Date: ________________ Name: ___________________________________

DEMONSTRATION EXERCISE 22
ANTI-RESET WINDUP (BATCH SWITCH)

OBJECTIVE: To demonstrate the behavior of anti-reset windup (also called a "batch switch") in certain types of applications, such as batch process start-ups and recovery from out-of-control situations.

NOTE: In a process control seminar, it is recommended that this exercise be conducted as an instructor-led demonstration exercise, rather than student exercise

BACKGROUND: Frequently encountered situations in the process industries are start-ups, grade changes, and recovery from out of control conditions. If the controller contains the integral mode and is in Automatic during these situations, the likely result will be a significant overshoot (or "undershoot") of the set point. Many manufacturers incorporate a special feature in their controllers (it may be an option, not necessarily a standard feature) variously called "anti-reset windup" or "batch switch." There are variations between manufacturers in the implementation details; this program demonstrates one of the most common forms of implementation, wherein once the controller output hits a limit, the proportional band is forced in the other direction. The objective is that, on the next start-up or control recovery, there will be a significant reduction in the overshoot.

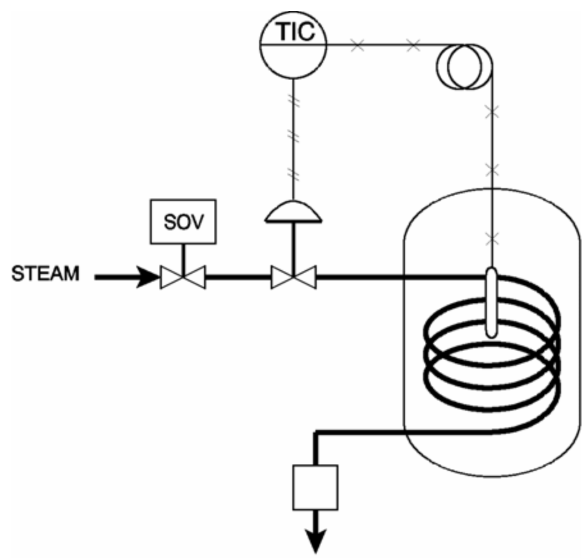

Figure 1
PROCESS AND CONTROL CONFIGURATION USED FOR APPLICATION EXAMPLE

An application scenario around which the demonstration exercise is written involves a batch reactor, or other batch operated process unit, in which there is a repetitious heating-cooling cycle. Figure 1 shows a possible process and control configuration.

Suppose the temperature controller is always left in automatic, with a constant set point. Suppose further, that at the end of the heating cycle, the heat source (say, steam) is removed simply by closing a remote operated block valve in series with the temperature control valve. The effect will be for the temperature to drop. The controller, still being in AUTO, will sense the drop in temperature and drive the control valve wide open.

On the next heating cycle, when the block valve is reopened, the controller will be in AUTO with its measurement far below its set point. The control valve will be wide open. Under these circumstances, full steam will be applied to the process. Without anti-reset windup, the proportional band will have shifted to the top of the scale, so that the temperature will have to rise a significant amount before the steam valve even begins to cut back. The result will be a significant temperature overshoot of the set point.

Following the same scenario, but with anti-reset windup in the controller, the proportional band will initially rise to the top of the scale, then forced downward by the action of the anti-reset windup function. When the next heating cycle commences (when the block valve is opened), full steam will initially be applied to the process as before. However, with a depressed proportional band, the valve will begin cutting back as soon as the temperature begins to rise. The result will be a significant reduction in temperature overshoot, as compared with the non-anti-reset windup situation.

This exercise demonstrate the scenario described above.

1. RUNNING THE PROGRAM

Start Windows.

Run **PC-ControLAB**.

2. SET UP

Verify that the control strategy is FEEDBACK, and that the GENERIC process model is in use.

Select **Control | Control Options**. In the "Anti-Reset Windup" panel, Verify that NO is selected. Then press **Clear**.

Press **TUNE**, then enter the following tuning values:

Gain:	3.5
Reset:	8.00 minutes/repeat
Deriv:	2.00 minutes

When all values have been entered, press **OK** to clear the tuning dialog box.

Confirm the following:

Set Point:	275
PV:	275
Controller Output:	35.0
Process Load (Grey trace on chart)	75.0 % of full scale

Select **View | Display Proportional Band**. Observe the proportional band (light blue bar) extends from about 182 DegC to 325 DegC, or a span of 143 Deg.

$$\text{Prop Band} = \frac{100}{\text{Gain}} = \frac{100}{3.5} = 28.6\,\%.$$

28.6 % X 500 DegC = 143 Deg

$$
\begin{aligned}
PB_{top} &= \text{Set Point} + \frac{\text{Controller Output}}{100} \times \text{PB (in Deg)} \\
&= 275 + \frac{35}{100} \times 143 \\
&= 325
\end{aligned}
$$

$$
\begin{aligned}
PB_{bot} &= \text{PBtop} - \text{PB (in Deg)} \\
&= 325 - 143 \\
&= 182
\end{aligned}
$$

Put the controller in Automatic.

The control loop should now be in normal operation, with the set point and process variable at 275 DegF and the controller output at 35%. Confirm this by making a set point change to 325. When the loop stabilizes, return the set point to 275. When the process restabilizes, proceed.

3. DEMONSTRATION OF SHUT-DOWN/START-UP WITHOUT ANTI-RESET WINDUP.

Select **View | Discrete Controls**.

In the panel labeled “System Heat”, notice that the current state of the shutdown system is ON. In the panel labeled “Sol Valve”, notice that the solenoid valve is now ON. Click **OFF** for the System Heat, and notice that the solenoid valve goes to OFF.

This simulates blocking the heat source from the control valve. Observe:

The process variable (temperature) drops;

The valve goes to a wide open position;

The proportional band bar rises toward the top of the scale, stopping when the output reaches a limit, then remains in a fixed position.

When the process variable has fully decayed, select System Heat: ON to reopen the block valve.

Observe:

The process variable (temperature) begins to rise almost immediately;

Since the proportional band is approximately in the middle of the scale, the process variable must rise a considerable distance before the valve even begins to cut back. (The valve begins to cut back before the measurement actually reaches the proportional band, due to the presence of derivative action in the controller.)

Note the amount that the process variable overshoots the set point.

Maximum temperature 305 DegC

Amount of Overshoot 30 Deg

Observe the length of time after the process variable begins to rise before the valve starts to cut back.

3 mins

4. DEMONSTRATION OF SHUT-DOWN/START-UP WITH ANTI-RESET WINDUP

When the control loop is stable at set point, put the controller in Manual.

Select **Control | Control Options**.

Select YES for “Anti-Reset Windup.”

Put the controller in Auto.

Select Select **Control | Control Options**. In the “Anti-Reset Windup” panel, select YES. Then press **Clear**.

Select **View | Discrete Controls**. Select OFF for “System Heat.
Observe:

The process variable (temperature) drops;

The valve goes to a wide open position;

The proportional band bar initially rises, but when the controller output reaches the top of the scale, then the anti-reset windup feature causes the proportional band to shift downward. (Colloquially, this is called "dumping the reset.") The proportional band comes to rest when the top of the PB is the “Preset” (percent of proportional band) below the set point.

When the process variable has fully decayed to the bottom of the scale, reopen the block valve.

Observe:

The process variable (temperature) begins to rise almost immediately;

Since the proportional band is now nearer the bottom of the scale, the process variable must rise a shorter distance before the valve begins to cut back. (The controller output appears to begin to cut back at about the same instant that the measurement begins to rise.)

The proportional band begins to shift as the controller nears the set point.

Maximum temperature: 285 DegC

Maximum overshoot of the process variable. 10 Deg

Observe the length of time after the process variable begins to rise before the valve starts to cut back. 1.5 mins

5. OTHER FACETS OF ANTI-RESET WINDUP

Two parameters available through the Control Options display govern the behavior of the anti-reset windup function:

> “Output maximum” limits the maximum controller output. In addition, when the controller output reaches this point, the anti-reset windup function begins to shift the proportional band downward.
>
> “Anti-reset windup preset” limits the amount by which the proportional band can be shifted downward. For example, suppose the controller is Reverse Acting, with a PB of 40% (GAIN = 2.5) and the set point is at 60%. Also suppose that the anti-reset windup preset is set for -25%. On a shut down, the anti-reset windup would force the PB down to where the top of the PB is at 50% of the PV scale. That's 10% below the set point, where 10% of PV scale is 25% of the PB width. (0.25 x 40% = 10%)
>
> If the anti-reset windup preset is set too high, the proportional band will not be shifted downward far enough, resulting still in an unwanted amount of overshoot.
>
> On the other hand, if the anti-reset windup preset is set to low, the proportional band will be shifted downward an excessive amount, resulting in the process variable beginning to cut back before reaching the set point.
>
> In essence, the anti-reset windup preset becomes an additional tuning parameter that must be matched to process dynamics and load conditions for optimum response.

Put the controller in Manual.

Select **Control | Controller Options**. Change the anti-reset windup preset from its present value (0.0) to -25.

Put the controller in Auto and repeat the shut down-start up procedure. This time you should see essentially the optimum response, meaning minimum overshoot. Record the amount:

0%

6. DISCUSSION

Some manufacturers achieve a similar function in different manners. For instance:

> Some manufacturers implement two-sided anti-reset windup. (This program only demonstrated one-sided anti-reset windup, effective when the controller output reached an upper limit.)
>
> One manufacturer leaves the proportional band at the top of the scale, but then when the measurement begins to recover, the integral time is reduced by a factor of 16, thus shifting the proportional band downward 16 times as fast as would a normal PID controller. This minimizes overshoot in start-up or recovery from loss of control.
>
> Some manufacturers simply limit the contribution to the controller output by the integral mode and refer to this as “anti-reset windup.” This should not be confused with the form of anti-reset windup demonstrated here.