The importance of control valves

in process control applications

Contents of this seminar

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- Who-what is TOP Control?

Concepts

- Review of process control concepts : process, impact of control valve, PID controller
- Tuning methods
- Performance in a process control loop
- How the valve affects performance

Examples with different control valves

- Slow process, aggressive tuning, moderately aggressive tuning, sluggish tuning.
- Fast process, aggressive tuning, moderately aggressive tuning, sluggish tuning.

Conclusions

The impacts of the valve on the performance of a process control loop.

Questions

After each section a period will be reserved for questions.

Presentation

Top Control Inc — *Réglages MIRE Inc.*

"Since this presentation is a technical presentation I will quickly describe" Top controls and myself"

Mission

Our company helps plants to optimize process and improve performance of control systems and operation.

Clients

- any plants with control loop.
- Our clients are in Quebec, Ontario, New Brunswick and also in North Africa.

What we do: optimize process control systems

by:

- maximizing control loops performance and behavior,
- solving process control and operation problems,
- helping design or improve process control strategies,
- training technicians and engineers.

Organization

I founded the company three years ago.
Our commercial agent is Optima Control and our offices are in the Quebec City area.
Optima Control Inc., Canada Panel Inc and Assyst Inc. distribute our services.

Michel Ruel

Background

I am a professional engineer and also a process control technician. I have been working in the process control field for the last twenty years. I also teach part time in a technical college.
I wrote five books and two software programs; all of them related to process control.
I hold seminars and conferences.

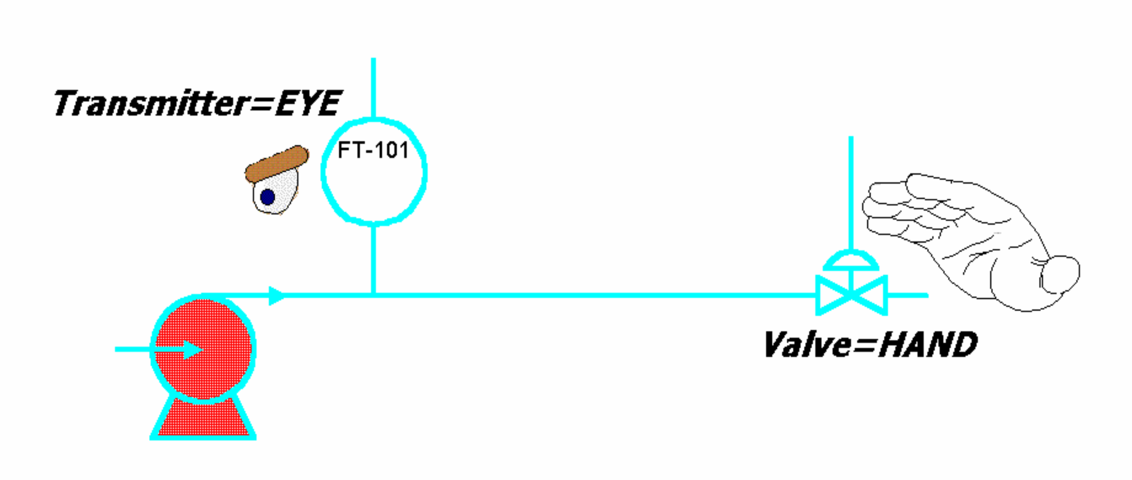
Associations

- ISA
- IEEE
- OIQ

Introduction

What is a process

A process is a sequence of operations modifying the properties of a product.
To control a process, a system is used to manipulate the flow of material or energy.



The **transmitter** is used to **look** into the process.

The **control valve** is used to **manipulate** the process.

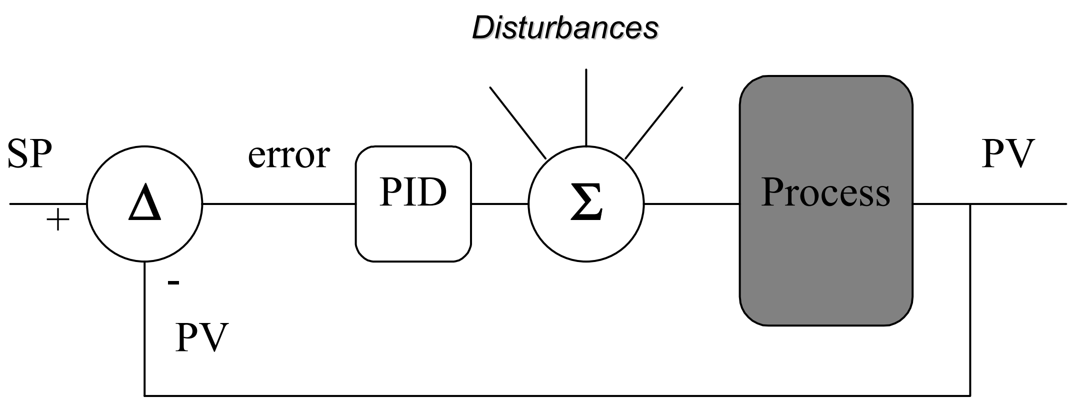
Many systems are used to feed commands to the valve. These systems compute the position of the valve or react to the deviation setpoint.

Comparison: Feedback and Feedforward

Feedback

Concept

A controller reacts to the error between the setpoint and the process value and so an error is needed to move the control signal.
If the valve moves, it implies an error has occurred.
It is impossible to obtain a straight line for the process value trend since the error drives the valve.
Tuning a loop means reducing the amount of error needed to move the valve, but ensuring the control loop is stable.



Low cost solution

Since the controller «reacts» to the error, its structure and algorithm are independent of the process and a universal controller has been developed: the PID controller.
This controller has only four parameters to choose from.

Poor performances

Since the controller «reacts» to the error, when a disturbance occurs the valve moves. An error is temporarily present and it is used to remove the disturbance. It is impossible to obtain an error free process.

Easy and simple

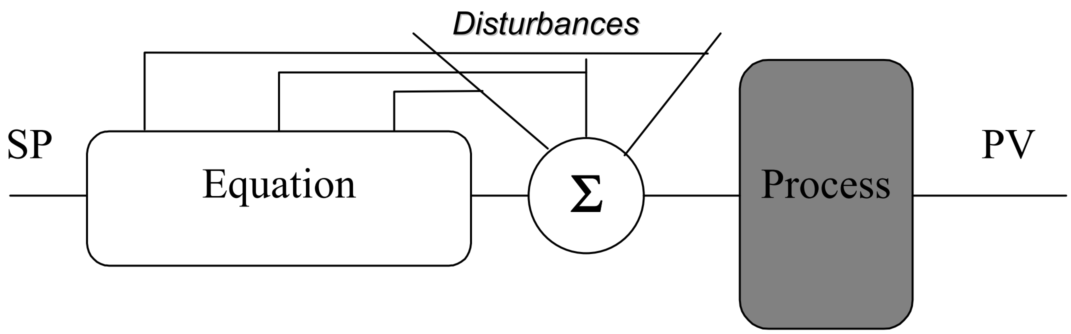
The controller, principle and control loop structure are always the same. Therefore the tuning methods are always the same.

Feedforward

Concept

A controller is designed to compute the output of the controller to ensure that the process variable is unaffected by any predictable disturbances.
The controller estimates the controller output (or position of the valve) so that the process variable won't deviate from the setpoint whatever the disturbances are.

Opposite to the feedback controller, which uses the error to correct the deviation, the feedforward controller determines how to maintain the process variable exactly at the same setpoint value.
It is possible to obtain a perfectly steady process value if the controller model is accurate.
Tuning a loop means to obtain the exact process model and to compute the necessary equations. Normally, it is necessary to measure many variables to be sure the process variable is maintained close to the setpoint.



Expensive solution

Since the controller equation is dependent on the process, the solution is unique and each controller is different. Hence a lot of computations and tests are needed to obtain the controller equation. If the process is slightly modified all the computations and tests must be done again! The algorithms used to compute these equations are very expensive. The controller is not easily tuned and the technicians and engineers must be specially trained.

Good performances

Since the controller predicts the behavior of the process, when a disturbance occurs, the valve moves exactly as needed and almost no error is present.

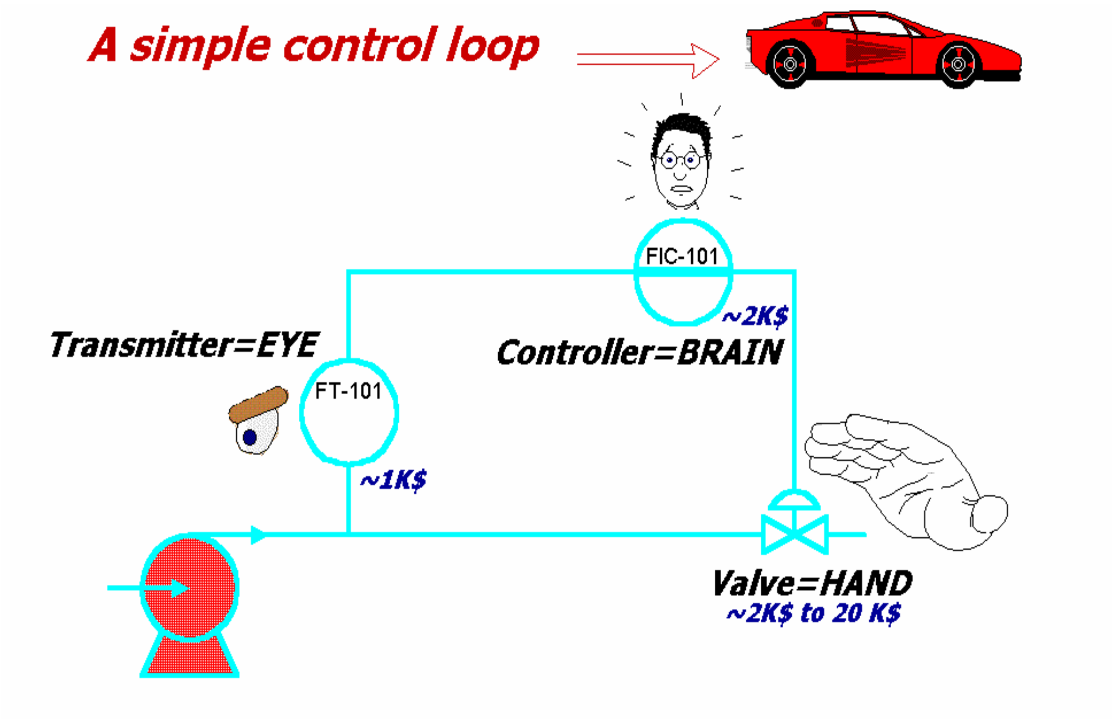
A practical solution

The feedforward is rarely used alone since a small error in the process model could destabilize the process or could drive the process variable out of setpoint.
Usually, when feedforward is used, a feedback controller is added to guarantee that the process variable be maintained close to the setpoint.
The feedforward solutions are only used when performance is essential. Economics rarely justify such an investment in money and time.

The feedback control loop

Analogy

The price of a control loop is of the same magnitude as a car. The price of the components plus the price of the installation ranges from 5000$ to 30000$.



Typically a medium size paper mills will have 500 loops X 15,000$ (Typical in P&P) = 7,500,000$

Curiously, it is common for plant personal to neglect control loops. Not surprisingly, without proper tune-ups and maintenance, control loops performances are deceiving.

Process control loop		*Human control*
Transmitter	↔	***Sight***
Controller	↔	***Brain***
Tuning	↔	***Experience, know how***
Valve	↔	***Hand***

Errors are normal: the error is used to move the valve

As previously explained, errors are parts of life with feedback controller. In such cases, the best performances are obtained:

- by reducing the time to remove a disturbance,
- by reacting quickly and strongly when moving the valve.

To obtain high performance:

- proper components must be selected, **particularly the valve,**
- the equipment must move fast, without mechanical errors,
- the components must be correctly maintained,
- the controller must be tuned tightly, using optimum tuning.

What is performance

In real life the definition can vary. Many processes have specifics needs dictated by the process itself.

A process control loop performs well if:

- the disturbances are removed quickly,
- the robustness of the selected PID parameters allows process model changes
- the stability is good, no cycling is present, the variability is low,
- the process variables reach the setpoint without overshoots,
- the errors are minimized.

The process model

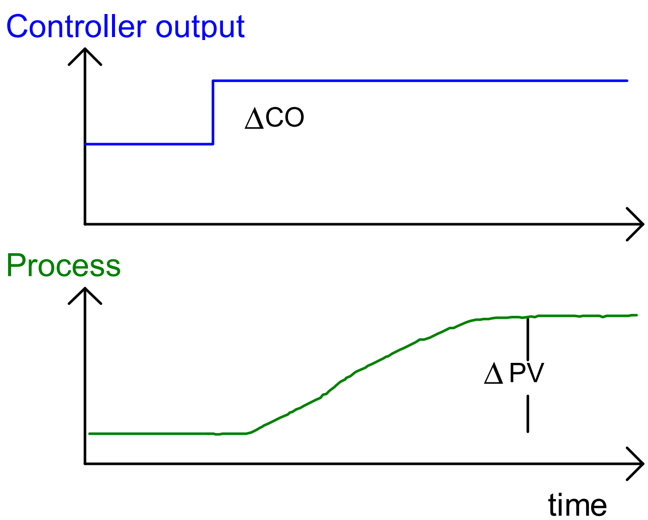
Self-regulating process

A self-regulating process stabilizes itself if the valve position is constant. When the valve is moved to a new position, the process moves and after a certain amount of time, the process stabilizes at a new value.

Sensitivity ⇒ process gain

Process gain

The sensitivity of the process is determined between two stable values. The process gain is the ratio of the process variable change over the valve position change.



$Gp = \frac{\Delta PV}{\Delta CO}$ where PV is the process variable and CO is the controller output.

Ideally, the process gain is near one. If the process gain is under one, the maximum PV won't be reached. If the process gain is too high, a small error of the valve position affects greatly the process variable; it can reduce performances and drive the process out of the setpoint.
To obtain a process gain of 1, the Cv must be carefully chosen. Since valves aren't manufactured for each application the gain will generally be greater than 1.

Linearity

Ideally, the process gain is fairly constant throughout the operating range and in all the situations. To obtain this, the inherent flow characteristic must be carefully chosen. The best way to chose an inherent flow characteristic curve is to choose it to obtain a fairly constant gain. . The best valve sizing softwares on the market allows this.

Transient response

The period of time when the process moves is called the time response. The behavior of the process during this period depends on the process model.

Dead time (td) ⇒ wait time

After the controller output is changed, the process variable won't react immediately. The dead time is the period of time the process takes to move after the initial demand.
Ideally, the dead time should be zero.

To reduce the dead time:

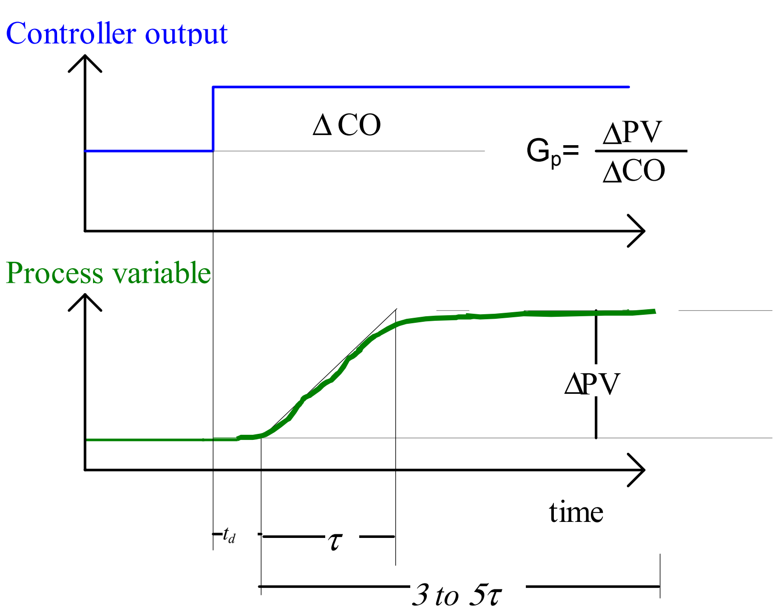
- the number of devices must be reduced,
- each piece of equipment must be fast.

Often, with fast processes, the dead time is mainly due to the valve. To improve the speed at which the valve reacts:

- the valve actuator must be strong enough,
- the supply must provide high flow for the air,
- the positioner must be properly selected and adjusted
- the use of amplifiers may even be required.

Time constant (τ) ⇒ response time

The time constant is the time the process needs would need to reach its final value if the speed obtained at the beginning of the movement is maintained at this speed gradually reduced when the process changes, the time needed to reach the final value is usually 3 to 4 times the time constant.
The time constant is also the time to reach 63% of the final value.
If the time constant is long, the controller can react strongly and move the valve quickly. Also, if a disturbance occurs, a long time constant reduces the impact on the process variable; the high capacity of the process makes it easier to controls.



Physical properties

	Process gain	Dead time	Time constant
Ideal	constant and ≈ 1	0	very large
Practical	0.5<Gp<3	1 sec to minutes	small to large

Non linearities

A real model does not fit perfectly a mathematical model. Typically, the dead time and the time constant are not constant and vary with the process variable, the load or the time.
The process gain is usually not constant, and if it is, the process sensitivity varies.

The control valve effects

The control valve usually introduces non-linearities into the process.
These non-linearities are:

	Time dependant	Amplitude dependant
Dead time	**Yes**	**Yes**
Time constant	**Yes**	**Yes**
Positioner overshoot	**Yes**	**Yes**
Hysteresis	**Yes**	**Yes**
Stiction	**Yes**	**Yes**
CV		**Yes**
Inherent characteristic curve		**Yes**

Hysteresis

Hysteresis mainly originates from mechanical backlash but it also includes all valve non-linearities ex: O-rings, packing friction etc…. The position of a valve with hysteresis is not the same when the signal is increasing and when the signal is decreasing. Valve hysteresis will introduce cycling perturbation and the performances decrease.

Stiction (stick + friction)

Stiction usually originates from the packing, o-rings and seats. A valve with stiction will not move unless the new signal is large enough to break the friction force. If an actuator is too weak, the problem is more visible.

Positioner overshoot

When a positioner overshots, the process variable moves too far and returns later at the final value. This overshoot can destabilize the control loop. This is important if the loop is fast.

Impact of the valve on the process model

If a process is fast (flow, pressure,…) the dynamic response of the valve is significant.
Hysteresis, stiction, CV and inherent characteristic are always a concern.

The PID controller

The PID controller is well known and is made of four parts:

- Proportional : reacts to the error,
- Integral : reacts to the duration of the error,
- Derivative : reacts to the speed of the error.
- Filter : smoothes the data.

Proportional : error

The proportional mode is the main part of the controller. The output of the proportional is the error times the proportional gain.

$Out_p = Kp * E$. **Output proportional to the error.**

If *Kp* is too high, the valve moves too much and the process variable cycle around the setpoint.
If *Kp* is too low, the valve moves too little and the process variable is not maintained near the setpoint.

Integral : duration

The integral mode is needed to remove an offset caused by the proportional mode. The output of the integral is the integral of the error times the integral gain.

$Out_i = Ki * \int E \mathrm{d}t$. Output proportional to the integral of the error.

Or

$\frac{\mathrm{d}Out_i}{\mathrm{d}t} = Ki * E.$ **Speed of output proportional to the error.**

If *Ki* is too high, the valve moves too much and the process variable cycles around the setpoint.
If *Ki* is too low, the valve moves too little and the process variable returns to the setpoint very slowly

Derivative : speed

The derivative mode is used to improve the speed of response. The output of the derivative is proportional to the speed of the error.

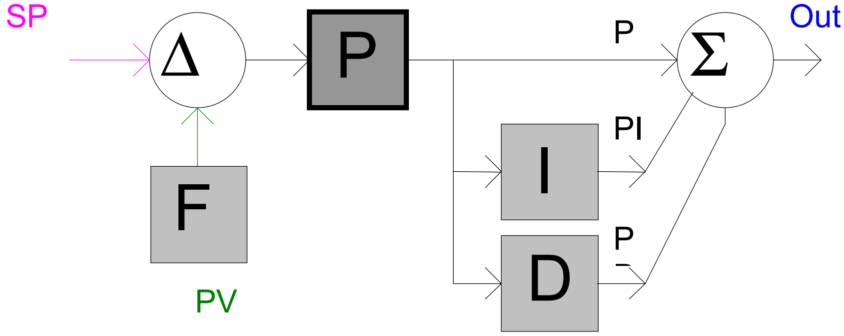
$Out_d = Kd * \frac{\mathrm{d}E}{\mathrm{d}t}$. **Output proportional to the speed of the error.**

If *Kd* is too high, the valve moves too much and the process variable cycles around the setpoint.
If *Kd* is too low, the valve moves too lttle and the speed is slow.

Filter : smoothes the PV

The filter is used to remove the noise. The parameter to adjust is the time constant τ.
If τ is too high, the controller doesn't receive the process variable immediately and this increases the equivalent dead time.
If τ is too low, the noise is not removed and the controller output also contains noise abusing final elements like valves.

	Proportional	Integral	Derivative	Filter
Output proportional to	Error	∫Error	Speed of error	
Goal	Correct error	Remove offset	Improve speed	Reduce noise
Disadvantage	Offset	Overshoot, Slow down	Sensitive to noise	Increase dead time
Parameter Alternate parameter	*Kp* Prop Band=1/*Kp*	*Ki* *Ti* = 1/*Ki*	*Kd* *Td*	τ



P is the main parameter, the others (F, I, D) are present to help the proportional.

Tuning a PID controller

Goal : Balance performance and stability.

Performance

Use the maximum gains (P, I, D).

Stability

Use low gains (P,I,D).

Robustness

A loop is robust if the stability is maintained when the process characteristics change.

Performance ⇔ Robustness

A loop is part of a system

A person tuning a PID controller acts as an orchestra conductor rather than a musician. Before tuning a loop, the entire process behavior must be considered because many loops are interrelated.
Rules:

- from the fastest to the slowest, the fastest loops are tuned first, leaving the others loops in manual; when a loop is tuned, they are left in automatic and consider as part of the process itself for the outer loops;
- loops affecting other loops; the slowest must be at least five times slower than the preceding;
- loops in parallel (stock mixing) must be tuned at the same speed.

Tuning a loop

To tune a PID controller, it is necessary to bump the process:

- test how the process reacts after a disturbance or a change in the controller output, in manual mode;
- try parameter values in the PID controller and observe the behavior of the loop.

The tests can be made by hand (trial and error, formulas) or with the help of a software program.

Preliminaries

- Understanding the process
- Operating the process
- Tests to determine if the loop operates properly :
    - Manual mode (preferred), bump tests
      sticking, hysteresis, positioner overshoot,
      process gain, noise band,
      linearity, asymmetry;
    - Automatic mode
      constant period,
      damped sine wave (distorted?),
      cycling;
- Choices
    - Performance : response time, overshoot, stability, error minimized, …
    - Speed : same as another loop, faster/slower than another loop, fastest;
    - Robustness: constant process model?

Analysis

Time analysis

Process conditions

	Process Pumps, piping, …	**Valve**	**Others** Transmitter, I/P, …
Process gain	√√√	√√√	√
Hysteresis		√√√	√
Stiction		√√√	
Linearity	√√	√√√	√
Asymmetry	√√	√√√	√
Noise	√√	√	√

Many tools (statistical, time series analysis) are available to find the above values, to analyze and to predict their effects.

Frequency analysis

Power spectrum

The power spectrum analyzes the frequency content (process variable and control output). Using such a tool, we can find if other loops induces cycling; if mechanical equipment vibrates, if the loop can eliminate the disturbances, …

Bode plot

The Bode plot is useful to analyze the process parameters, to find the process model, to compute the tuning parameters (P, I, D, F) and to predict the behavior of the process.

Other

Other tools are available to analyze the process and the loop: Nyquist plot, Nichols plot, and robustness plot.

Process model

The process model is estimated for the worst case (process conditions, maximum dead time, maximum process gain, and minimum time constant) and the tuning parameters are chosen according to the performance criterion selected.

Worst case	**Process model**
	↓
Speed, overshoot, other loops, … Stability, robustness	**Performance criterion**
	↓
PI or PID, special functions	**Tuning parameter**
	↓
Tests in automatic mode	**Performance obtained**

Four 3 rule

	Practical	Ideal	How (valve impact)
Process gain	$Gp < 3$	**1**	**Choose the correct CV**
Linearity	$\frac{Gp_{\max}}{Gp_{\min}} < 3$	**1**	**Choose the appropriate inherent characteristic**
Hysteresis	$Hyst < 3\%$	**0**	**No backlash, A strong actuator** **Properly selected conventional or smart positioner**
Noise band	$N.B. < 3\%$	**0**	

Process gain

If too high, the valve problems are emphasized; the controller must be detuned; the performances are greatly reduced.

Solution: **rerange the transmitter or**
reduce the Cv.

Linearity

The loop must be tuned at the point where the *Gp* is maximum. At the point where the *Gp* is minimum, the performances will be reduced.

Solution: **change the inherent valve characteristic or**
linearize the PV (using a segment characterizer or an equation).

Hysteresis (including stiction)

If too high, the dead time is increased when the amplitude of the control output is small. This increasing dead time increases the period; hence, as the process variable returns near the setpoint, the period (of the damped sine wave) increases. This effect destabilizes the loop.

Solution: **repair the valve/positioner or**
use a stronger actuator.

If the valve sticks, the controller output will increase gradually until the valve moves. If the stiction is important, the valve moves too much and the controller output decreases gradually and the same phenomenon repeats. The controller output trend is like a sawtooth and is a good indicator of sticking or valve oversized.

Noise

If the noise is too high the loop must be detuned. The controller amplifies this noise and the controller output induces unnecessary movements to the valve. The valve life is greatly reduced.

Solution: **remove the noise source or**
use a filter.

If the valve actuator is weak, the process noise causes the valve to move. This movement increases the noise.

The time scale

It is possible to compute the tuning parameters and the control loop periods from the process model. All these values are related to the dead time. So, if the dead time increases (stiction, hysteresis, more devices, response time from a device, …), the performances decrease and the tuning parameters must be reduced. For example, the filter time constant must be chosen smaller than the dead time but the damped sine wave (process value) will be many times the dead time.
Another example is the minimum period of a disturbance, which can be rejected by the control loop; this period is necessarily longer than the damped sine wave.

Values related to dead time

If a controller is tuned to reach performances (not sluggish), then the performances are directly proportional to the equivalent loop dead time.

Dead time

o ———————————————————————————— **t (s)**

Sampling period
Filter time constant
Derivative time
Shorter than dead time

Disturbance period rejected
Damped sine Wave
Integral time
Longer than dead time

Dead time, does it really matter?

The dead time is the enemy of the performance!

To obtain performance, the **dead time must be reduced** and the **controller must be tuned**.
If the controller is not properly tuned, the effect of the dead time is irrelevant.
For example, in a consistency loop where the dead time is 5 seconds and the valve adds 2 or 3 seconds, it really matters if the loop is properly tuned but it doesn't matter if the tuning is sluggish!

If the tuning is moderately aggressive, the performance will be decreased by more than 30 % if the valve adds 3 seconds dead time.

If a process is slow (long dead time) it doesn't matter if the valve is slow. For example in a basis weight control loop (properly tuned, but not at all aggressive) where the dead time is 15 minutes, if the valve adds 10 seconds, the impact on performance is less than 1%.

Typical values

	Typical dead time	**Approximate effect on the performance if the valve adds a 1 s dead time**		
		Tightly tuned loop	Sluggish loop	Very Sluggish loop
Flow	1 s	-100 %	-30 %	negligible
Pressure	1 s	-100 %	-30 %	negligible
Speed	2 s	-50 %	10 %	negligible
Consistency	5 s	-20 %	-1 %	negligible
Level	30 s	-3 %	negligible	negligible
Temperature	100 s	-1 %	negligible	negligible
pH	100 s	-1 %	negligible	negligible
Basis weight	500 s	-0.2 %	negligible	negligible

In North America, most of the loops are not properly tuned and a slow valve does not affect the control loop performance.

Valve requirements

	Characteristic	Main impact	Goal
Size	Cv	Process gain	Near 1
Linearity	Inherent characteristic	Process gain	Fairly constant with load
Precision Strength	Actuator, Assembly, Positioner Tubing Valve friction	Hysteresis Stiction Overshoot Dead time Process gain Imprecision	< 1%, < 1%, <20%, <<<< Fairly constant < 1%

	Process			Loop			
Valve Characteristics	Process gain	Non-linearity	Dead time	Speed	Stability	Precision	Performances
High Cv	↗				↘		↘
Bad inherent characteristic		↗			↘		↘
Hysteresis	↘	↗	↗	↘	↘	↘	↘
Stiction		↗	↗	↘	↘	↘	↘
Dead time			↗	↘	↘		↘
Time constant			↗	↘	↘		↘
Large overshoot			↘	↗	↘	↘	↘
Weak actuator		↗	↗	↘	↘	↘	↘

Design and realistic values

To select the valve and his actuator for an application, it is essential to select and compute the parameters using real data.
For example, the flow and pressures (before and after the valve) must be carefully estimated and computed to ensure that the Cv and the inherent characteristic will be adequate. Often, the chemical engineer adds 50 %, the mechanical engineer add 30 %, the salesman adds 30 % and so on… So, it's not a surprise to find process gains over 3, equal percentage valve working at 50 % opening, but 17% of their real maximum capacity!

Using the good data and realistic estimates are the first steps in a good design. And unfortunately one of the most neglected.

Speed

When is a fast response valve is needed

- **Fast loops AND tuned aggressively or moderately AND performance is a concern**

How to obtain speed when choosing the valve

- Positioner correctly adjusted (tuned) and sized, the output flow should be appropriate, new smart positioner also properly sized and adjusted.
- Supply pressure at the maximum pressure permitted,
- Pressure regulator with appropriate flow characteristics, if a pressure regulator is needed,
- Large diameter tubing (or pipe) have shown to give significant improvement,
- Strong actuator.

Performance ⇔ low price

Strange paradoxes

- **Loops are tuned sluggishly and people are asking for quick response from the valves.**
- *It's like a person very very careful, driving a performing Ferrari.*
- *The road may be good, the engine is powerful, the tires amazing, but if you don't «demand» from the car, you won't achieve performance!*
  If a loop is not properly tuned, you won't achieve performance even if you have the best hardware. You will not request the available performance like the careful driver will still take one hour to drive 80 km even with the fastest car on earth.

Precision

When is precision needed

- **Performance is a concern AND the loop is stable (properly tuned).**

How obtaining precision when choosing the valve

- Positioner correctly adjusted and sized or new smart positioner also properly sized and adjusted.
- Supply pressure at the maximum pressure permitted,
- Strong actuator.
- Mechanical links correctly installed to remove hysteresis.
- Packing properly chosen to reduce stiction.

Strange paradoxes

- People want high performance, buy huge DCS, buy quick valves with expensive actuators but their loops are not properly tuned.
- *It's like not investing the extra time and money to adjust the Ferrari ignition. Why buying such an expensive equipment? Don't forget your old equipment properly tune with modern techniques will most of the time give you performance you have never seen before!*

Stability

When is stability needed

- Always! The loop must be tuned, the devices must function properly.

How to obtain stability when choosing the valve

- by using the correct valve and properly calculated Cv,
- by removing non-linearity : inherent characteristic, hysteresis, stiction,
- by having good mechanics : no backlash, no stiction, no weak parts,
- by using positioner correctly adjusted and sized or new smart positioner also properly sized and adjusted
- by choosing strong actuator,
- With fast loops, reduce dead time and time constant (valve).

Strange paradoxes

- People want high precision and performance, they invest in expensive equipment, like performing control valves with expensive actuators and positioner but their loops are not tuned.
- *It's like driving a Ferrari with a poorly tuned engine. Results : the car isn't performing, it consumes more fuel than necessary, the engine is abused and overheating, it pollutes the atmosphere. Does it sound like some of our industrial processes?*

Examples

Tuning parameters

The tuning parameters for the following experiments were obtained using a loop analyzer software with the process model specified. These experiments confirm consistent results :

Choice of tuning parameters	Goal	Pro	Con
Aggressive	Reduce the impact of a disturbance	Performance	Not robust, if the process characteristics vary, the stability may be lost
Moderately aggressive What we recommend in most of the cases	Good balance between performance and stability	Performance and robustness. Same robustness for any process	
Lambda tuning	Simple method used in the pulp and paper industry	Simple Good results only with dead time dominant processes	Usually sluggish tuning, Stable but without performance.

The derivative is not used in the simulation since the Lambda tuning does not use it. With moderately aggressive tuning, using the derivative can increase the performance by more than 50% with many processes. Also, using the derivative reduce the impact of the control valve problems.

Flow process

A flow process having the following characteristics is used to determine the effect of the valve characteristics.
The process model is: Gp = 1; td = 3s; tau = 1s.

The process is tested for :

- a setpoint change from 60% to 50%,
- a load change of 20%.

The following valves were used :

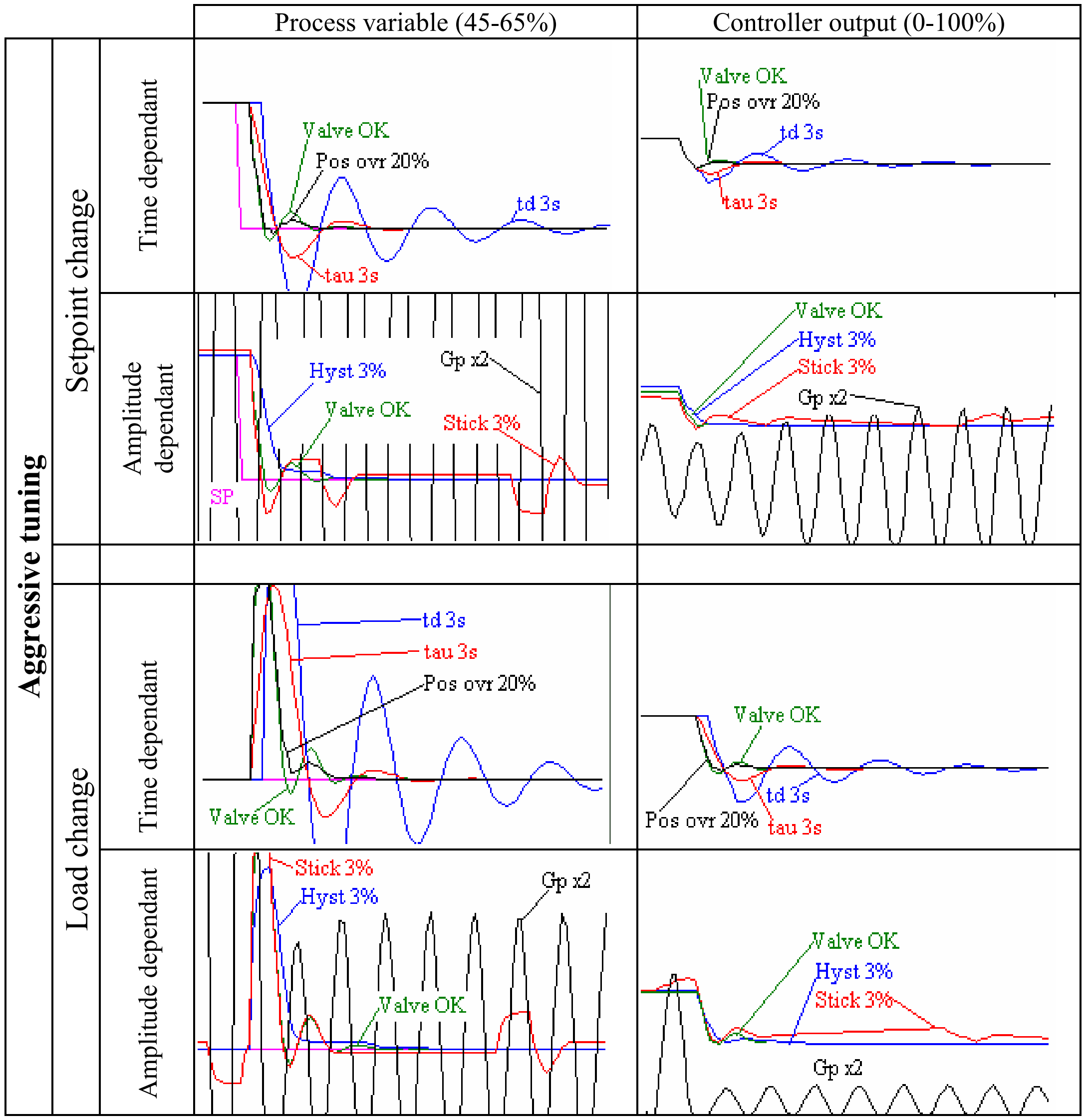
• Perfect valve	
• Time dependant characteristic	With a dead time of 3 s
	With a time constant of 3 s
	With a positioner overshoot of 20 %
• Amplitude dependant characteristic	With hysteresis of 3 %
	With sticking of 3 %
	With a Cv twice the required value

A flow process reacts quickly, the valve characteristics are important and this type of process has a dominant dead time (td>tau).

Flow processes are the most common in plants and are usually tuned too sluggishly.

Flow process. Aggressive tuning

Each graph, 100 seconds.



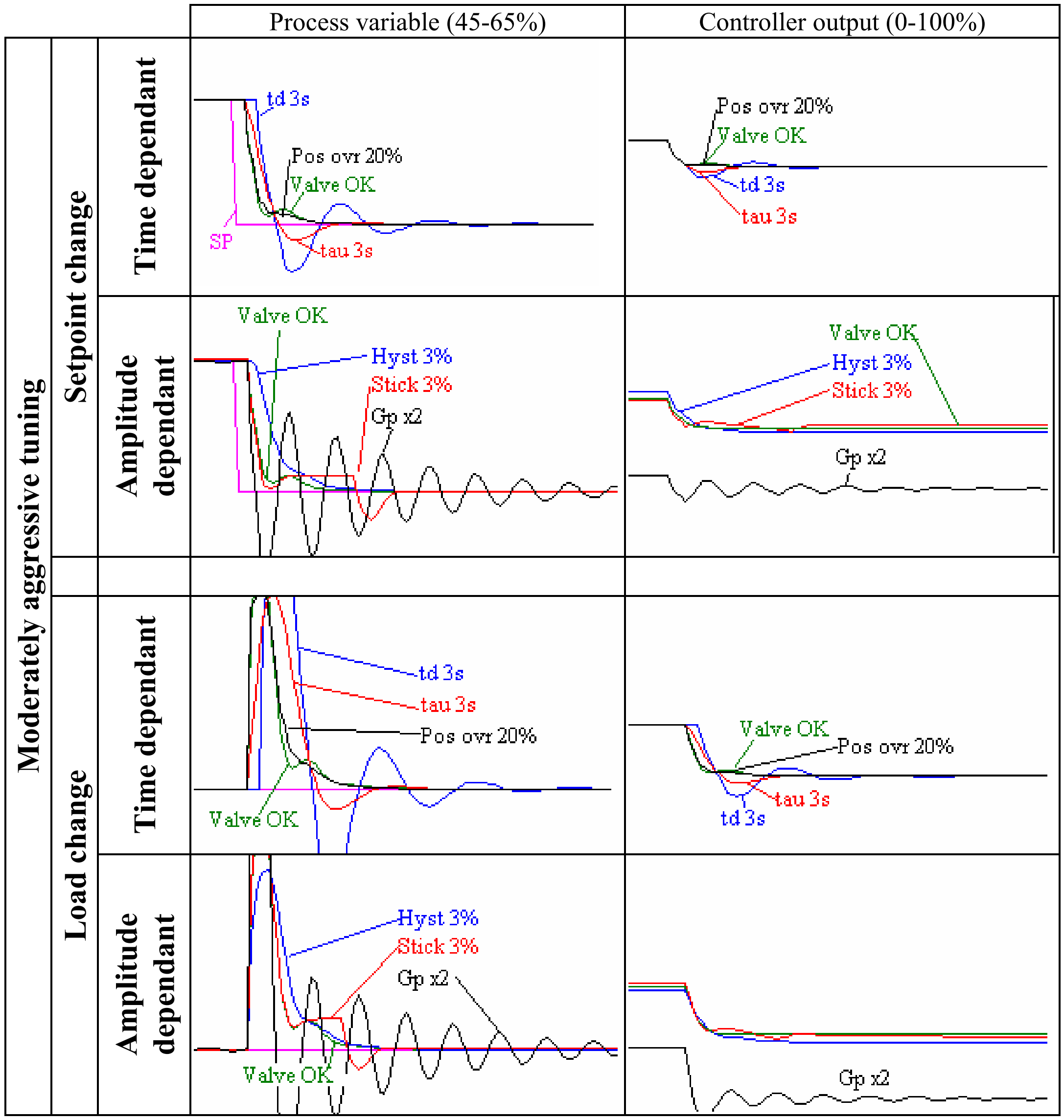
Using aggressive tuning : valve characteristics are important.

By order of importance :

1. Process gain (Cv and inherent characteristic)
2. Dead time
3. Sticking
4. Hysteresis
5. Time constant
6. Positioner overshoot

Flow process, moderately aggressive tuning

Each graph, 100 seconds.



Using moderately aggressive tuning : valve characteristics are important.

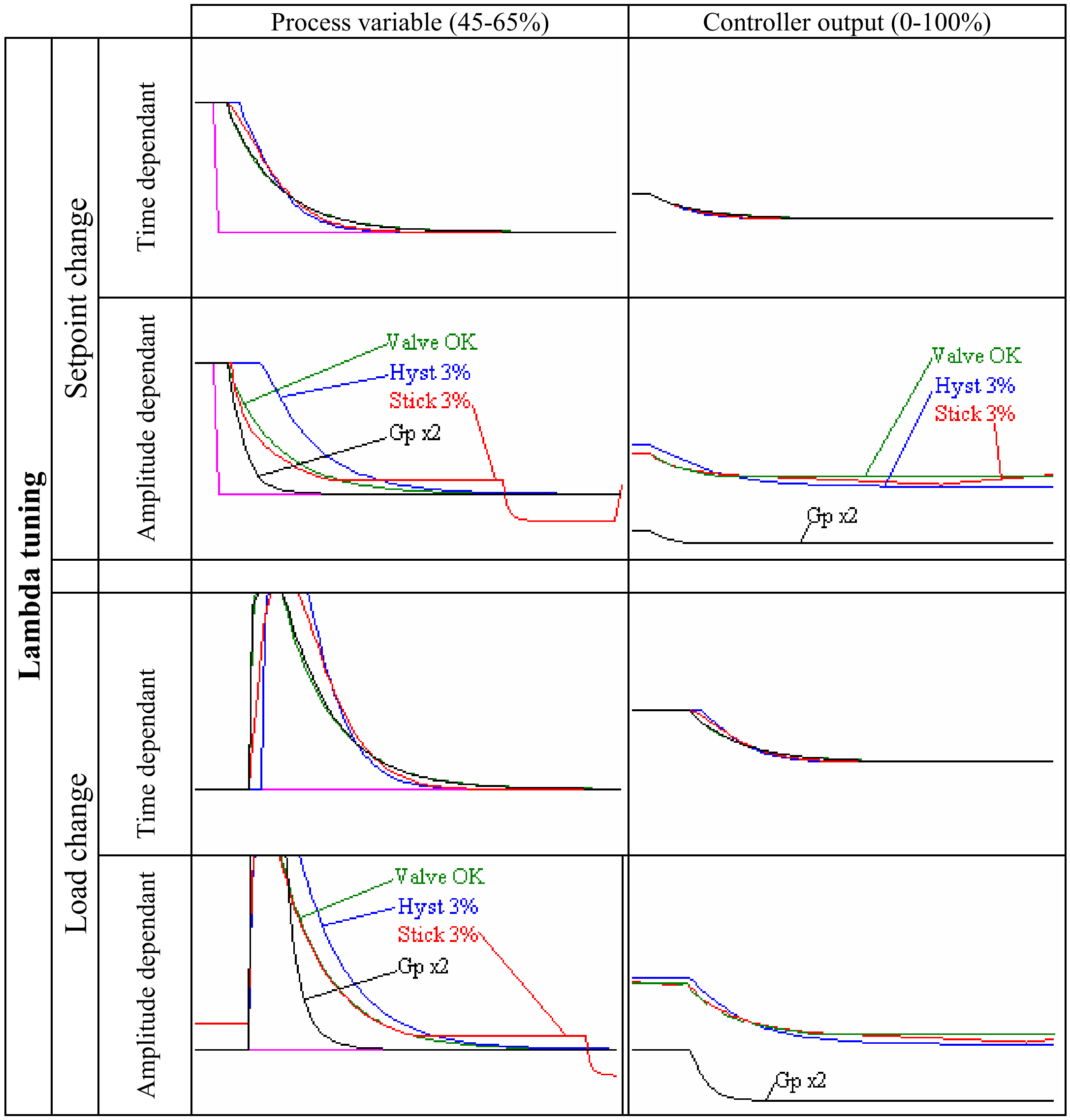
By order of importance :

1. Process gain (Cv and inherent characteristic)
2. Dead time
3. Sticking
4. Hysteresis
5. Time constant

The positioner overshoot is unimportant.

Flow process, Lambda tuning

Each graph, 100 seconds.



Using sluggish tuning : valve characteristics are not critical.

By order of importance :

1. Hysteresis
2. Sticking
3. Process gain (Cv and inherent characteristic)

As expected the time dependent characteristics are unimportant.

If a fast loop is tuned sluggishly, a quick valve is not needed and the other characteristics of the valve have little impact on the performance of the control loop. This is because the controller reacts slowly. The controller compensates the valve problems since response of the loop is so slow.

Temperature process

A temperature process having the following characteristics is used to determine the effect of the valve characteristics.
The process model is: Gp = 1; td = 100s; tau = 500s.

The process is tested for :
- a setpoint change from 60% to 50%,
- a load change of 20%.

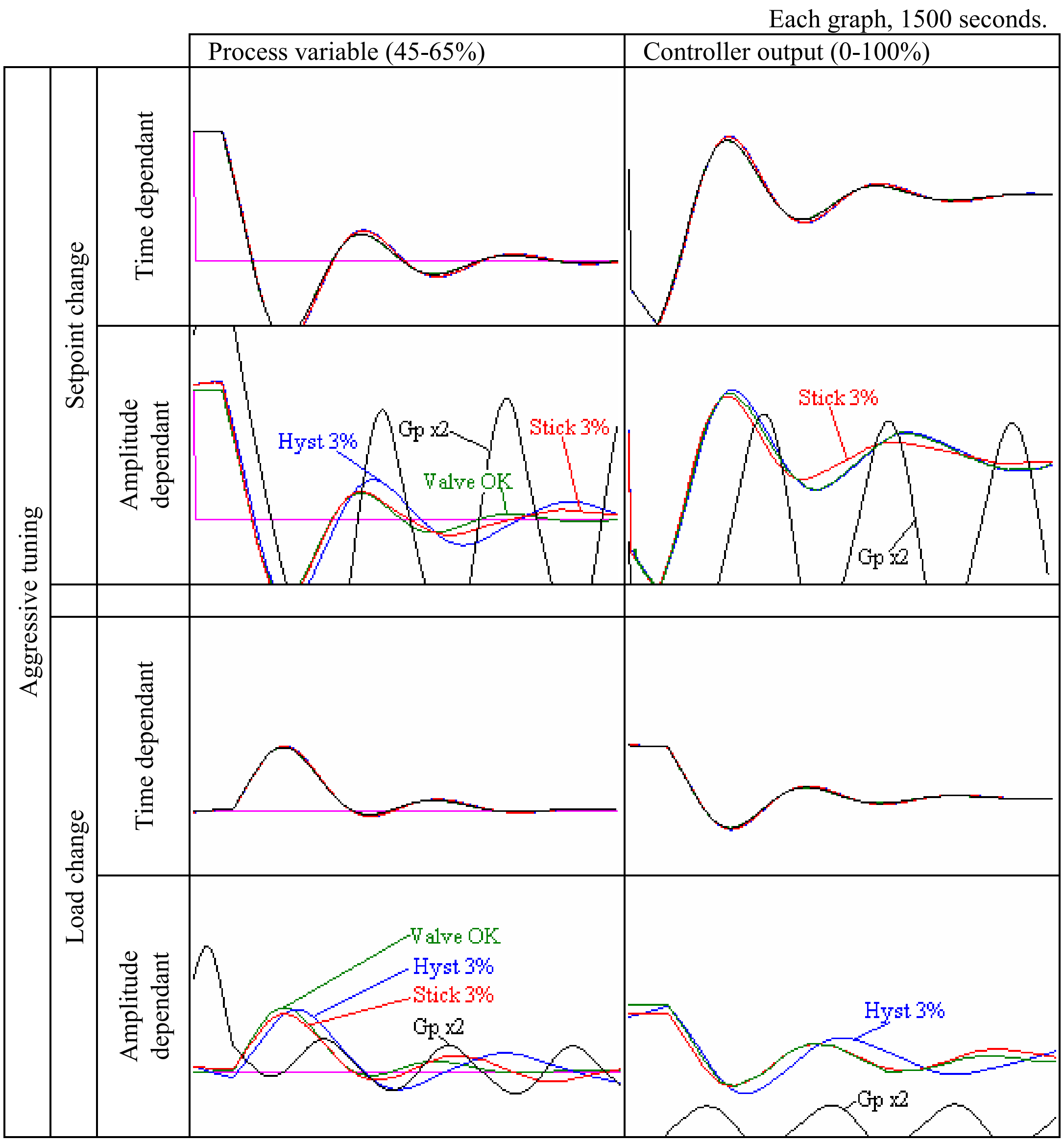
The following valves were used :

• Perfect valve	
• Time dependant characteristic	With a dead time of 3 s
	With a time constant of 3 s
	With a positioner overshoot of 20 %
• Amplitude dependant characteristic	With hysteresis of 3 %
	With sticking of 3 %
	With a Cv twice the required value

A temperature process reacts slowly, the valve characteristics are less important.

The temperature processes (and other slow processes) are usually tuned sluggishly.

Temperature process. Aggressive tuning



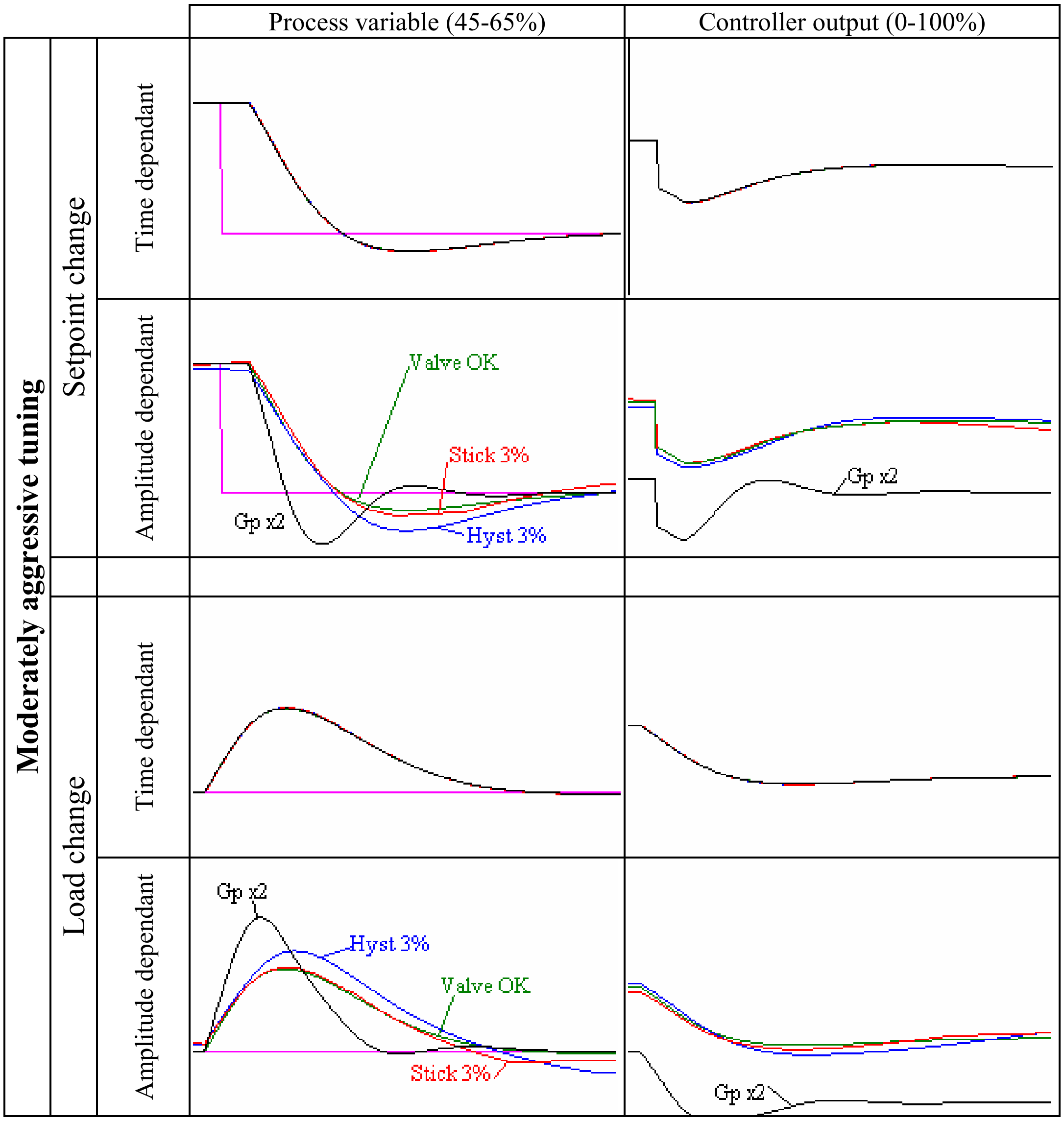
Using aggressive tuning : the valve characteristics which are amplitude dependant are important.
By order of importance :

1. Process gain (Cv and inherent characteristic)
2. Hysteresis
3. Sticking

The time dependant characteristics are unimportant.

Temperature process. Moderately aggressive tuning

Each graph, 1500 seconds.



Using moderately aggressive tuning : the valve characteristics which are amplitude dependant are important.

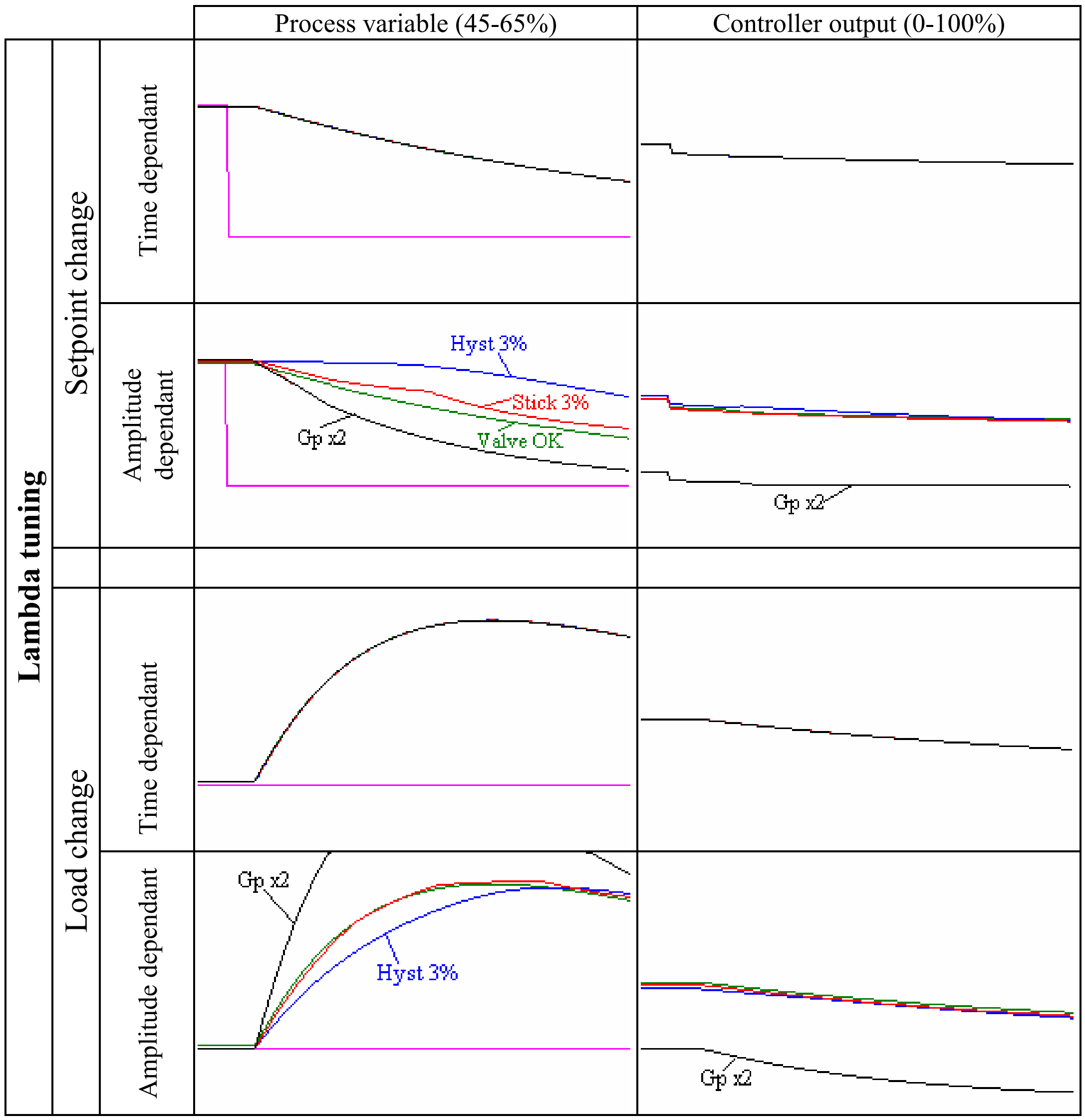
By order of importance :

1. Process gain (Cv and inherent characteristic)
2. Hysteresis
3. Sticking

The time dependant characteristics are unimportant.

Temperature process. Lambda tuning

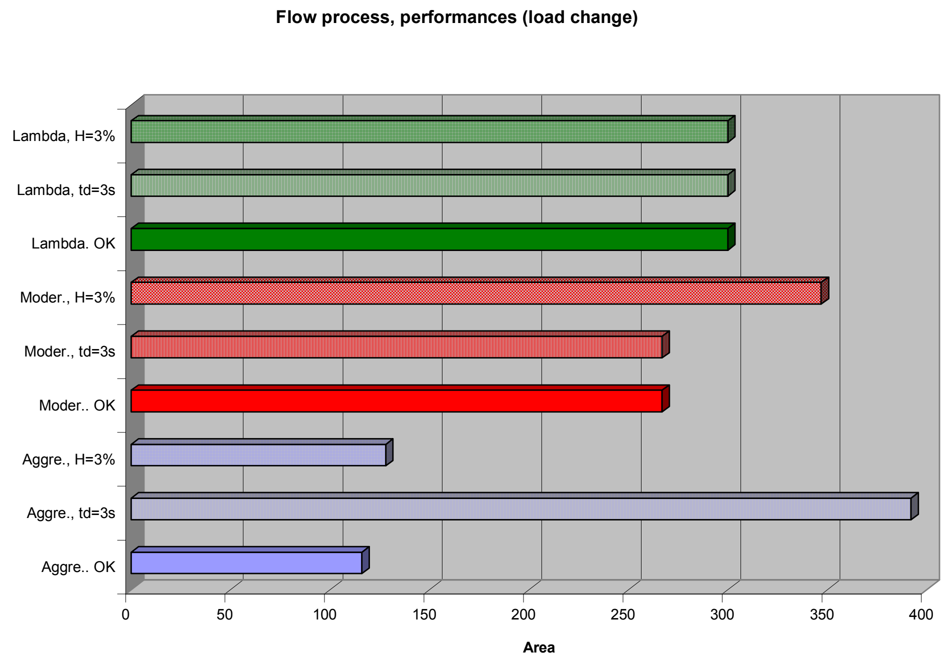
Each graph, 1500 seconds.

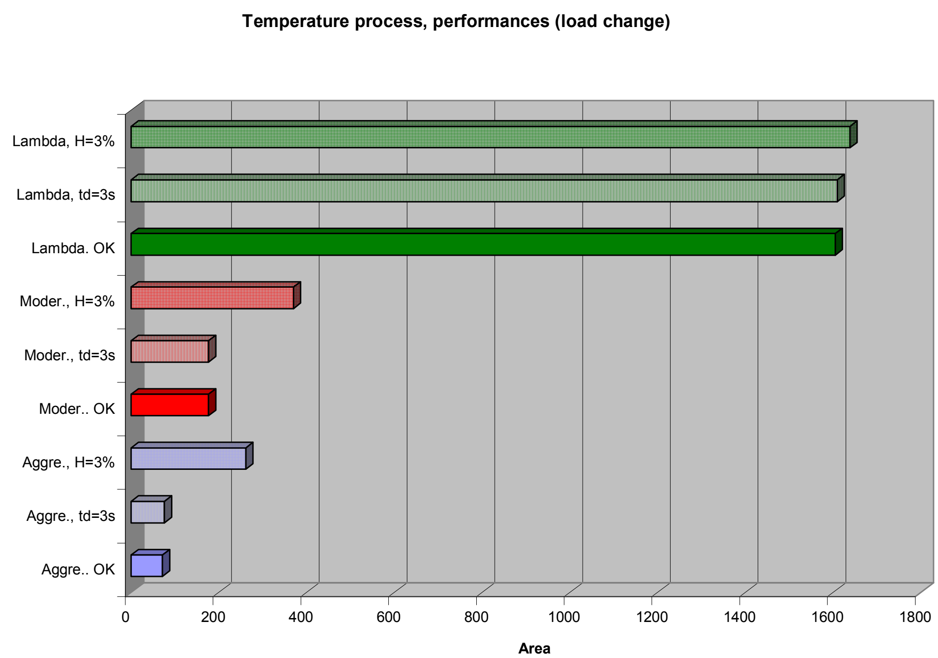


Using sluggish tuning : the valve characteristics are not critical but the Cv and the hysteresis are.

Conclusions based on the above examples

A simple way to measure the performance of a control loop is to compute the area (absolute) of the error. This cumulative error is small for a performing loop and large for the opposite. The graphes below give this measure following a load change of 20 % for a perfect valve, a valve with hysteresis and a valve with dead time. Three sets of tuning parameters are analyzed: aggressive, moderate and Lambda. The two preceeding processes are used : temperature and flow.





Time dependent characteristics affects only **fast loops tuned properly**.
Amplitude dependent characteristics are always a concern.

Conclusions

Remainder

1. The **tuning parameters** have more impact on the **performance** of a control loop than the valve characteristics.
2. If the **performance** is a concern, the valve must be carefully chosen **and** the controller must be tuned.
3. **Knowledge** of process conditions (normal and extreme) is **essential** to select the appropriate control valve: fluid, pressures, pressures vs load, piping losses, pump curve flow, etc.
4. With **fast loops**, the **dynamic characteristics** (time dependent) of the valve are important.
5. The amplitude dependent characteristics always affect the control loop performance if properly tuned but not as much as poor tuning parameters.

Guidelines

Process	Speed	Tuning	Problem (valve)	Impact on performances
Temperature Basis weight Analysis	Slow	*Sluggish*	non linearity,	small
			hysteresis,	small
			sticking,	small
			positioner overshoot,	nil
			oversized valve,	small
			poor dynamic	nil
		Aggressive	non linearity,	high
			hysteresis,	moderate
			sticking,	moderate
			positioner overshoot,	nil
			oversized valve,	high
			poor dynamic	nil
Consistency Flow Pressure	Fast	*Sluggish*	non linearity,	small
			hysteresis,	small
			sticking,	small
			positioner overshoot,	nil
			oversized valve,	small
			poor dynamic	nil
		Aggressive	non linearity,	high
			hysteresis,	moderate
			sticking,	moderate
			positioner overshoot,	small
			oversized valve,	high
			poor dynamic	high

Good practices for old loops:

1. Tune your actual loops.
2. If the loop analysis have shown major hardware problems like valve oversize do the modification. Be sure you use modern diagnosis techniques to clearly identify problems.
3. If the loop performance isn't still satisfactory look at loop design including the possibility of replacing the positioner and/or the valve by more modern equipments
4. Check your loops at least once a year.

Good practices for new loops:

1. Take a great attention to your loops design and control strategy. In doubt refer to control specialists.
2. Buy low friction control valves with an actuator at least twice stronger than the minimum force required by the valve (at your minimum available air pressure). Be sure the positioner is properly selected and adjusted. Use at least 3/8" tubing on small actuator and ½" tubing on larger actuator. Smart positioner may not be the best choice for large quantity of control valves since reliability isn't proved yet. Specify less than 1% hysteresis.
3. Buy reliable transmitters and specify appropriate span for calibration.
4. Do tune your new loops with modern techniques. Too many new loops are left with original sluggish tuning parameter for years.
5. Check your loops at least once a year.

Conclusions

Unfortunately loop performance evaluation in many North American plants are considered OK if the process operation do not complain. Peoples are so use to see loops performing this they do not even realize how well actual installation can perform.

The valves are the Achilles' heel of the loop. Valves are mechanical devices; the valve is the only component that really works in the loop. They will certainly have problems over time, so they need to be verified periodically.

Loop tuning on the other hand should be considered today at nothing less than the missing link of the loop. Loop tuning is critical in loop performance and it's the only way to maximize the hardware usage.

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The importance of control valves in process control

By *Michel Ruel*, p. eng.