בחירת שסתומי בקרה
מותאמים ליישום וכאלמנט
סופי של חוג
בקרה

שמעון טריגרמן בז"ן

BAZAN בזן
בתי זיקוק לנפט בע"מ

Traditional Control Valve Selection

Traditional valve-sizing methods have often been used as a guideline for selecting the “right” valve in each application. Process details are gathered to make sure a control valve is made from the right materials, can handle process temperatures and pressures, and has enough capacity to Handle minimum/nominal/maximum flow conditions.

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LOGAN LAKE




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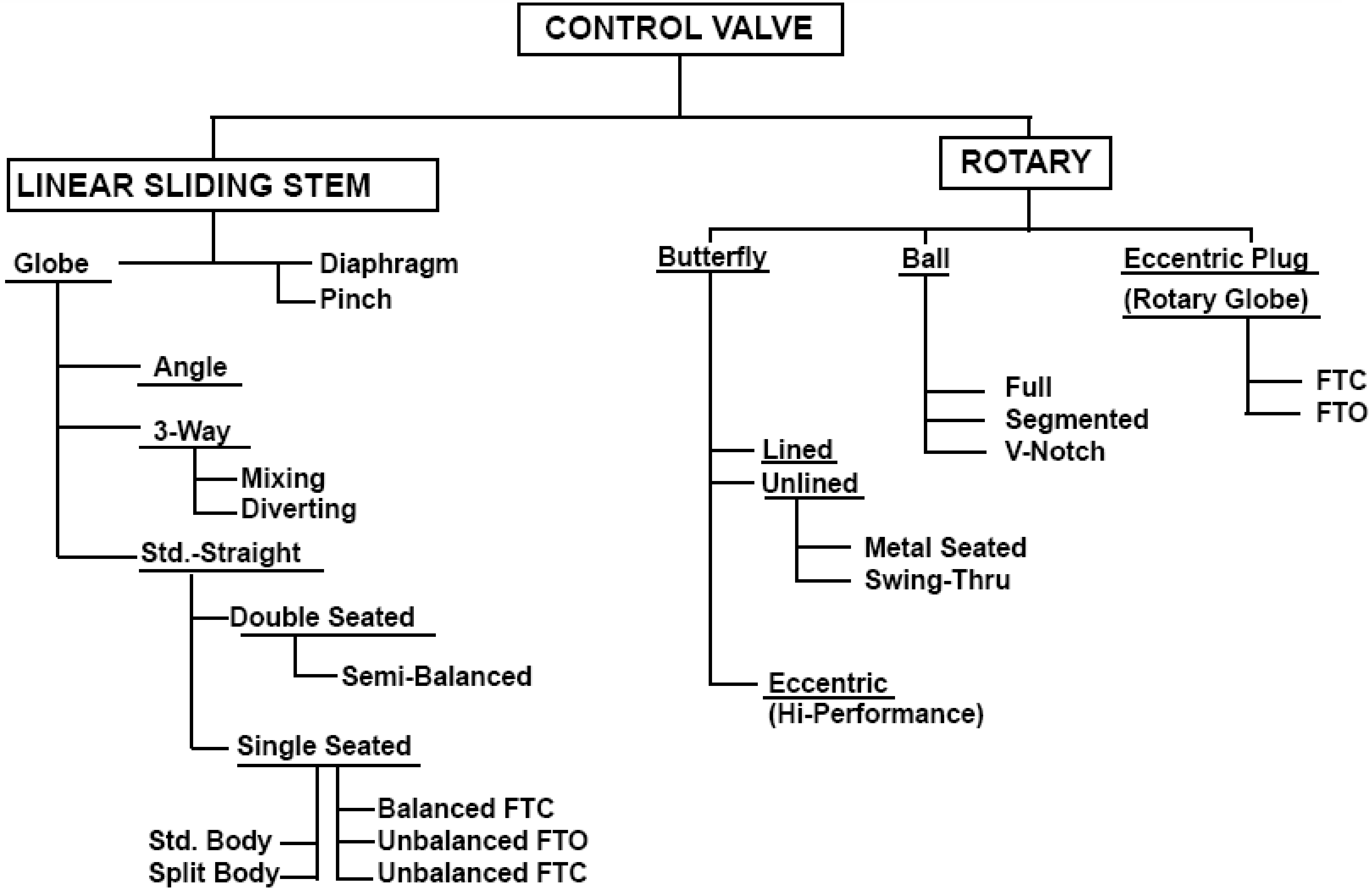
CONTROL VALVE CLASSIFICATION

In addition to LINEAR and ROTARY, control valves are also classified according to their GUIDING METHODS, CHARACTERIZATION METHODS, and the nature of SERVICES they are applied within.



Control Valve Characteristics Summary

Here are the relative differences in three commonly used control valve designs.

	Globe valve	Segmented V-ball	High-performance butterfly valve
Capacity	Good	Excellent	Excellent
Characteristic	Unlimited selection	One, usually equal percentage	One, usually linear
Noise control	Excellent	Limited	None
Cavitation protection	Excellent	Limited	None
High flowing pressure drops	Good	Limited	Poor
Tight shutoff	Good	Good	Good
Usable control range	Wide	Limited	Narrow
Cost	Highest	Medium	Lowest

Source: Control Engineering with data from Fisher Controls

For more information...

Industries:

- Petrochemical
- Pulp & Paper
- Chemical
- Pipeline
- Refining
- Government/Military test
- Power
- Steel
- Aerospace

CONTROL VALVE APPLICATIONS AND SERVICES

Applications:

- Anti-Surge
- Blowdown
- Letdown
- Attemperator spray control
- Spillback
- Turbine Bypass
- Feedwater
- Sour Water
- Unit Depressurization
- General Process

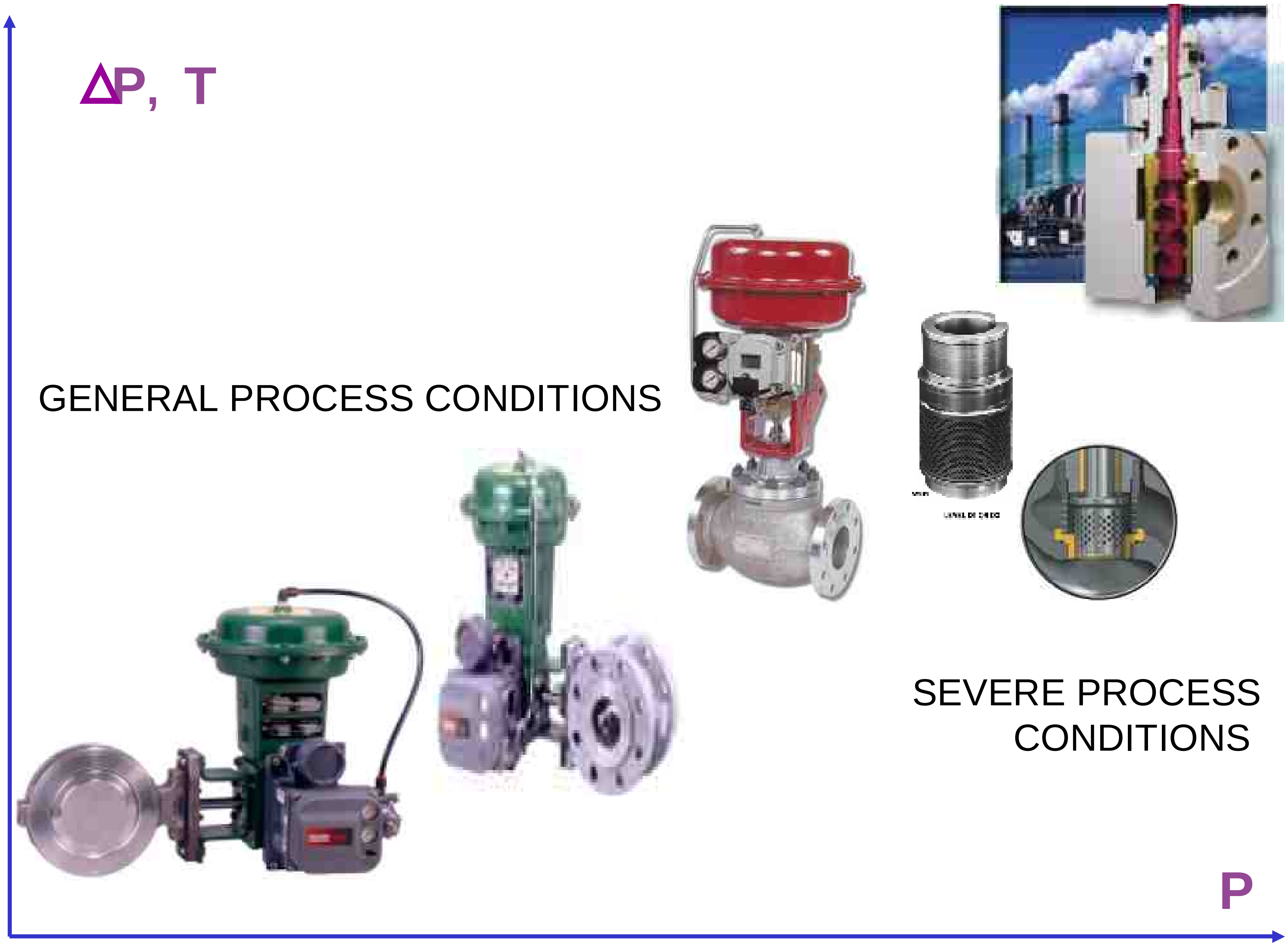
Services:

Corrosive
High Pressure
Severe***
Cryogenic
Erosive
Toxic
Slurry
Oxigen

***Noise, Flashing, Cavitating, Abrasive….

Control Valve Specification

GENERAL	1	Tag No.					
	2	Service					
	3	Line No.	P & ID No				
	4	Area Classification					
	5	Ambient Temperature:		Min.	Max.		
	6	Allowable Sound Pressure Level dBA					
	7	Tightness / NACE MR0175 Requirements					
	8	Available Air Supply Pressure:		Min.	Max.		
	9	Power Failure Position					
	10	Application	Toxic	Corrosive	Erosive		
PIPE LINE	11	Line Size and Schedule		Inlet	Outlet		
	12	Design Pressure Min/Max	Design Temp. Min/Max				
	13	Process Fluid	Base Density				
	14	Fluid State	Fluid Phase				
	15	Max Shut-off Differential Pressure					
	16					Units	@ Ma
	17	Critical Pressure	Critical Temperature			–	


ΔP, T
GENERAL PROCESS CONDITIONS
SEVERE PROCESS
CONDITIONS
P

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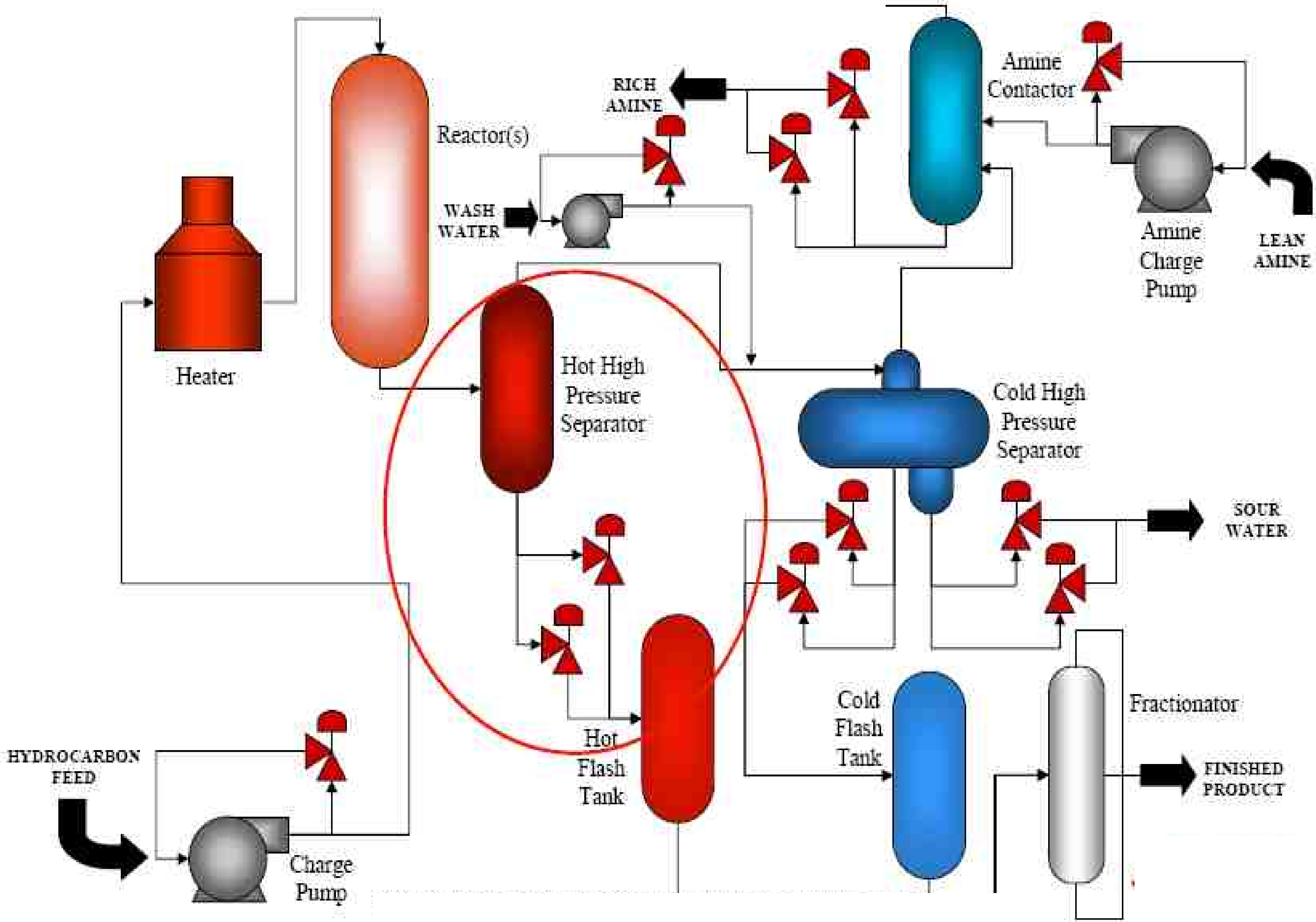
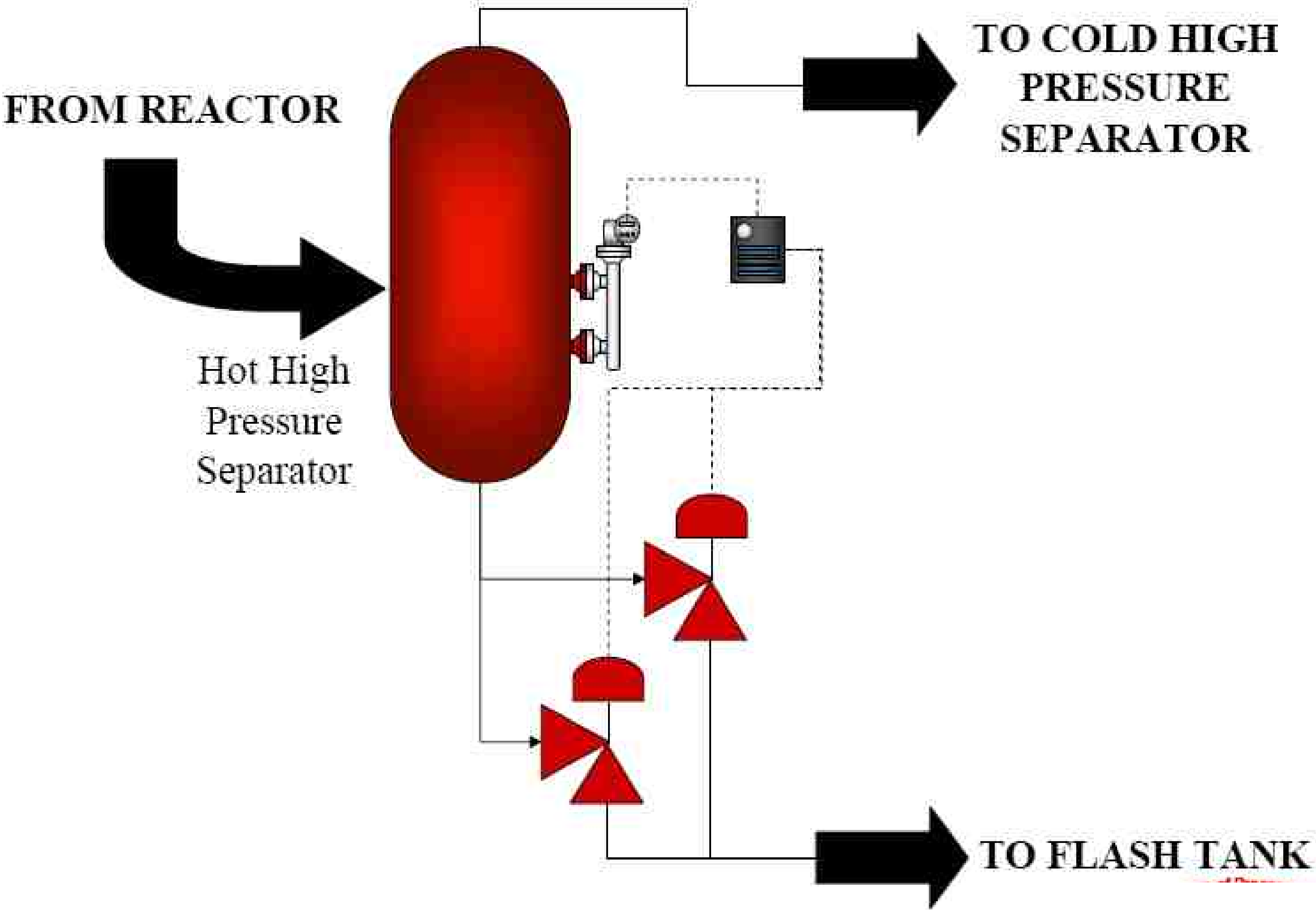
INDUSTRIES SERVED

Oil and Gas	Power Generation	Refining and Petrochemical	Nuclear Power	Other Process Industries
				



Reactor(s)
Heater
WASH WATER
RICH AMINE
Amine Contactor
Amine Charge Pump
LEAN AMINE
Hot High Pressure Separator
Cold High Pressure Separator
SOUR WATER
Hot Flash Tank
Cold Flash Tank
Fractionator
FINISHED PRODUCT
HYDROCARBON FEED
Charge Pump

Hot High Pressure Separator Letdown



HHPS Letdown (Application Difficulties)

- •High pressure drop
  - •Potential for cavitation leading to trim, body and piping damage
- •High Level of Entrained Gases
  - •Off-Gassing Can Lead to Choking of Traditional Valves
- •Corrosive process fluid
  - •Attacks on incorrectly selected materials
- •Entrained solids
  - •Any small holes will become clogged and prove ineffective
- •High temperature feed
  - •Failure of soft trim components (teflon seals)

HHPS Letdown (Required Features)

- Multi-Stage Trim With High F_L to Eliminate Cavitation Potential
- Expanding Area Trim Properly Engineered to Handle Off-Gassing
- Expanded Outlet Area to Further Aid in Off-Gassing
- ANSI Class V Shut-Off with Metal Seats
- Axial Flow Trim Design for Smooth Throttling
- Large Flow Passages to Pass Any Entrained Solids

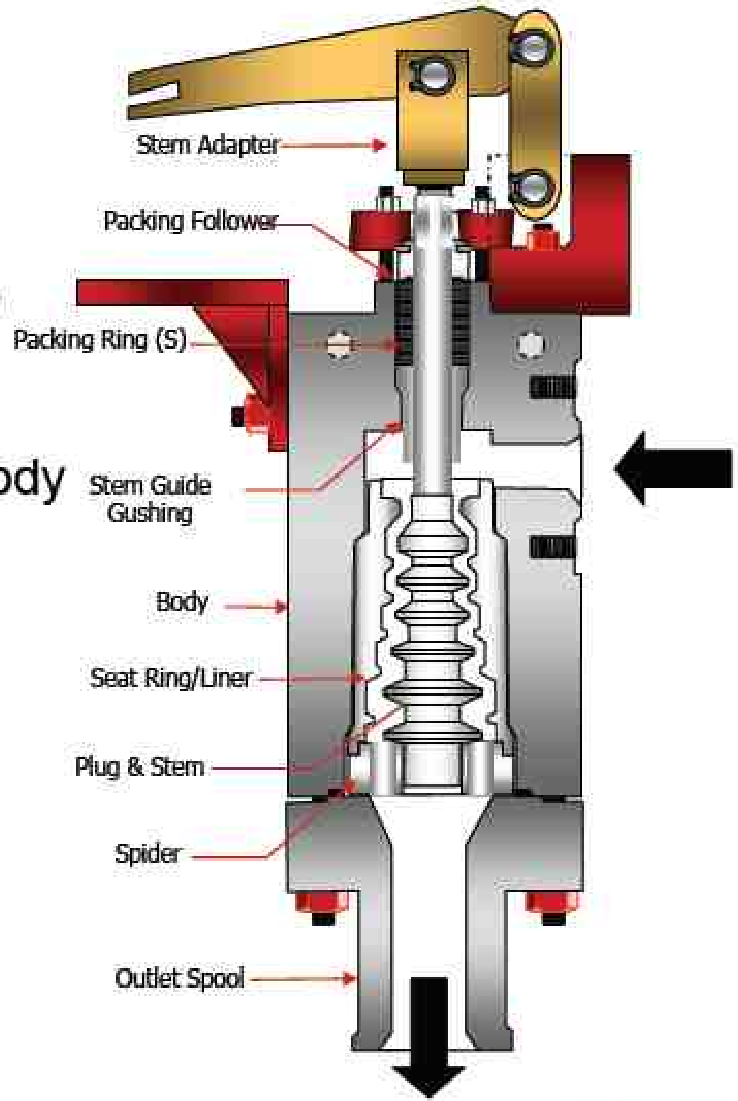
  Drilled hole or labyrinth style stacked plates should be avoided due to potential for clogging

- Rugged Top and Bottom Guided Design for Added Stability
- Specialty Actuation Solutions for High Force, Unbalanced Designs
- Upgraded Trim Materials for High Temperature & NACE

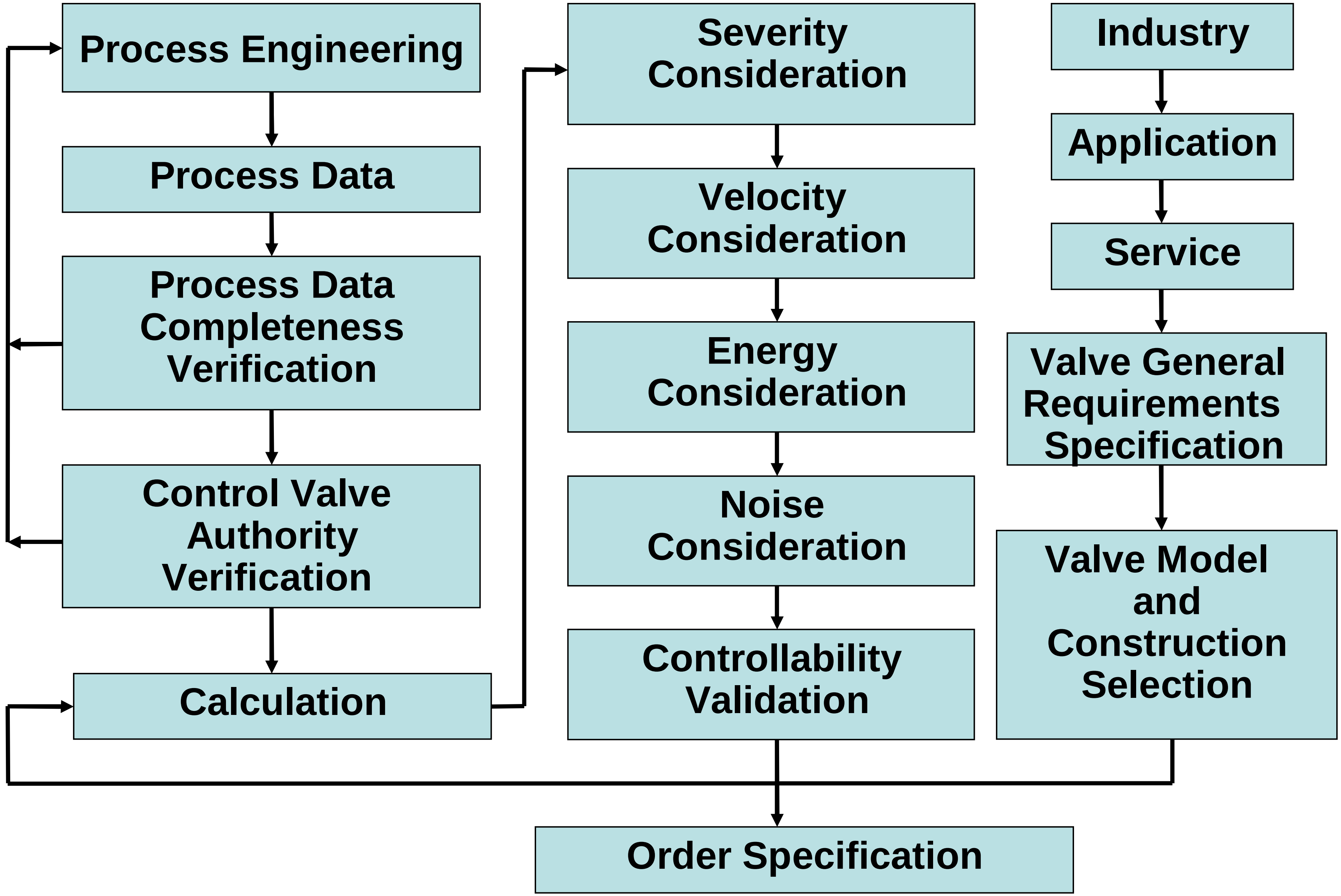
HHPS Letdown (Masoneilan Solution)

- •77000 Series Axial Flow Valve
- •5-9 Stages Standard (A & B Trim)
- •Expanding Area Trim
- •Dual Heavy Guiding (Upper and Lower)
- •Stainless Trim with Stellite Overlays
- •Chromoly Steel or 321/347 Stainless Body
- •Standard Valves from 2"x3" to 8"x10"
- •ANSI 600 – 2500 (Up to 4500 Custom)
- •Trash Tolerant Trim Design

  No small openings that can clog
- •BWE, RFF and RTJ Connections
- •Seat at First Stage



Control Valve Calculation and Selection Procedure.



Compatibility with Process Environment

Each valve body will function for specified fluid properties. Conditions requiring special consideration include slurries, very viscous fluids, flashing and cavitation. In addition, some applications require a tight shutoff. Naturally, the parts of the valve that contact the process must be selected appropriately to resist corrosion or other deleterious effects.

Valve Authority

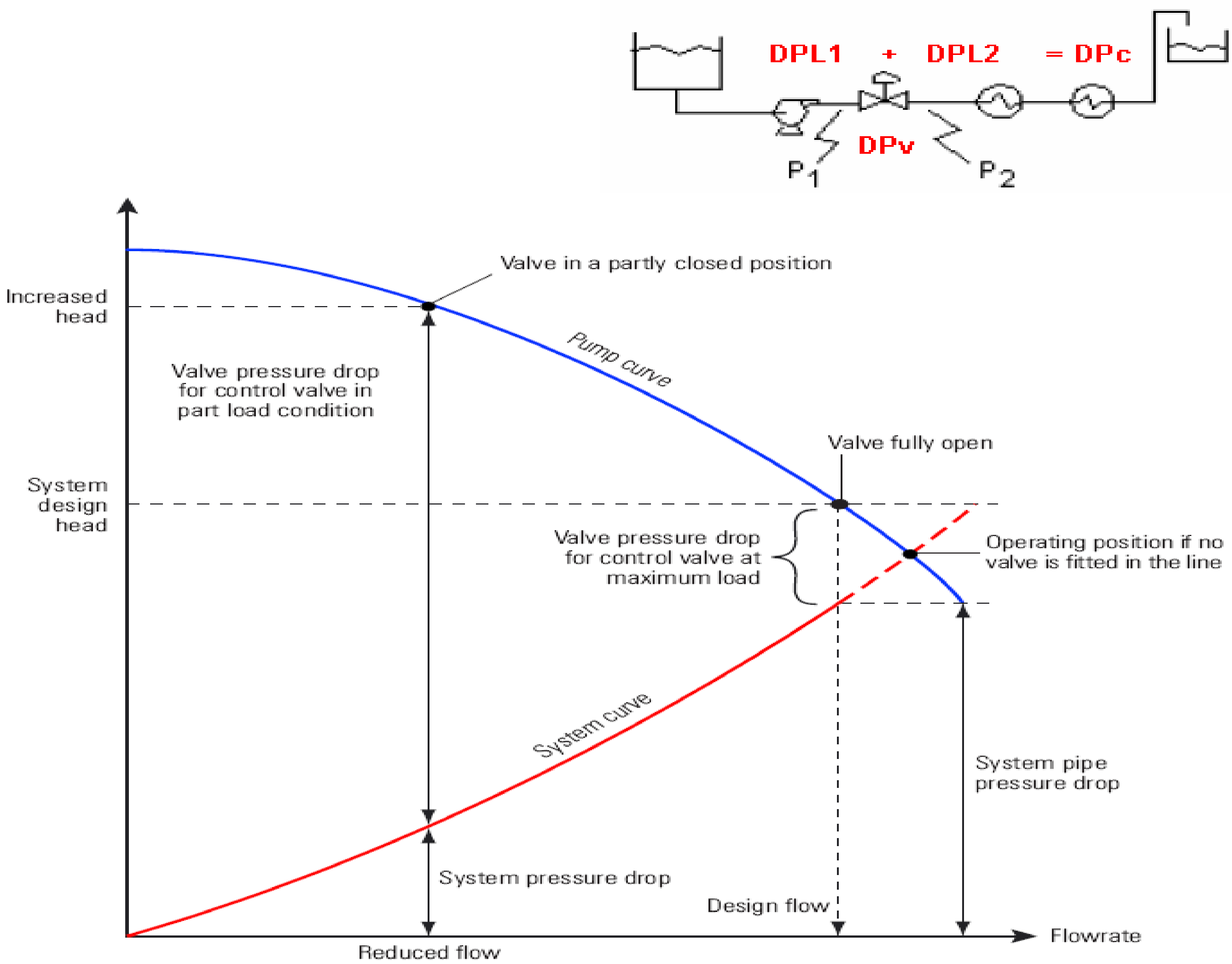
Mathematically it is easy to understand this concept, as the authority of a control valve ratio is defined as:

N = DPv / (DPv + DPc).

- Where: DPv = Pressure drop across a fully open control valve.
- DPc = Pressure drop across the remainder of the circuit.

It is a common practice in the industry to consider the range between 0.2 – 0.5 as “acceptable”.

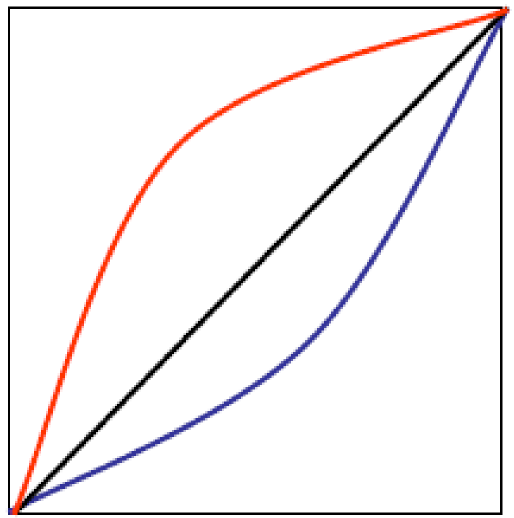
Better Value N = 0.3



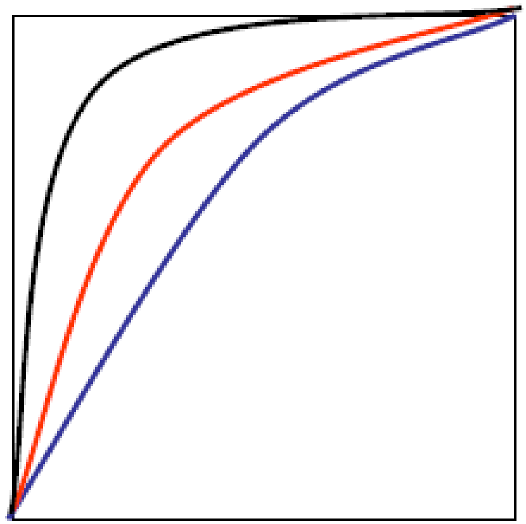
DPL1 + DPL2 = DPc
DPv
P1
P2
Valve in a partly closed position
Increased head
Pump curve
Valve pressure drop for control valve in part load condition
Valve fully open
System design head
Valve pressure drop for control valve at maximum load
Operating position if no valve is fitted in the line
System curve
System pipe pressure drop
System pressure drop
Design flow
Flowrate
Reduced flow

Effect of Valve Authority

Coil Control w/ Good Valve Authority .4 or greater.



Coil Control w/ Poor Valve Authority .2 or less

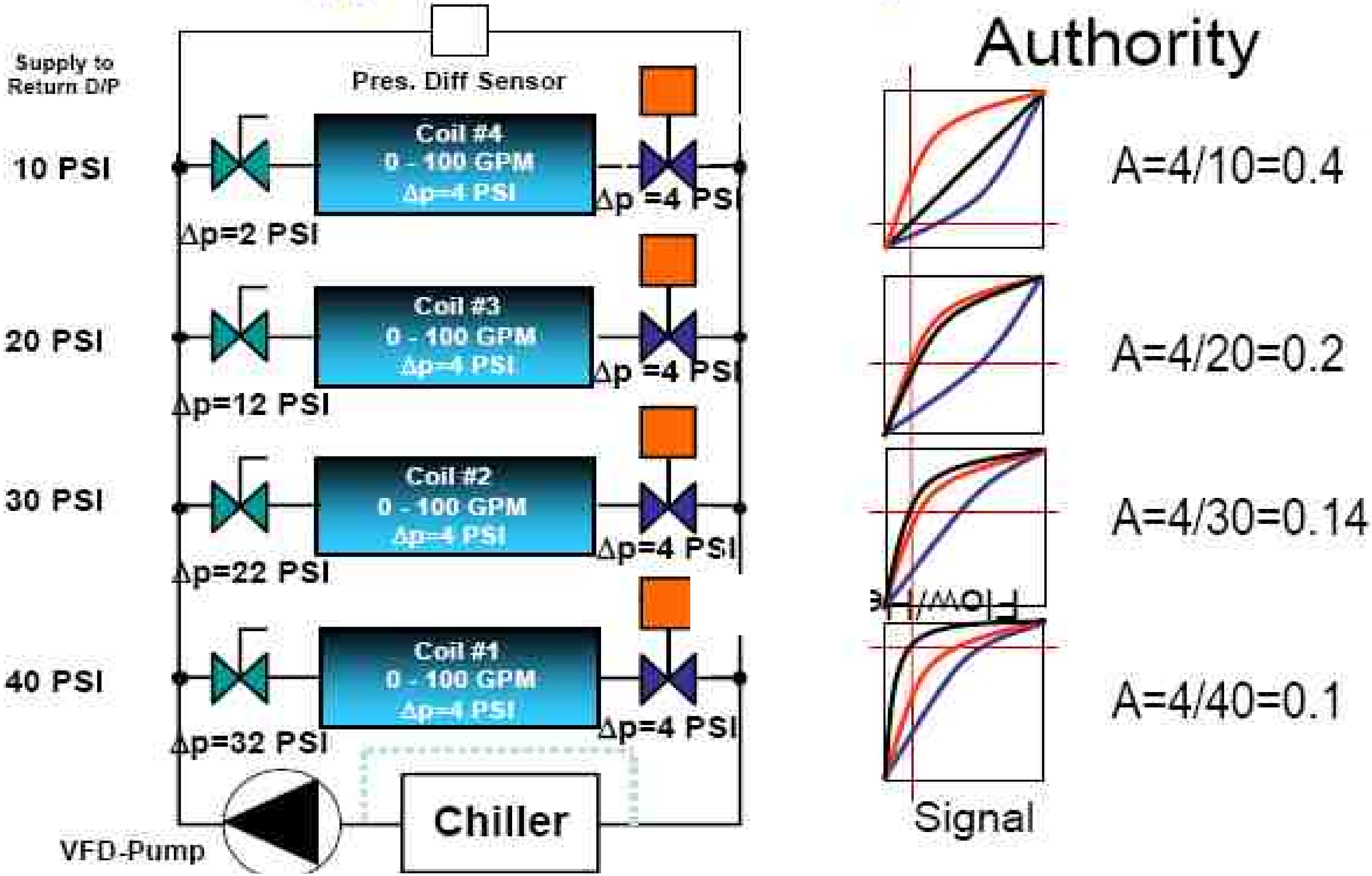


Red = Typical Coil Heat Response Curve (x = media flow, y = BTUH capacity)

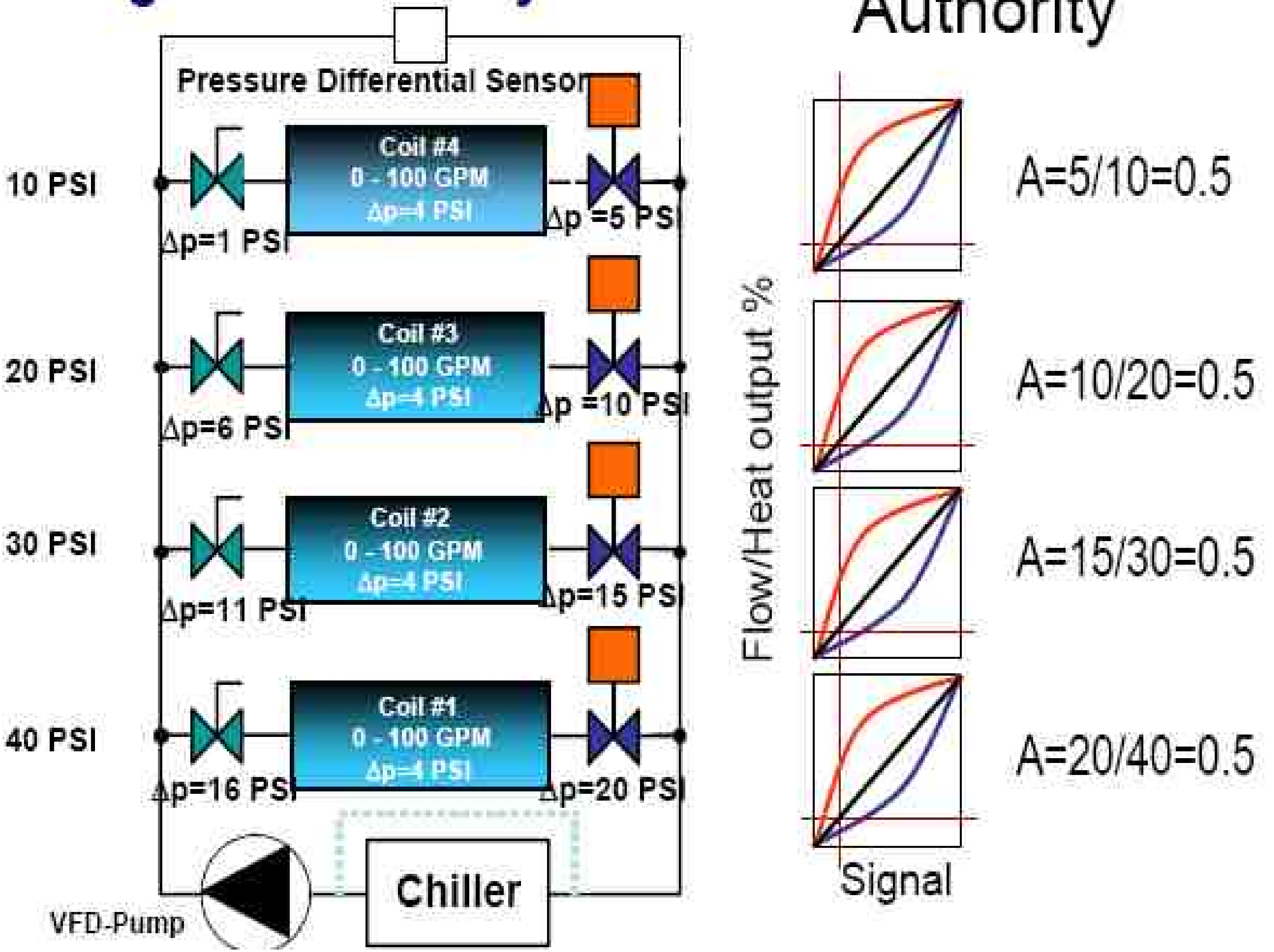
Blue = Valve Flow Response Curve (x = control output, y = media flow)

Black = Controller Output to Heat Response   (x = control output, y = BTUH

Standard Application with 2-way Valves



Sizing with Authority Method

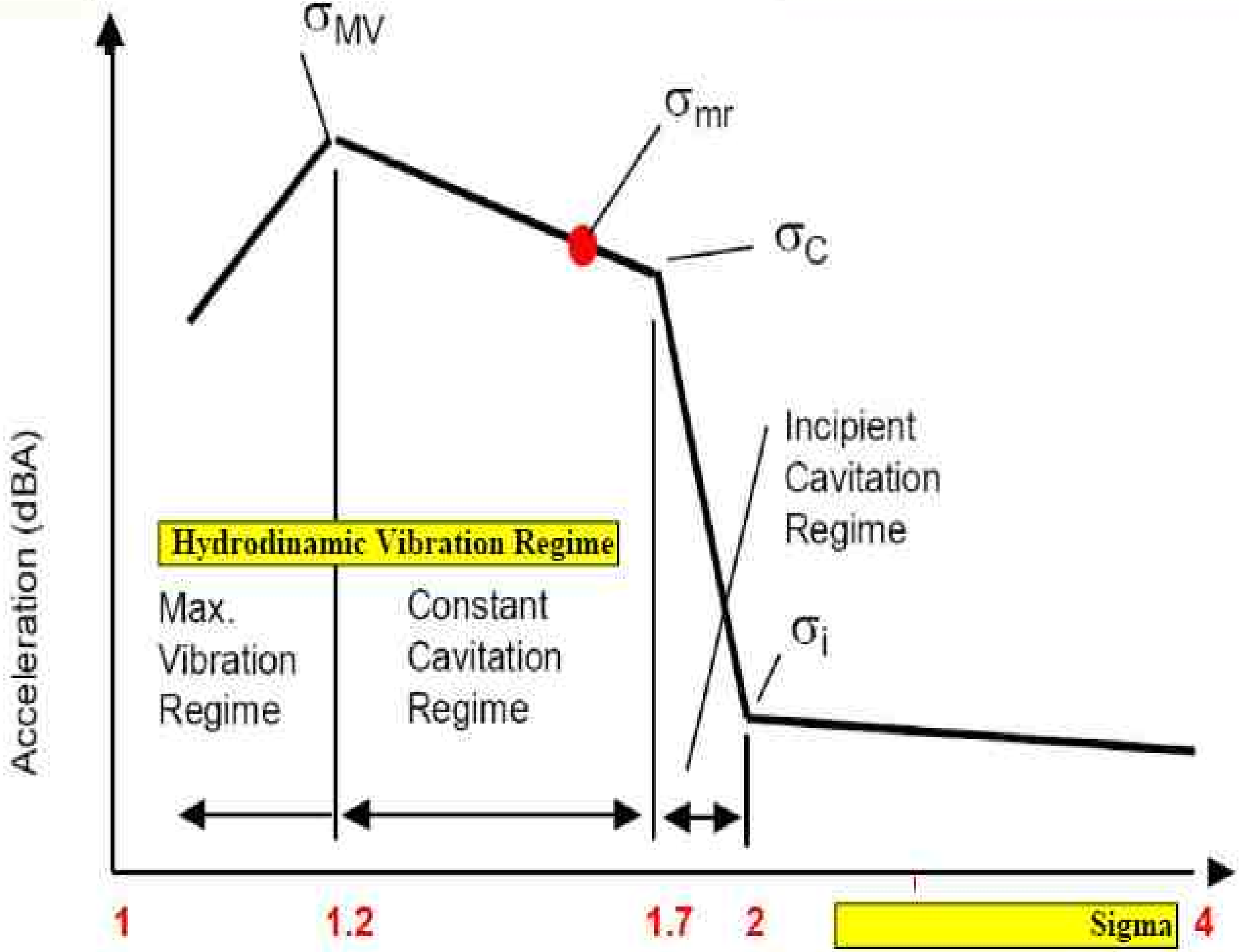


Control Valve Cavitation, Damage Control

Sigma Method

σ_i = Inception
σ_c = Constant
σ_{mv} = Maximum Vibration

$$\left(\frac{P_1 - P_V}{P_1 - P_2} \right) = \text{Sigma}$$



Severity Consideration

The Vendor shall supply the Control Valve with Cavitation Index σ**v** which lower than σ**s** and where pressure,pipeline and valve sizes scaling coefficients are applied.

- **Incipient Cavitation** (1.7< σ**s** < 1.97) - Hardness Materials, High recovery coefficient valves shall be used.
- **Moderate/ Severe Cavitation** 1.2< σ**s** < 1.7) – Special Anti-cavitation trims shall be used. (For clean fluids only).
- **Extreme Cavitation** (σ**s** < 1.2) – Multi-stage trims shall be used or valves installed in series.

Nominal values of valves sigma (σv) are as follows:

- a. Butterfly or ball - 2.0 to 2.3
- b. Globe and angle -1.9 to 2.0
- c. One/Two-gradation anti-cavitation trim - 1.2 to 1.7
- d. Multi-stage trim –-1.02 to 1.2

Fluid Velocity Considerations

Recommended limitations in Liquid applications

- Valve Body inlet velocity shall be less than 10 m/sec, for clean liquids.
- Valve Body inlet velocity shall be less than 5 m/sec, for erosive liquids.
- Valve Trim outlet velocity shall not exceed 30m/sec for clean liquids.
- Valve Trim outlet velocity shall not exceed 23m/sec for erosive liquid

Above Criteria's will be overruled by Noise Limitation

Recommended limitations Vapors & Gases applications

- Gas/Vapor Valve Body outlet velocities shall not exceed 0.3 Mach for clean fluids.
- Gas/Vapor Valve Body outlet velocities with solid particles shall not exceed 0.15 Mach

Above Criteria's will be overruled by Noise Limitation

Recommended limitations in Steam Applications

- Saturated Wet Steam Valve Body outlet velocities shall not exceed 0.15 Mach
- Saturated Dry Steam Valve Body outlet velocities shall not exceed 0.3 Mach
- Saturated Dry Steam Valve Body outlet velocities shall not exceed 150 m/s
- Superheated Steam Valve Body outlet velocities shall not exceed 0.3 Mach for carbon steel.
- Superheated Steam Valve Body outlet velocities shall not exceed 0.4 Mach for alloy steel.
- Superheated Steam Valve Body outlet velocities shall not exceed 200 m/s for carbon steel.
- Superheated Steam Valve Body outlet velocities shall not exceed 250 m/s for alloy steel.

- **Above Criteria's will be overruled by Noise Limitation**

Kinetic Energy Consideration

The Kinetic Energy (KE) is defined as follows:

$$KE = 0.5 \times 10^{-3} \rho V^2 ,$$

where, **KE** in kPa,

ρ is fluid density in kg/m^3,

V is Valve Trim Outlet Velocity in m/s

Kinetic Energy Consideration

Recommended limitations in Liquid applications

Kinetic Energy at Valve Trim Outlet shall not exceed 480 kPa for normal process.
Kinetic Energy at Valve Trim Outlet shall not exceed 40 kPa for cavitating process.

Recommended limitations Vapors / Gases & Steam

Kinetic Energy at Valve Trim Outlet shall not exceed 480 kPa for normal process.

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Noise Consideration

The maximum noise level emission from a control valve manifold shall not exceed the following limits for any specified operating condition.

85 dBA for process control/feed regulation, continuous letdown.

Noise shall be calculated in accordance with methodology outlined in ISA SP75.17 guidelines.

Control valve noise shall be treated as noted below:

- The provision of low-noise multipath multi-stage trim designs is generally most costeffective.
- Diffusers, and silencers, downstream of the valve may be used.
- A maximum of 5 dBA credit may be used for the application of insulation for noise reduction.
- Larger Valve Body size for calculated trim may be used.

Control Valve Specification

PROCESS	20	Pressure Drop @ Flow						
	21	Temperature						
CONDITIONS	22							
	23	Compressibility Factor		—				
	24	Viscosity						
	25	Specific Heats Ratio	Flashing %	—				
	26	Vapour Pressure						
CALCULATED	27	Flow Coefficient Cv	Travel %	—				
	28	Valve Inlet Velocity	Valve Outlet Velocity	m/s \ Mach				
RESULTS	29	Sigma Service / Instal	Valve Gain Ratio					
	30	Sound Pressure Level	Flow Condition	dBA				
	31	MFR / Model			56	MFR	Model	
	32	Body Type			57	Signal: Inlet	Action	

Process-Loop Performance

The control valve plays an extremely important role in producing the best possible performance from the control loop. Process optimization means optimizing the entire process, not just the control algorithms used in the control room equipment.

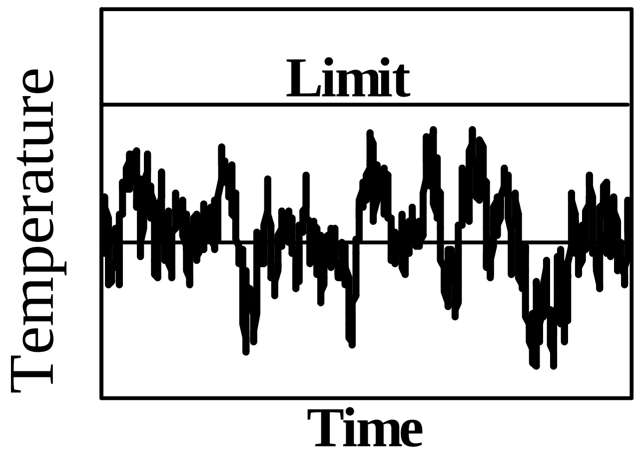
It makes no sense to install an elaborate process control strategy and hardware instrumentation system capable of achieving 0.5% or better process control and then to implement that control strategy with a 5% or worse control valve.

Economic Results

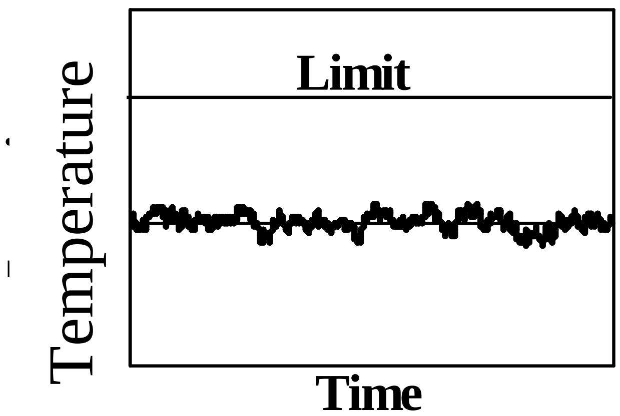
Consideration of the factors discussed below have a dramatic impact on the economic results of an operating plant.

More and more control valve users focus on dynamic performance parameters such as dead band, response times, and installed gain as a means to improve process-loop performance.

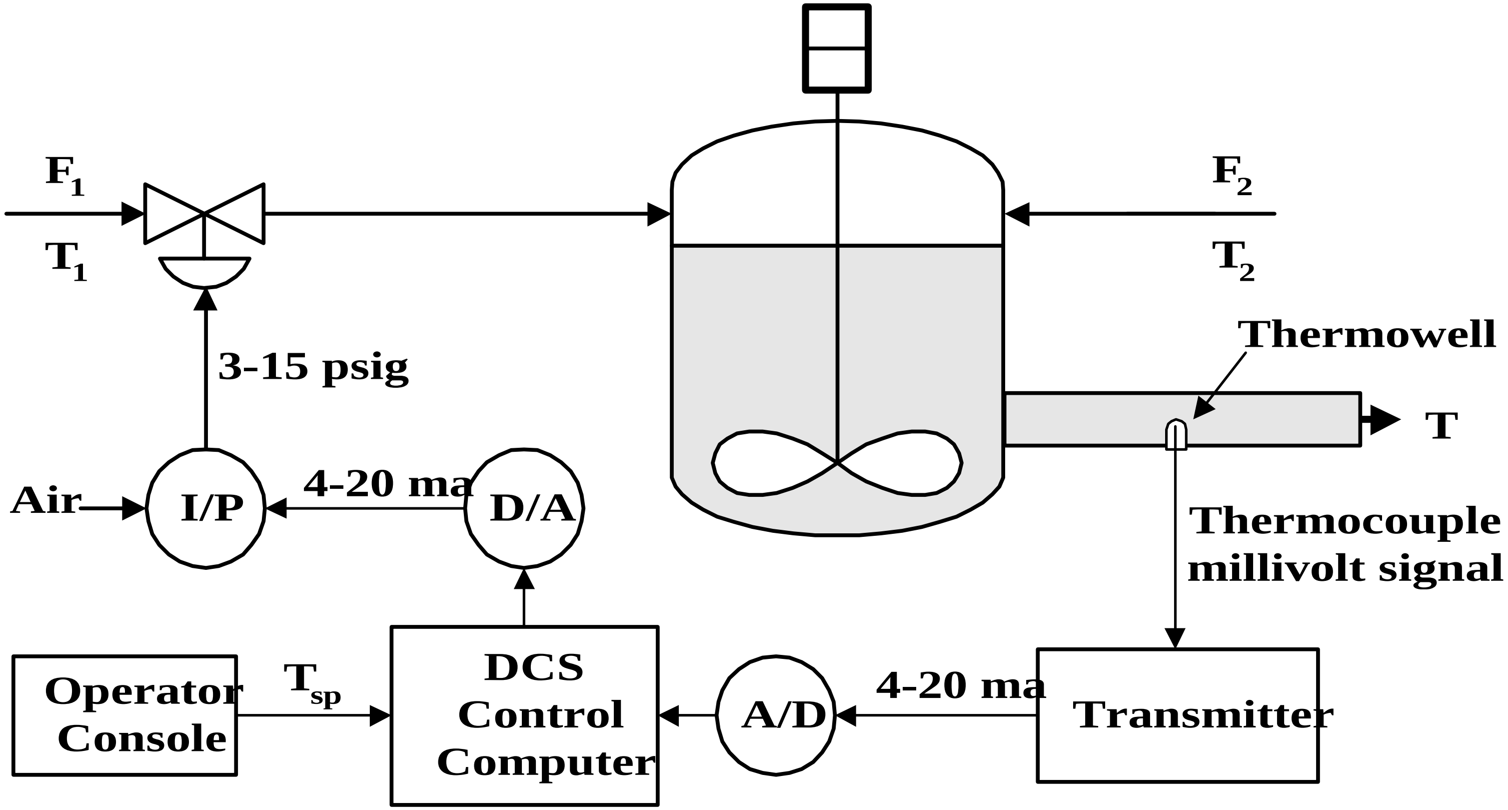
Old Controller (5%)



New Controller (0.3%)



Components and Signals of a Typical Control Loop



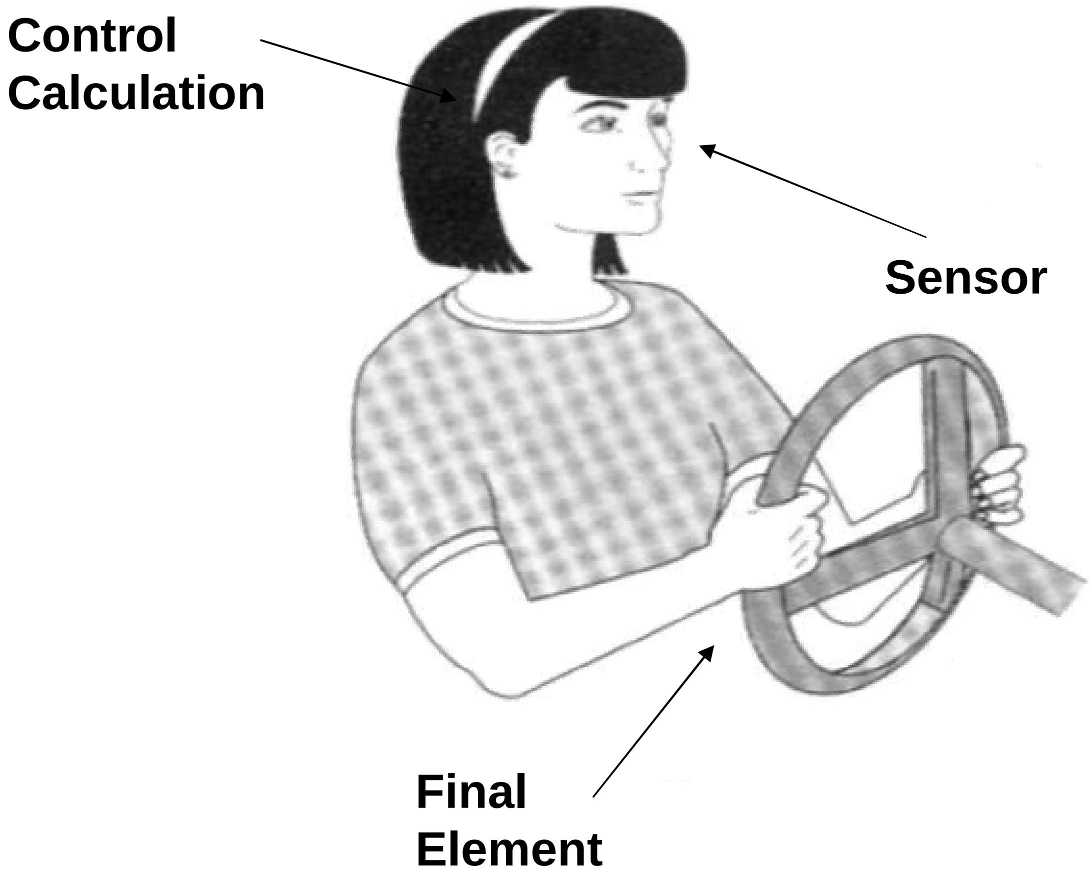
What is Process Dynamic ?

Process Dynamics is behavior of a system in un-steady & transient state.

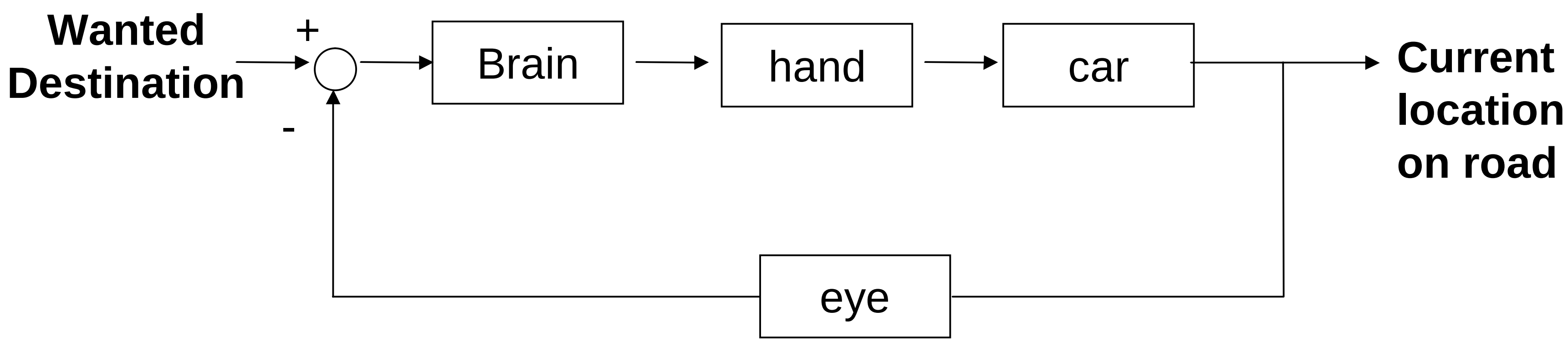
Dynamics study is required to study situations like plant start-ups and shutdowns, unusual process disturbances and planned transitions from one product grade to another.

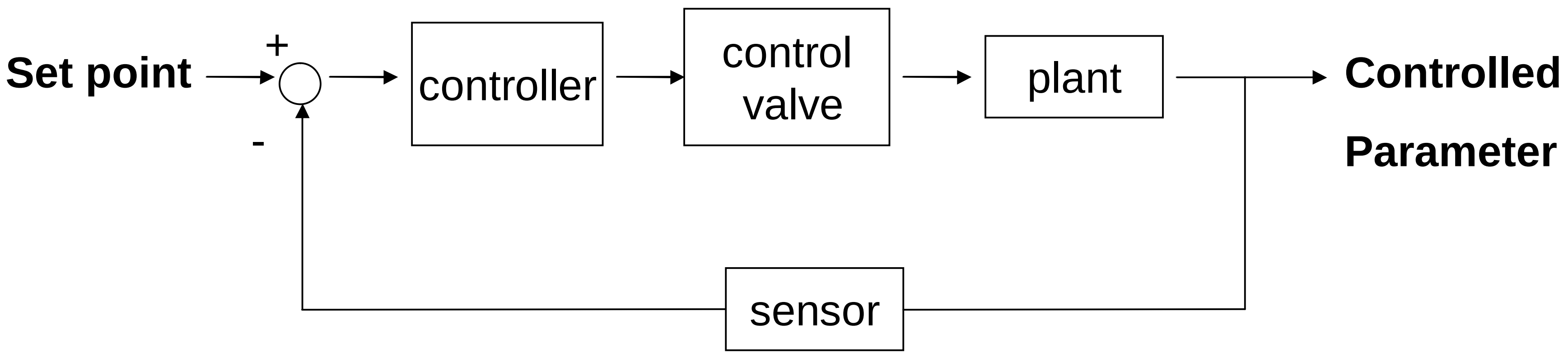
Dynamics plays an important part in deciding the control strategies for a process.

Example of Control Loop



Schematic of Feedback Loop and Car example





Control Valve Performance or
Control Valve Controllability

- **Capacity**
- **Variability**
- **Dead Band**
- **Stroking Time**
- **Valve Response Time**
- **Rangeability**
- **Resolution**
- **Gain**
- **Characteristic**

Control Valve Performance

Capacity

Capacity - The maximum flow rate through the flow

- system (pipes, valves, and process equipment) must
- meet operating requirements. Guidelines are available
- for calculating the pipe diameter for a desired flow rate,
- and guidelines are given here for the percentage of the
- system pressure drop contributed by the valve.
- The driving force for flow, i.e., the pressure,
- must be provided by a centrifugal pump or
- static pressure difference between vessels.

Control Valve Performance

Variability

Variability of 1% of mean can be considered high, 0.5% is good, below 0.3% is excellent.

Control Loop Design and Tuning Criteria needed to minimize process variability, but successful results could be achieved, by taken in consideration during Control Valve Calculation and Selection.

Control Valve Performance

Dead Band

Dead band - Upon reversal of direction, the greatest amount that the signal to the valve can be changed without a change to the valve opening (stem position).

May be variety of causes such as:

friction, backlash, shaft wind-up, relay or spool valve dead zone, etc..

Control Valve Performance

Stroking Time

A **Stroking Time** is a time which takes the valve assembly to complete its full stroke in either direction, during 100% step change in the input signal

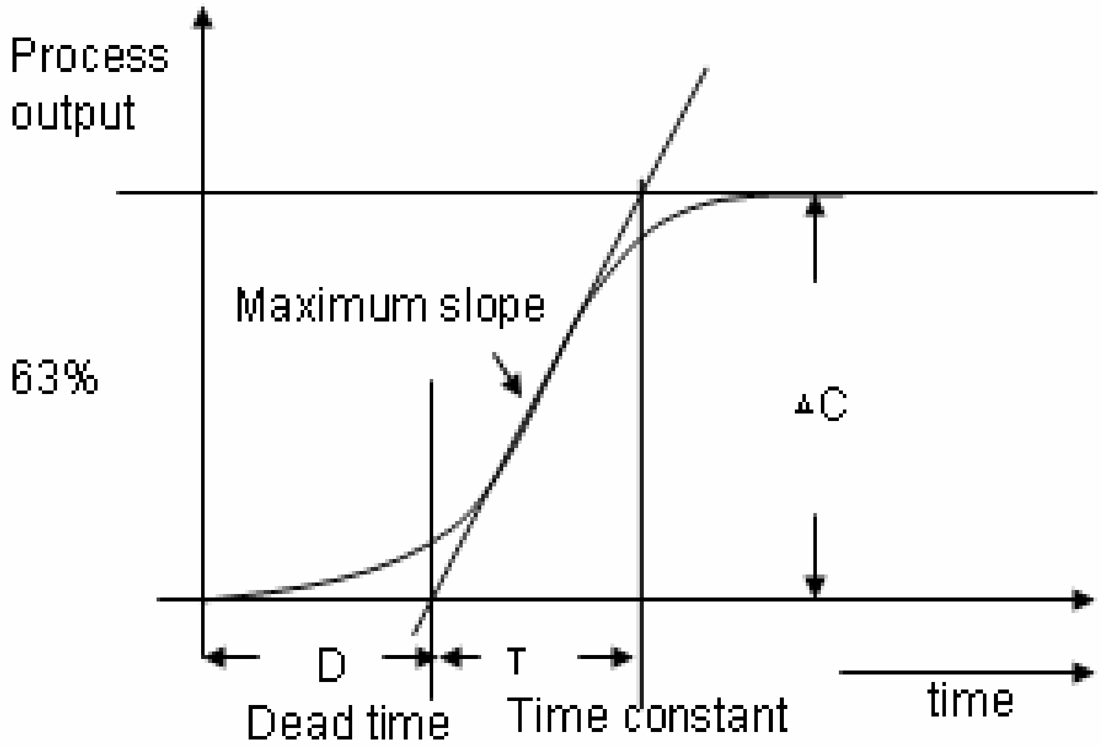
Control Valve Performance

Valve Response Time

For optimum control of many processes, it is important that the valve reach a specific position quickly. A quick response to small signal changes (1% or less) is one of the most important factors in providing optimum process control. Valve response time is measured by a parameter called T63. The dynamic time is a measure of how long the actuator takes to get to the 63% point once it starts moving.

Control Valve Performance

A Practical Example Method of Reaction Curve



Control Valve Performance

Rangeability

Rangeability is defined as the ratio of the Maximum Flow to the Minimum Controllable Flow.

Very small and large flows cannot be maintained at desired values in same valve

The most manufacturers publish a theoretical value for the Rangeability of their valves. Indeed rotating valves, like butterfly valves may theoretically achieve a 1:100 rangeability ratio. However, butterfly valves are not useful when traveling between 0% - 10% and 60% Meaning their actual rangeability ratio would not effectively go over 1:6.

Control Valve Performance

Resolution

Resolution - The smallest amount that the signal to the valve can be changed without a change to the valve opening (stem position). This change is after a change that has overcome deadband and is in the same direction.

Control Valve Performance

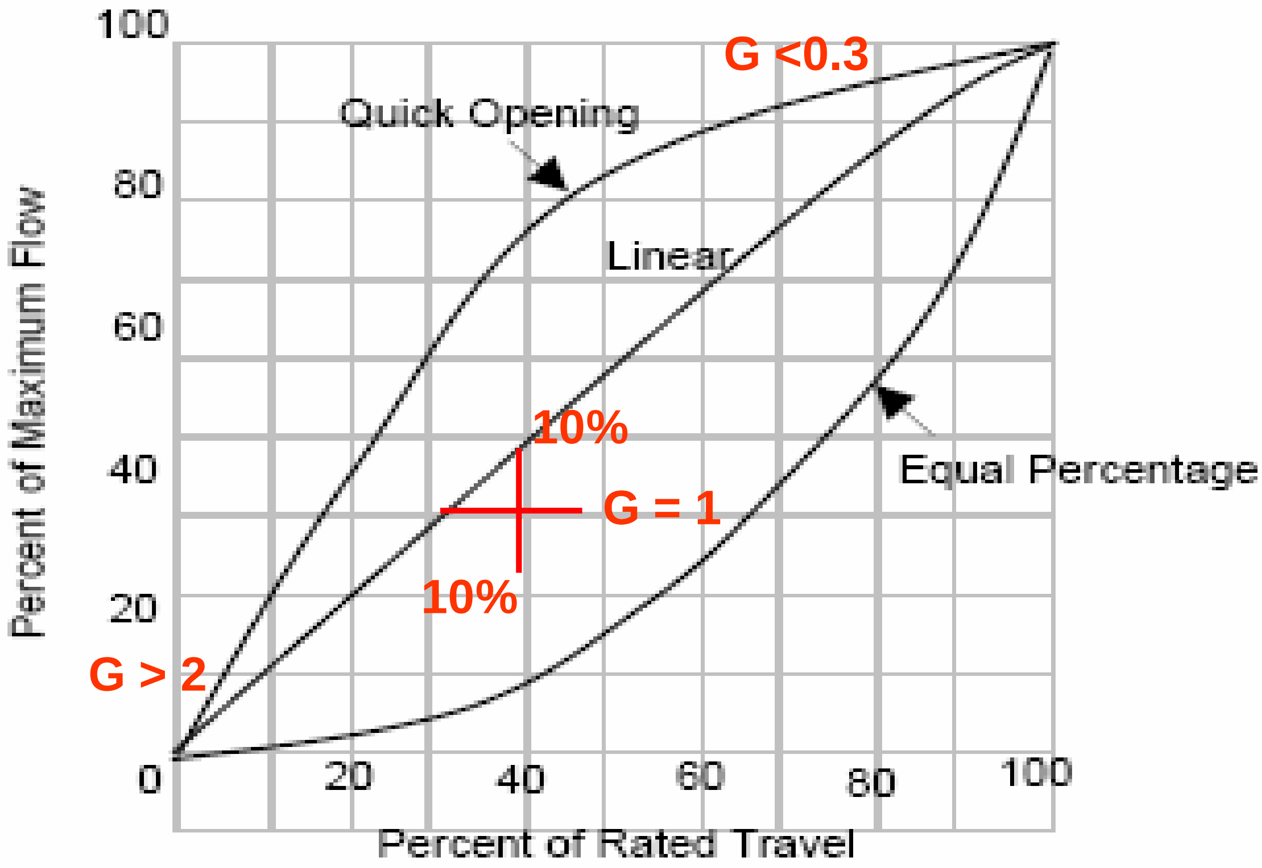
Gain

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; that is, Inherent Valve Gain = (change in flow)/(change in travel) = slope of the inherent characteristic curve.

Usually, the measured variable is expressed as a percentage of the normal range (or sensor range). If a sensor had a range of 0-200 °C, a five degree change would be 2.5%.
A typical range for the gain is 0.2 to 6 (dimensionless).

Control Valve Performance

Gain



Control Valve Performance

Gain

If *process gain* varies over the operating range of the process, determines the degree to which the control loop will be difficult to tune.
Poor tuning leads to control loop cycling and higher process variability.

To ensure good dynamic performance and loop stability for wide range of operating conditions, industry experts recommend that loop equipment be engineered so the process gain remains within the range of 0.5 to 2.0

Model

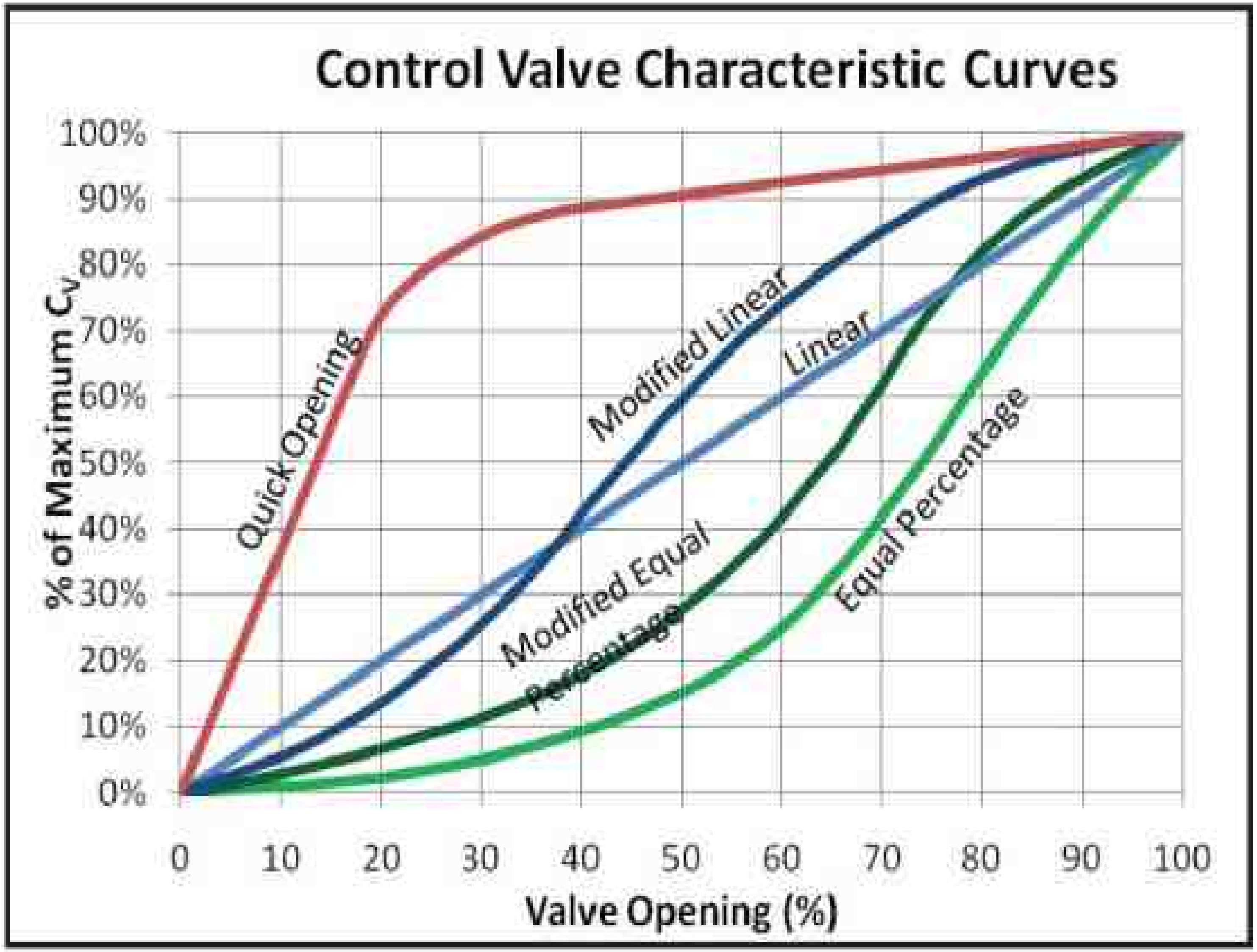
Control Valve Performance

Inherent flow characteristics

The inherent flow characteristics are determined by the valve orifice and the plug geometry.

It refers to the flow characteristic when there is a **Constant Pressure Drop** across the control valve. Typically there are three types of inherent flow characteristic: linear, quick opening and equal percentage. These flow characteristic can be represented graphically as illustrated below.

Valve Characteristics



Control Valve Performance

Installed flow characteristic

Installed Flow Characteristic refers to the flow characteristic of the control valve when the valve is installed and subjected to variable pressure drop, flow and other changes of the system. When the control valves are combined with other fluid handling

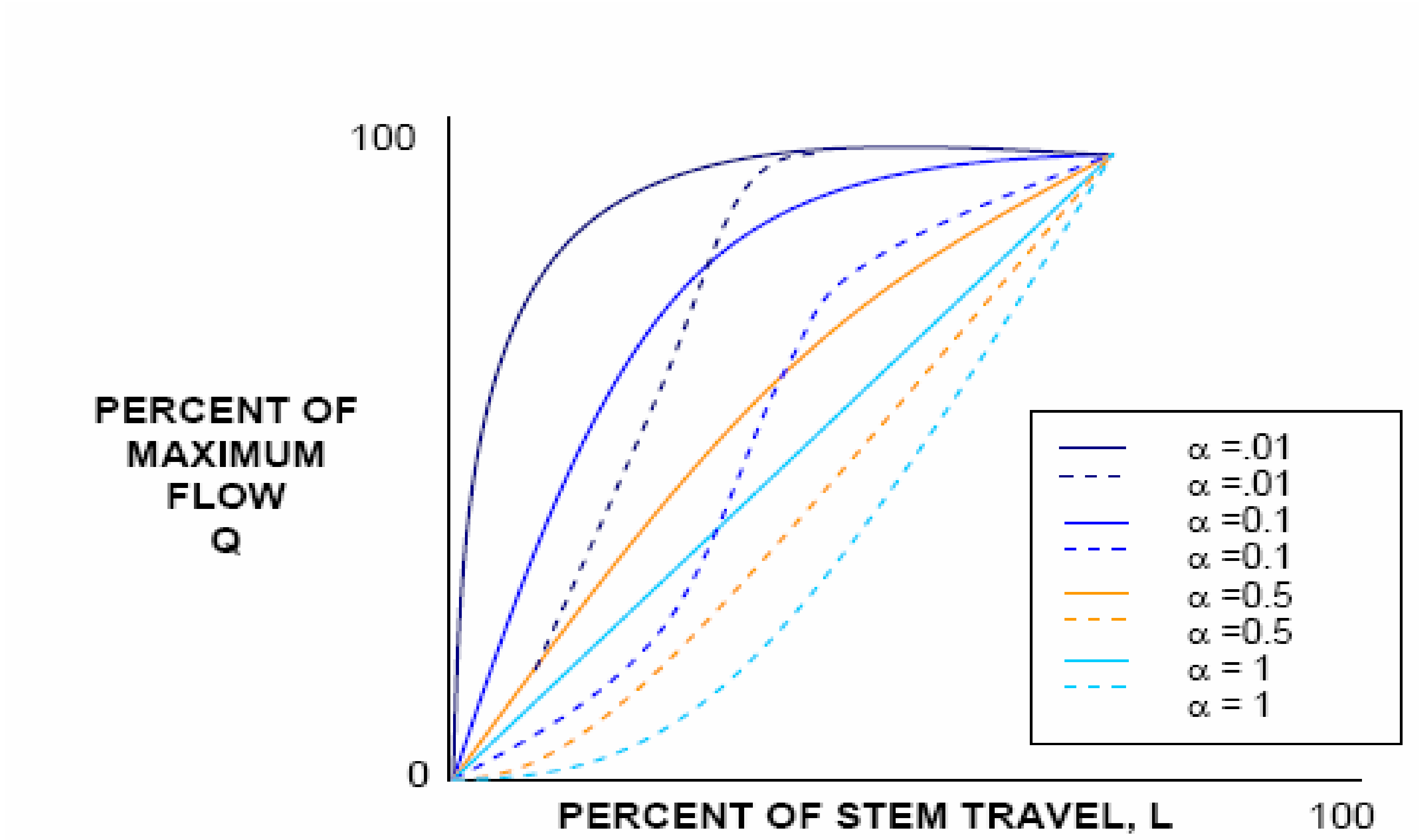
equipment in processing systems, the composite flow rate characteristics differ from the characteristics of any single component in the system. Flow rates through the

valve are no longer determined solely by the geometry of the valve body and plug.

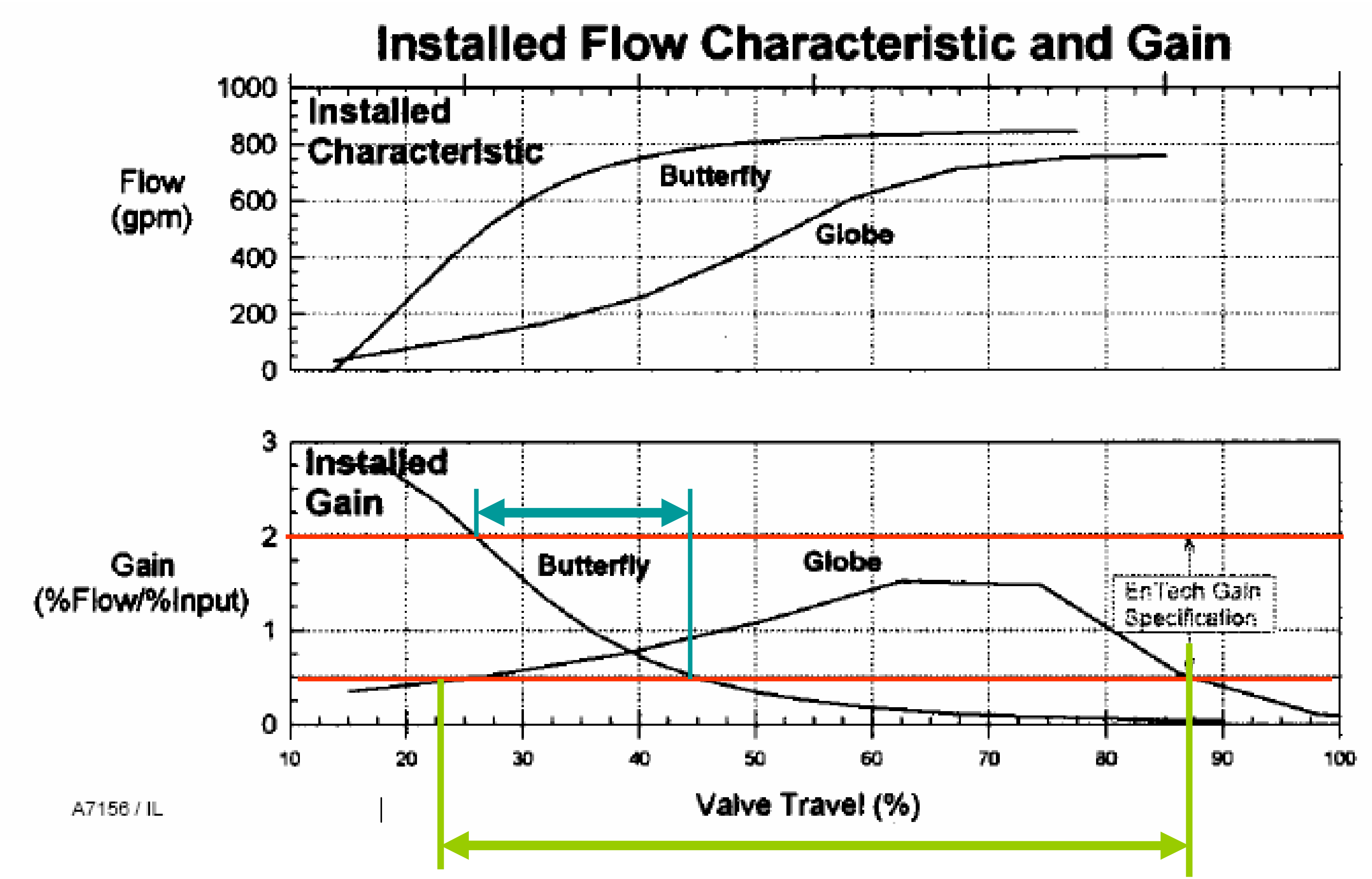
The effect of resistances resulting from pipelines, orifices, or other equipment in series with the control valve and the variation of available head with flow rate affect the flow versus stem position relationship.

Installed Flow Characteristic

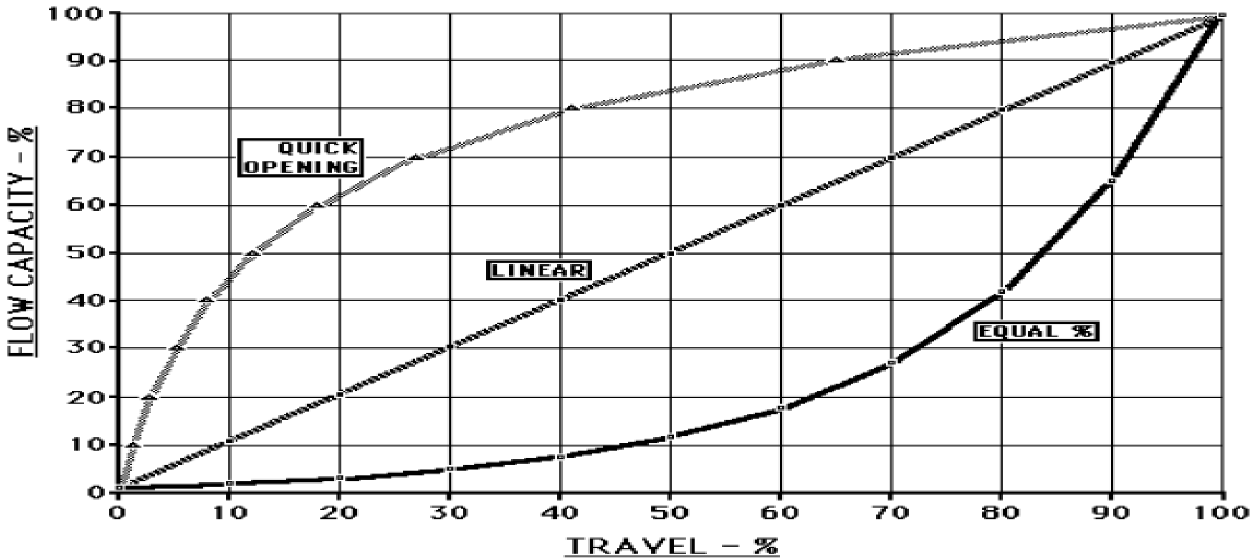
$$\alpha = \frac{\text{valve head differential at maxflow}}{\text{valve head differential at zero flow}}$$



Effect of Valve Style on Control Range



COMMON FLOW CHARACTERISTIC CURVES



PRESSURE CONTROL SYSTEMS	
APPLICATION - SERVICE	**BEST CHARACTERISTIC**
Liquid Process.	Equal %
Gas Proceses.----- Small volume. Less than 10 ft. of pipe between control valve and flow destination.	Equal %
Large volume. Receiver volume tank in system; greater than 100 ft. of pipe volume. Decreasing ΔP with increasing volume. ΔP at max. load > 20% of min. load.	Linear
Large volume. Decreasing ΔP with increasing volume; ΔP at max load < 20% of min. load.	Equal %

LIQUID LEVEL CONTROL SYSTEMS	
APPLICATION - SERVICE	**BEST CHARACTERISTIC**
Constant ΔP.	Linear
Decreasing ΔP with increasing flow. ΔP at max. flow > 20% of min. flow ΔP.	Linear
Decreasing ΔP with increasing flow. ΔP at max. flow < 20% of min. flow ΔP.	Equal %
Incresing ΔP with increasing flow. ΔP at max. flow < 200% of min. flow ΔP.	Linear
Increasing ΔP with increasing flow. ΔP at max. flow > 200% of min. flow ΔP.	Quick Opening

MISCELLANEOUS SYSTEMS	
APPLICATION - SERVICE	**BEST CHARACTERISTIC**
3-way valve or two 2-way valves used as a 3-way valve.	Linear
Compressor gas recycle.	Linear
ΔP = Constant.	Linear
Temperature control wher valve ΔP < 50% of total system ΔP.	Equal %
pH Control:----- ΔP < 50% of system ΔP.	Equal %
ΔP > 50% of system ΔP.	Linear
Heating - Cooling	Linear
Split-ranged	Linear
ON-OFF	Quick Opening

FLOW RATE CONTROL SYSTEMS			
APPLICATION - SERVICE		**BEST CHARACTERISTIC**	
FLOW ELEMENT OUTPUT SIGNAL TO CONTROLLER	**LOCATION OF CONTROL VALVE WITH RESPECT TO FLOW ELEMENT**	**RANGE OF FLOW**	
		WIDE	**SMALL***
Linear, propor-tional to flow; ie. with square root extractor.	In Series	Linear	Equal %
	In Bypass	Linear	Equal %
Non-linear, not proportional to flow; no square root extractor. Proportional to flow squared.	In Series	Linear	Equal %
	In Bypass	Equal %	Equal %

* With large ΔP change with increasing flow.

Simple Method For Selecting Valve Characteristic

Inherent flow characteristic for optimum, installed flow characteristic, which is as linear as possible.	Valve authority dp90/dp0 Qmax = 0.9 q100	Total valve authority dp100/dp0
Equal percentage IEC 534-2-4 Equal percentage up to s = 0.8	Vqmax < = 0.27 0.27 < Vqmax < = 0.31 0.31 < Vqmax < = 0.43	V < 0.15 0.25 < V < 0.3
Modified linear Linear	0.43 < Vqmax < = 0.6 0.6 < Vqmax < = 1	0.3 < V < 0.5 0.5 < V < 1

The “Smart valve” revolution

Currently, valve technology is experiencing a dramatic change. While the basic physics of valves is not changing, valves are being enhanced by the addition of microprocessors at the location of the actuator and valve body. This change makes the following features possible that were not available with older technologies.

The following assumes a **Digital Valve Positioner**.

Summary of Dynamic Performance

Performance with Smart Positioner shall be provided by Vendor as follows:

- Signal Step Resolution …….. will not exceed 0.1%Valve Static
- Dead band ……………………... will not exceed 0.1%
- Total Hysteresis ……………… will not exceed 0.2% (6% without Positioner)

Valve Dynamic Performance with Smart Positioner.

- Dead Time (**Td**)…………………will not more than 0.1 sec
- Overshooting ……………………will not more than 5% of Step Rate
- Step Response will be checked with steps of 2% and 10% in both direction around 15% , 30%, 60% of input signal range.
- Valve Response Time (**T63**) in both direction around same point of signal **shall be same.**

Traveling Time in both direction will not exceed limitation, as defined:

2 inch and under 10 seconds	6 inch 20 seconds
3 inch 15 seconds	8 inch 25 seconds
4 inch 15 seconds	10 inch 35 seconds

Cost

Engineers must always consider cost when making design and operations decisions. Valves involve costs and when selected properly, provide benefits. These must be quantified and a profitability analysis performed

Remember that the total cost includes costs of plant operations, installation , documentation, and maintenance over the life of the valve.

בחירת שסתומי בקרה מותאמים ליישום וכאלמנט סופי של חוג בקרה

בהצלחה !!!

BAZAN בזן
בתי זיקוק לנפט בע"מ