300°F (hot acid). Use Monel trim. Monel 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.

7.11.5.3 Quality Control

Because of the toxic nature of HF, the quality of the foundry and valve manufacturer is important. Verification of materials is required. 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.

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7.13 Sulphur Plant

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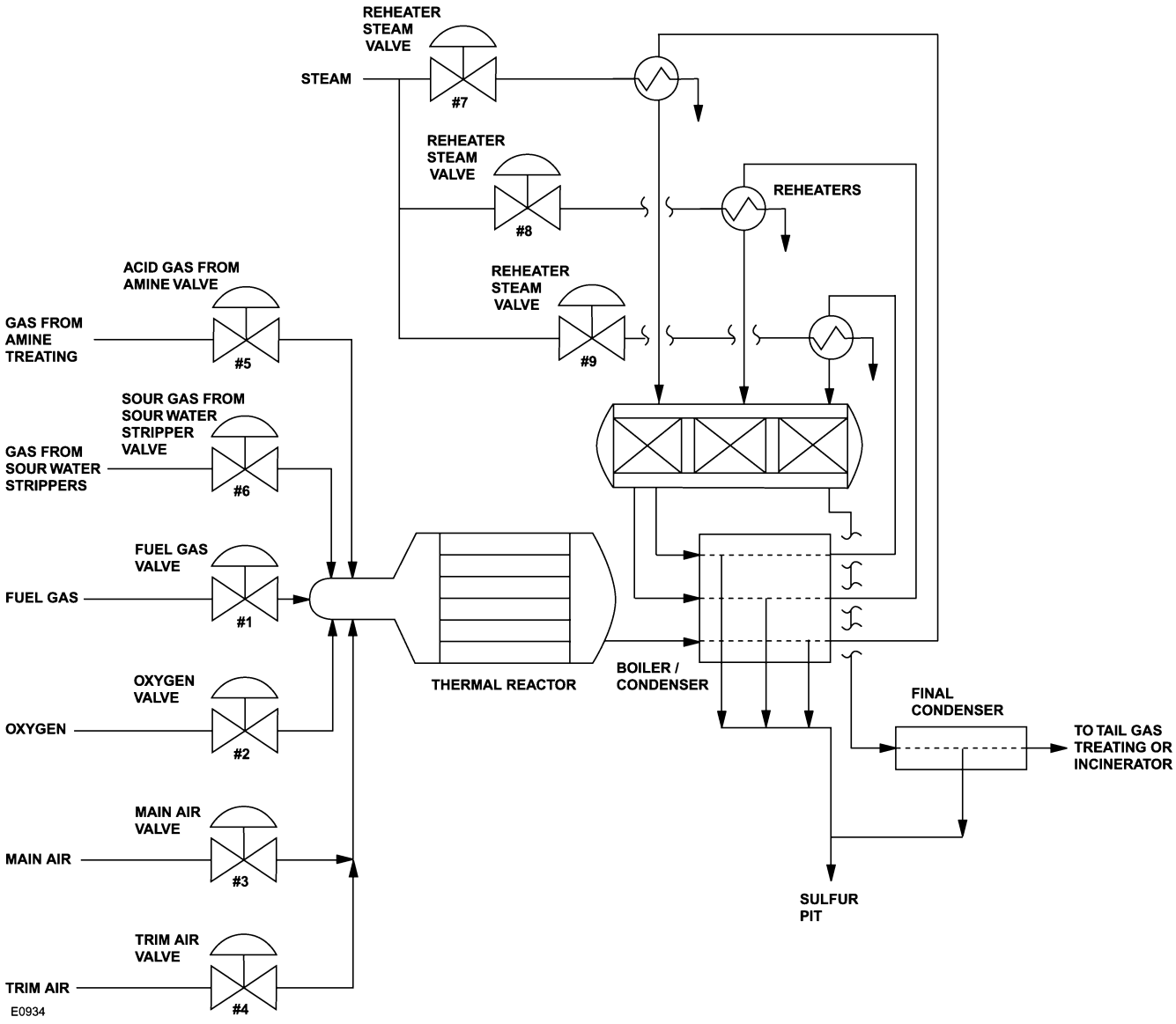


FIGURE 42 - SULPHUR PLANT

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7.13.1 SULFUR PLANT - ACID GAS (VALVE #5)

7.13.1.1 Operating Conditions

Fluid: Gas. Acid Gas - High Concentration of H2S

	Normal	Maximum
Flow km3/h (kscfh)	19 (670)	34 (1200)
P1 bar (psig)	0.6 (9)	0.7 (10)
dP bar (psig)	0.07 (1)	0.14 (.2)
T °C (°F)	49 (120)	177 (350)
SG (MW)	(37.1)	

7.13.1.2 Valve Specification

A **high performance butterfly style** control valve will perform in this service. Carbon steel body, NACE MR01-75 certified materials, double TFE packing required. On/off service, Fail Closed on loss of air supply or electric power to solenoid pilot. Open and closed limit position switches with hermetically sealed contacts. Stainless steel tubing and fittings. No copper or brass components allowed.

7.13.1.3 Trim

Stainless steel disk and shaft.

7.13.1.4 Sizing

Conventional.

7.13.1.5 Application Notes

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

7.13.2 SULFUR PLANT - FUEL GAS (VALVE #1)

7.13.2.1 Operating Conditions

Fluid: Gas

	Normal	Maximum
Flow m3/h (kSCFH)	1133 (40)	1868 (66)
P1 bar (psig)	2.8 (40)	2.6 (38)
dP bar (psig)	0.7 (10)	0.7 (10)
T ºC (ºF)	38 (100)	82 (180)
SG (MW)	(11.9)	

7.13.2.2 Valve Specification

These valves are usually a **sliding stem globe style** control valve with ANSI Class 300#, a Carbon steel body, Teflon packing and a Fail Close actuator and positioner for throttling control.

7.13.2.3 Trim

416SS.

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7.13.2.4 Sizing

Conventional.

7.13.3 SULFUR PLANT - OXYGEN (VALVE #2)

7.13.3.1 Operating Conditions

Fluid: Gas

	Normal	Maximum
Flow m3/h (kSCFH)	4813 (170)	5946 (210)
P1 bar (psig)	2.6 (38)	2.3 (34)
dP bar (psig)	1.7 (25)	1.1 (16)
T ºC (ºF)	38 (100)	66 (150)
SG (MW)	(32)	

7.13.3.2 Valve Specification

These valves are usually a **sliding stem globe style** control valve with ANSI Class 300#, a 316SS body, Teflon packing and a Fail Close actuator and positioner for throttling control. Special Cleaning required for Oxygen service.

7.13.3.3 Trim

Monel.

7.13.3.4 Sizing

Conventional.

7.13.4 SULFUR PLANT - COMBUSTION AIR (VALVE #3)

7.13.4.1 Operating Conditions

Fluid: Gas

	Normal	Maximum
Flow km3/h (kSCFH)	37 (1300)	45 (1600)
P1 bar (psig)	0.6 (9)	0.7 (10)
dP bar (psig)	0.06 (.8)	0.05 (.7)
T ºC (ºF)	93 (200)	149 (300)
SG (MW)	(28.1)	

7.13.4.2 Valve Specification

These valves are usually a **Butterfly style** control valve with ANSI Class 300#, a Carbon steel body, Teflon packing and a Fail Open actuator and positioner for throttling control.

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7.13.4.3 Trim

416SS.

7.13.4.4 Sizing

Conventional.

7.13.5 SULPHUR PLANT - SULFUR VAPOR TO EDUCTOR

7.13.5.1 Operating Conditions

Fluid: Gas. Sweep Air from Sulphur Pit

	Normal
Flow m3/h (SCFH)	57 (2000)
P1 bar (psig)	-0.04 (-0.6)
dP bar (psig)	-0.003 (-0.05)
T ºC (ºF)	149 (300)
SG	1.0

7.13.5.2 Valve Specification

These valves are usually a **butterfly or plug valve**. Fail closed actuator with solenoid pilot, limit switches at open and closed positions. Carbon steel body, steam jacketed on/off service. NACE specification materials. No copper or brass components allowed.

7.13.5.3 Trim

416SST. Tight shut-off required.

7.13.5.4 Sizing

Conventional.

7.13.5.5 Application Notes

Line and valve are steam jacketed with 50 psig steam to prevent sulfur buildup in valve.

7.13.6 LIQUID SULFUR TO STORAGE

7.13.6.1 Operating Conditions

Fluid: Liquid Sulphur

	Normal
Flow m3/h (GPM)	1.1 (5)
P1 bar (psig)	2.1 (30)
dP bar (psig)	0.7 (10)
T ºC (ºF)	138 (280)

7.13.6.2 Valve Specification

These valves are usually either an **Eccentric rotary style or general service Globe style** control valve with ANSI Class 300#, a Carbon steel body, Teflon packing and a Fail Close actuator and positioner for throttling control.

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7.13.6.3 Trim

416SST.

7.13.6.4 Sizing

Conventional.

7.13.6.5 Application Notes

Body and flanges are usually steam jacketed, 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 should be fire-safe. A gate valve, metal-seated ball valve, or high-performance butterfly valve is considered to be fire-safe. The valve selected should have been tested to API Spec 6FA, *Fire Test for Valves*, or an equivalent standard test.

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 must approve the use of a control valve as an EBV. In addition, the control valve must 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 VI 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 required in all suction and discharge lines.

8.1.1.3 An EBV is required between stages and inter-stage equipment if the inter-stage equipment holds greater than 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 2000 gallons of light ends or hydrocarbons above the auto ignition point or above 600°F.

8.1.2.2 An EBV is required where the upstream vessel contains greater than 4000 gallons of liquid hydrocarbons.

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8.1.3 Vessels

8.1.3.1 An EBV is required for vessels containing light ends or toxic material. The flow from these vessels must 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 must have its own EBV.

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

8.1.3 Heaters

8.1.3.1 An EBV is required for each fuel gas or oil line to fired heaters and boilers. A double block and bleed arrangement with a single or multiple valves is often used. Reopening after a trip requires a manual reset which permits relatching only after all safety interlock parameters have been satisfied. Refer to API RP 556, *Manual on Installation of Instrumentation, Control, and Protective Systems for Fired Heaters.*

8.1.3.2 An EBV is required for each feed line to a fired heater that contains flammable fluid. The EBV should be located outside the firewall or firezone, which contains the heater.

8.2 ACTUATOR SELECTION

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 pounds (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.

8.2.1 Electric Motor Actuator

8.2.1.1 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 must 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.

8.2.1.2 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.

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

8.2.1.4 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.

8.2.2 Pneumatic Actuator

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

8.2.2.2 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 involvment in the fire. No fireproofing is necessary.

8.2.2.3 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.

8.2.2.4 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 must also be made of materials that will withstand a fire until the valve can be closed.

8.3 FIREPROOFING

8.3.1 EBV air supply, critical electrical wiring, local control panel, and actuator must withstand a 2000ºF petroleum fire while keeping all internal electrical controls and wiring below 2000ºF 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 Publication 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.

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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 must 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 50 to 100 feet 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.

9.0 Safety Instrumented System (SIS) Valves

9.1 Unlike a control valve which is used to throttle (i.e. make small changes to) the process, a safety instrumented system (SIS) valve is an On/Off device used to isolate a process stream (e.g. Fuel gas on a Fired Heater) when an unsafe process condition exists. Depending on the process application, under normal operating conditions, an SIS valve can either be Fully Open or Fully Closed. When an unsafe condition occurs, as detected by logic that resides in a Safety Instrumented System, the SIS valve automatically goes to its fail-safe state. SIS valves can also be manually operated to Open or Close through a Pushbutton command.

9.2 SIS valves should not be provided with hand wheels which could hinder their operation.

9.3 SIS valves once activated to their fail-safe state should remain in that state requiring a manual reset locally at the valve, or within view of the valve. SIS valves should not automatically reset themselves.

9.4 SIS valves should provide tight shutoff, per ANSI / FCI 70-2 Class V or VI or a valve that is rated as bubble tight per API 598.

9.5 SIS valves should either be fire safe per API 607 or API 6FA or be located in a fire safe area.

9.6 SIS valves should be provided with position indication to permit its SIS logic to verify the valve moved to the correct state following a trip command.

9.7 SIS valve travel times are usually dictated through an understanding of the process response (safety) time required. If not specified, the following maximum travel times may be used as a guide:

Valve Size (inches)	Time (seconds)
Up to 4"	3
6" to 8"	4

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8" to 12"	5
12" to 18"	6

In liquid applications, the effects of water hammer on the line should be considered when determining a closure time. Water hammer is caused if a valve is closed to quickly.

9.8 SIS valves operated by receiving either a digital or analog signal from a SIS. A digital signal is the more common of the two. This signal is usually employed along with a 3-way Solenoid valve (SOV) in the air supply line to the SIS valve's actuator. Depending on whether the SOV's coil is energized or de-energized, this results in a specific lineup of the SOV's pneumatic ports. Air is either permitted to flow to the actuator or air is being dumped from the actuator.

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 3-way SOV may be needed. This is called voting. Below are examples of the two commonly used 3-way SOV arrangements. Other voting arrangements, and pre-packaged SOV cabinets also exist.

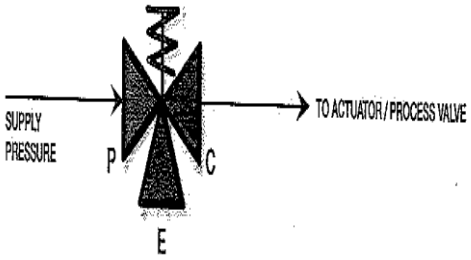


FIGURE 43 - 1 out-of 1 SOV Arrangement (1oo1)
(Courtesy of Automatic Switch Company)

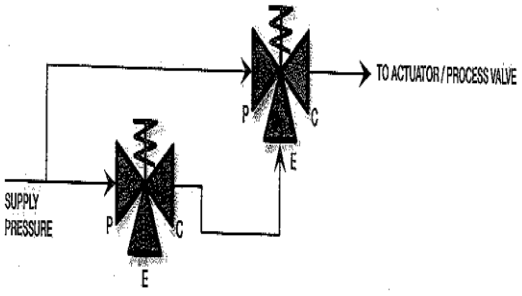


FIGURE 44 - 2 out-of 2 SOV Arrangement (2oo2)
(Courtesy of Automatic Switch Company)

The 2oo2 arrangement is more commonly used for high availability applications. In this arrangement, if one SOV were to spuriously trip, the second SOV would still maintain the position of the actuator at its operating state. Both SOVs must close in order to shift the actuator to its non-operating state.

When SOVs are used, the air must be clean, and dry. If Inert gas is used instead, it should be filtered to 50 microns or better. To prevent freezing, the dew point of the air or gas should be at least 18 degrees F (-8 degrees C) below the minimum temperature to which any portion of the clean air or gas could be exposed.

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9.9 SIS valve actuators should be sized with a safety factor of 25 to 40% more power in addition to typical considerations of the minimum instrument air pressure, operating conditions, and breakaway force or torque required to move the valve.

9.10 Special Form of Digital Valve Controller with Partial Stroke Testing (PST) Functionality

9.10.1 When a control valve in series with an SIS valve is used as a "secondary" isolation device, its digital valve controller can also be used to provide ON/OFF functionality equivalent to conventional solenoid operated valves (SOVs). In these cases, the digital valve controller can also provide a function called Partial Stroke Testing (PST) which provides a degree of assurance that the control valve will mechanically respond to a trip, in cases where no block and bypass valves have been provided for on-line proof testing. The PST function physical permits the valve to stroke a fixed amount of travel to validate the valve response to a demand. Digital valve controllers with PST can also be used on conventional SIS valves as well.

9.10.2 There are two types of SIS interfaces to a digital valve controller, the traditional 0-24 Vdc interface which is typically associated to legacy systems and referred to as "Discrete Safety Demand (DSD)". They will either provide 0 or 24 Vdc to the digital valve controller, and nothing in between. The other interface is 4-20mA referred to as "Analog Safety Demand (ASD)" found in newer Logic Solvers. The benefit of applying ASD over DSD is that during a trip; the instrument remains powered and is capable of capturing and saving a "Valve Trip Signature" if the digital valve controller is commanded to move to the safe position. This then serves as the "Proof Test Signature" used by most plant safety engineers to validate that the valve can in fact move to the safe position if required.

9.11 SIS Valve Bypasses

9.11.1 Bypass valves may be installed in parallel with the SIS valve(s) for purposes of periodic on-line testing and maintenance of SIS valves.

9.11.2 The bypass valve should be treated as a Car Sealed type valve with appropriate color-coding, signage, locks and chains to prevent inadvertent use. SIS bypass valves should be provided with position indication to alarm in a manned location when not in the Car Sealed position. A formal policy, procedure, permitting, or signed authorization should be required prior to using the SIS bypass valve.

9.11.3 SIS bypass valves should either be fire safe per API 607 or API 6FA or be located in a fire safe area.

10.0 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 locally and remotely operated, manually and/or automatically controlled depressurizing valves discharging into a closed system. The system should be designed to comply with the trip reliability and spurious trip availability 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 reliability and availability

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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 depressure the system within 15 minutes to 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 line spec 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 must 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 2-inch 300# ANSI 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. Top or cage-guiding is acceptable. 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 Class V shutoff.

11.0 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 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

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tubing, servo valves, high pressure accumulators, pump controls, positioner electronics, pressure gauges and miscellaneous other instrumentation.

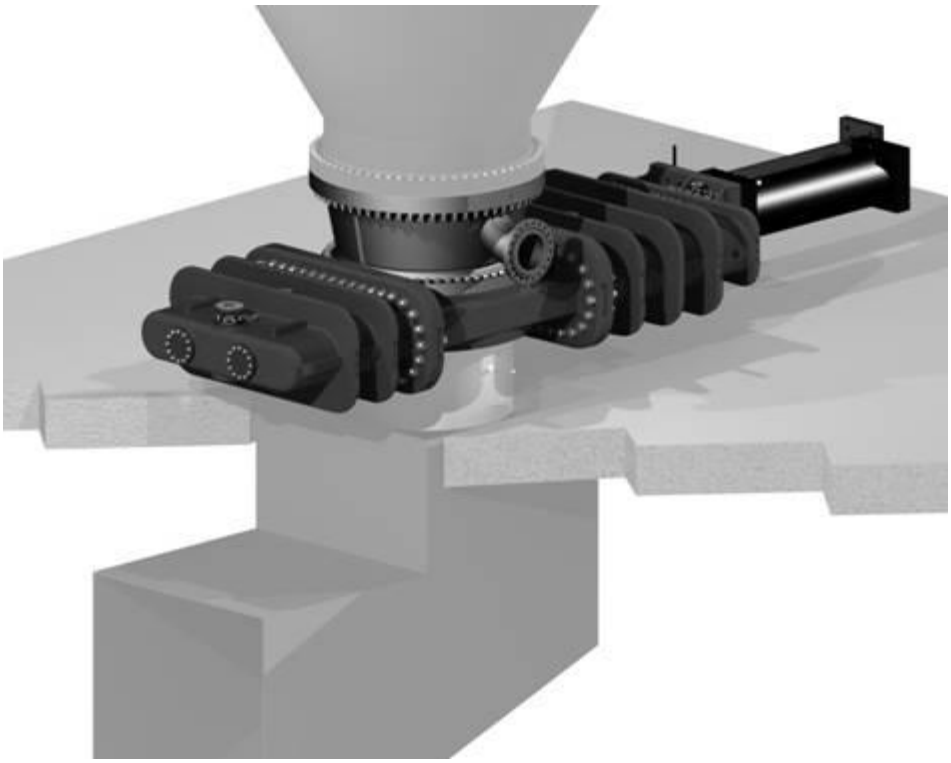


Figure 45 - Typical Slide Valve Installation
(Courtesy of Flowserve)

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 should be constructed of 300 series stainless steel. The reservoir should be equipped with vent and vacuum breaker valves set at no more than 2 psig positive and 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 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.

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11.2.4 The hydraulic power unit must 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.

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.

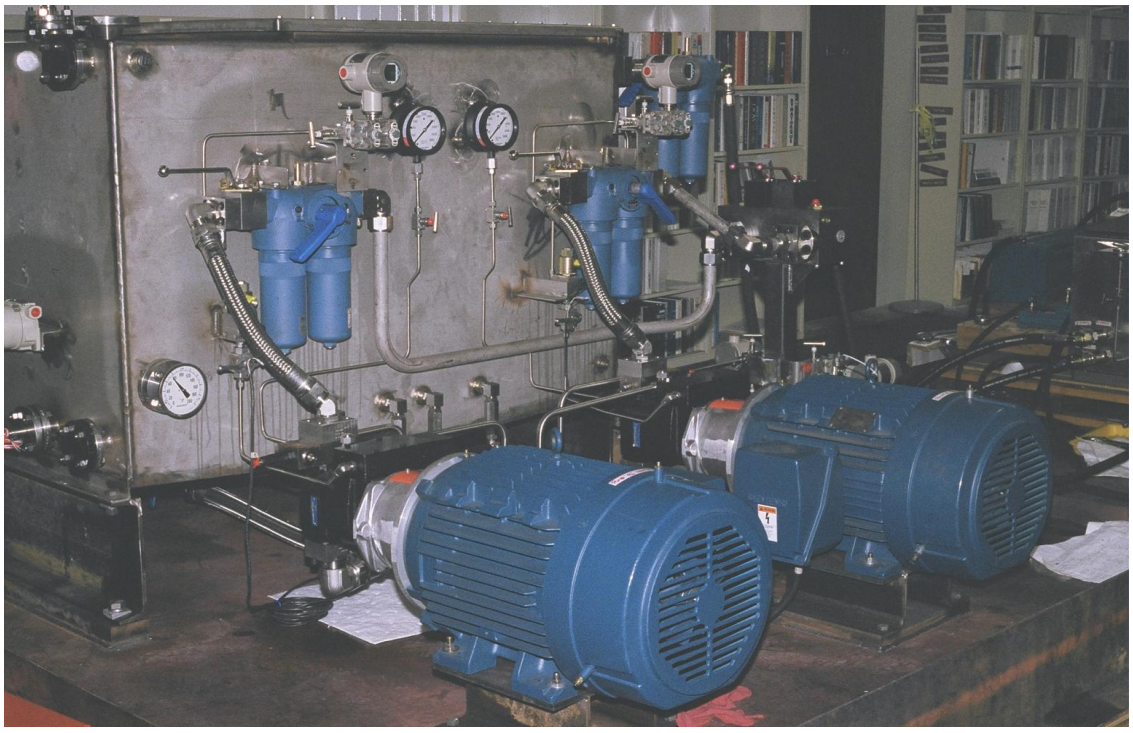


Figure 46 - Typical HPU Unit
(Courtesy of Flowserve)

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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 must 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 required. 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 must 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 4–20 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 4–20 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 must 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.

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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 no-selected pump automatically becomes the "stand-by."

11.4.13 Alarms

11.4.13.1 The package must 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*.

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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 percent full stroke.

11.5.2 Tracking error (setpoint deviation) should be ± 2 percent 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 percent of full stroke (cyclical, peak to peak).

11.6 ELECTRICAL REQUIREMENTS

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

11.7 TESTING AND INSPECTION

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

11.8 SLIDE VALVE ACTUATOR SERVICE

11.8.1 Following is an example of a typical slide valve/actuator data sheet:

Location:	Regenerator
Valve Size:	36"
Stroke Including Overlap:	23"
Controlling Stroke:	$19^{1}/_{8}$"
Welded or Flanged:	Welded
Hot or Cold Wall Valve:	Hot
Jacking Conn. on Body:	Yes
Lip Seals Provided:	Yes
Purges:	Bonnet

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Orifice Opening:	292 sq inches
Orifice Shape:	Bonnet
Actuator Type:	Hydraulic
Operating Modes:	Auto/Manual
Input Control Signal:	4–20 ma.
Local Control:	Yes
Cylinder ID:	14"
Stroke Travel Time:	30 seconds
Handwheel:	Yes
Air Motor:	No
Positioner Type:	Electronic
Position Indicator:	Yes
Limit Switches:	No
Hydraulic System Pressure:	250 psig or 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:	
Backup # of Strokes:	

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