CLS200 and MLS300 Cascade Control
Setup and Tuning of Cascade Functions

Cascade Control

This paper describes the use of cascade control utilized for processes with long lag times between a change in the control output level and a change in the process variable such as temperature. A lag time period of 10 to 30 minutes or longer would be suitable conditions for considering cascade control. A commonly used process that is described as needing cascade control is the water tank example. Another common process that uses cascade control is aluminum melt furnaces.

It is not the type of process; rather the <u>qualifying condition is the long lag time</u> of a slow process that is always out of control. The PV will be lagging so far behind the change in the output so that no amount of PID tuning will correct the condition. The water tank example is using the input (cold) water temperature and looking at the outlet (hot) water temperature that is the controlling point. The outlet temperature may always lag behind the heating of the inlet water thus providing a variance of the outlet water temperature that is out of tolerance no matter the PID settings.

The aluminum melt furnace has a problem in the melting of cold aluminum bars as the bars are introduced into the melt furnace. The temperature of the heating zone will rise so high due to a "cooler" condition of the melt pot and to the long lag time that it will overheat the melt furnace. Cycling will be very severe and the melt pot will be out of control.

The use of two TC or other types of temperature sensors at two different locations can provide for control of long lag time response process. By placing one sensor to measure the outlet of the process temperature and another one to measure the process product inlet temperature, we can now measure the process for cascade control.

The outlet sensor as it measures the process product outlet temperature will provide for the desired product temperature. This is known as the temperature Setpoint Control and has other labels as well such as Outer Loop. This loop will provide the SP level for the temperature Heat Control zone also known as the Inner Loop.

The inlet sensor will measure the process product inlet temperature and using the SP level from the Setpoint Control of the outlet sensor provide the heat control required for controlling the inlet temperature to meet the desired temperature for the outlet temperature. It does this by using the control output level of the SP Control Loop to set the SP level of the Control Loop.

As the outlet temperature decreases it will increase the SP level for control of the inlet temperature control zone. As the outlet temperature increases it will decrease the SP level for control of the inlet temperature control zone. In providing this cascade of control it overcomes the long lag time of the process. By looking at the difference between the two sensors and making corrections as to the heat control level, the output level can be maintained at a closer level of control.

CLS200 and MLS300 Cascade Control Terms

Nominal heat only control cascade has two parameters for adjustments. Dual heat and cool control would have four parameters.

The Control Loop Setpoint (Inner Loop) for heat or cool outputs has a parameter for setting the desired SP value when the SP Control Loop (Outer Loop) output level is at 0%. It also has a parameter for setting the desired SP value when the SP Control output level is at 100%. Full PID control modes of the Control Loop will be used for controlling the control output level.

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The Setpoint Loop will use the loop's SP as set by the operator for the desired temperature of the product or process. The Setpoint Loop PID control modes will <u>only use P and I control modes</u>.

There is a possibly of six parameters that will need to be set for using cascade control when using the CLS200 or MLS300 Dual Control Outputs. There are five when only using the Heating Control Output.

Follow User Guide instructions for changing parameters from the front panel keys.

<u>First</u>, the assignment as to which loop will be the temperature SP control loop (Primary Loop) and which loop will be the cascade temperature Control Loop (Secondary Loop).

In the front panel display, select the Cascade Menu while in the loop number that the inlet sensor is connected to, which is the heat control loop or Secondary Loop. For instance if Loop 2 is the heat control loop with an output to the heat control device, the display should show Loop 2 before going into the Cascade Menu.

While in the Cascade Menu and using the keys select the PRIM. Loop or the SP Control Loop. Select any number, but number 2. The number selected should be the output sensor loop. For instance if the outlet sensor is connected to Loop 1, select Loop 1.

<u>Second</u>, the Base SP, Min SP, Max SP, and Heat Span, and Cool Span parameters need to be set. <u>All parameters are in the engineering units of the Control Loop or Secondary Loop.</u>

If the process is controlling a process with a SP at 140°F and at -22°F while not wanting any control output at ambient, which is consider to be 75°F, the following will apply.

BASE SP = 75, this is the base value at which all other values will be referenced from. This value must be set whenever using heat, cool, or heat and cooling control outputs.

Min SP = -35, this is the value at which the lower SP value cannot exceed and must be greater than the cooling SP of -30. This value can be set to the input range lowest value, if desired so that it would not need to be included in any future resetting of cascade parameters.

Max SP = 145, this is the value at which the higher SP value cannot exceed and must be greater than the heating SP of 140. This value can be set to the input range highest value, if desired so that it would not need to be included in any future resetting of cascade parameters.

Heat Span = 65, this is the value which is the span between the Base SP and the desired heat SP. i.e. 140 – 75 = 65. This is the value that must be set if using heat only or heat and cooling outputs as well as the Base SP.

Cool Span = 105, this is the value which is the span between the Base SP and the desired cool SP i.e. -75 + -30 = 105. This value must be set when using heat and cooling or cooling only outputs as well as the Base SP.

Heat only example: Low SP = 1200 and High SP =1600.

Base SP = 1200 and Heat Span = 400.

Cool only example: High SP = 50 and Low SP = 30.

Base SP = 50 and Cool Span = 20

Tuning Cascade Loops

The proper procedure for tuning cascade control loops is to first tune the secondary (inner) heat or cool control loop using all three of the PID modes. This loop must first be tuned to good PID control parameters before doing any tuning of the SP temperature control loop. Do not try tuning both loops at the same time unless you are an expert in tuning PID loops and have experience with cascade control systems.

If cooling is in use and there is a proportional component to the cooling control such as using a TP output with a solenoid valve, then the PID modes can be tune as well.

The use of autotuning or adaptive tuning can be used to achieve the PID control parameters. If these tuning functions are not available then use manual PID tuning methods. After a satisfactory control is achieved with the heat control loop, take note of the P and I values.

To tune the primary (outer) SP control loop, first check the actual range of the SP of the secondary loop by placing the SP loop control into manual mode. With a heat output of 0%, the SP of the heat control loop should be at the low SP value as set in the cascade menu. Change the output to 100%, the SP of the heat control loop should be at the high SP value as set in the cascade menu. If using cooling control do the same thing with the heat output at 0% and then changing the cooling output to achieve the same values as set in the cascade menu.

Use the values as noted in the PB mode and TI or RM of the Integral/Reset mode of the heat control loop and place them in the PID parameters of the heat control output. If PID values are obtained for the cooling, use them for the cooling PID parameters. DO NOT USE THE DERIVATIVE MODE. IT MUST BE TURNED OFF.

Place the control mode of the SP loop into Auto control mode. The SP loop control output should start changing which in turn will be changing the SP of the secondary or heat control loop. Allow the process to settle down. If there is any unwanted cycling of the temperature, use and change the PID parameters of the SP control loop for changing any unwanted control deviations from SP. Do not use the heat control loop for making any changing to the PID parameters.

A slow process will take time to see how the tuning is doing so don't be in a hurry. A space of 20 to 30 minutes is not too long in most cases.

If you are not knowledgeable or trained and have experience with PID and tuning be sure to see the instructions on PID and PID tuning before attempting to tune cascade loops.

Watlow TRU-TUNE+ can do the tuning for you. First, perform an auto tune of the heat control loop by placing the control mode into Tune. After the adaptive mode has been active for a while such as 1 or 2 hours, use the P and I values as obtained in the adaptive mode for the P and I values of the SP loop. Place the SP loop directly into Adaptive Mode for final tuning of the SP PID values.

TRU-TUNE+ is not available in the CLS200 or MLS300 Series controllers, but is available in the CPC400. Also cascade is standard firmware in the CPC400 as well. Order option "EF" in the CLS200 and MLS300 to use cascade control.