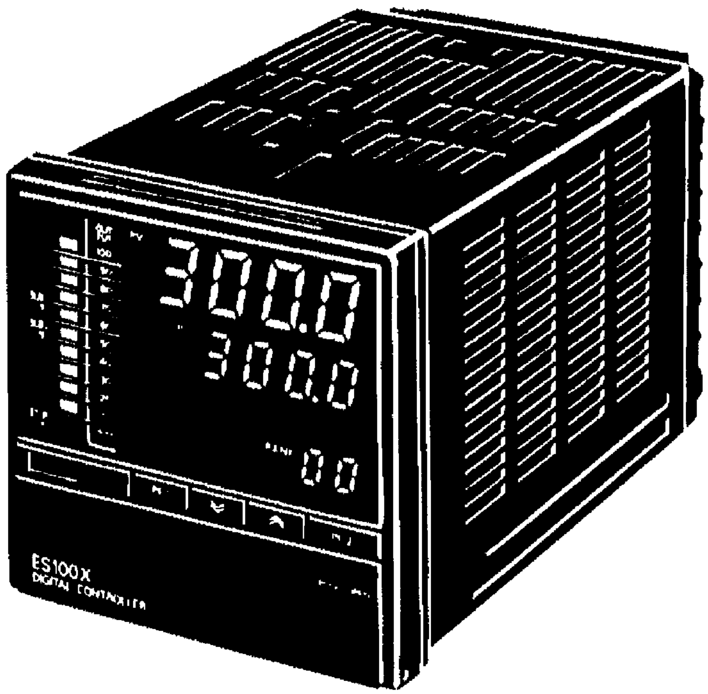
# Model ES100
# Process Controller

## ESTOOLS Software Programming Manual and Application Road Map

*January 1996*



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**DANGER!** Indicates information that, if not heeded, could result in loss of life or serious injury.

**Caution** Indicates information that, if not heeded, could result in minor injury or damage to the product.

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# General Information

Omron's ES100 Digital Process Controller provides advanced, accurate control in a wide variety of process and temperature control applications. This document was developed to help you to take full advantage of the ES100's extensive programming and control features using ES/TOOLS. ES/TOOLS is a DOS-based program with an intuitive graphical user interface that enables you to quickly program complex control schemes such as Cascade and Proportional control from your personal computer.

Sections 1 through 5 of this manual cover specific control strategies that can be implemented using the ES100. These include Cascade Control, Position Proportional Control, Heat/Cool, Ratio Control, and Feed Forward Control Strategies. We recommend that you have manuals ES100X (H070-E1-1) or ES100P (H069-E1-1) on hand for reference before you begin.

This manual begins with a general introduction to programming the ES100 using ES/TOOLS software. The following sections will guide you through the initial three-step software setup that prepares ES/TOOLS for use with your controller and specific applications found later in this document. These procedures include:

1. **Registration -** Prepares the ES/TOOLS for your specific ES100 controller model.
2. **Configuration -** Configures ES/TOOLS for your application process inputs.
3. **Analog Operation Table Setup -** Determines which calculations ES/TOOLS should perform.

You must follow these procedures in the sequence as listed above.

# 1–1 Registering Your Controller with ES/TOOLS

The first time you use ES/TOOLS to program a new application, you must allow the software to determine which model of ES100 you have. To do this, start ES/TOOLS and follow the steps below.

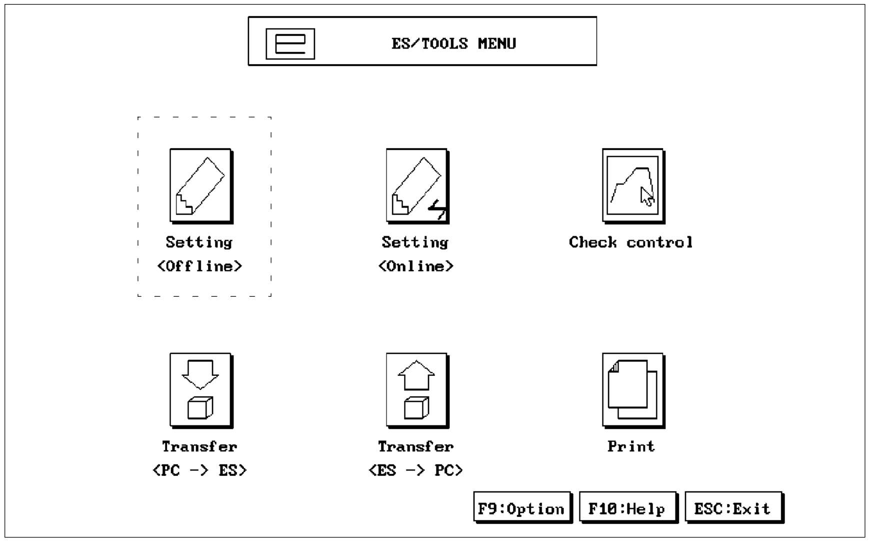



Figure 1

1. Select a COM port as follows:

   a. From the ES/TOOLS menu (Figure 1), click on the **F9: Option** button. Then select the **Select system parameters** button. A Communications Menu appears.

   b. Double-click on the **COM PORT** button.

   c. Click on COM1 or COM2 to select the COM port you wish to use on your PC.

   d. Click on the **ESC:Exit** button. You will return to the ES/TOOLS Main Menu.

2. Register the controller as follows:

   a. Select the **Setting <Offline>** icon (see figure 1) by double-clicking on it.

   b. At the pop-up menu, double-click on the **New** button. (If you wish to load a saved ES100 configuration, select the **Load** button and follow the prompts.)

   c. Double-click on the **ENT: OK** button. The “New – Controller Type” menu appears (Figure 2).

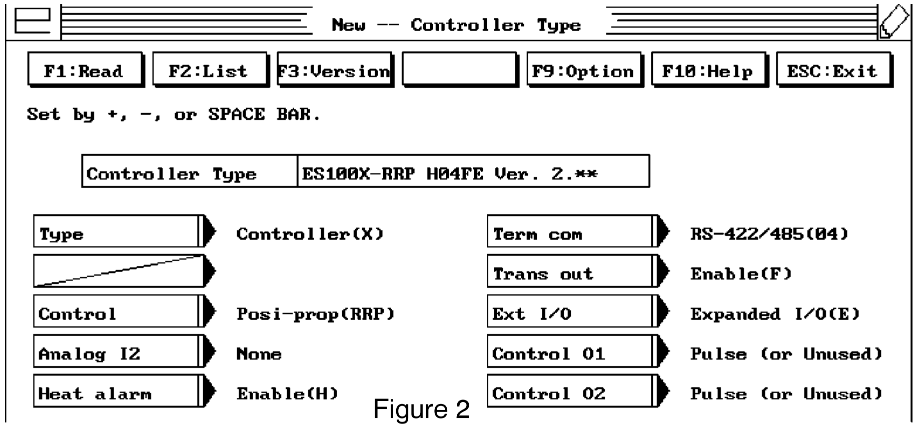



Figure 2

You may now use one of three methods to register your controller with ES/TOOLS. The first method (recommended) allows the software to automatically determine the controller type and hardware options of the controller currently to ES/TOOLS. The second method lets you choose the controller type from a list. The third method allows you to build a controller type based on the hardware options of the controller. This method is useful for setting up configurations for different controllers and different applications.

**Method 1 - Automatic**

**Note:** Method number 1 displays the exact controller type and hardware options available for the controller currently connected to ES/TOOLS.

1. Connect an RS-232 cable from the front panel of the ES100 to COM port on your computer that you selected earlier.
2. Double-click on F1: Read. A confirmation window appears. Select the ENT:OK button. The software will attempt to automatically determine which ES100 controller type you have and display the controller part number on the screen.
3. When finished, click on the ESC:Exit button. A pop-up menu appears. Select ENT:OK, the **Configuration parameters** menu will appear.

**Method 2 - Select from a list**

1. Double-click on the F2: List button. A list of ES100 part numbers appears.
2. Select the appropriate part number from the list by double-clicking on it or by scrolling down to highlight it and pressing <Enter>. The controller type should now appear on the screen along with its associated hardware options.
3. When finished, click on the ESC:Exit button. A pop-up menu appears. Select ENT:OK, the **Configuration parameters** menu will appear.

**Method 3 - Build your own controller type**

1. In the “New – Controller Type” menu, use the buttons to select the appropriate features of your ES100. To assist you, a list of buttons along with brief descriptions appears below. When finished, a corresponding controller type part number should appear on the screen. To modify feature options simply double-click on the button and select a new option from the pop-up menu.

2. When down, double-click on the **ESC:Exit** button.

**Caution:** As you change the hardware options the part number shown in the "Controller Type" dialog box will also change. When using this registration method it is possible to create a controller type that does not exist. Therefore, it is important to verify that you have built an appropriate part number. Failure to verify a part number will result in the inability to download a program. To verify, simply select **ESC:Cancel** then select **ENT: OK**. A pop-up window will alert you that the part number does not exist.

The following defines the available selections in the **New –– Controller Type** menu.

**Type** Displays the controller type: (P) Ramp/Soak controller; (X) Eight-bank memory.

**Control** Displays control method type; Heat/Cool (standard) or Posi-Prop (RRP) Valve Positioning.

**Analog I2** Enables a second input if the controller is equipped with one.

**Heat Alarm** Enables a heater burnout alarm if the controller is equipped with one.

**Term com** Displays controller communication type:"None", RS-232C (01), or RS-422/485 (04). Note that (01) or (04) are added to the part number and are not part of the communications protocol.

**Trans out** Enables the Transfer Output if the controller is equipped with one. The choices are Enable (F) or None.

**Ext I/0** Displays the type of digital I/O you have on your controller. Digital I (B) corresponds to three rear terminal inputs only; Digital I/O (D) corresponds to three inputs and two outputs on the rear terminal; Expanded I/O (E) corresponds to eight inputs and eight outputs connected to the controller by an external cable.

**Control 01** Displays the type of control output to be used in Control Output 1, Current or "Pulse/Unused". Current is used for all linear analog outputs, (i.e. 4-20 mA, 0-20 mA, 1-5 VDC, 0-10 VDC). "Pulse/Unused" is used for all time proportional outputs (i.e. mechanical relay, SSR, transistor/voltage).

**Control 02** Displays the type of control output to be used in Control Output 2. Current or "Pulse/Unused". Current is used for all linear analog outputs, (i.e. 4-20 mA, 0-20 mA, 1-5 VDC, 0-10 VDC). "Pulse/Unused" is used for all time proportional outputs (i.e. mechanical relay, SSR, transistor/voltage).

# 1–2 Configuring the ES100

**Note:** This procedure is available from ES/TOOLS menu.

The Configuration menu may be viewed in two ways. The default option is *Optimize Mode – EFFECT.* This configuration menu option displays most of the available options. There are some parameters that will not show but may need to be altered (i.e. technical parameters such as PID, Fuzzy Logic Setting). The second option, *Optimize Mode – UNEFFECT,* displays all possible configuration fields for all ES100 controller types. It is useful for fine tuning parameters or reconfiguring the controller's features at a later date.

1. Click on **F9:Options** button. An options Menu appears (Figure 3).

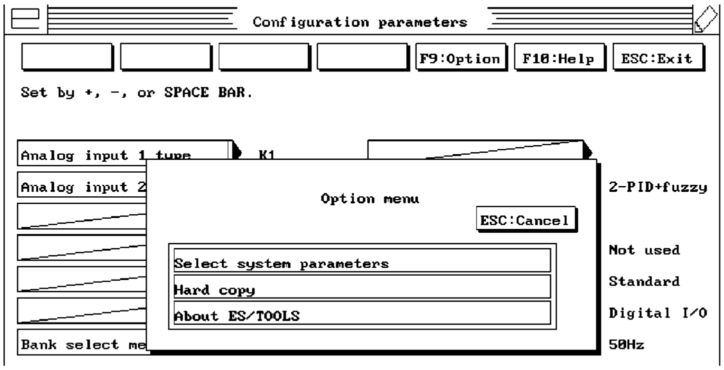



Figure 3

2. Click on **Select system parameters** button.
3. Double-click on the **Optimize Mode: Effect** button.
4. Double-click on either the **Effect** or **Uneffect** button to select the menu option you wish to enable.
5. Click on the **ESC:Cancel** button.
6. You may now configure your ES100 (Figure 4). Once you have completed configuring your ES100, click on the **ESC:Exit** button. A pop-up menu appears to create a new file, then select **ENT:OK**. The main screen for **Setting <offline>** will appear.

To configure the software parameters of hardware options that were selected from the **New –– Controller Type** menu, double-click on a parameter button and select the new value from the pop-up menu.

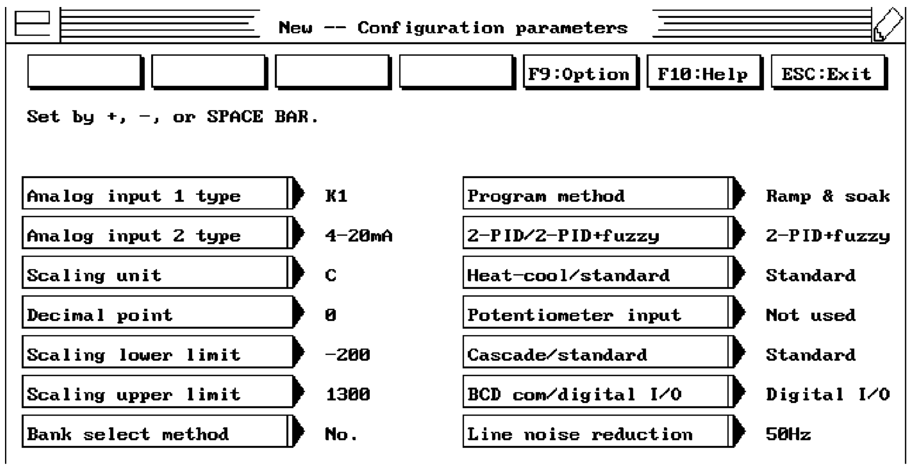



Figure 4

The list below describes the function of each button selection in the **New –– Configuration parameters** menu. The **New –– Configuration parameters** menu allows you to configure the software parameters of hardware options that were selected from the **New –– Controller Type** menu.

**Analog Input 1 Type** Displays the active input type: Thermocouple, RTD, or Analog.

**Analog Input 2 Type** Displays the active input 2 type: 1-5 VDC or 4-20 mA.

**Scaling Unit** Displays the active unit of measure for your process: F° = Fahrenheit, K° = Kelvin, m = meter, m/s = meter/second, f/s = feet/second, etc.

**Decimal Point** Displays the active number of decimal places to be displayed on the controller.

**Scaling Lower Limit** Displays the scale value for the controller to display for the lowest input value. (Note: This should only be changed on an analog type input. Thermocouple and RTD inputs are pre-scaled.)

**Scaling Upper Limit** Displays the scale value for the controller to display for the highest input value. (Note: This should only be changed on an analog type input. Thermocouple and RTD inputs are pre-scaled.)

**Bank Select Method** (ES100X only) Displays the operating mode: time mode or bank mode. In time mode, the bank runs for a specific programmed time period. In number mode, the bank selected runs indefinitely.

**Program Method** (ES100P only) Displays the operating mode: Ramp/Soak or Soak Step.

**2-PID/2-PID+Fuzzy** Turns the Fuzzy Logic ON/OFF. With this setting you may choose to run the ES100 in PID only or PID using Fuzzy Logic.

**Heat-Cool/Standard** Displays the active controller operation method: heat/cool or standard.

**Note:** If heat/cool is selected, ES/TOOLS automatically configures the Analog operation assignment.

**Potentiometer Input** Displays the active potentiometer input status: Used (slide wire feedback mode) or Not used (velocity mode; where the position is stored in memory based upon a travel time).

**Note:** This display will be activated only when using a valve-positioning type controller (ES100_-RRP_ _ _ ).

**Cascade/Standard** Displays the active selection for controller operation: internal cascade or standard.

**BCD Com/Digital I/O** Displays the active I/O selection: Digital I/O (standard) or BCD com (BCD communications).

**Line Noise Reduction** Displays the active power source type: 50 Hz (European and Japanese) or 60 Hz (standard U.S.).

## 1–3 Analog Operation Assignment Table

The Analog Operation Table (Figure 5) displays all of the mathematical functions for each of the ES100's I/O points including scaling, adding, subtracting, multiplying, square root, etc. **You do not need to make any changes to the Analog Operation Assignment Table unless your process requires special mathematical functions such as straight line approximation, etc.** While in most cases no changes are needed, it is recommended that you review the table so that you know how the controller is set up to operate. If changes are required, simply select the value you wish to modify by clicking on it with the cursor and select from the pop-up menu.

When done, select **ESC:Exit** to return to the Main Menu.

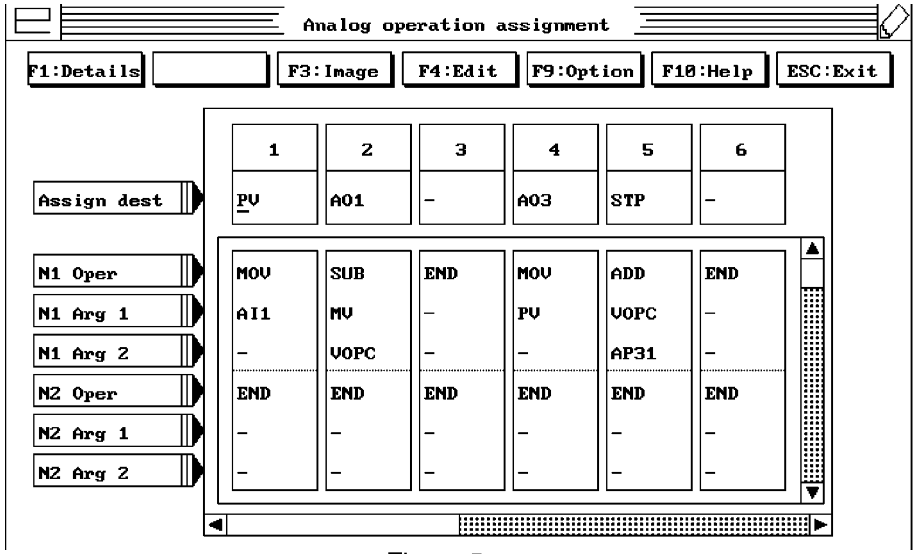



Figure 5

You have now completed the steps necessary to setup your controller. Now refer to the appropriate section of this manual to continue setting up the ES100 for specific operations.

# SECTION 1
# Cascade Control

# 1–1 Definition of Cascade Control

Cascade control is used in processes where more than one item in the process needs to be controlled to achieve the desired result. An example would be controlling furnace temperature by controlling the fuel supply to the furnace.

## 1–1–1 Conventional Control Method

In the following example a gas furnace (Figure 1) is controlled with a single controller. The furnace requires a long time for the internal temperature to change, once the gas flow has been adjusted.

When the pressure in the gas line fluctuates, this causes unwanted changes in the flow of gas to the furnace and causes unwanted temperature changes. The change in gas flow cannot be detected by the controller until it is reflected as a temperature change in the furnace.

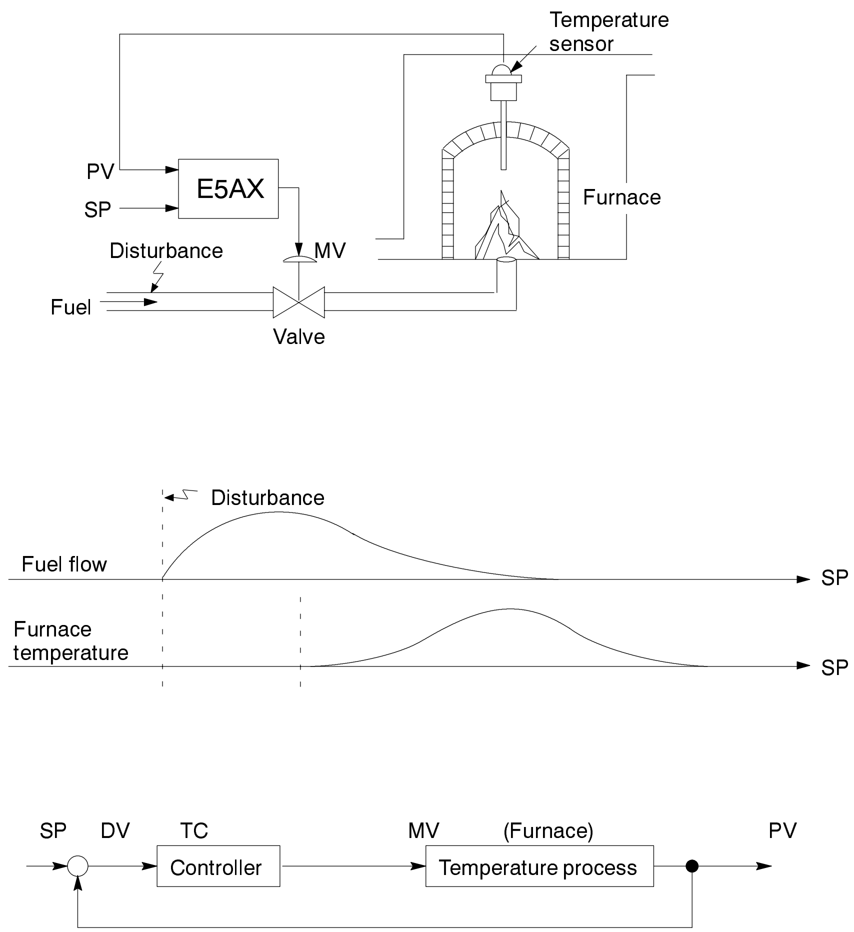



Figure 1

# 1–2 Cascade Control

Unlike conventional control methods which use a single control loop to monitor and regulate, cascade control uses two control loops to control processes where more than one item in the process needs to be controlled to achieve the desired result. An example would be controlling furnace temperature by controlling the fuel supply to the furnace.

In this example (Figure 1), the primary loop controls the temperature inside the furnace, and the secondary loop controls the fuel flow.

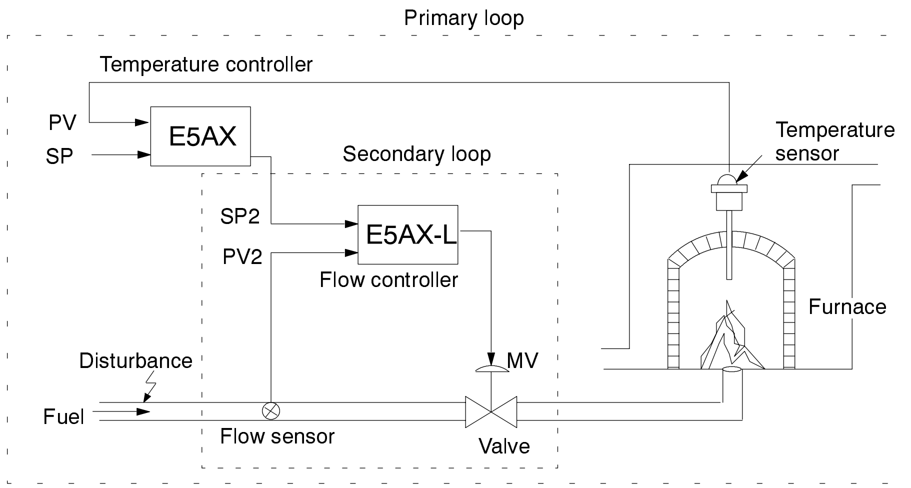



Figure 1

To maintain the proper temperature in the furnace, we need to control the amount of gas fed to the furnace to maintain temperature, but we must also try to compensate for fluctuations in the gas line which create unwanted changes in temperature (Figure 2).

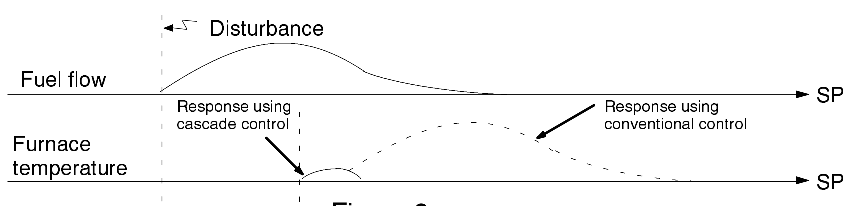



Figure 2

Cascade control uses two control loops to control a process. In our furnace example, the primary loop is used to control the temperature in the furnace by setting the flow rate of the gas entering the furnace. The secondary loop is used to maintain a steady flow rate by compensating for pressure fluctuation in the gas line (Figure 3).

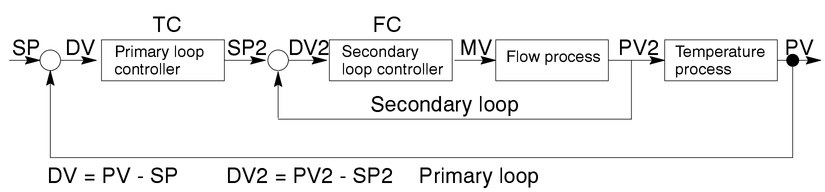



Figure 3

The output of the primary loop controller is used to establish the set point of the secondary controller. The secondary controller acts as a slave (Figure 4) to the primary controller. The primary controller monitors the temperature, and tells the secondary controller which flow rate to maintain.

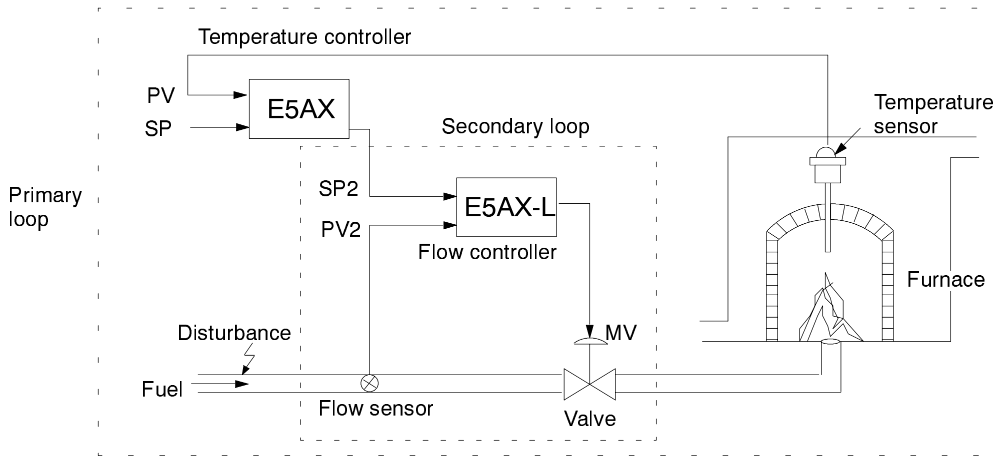



Figure 4

## 1–2–1 ES100 Internal Cascade Control

The ES100 offers a very efficient means of establishing a cascade control system, which eliminates the requirement for a second controller. The ES100 controller has two control loops built into the same controller which is referred to as internal cascade control . The equivalent wiring for an ES100 system is shown in the Figure 5.

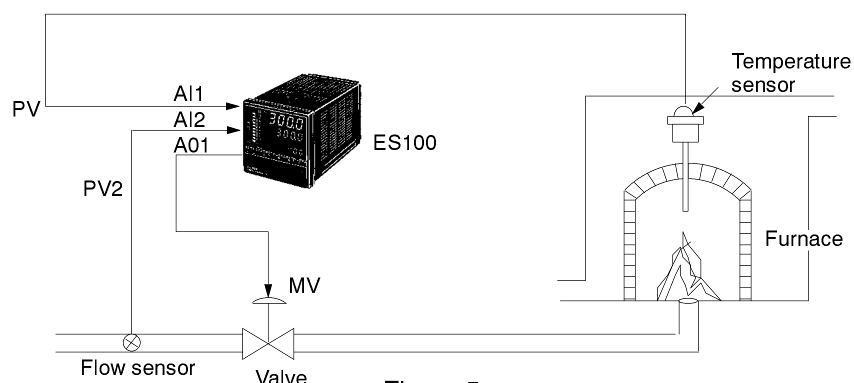



Figure 5

Any type of ES100_-_ _ W_ _ _ _can be used to perform cascade control. The W signifies the controller has two analog inputs. Figure 6 shows a wiring diagram for our furnace example. Analog input 1 is operating as the primary input, and analog input 2 is acting as our secondary input. Analog output 1 operates as the primary control output to the valve actuator.

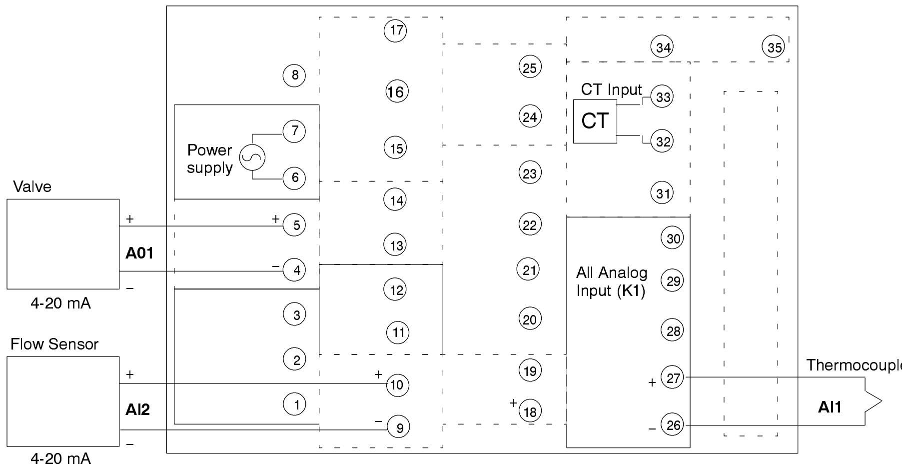



Figure 6

## 1–2–2 Start-Up Procedure

**Note:** For the following procedures, the ES100 must be powered up and connected to the COM port of the computer running ES/TOOLS via an RS-232 cable.

1. If you haven't already done so, follow the registration and configuration set up guidelines at the beginning of this manual.
2. From the ES/TOOLS Menu, double-click on the Setting <Offline> icon. The Setting Menu <Offline> will appear (Figure 7).

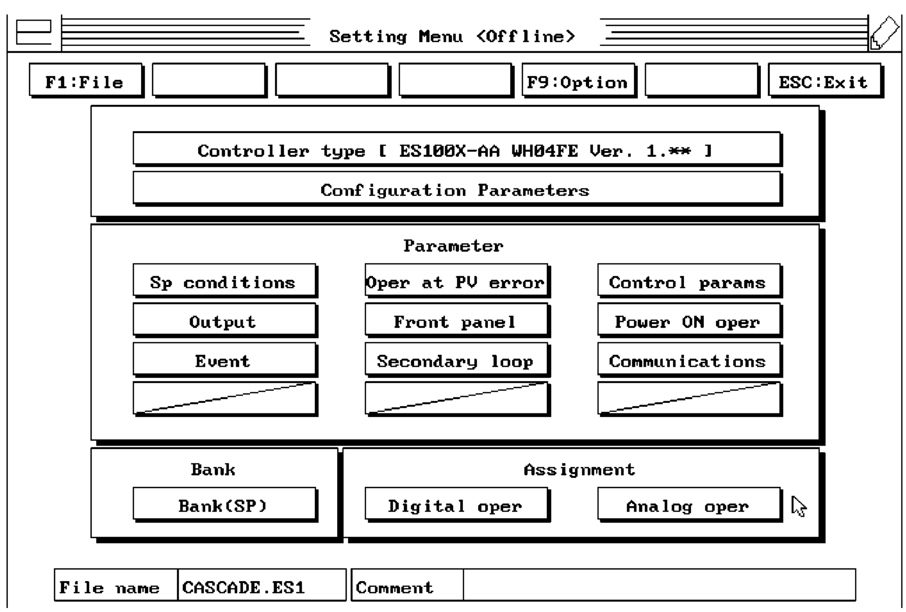



Figure 7

3. Double-click on the **Analog oper** button. The Analog operations assignment menu will appear (Figure 8).

**Note:** Only the first six entries are shown in the Analog operation assignment window. Use the scroll bar to view table entries 6, 7, 8, 9 and up.

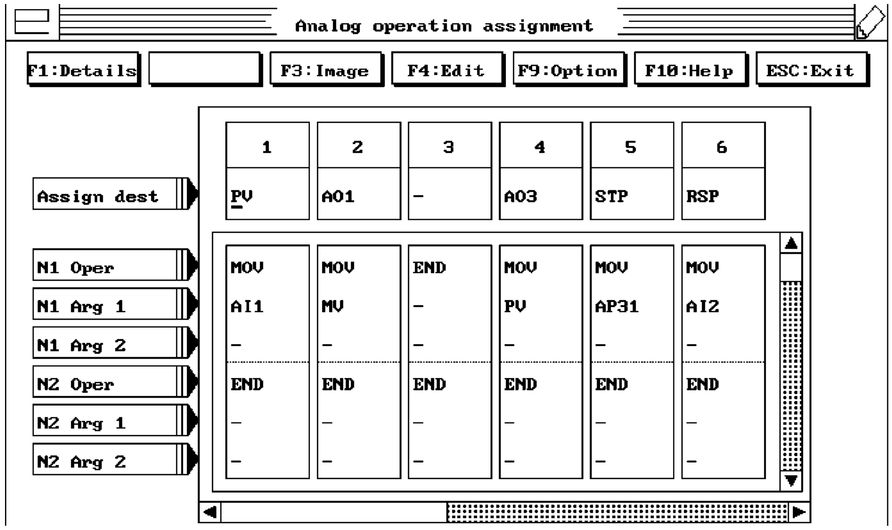



Figure 8

Analog assignment 6, 7, 8, and 9 make the internal connections. These connections allow the following functions to be performed.

- Analog input 2 to be used as the PV of the secondary loop.
- The output of loop 1 to act as a setpoint (CSP) of loop 2.
- Analog assignment Column 7 moves PV2 to an internal buffer which we can then display on the front panel of the controller.

The controller is configured for cascade control operation by default. No changes are necessary to this table unless special functions are needed. Proceed to Operation and Tuning.

## 1–3 Operation and Tuning

It is necessary to remember that in cascade control configurations there are essentially two separate PID control loops. The ES100's autotuning feature can not be invoked when setting up the controller for Cascade Control operation. Therefore, the secondary loop must be tuned manually or by using the Fuzzy Logic Fine Tuning method, as described in Section 1-2-3.

**Note:** In cascade control applications, it is required to accurately tune the secondary loop first.

There are two different methods of tuning the secondary loop. They are:

1. Limit Cycle Tuning, Section 1-2-1
2. Fuzzy Logic Fine Tuning, Section 1-2-3

## 1–3–1 Limit Cycle Tuning

**Caution: Limit Cycle Tuning may be used as long as your process will not be negatively affected by the generation of a limit cycle. If your process or system safety will be compromised by the generation of a limit cycle, refer to the Fuzzy Logic Fine Tuning Method later in this section.**

The Limit Cycle method of tuning a Cascade Control loop forces the process into a repeating oscillation, or hunting state. It is achieved by using a proportional band equal to one hundred percent of full scale.

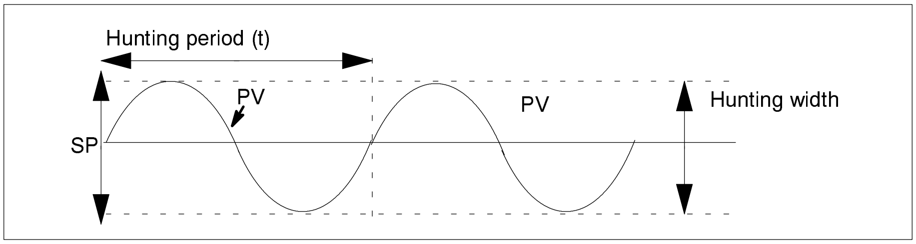



Figure 9

By forcing your process into an oscillating state of operation, you are able to observe the Peak-to-Peak temperature that it will achieve as well as how fast it will react to the oscillation. By forcing the process to oscillate, you are allowing it to attain its natural or resonant state, represented by ‘t’ in Figure 9. The period ‘t’ will be used to calculate the P, I and D values that will provide you with the optimum performance of the ES100.

### Isolating the secondary Loop

**Note:** You must have the controller powered up and the communication cable installed between the computer and ES100. This procedure also requires that ES/TOOLS be in the “optimize-uneffect” mode (see Section 1-2).

The first step in tuning the secondary loop is to isolate it from the primary loop. Isolate the secondary loop from the primary loop as follows:

1. Select the **Check control** icon from the ES/TOOLS menu by double-clicking on it (Figure 10). The **Check control** menu appears

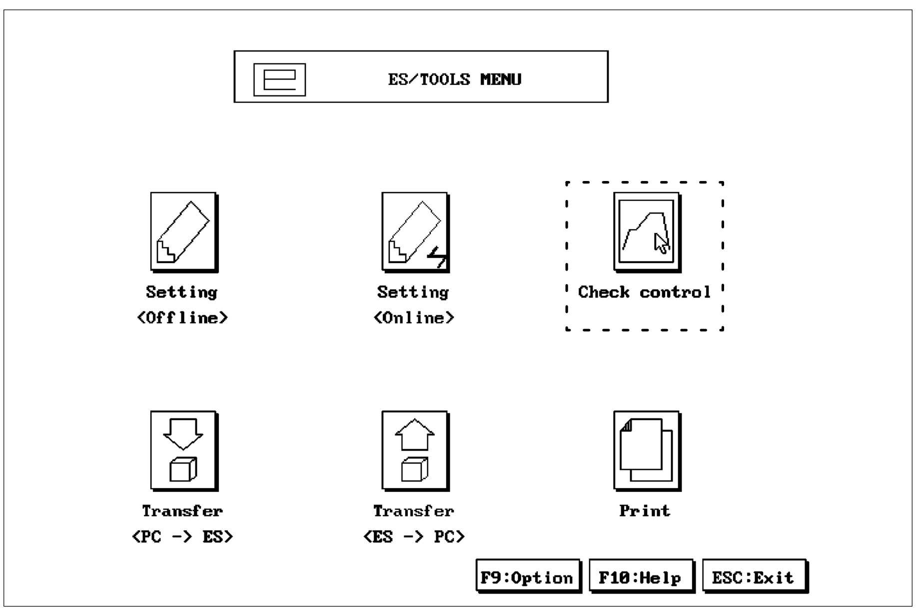



Figure 10

2. In the **Check control** menu click on F4:Command (Figure 11).

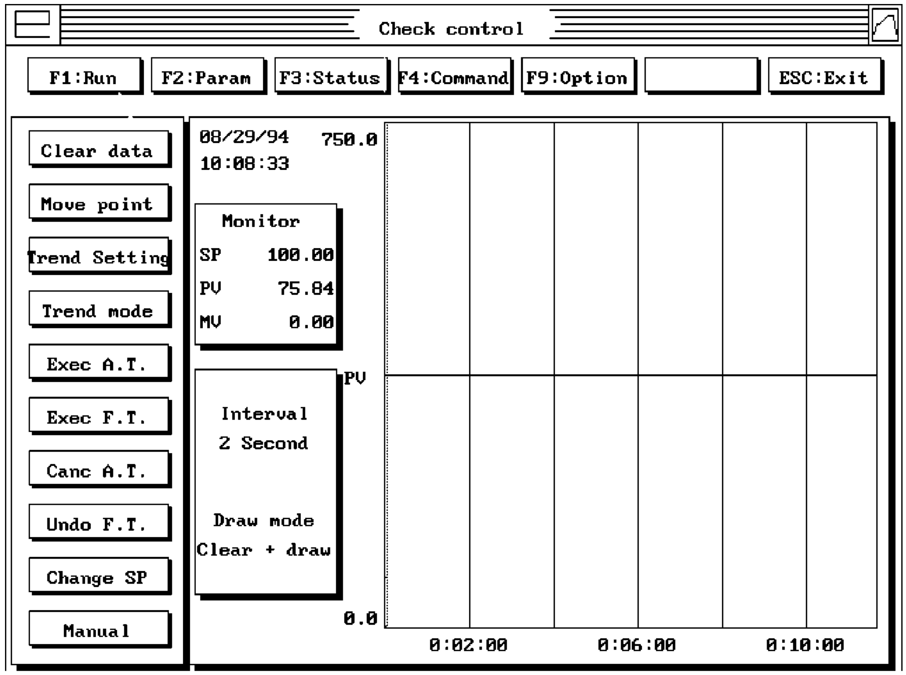



Figure 11

3. From the pop-up menu select Change Cascade OPEN/CLOSED, then select OPEN. Another pop-up menu then confirms switching cascade to open.
4. Select ENT: OK to confirm.
5. Select ESC:Cancel to return to the **Check control** menu.

The secondary loop now is independently controlled from the primary loop by the ES100. Figure 12 represents an open cascade loop with the secondary loop isolated. Note that the secondary loop is the only loop being controlled.

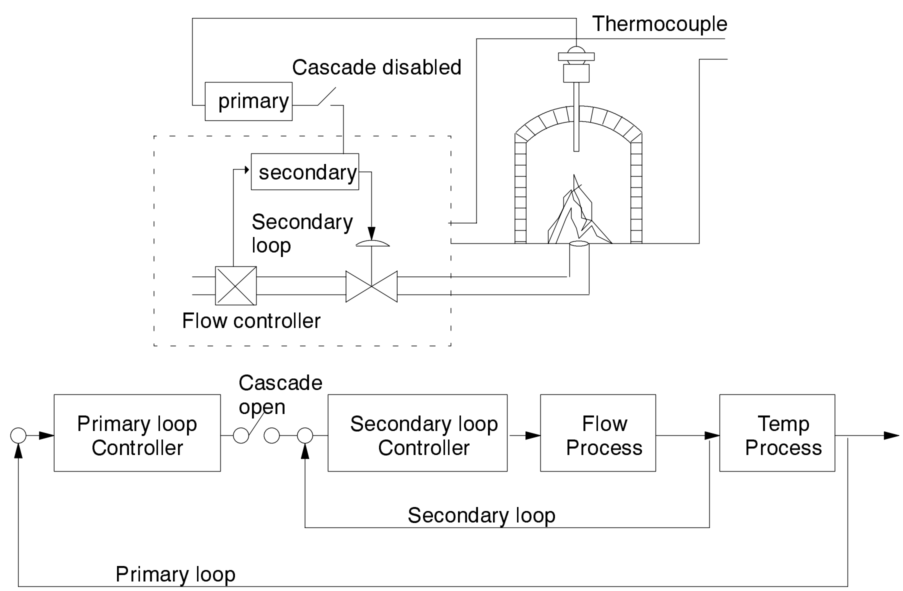



Figure 12

## Setting Secondary Loop PID Values

By isolating the secondary loop from the primary loop, you are able to view/ modify the secondary PID loop default settings.

**Note:** If you are familiar with your system PID values, use them in place of the default values. If you don't know your system's PID values, use the default values.

1. From the **Check control** menu, select **F2:Param**.
2. From the vertical menu on the left side of the screen select **PID param**.

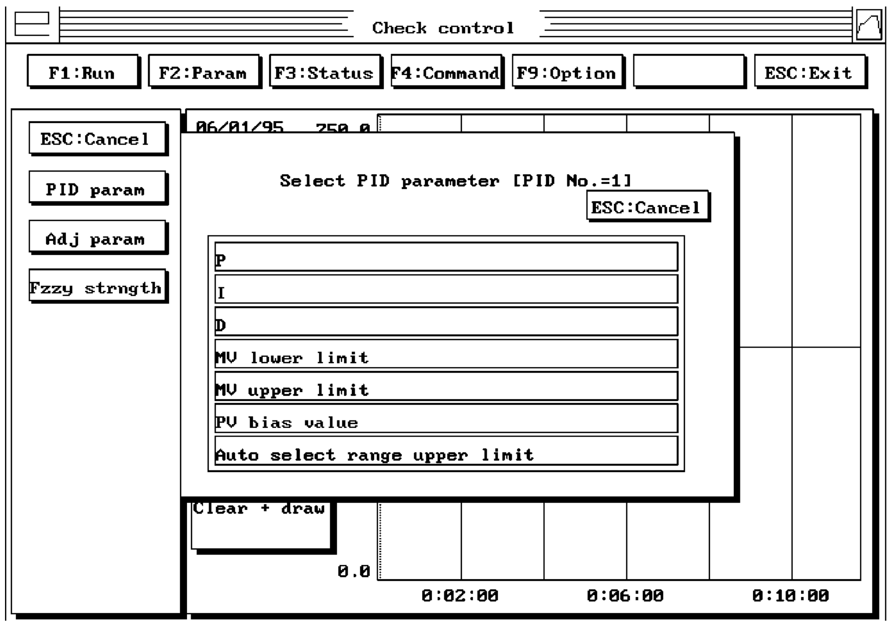



Figure 13

3. Enter the bank number and select the **ENT: OK** button.
4. From the pop-up, double-click on 'P' (Figure 13). Note that the default value is 100% which should be adequate for most applications. If a new value is desired, simply type in the new value.
5. Select **ENT: OK** button.
6. Scroll down and select 'I'. Note that the default value is 60 seconds which should be adequate for most applications. If a new value is desired, simply type in the new value.
7. Select **ENT: OK** button.
8. Scroll down and select 'D'. Note that the default value is 0 seconds which should be adequate for most applications. If a new value is desired, simply type in the new value.
9. Select **ENT: OK** button.
10. Select the **ESC:Cancel** button from the pop-up window.
11. A new window appears that will let you change PID bank #'s if you wish to. Then select **ESC:Cancel**.
12. Select the **ESC:Cancel** button from the vertical menu on the left side of the screen.

## Setting the Fixed Value Set Point for the Secondary Loop (FSP2)

**Note:** If you know what the setpoint of your secondary loop should be, use the following procedure. If you do not know, go to the Manual Output Control method later in this section.

Because the primary loop has been temporarily disconnected from the secondary loop, its output is no longer available as the setpoint of the secondary loop. Therefore, you will need to establish an approximate value for the secondary loop setpoint. This approximate value should be known to the operator/engineer with a knowledge of the system. If it is not known you can use the Manual Output Control method described later in this section. Please note that the unit of the SP2 is a percentage value. The output variable of the primary loop can be set any where between 0% (Fully OFF) and 100% (Fully ON).

1. From the ES/TOOLS menu, select **Check control**.
2. From the **Check control** menu, select **F2:Param**.

**Note:** All the options on the left side of the screen will change as shown in Figure 14

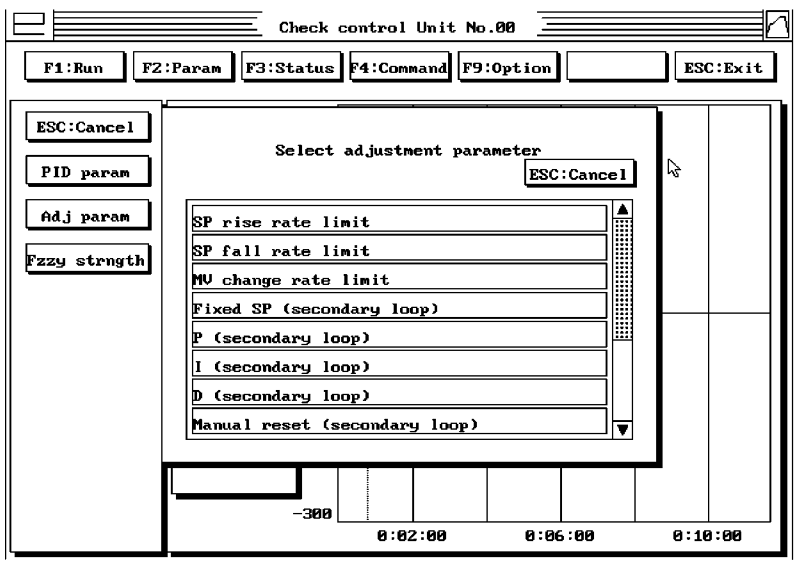



Figure 14

3. Select **Adj param**.
4. Scroll down and select **Fixed SP (secondary loop)** from the pop-up menu.
5. In the pop-up window, type in the percentage of output that you want for the setpoint of your secondary loop, then press the <Enter> key on the keyboard.
6. Select **ENT: OK** button.
7. Select the **ESC:Cancel** button from the pop-up menu.
8. Select the **ESC:Cancel** button from the vertical menu on the left side of the screen to return to the main menu.

## Displaying Process Trends

Use the following procedure to display loop process values (PV2, SV2 and MV) on your computer. You will need to monitor this display to measure hunting and width to determine PID values for the primary and secondary loops.

1. From the **Check controls** menu, select **Trend Setting**.
2. From the pop-up menu, select **Trend Item** (Figure 15).

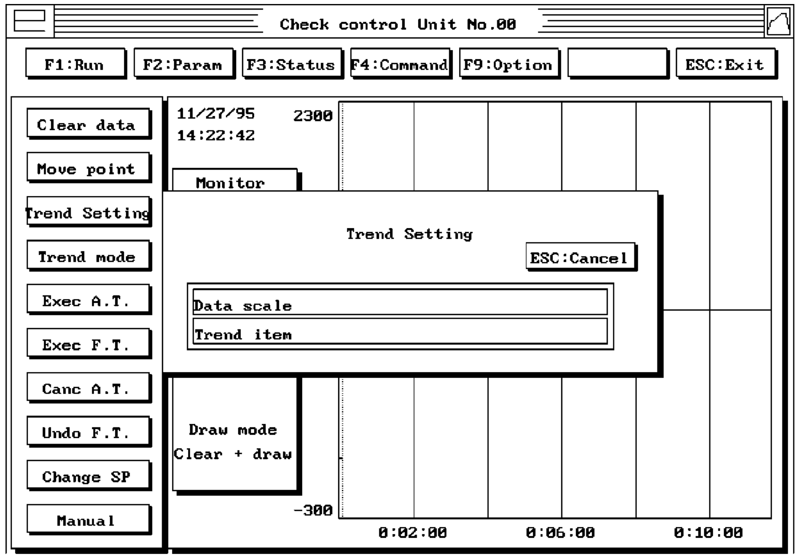
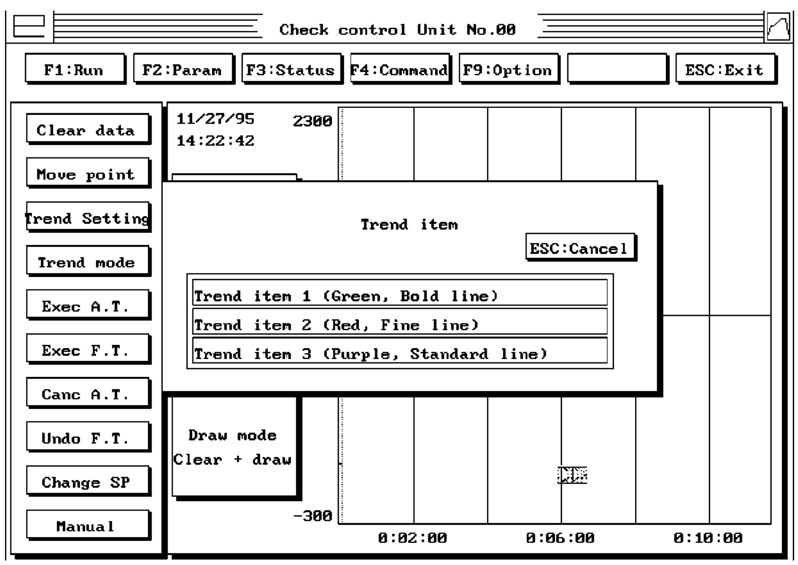



Figure 15

3. Select **Trend Item 1** (Green, Bold Line). Refer to Figure 16.




4. From the pop-up menu, select **SP2**.
5. Select **Trend Item 2** (Red, Fine Line).
6. From the new pop-up menu, select **PV2**. MV is automatically set up to display on ES/TOOLS.
7. Select the **ESC:Cancel** button from the pop-up window to return to the main menu.

## Manual Output Control (Optional)

**Note:** The following procedure can be used to approximate a value for SP2 if required, otherwise, proceed to the next section.

It is possible to incrementally increase the MV until the PV comes as close as possible to the SP that you require. Follow the steps below using small incremental increases of MV to reach your SP2.

Example: Your system = Control valve (able to control 0-20 cubic feet of gas/min), ES100, SP2 is equal to 12.5 $f^3$/m.

Begin running your process in a normal fashion. Use the instructions below to change MV to 10%. Record the MV and PV that you used once the flow of gas has stabilized. If the gas flow is not yet at 12.5 $f^3$/m, increase the MV again using the instructions below. Once you get near the SP2 increase the MV in smaller increments until you are as close as possible to the required SP2.

1. From the Main Menu, select **Check control**.
2. Select **F4:Command**.
3. Scroll down and select **Auto/Manual** from the pop-up menu.
4. Select **Manual** from the second pop-up menu.
5. Select **ENT: OK** when prompted by ES/TOOLS.
6. Select **ESC:Cancel** and go back to the **Check control** main.
7. From the **Check control** menu, go to the left side of the screen and select **Manual**.
8. From the pop-up window, set the desired output value between 0 and 100% (0% = Fully OFF; 100% = Fully ON), and select **ENT: OK**.
9. Proceed to the Limit Cycle for your secondary loop.
10. Return the controller back to Auto mode.

## Starting the Limit Cycle and Loop PID Calculations

1. Make sure that the loop PID constants are set to: P = 100. I = 0, and D = 0.
2. From the ES/TOOLS menu select **Check control**.
3. Select **F1:RUN**.
4. From the vertical menu on the left side of the screen, select **RUN**.
5. Enter the PID bank number then press the <Enter> key on the keyboard. A confirmation window appears.
6. Select **ENT: OK**.
7. The controller begins to perform an oscillating control pattern on your process. It is very important to monitor the Hunting Width and Hunting Period as closely as possible. These values will be used to calculate your final PID values (Figure 17).

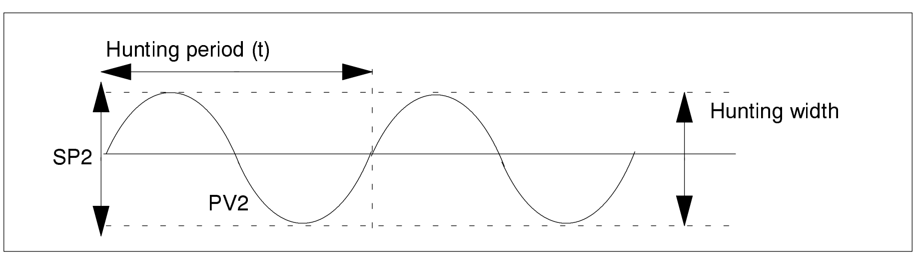



Figure 17

Use the table below to calculate your Loop PID values. In the back of this manual, there is a general discussion of PID for your review.

| Full PID control: | PI control: | P control: |
|---|---|---|
| P = 1.7 X Proportional Band (% FS) | P = 3 X Hunting Width (% FS) | P = 3 X Proportional Band (% FS) |
| I = 0.5 X Hunting Period (time in minutes) | I = 1.17 X Hunting Period (time in minutes) | I = 0 |
| D = 0.125 X Hunting Period (time in minutes) | D = 0 | D = 0 |

When you have completed inserting your calculated secondary loop PID values into the controller (see setting secondary loop PID values earlier in this section). Return to the **Check control** menu and reconfigure the trending screen to display primary loop process values (PV, SP, and MV). See the displaying process values section earlier in this chapter. The secondary loop is now tuned.

8. Return back to the **Check control** menu and stop the controller by selecting the **Reset: Stop** button.

## 1–3–2 Tuning the Primary Loop

**Note:** Before attempting to tune the primary loop, make sure to close Cascade by following the steps below.

1. From the ES/TOOLS menu, select **Check control**.
2. From the **Check control** menu, select **F4:Command**.
3. From the pop-up menu, select **Cascade OPEN/CLOSED**.
4. Selections **Cascade OPEN** and **Cascade CLOSED** appear.
5. Select **Cascade CLOSED**.
6. Select **ENT: OK** when prompted.
7. Select **ESC:Cancel** to return to the **Check control** menu.

You have now reconnected the Primary loop to the Secondary loop so your control configuration will look like Figure 18:

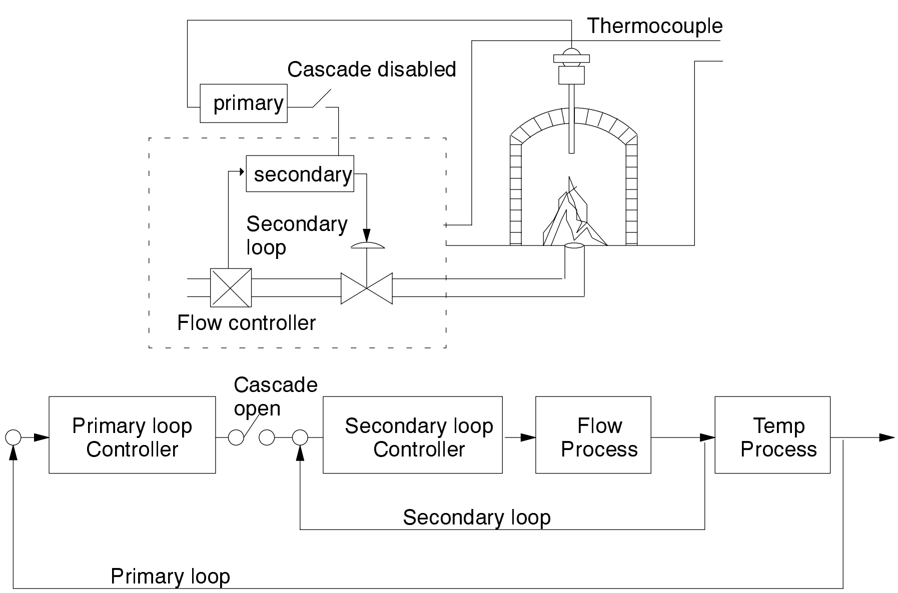



Figure 18

**Setting primary loop PID values**

Before you can set the PID values, you must set the SP (set point) for the primary loop.

1. From the **ES/TOOLS menu**, select **Check control**.
2. At the left vertical menu, select Change SP. Enter the desired set point.
3. Select **ENT: OK**.
4. Select **ESC:Cancel** from the pop-up window.
5. Select **F2: Param**.
6. Select **PID: Param** from the vertical menu from the left side of the screen. A pop-up menu will appear.
7. Select the PID bank that you are using. Select **ENT: OK**.
8. From the pop-up window, select P, I, and D separately and enter the value you need.
9. Select **ESC:Exit** until you are back to the main menu of the Check Control.
10. Refer back to Starting the Limit Cycle and Loop PID Calculations to complete tuning the primary loop.

You have now completed the setup required for using the Limit Cycle Method of determining PID values. Proceed to Fuzzy Logic Fine Tuning.

## 1–3–3 Fuzzy Logic Fine Tuning

**Note:** If you have already tuned your controller using the Limit Cycle method and want to use the Fuzzy Logic Fine Tuning as an enhancement, then go directly to the *Using Run Mode* subsection.

Fuzzy Logic Fine Tuning may be substituted for the limit cycle tuning method if a limit cycle adversely effects the process or system safety. It may also be used to complement the Limit Cycle method to enhance your ES100 performance.

Fuzzy Logic Fine Tuning is effective only with PI or PID control strategies. If you are only using P control, you must change the constants manually. The engineer or operator in charge of your process should have an approximate idea of these values in order to complete the tuning process.

### Isolating the Secondary Loop

The first step in tuning the secondary loop is to isolate it from the primary loop. Isolate the secondary loop from the primary loop as follows:

**Note:** You must have the controller powered up and the communication cable installed between the computer and ES100.

1. Select the **Check control** icon by double-clicking on it. The **Check control** menu appears

2. In the **Check control** menu double-click on F4:Command (Figure 19).

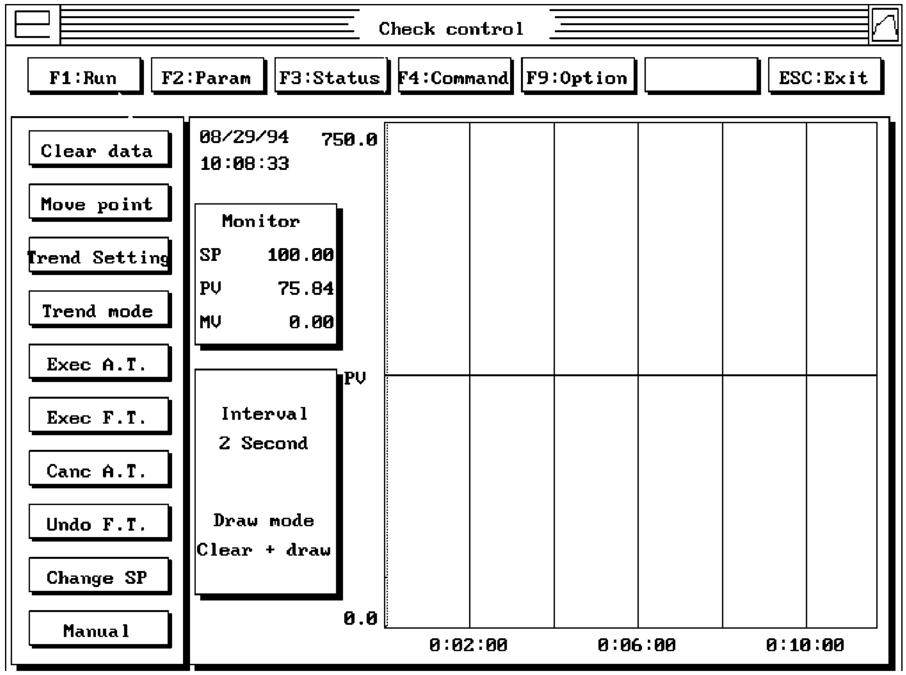



Figure 19

3. From the pop-up menu select Change Cascade OPEN/CLOSED, then select OPEN. Another pop-up menu then confirms switching cascade to open.
4. Select ENT: OK to confirm.
5. Select ESC: Cancel to return to the **Check control** menu.

The secondary loop now is independently controlled from the primary loop by the ES100. Figure 20 represents an open cascade loop with the secondary loop isolated. Note that the secondary loop is the only loop being controlled.

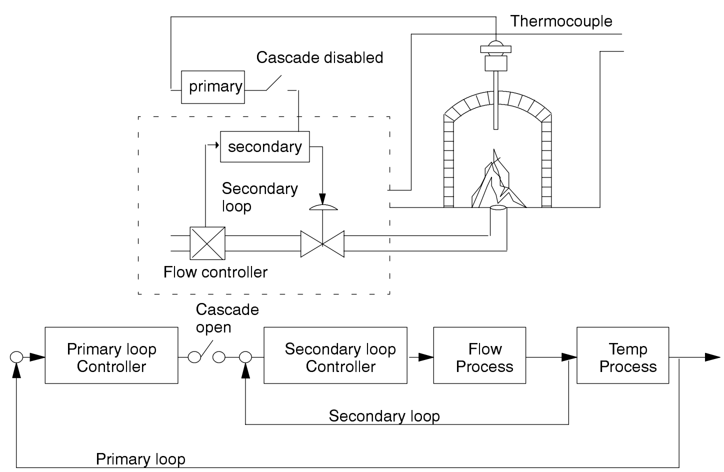



Figure 20

## Setting Secondary Loop PID Values

By isolating the secondary loop from the primary loop, you are able to view/modify the secondary PID loop default settings.

**Note:** If you are familiar with your system PID values, use them in place of the default values, if you don't know them simply use the defaults.

**Note:** You must have the controller powered up and the communication cable installed between the computer and ES100.

1. From the **Check control** menu, select F2:Param.
2. From the vertical menu on the left side of the screen select PID param.

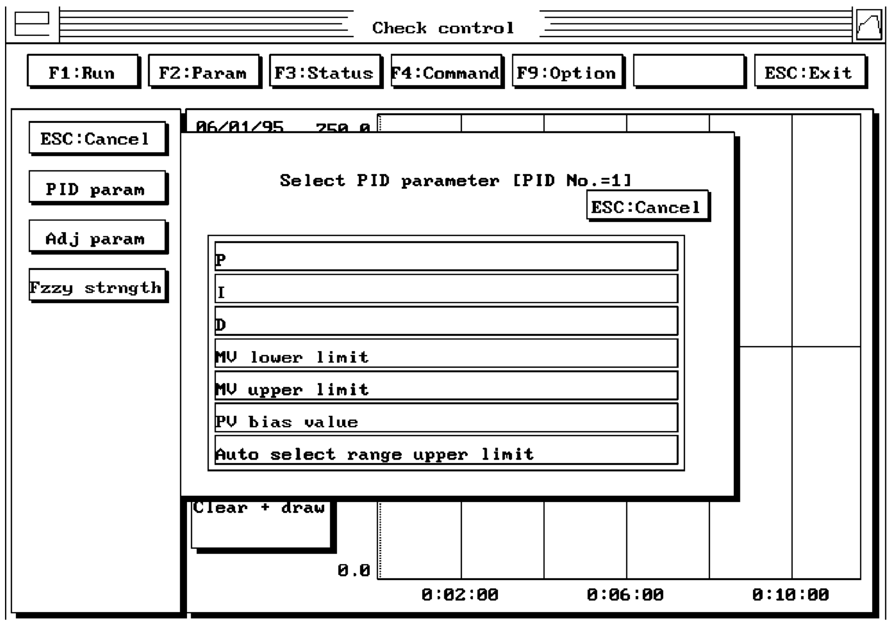



Figure 21

3. From the pop-up, double-click on 'P' (Figure 21). Note that the default value is 100% which should be adequate for most applications. If a new value is desired, simply type in the new value.
4. Select ENT: OK button.
5. Scroll down and select 'I'. Note that the default value is 60 seconds which should be adequate for most applications. If a new value is desired, simply type in the new value.
6. Select ENT: OK button.
7. Scroll down and select 'D'. Note that the default value is 0 seconds which should be adequate for most applications. If a new value is desired, simply type in the new value.
8. Select ENT: OK button.
9. Select the ESC:Cancel button from the pop-up window.
10. A new window appears that will let you change PID bank #'s if you wish to. Then select ESC:Cancel.
11. Select the ESC:Cancel button from the vertical menu on the left side of the screen.

## Setting the Fixed Value Set Point for the Secondary Loop (FSP2)

**Note:** If you know what the setpoint of your secondary loop should be, use the following procedure. If you do not know, go to the Manual Output Control method later in this section.

Because the primary loop has been temporarily disconnected from the secondary loop, its output is no longer available as the setpoint of the secondary loop. Therefore, you will need to establish an approximate value for the secondary loop setpoint. This approximate value should be known to the operator/engineer with a knowledge of the system. If it is not known you can use the Manual Output Control method described later in this section. Please note that the unit of the SP2 is a percentage value. The output variable of the primary loop can be set any where between 0% (Fully OFF) and 100% (Fully ON).

1. From the ES/TOOLS menu select **Check control**.
2. From the **Check control** menu, select F2:Param.

**Note:** All the options on the left side of the screen will change as shown in Figure 22.

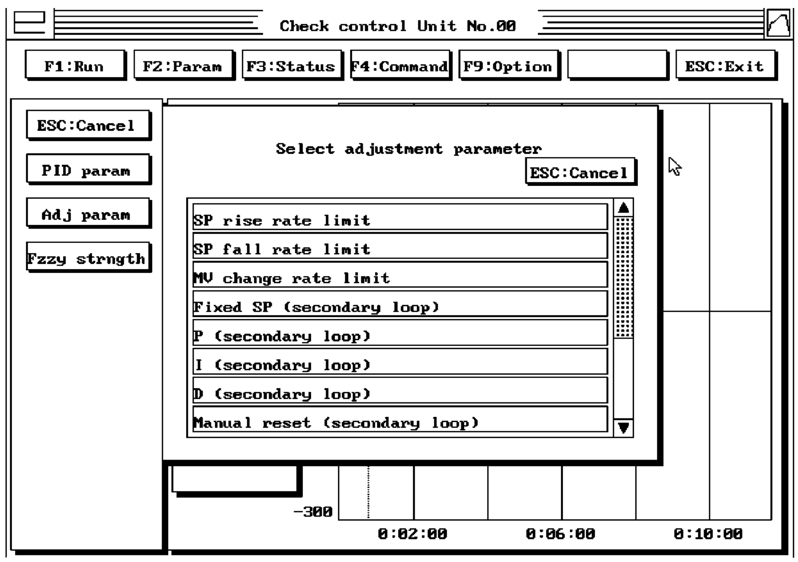



Figure 22

3. Select Adj param.
4. Scroll down and select **Fixed SP Secondary** loop from the pop-up menu.
5. In the pop-up window, type in the percentage of output that you want for the setpoint of your secondary loop, and select <Enter> on the keyboard.
6. Select ENT: OK button.
7. Select ENT: OK button.
8. Select the ESC:Cancel button from the pop-up menu.
9. Select the ESC:Cancel button from the vertical menu on the left side of the screen to return to the main menu.

## Displaying Process Trends

Use the following procedure to display loop process values (PV2, SV2 and MV) on your computer. You will need to monitor this display to measure hunting and width to determine PID values for the primary and secondary loops.

1. From the **Check controls** menu, select Trend Setting.
2. From the pop-up menu, select Trend Item (Figure 23).

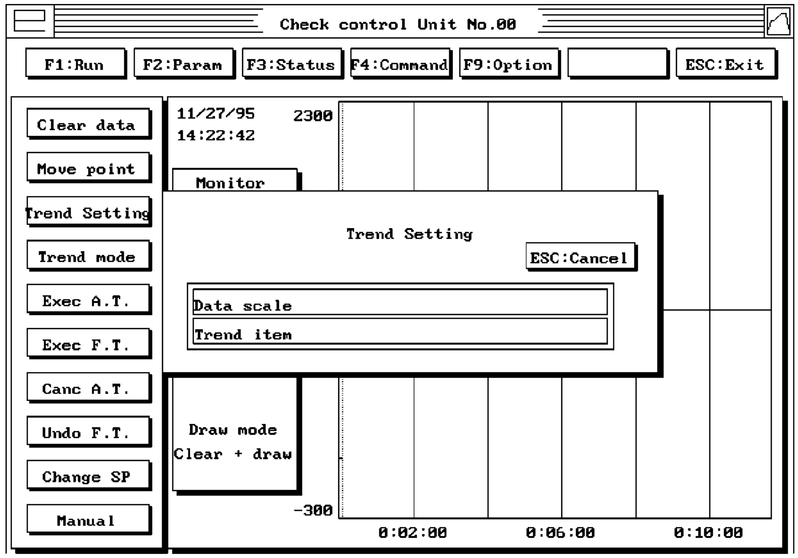



Figure 23

3. Select Trend Item 1 (Green, Bold Line). Refer to (Figure 24).

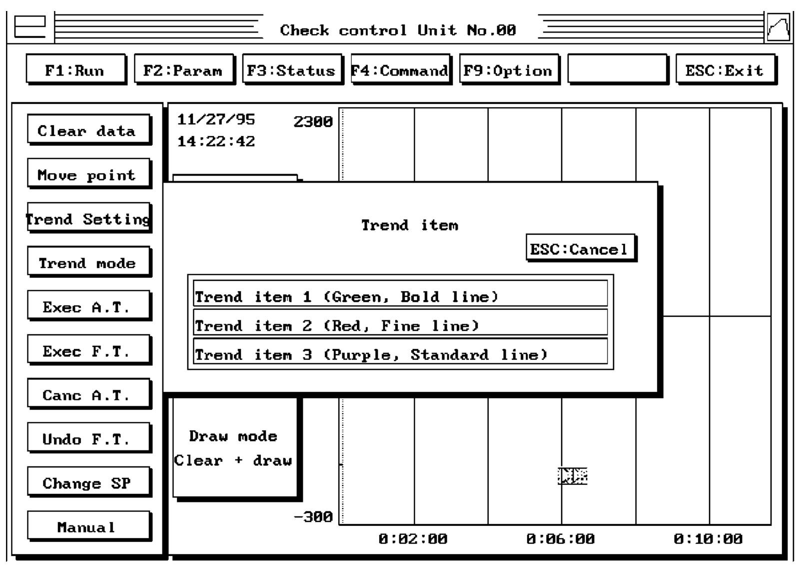



Figure 24

4. From the pop-up menu, select SP2.
5. Select Trend Item 2 (Red, Fine Line).
6. From the new pop-up menu, select PV2. MV is automatically set up to display on ES/TOOLS.
7. Select the ESC:Cancel button from the pop-up window to return to the main menu.

## Manual Output Control (Optional)

**Note:** The following procedure can be used to approximate a value for SP2 if required. If you do not need to approximate this value proceed to the next section.

It is possible to incrementally increase the MV until the PV comes as close as possible to the SP that you require. Follow the steps below using small incremental increases of MV to reach your SP2.

Example: Your system = Control valve (able to control 0-20 cubic feet of gas/ min), ES100, SP2 is equal to 12.5 $f^3$/m.

Begin running your process in a normal fashion. Use the instructions below to change MV to 10%. Record the MV and PV that you used once the flow of gas has stabilized. If the gas flow is not yet at 12.5 $f^3$/m, increase the MV again using the instructions below. Once you get near the SP2 increase the MV in smaller increments until you are as close as possible to the required SP2.

1. From the Main Menu, select **Check control**.
2. Select **F4:Command**.
3. Scroll down and select **Auto/Manual** from the pop-up menu.
4. Select **Manual** from the second pop-up menu.
5. Select **ENT: OK** when prompted by ES/TOOLS.
6. Select **ESC:Cancel** and go back to the **Check control** main.
7. From the **Check control** menu, go to the left side of the screen and select **Manual**.
8. From the pop-up window, enter the appropriate output value, 0 to 100% (0% = Fully OFF; 100% = Fully ON), and select O.K.
9. Proceed to the Limit Cycle for your secondary loop.
10. Return the controller back to the auto mode.

## Using Run Mode

1. Select **Check control** from the ES/TOOLS menu.
2. Select F1:Run.
3. From the new vertical menu on the left side of your screen, select Run.
4. Enter the PID bank number, then press the <Enter> key on the keyboard. A confirmation window comes up to verify the RUN COMMAND. Select the ENT: OK button.

Check the start-up response of the controller by monitoring it from the controller or from **Check control** menu trend view.

If the performance of the controller is not satisfactory, you may improve the performance of the ES100 by using the Fuzzy Logic Fine Tune. Follow these steps to get to the Fine Tune portion of the ES/TOOLS program.

1. From the ES/TOOLS menu select **Check control**.
2. Select Exec F.T. (Execute Fine Tuning) button.
3. You should now see a pop-up window that prompts you to input the appropriate PID set number (Figure 25).
4. Select ENT: OK.

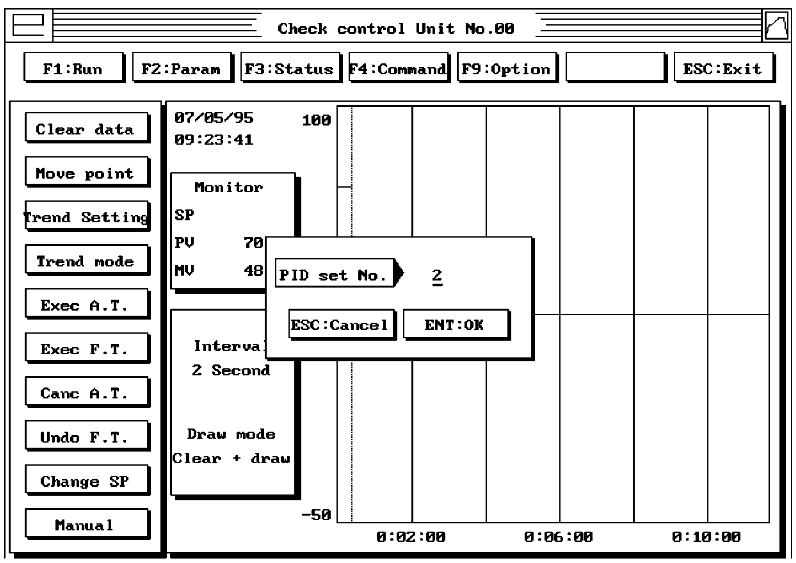



Figure 25

5. A pop-up menu will appear (Figure 26).

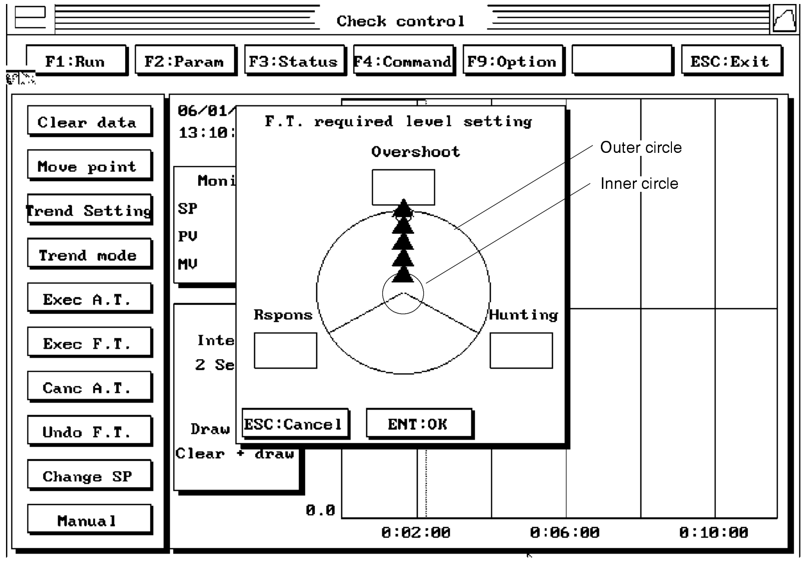



Figure 26

6. There are five different levels of response that you can initiate using Fuzzy Logic Fine Tuning. Each triangle represents one level of strength. The more triangles you select the greater the reaction will be from the Fine Tuning effect of Fuzzy Logic. You can select one parameter (as is shown) or a maximum of two parameters, such as Response/Hunting, or Overshoot/Hunting. Use the keyboard cursor controls to move the red inner circle around the inside of the outer circle. The arrowheads will automatically fill in based on the position of the red circle.
7. Select **ENT: OK** after you have selected the level of corrective action you require.
8. ES/TOOLS will prompt you to execute fine tuning, select **ENT: OK**.

**Note:** If you have already used the limit cycle method of tuning and are using Fuzzy Fine Tuning as an enhancement then STOP! You have completed your tuning. If you are using Fuzzy Logic Fine Tuning as your main tuning procedure, continue below with Close Cascade and Tune Primary Loop PID Constants.

## Close Cascade and Tune Primary Loop PID Constants.

1. From the ES/TOOLS menu select **Check control**.
2. From the **Check control** menu, select **F4:Command**.
3. From the pop-up menu, select **Cascade OPEN/CLOSED** which brings up a pop-up menu that gives you a choice of Cascade OPEN or Cascade CLOSED.
4. Select **Cascade CLOSED**.

You have now reconnected the primary loop to the secondary loop so your control strategy will look like this (Figure 27).

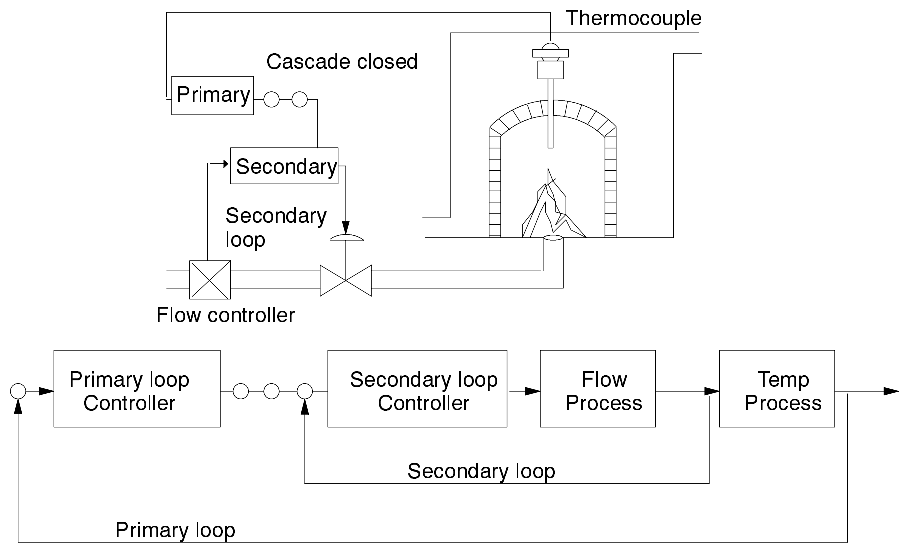



Figure 27

## Set Point (SP)

**Now set the SP (Set Point) for the Primary loop**

1. From the main menu of the **ES/TOOLS,** select the **Check control** icon.
2. Go to **F4: Command**.
3. Select **Change Setting Mode**.
4. Double-click on **Setting mode: Remote**. This mode will enable you to adjust the Fixed Value Setpoint for autotuning or limit cycle tuning process. The FSP (Fixed Value Set Point) is a separate set point that can be used for tuning purposes or when the running program is finished as a default settings. It can also be used when an input error is detected (broken thermocouple). The FSP can be used to continue running the process at a safe setting.
5. A pop-up window will verify the selection of Remote Setting Mode. Select **ENT: OK**.
6. From the same window that Change Setting Mode was selected from, double-click on **Change SP Mode**.
7. From the pop-up window, double-click on **SP Mode: Fixed value**. This will make the controller respond only to the FSP.
8. A pop-up window will verify the selection of Fixed value for Change SP mode.
9. Select **ESC:Cancel**.
10. Select **ESC:Cancel**.
11. Select **Change SP**. Enter the new set point and select **ENT: OK**.

## Run Mode

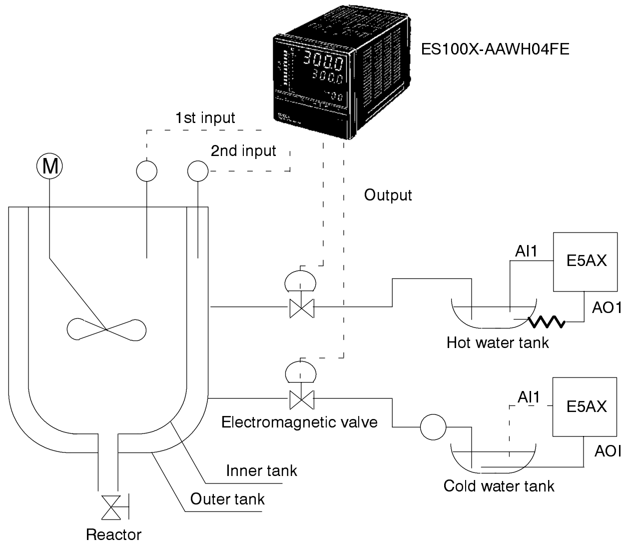
**Place the ES100 into RUN Mode using the Check control menu**

1. Go to the **Check control** menu from the Main Menu in ES/TOOLS.
2. Select **F1:Run**.
3. From the new vertical menu on the left side of your screen, select **Run**.
4. Select **ESC:Cancel** to return to the **Check control** menu.

You have now completed the Fuzzy Logic Fine Tuning of the ES100 Controller. If your control is still not satisfactory, you may use the autotuning feature as often as necessary until your control operation is satisfactory to you.

# 1-4 Applications

## 1-4-1 Chemical Reactor



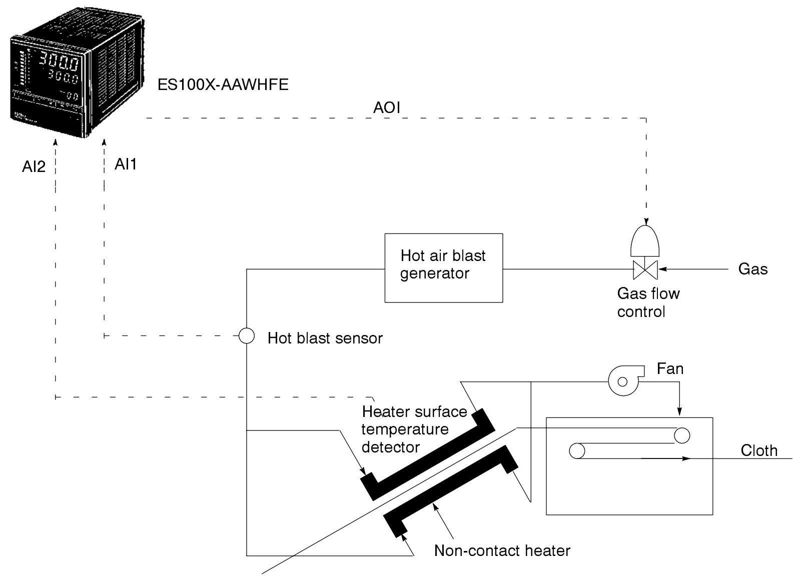

**Process Requirements**

1. The chemicals involved in this reaction are maintained at a specific viscosity to enable the proper reaction to occur. Viscosity for this process can be controlled with temperature.
2. The temperature of the reaction must be controlled by maintaining the temperature of the water jacket. The water temperature is controlled by utilizing two control valves. One for hot water the other for cold water.
3. A digital signal is sent to the recorder from a viscosity sensor for an alarm.

**Model Selection**

1. With Cascade control, the ES100 was able to provide a very close tolerance in the process during testing.
2. The digital I/O capabilities of the controller are utilized in sequencing of the process.

## 1-4-2 Touchless Clothes Dryer



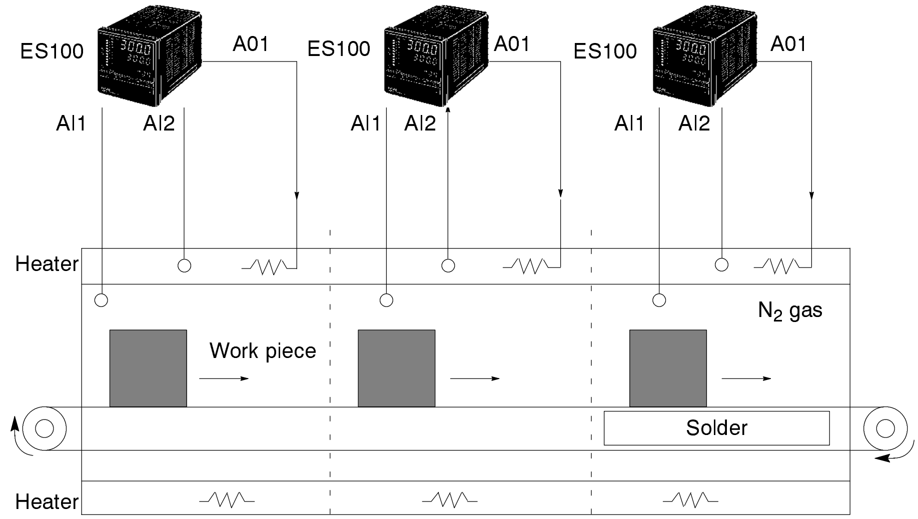

**Process Requirements**

1. The process show depicts a touchless clothes dryer. By precisely controlling the temperature of a non-contact heater, the clothes can be dried without damage more efficiently.
2. The clothes will be dried with a combination of the non-contact heater and periodic hot air blasts.

**Model Selection**

1. During testing, the Cascade Control Strategy provides precise temperature control.
2. With the bank PID selection, several product lines can be controlled without reprogramming the controller.

## 1-4-3 Gas Solder Machine



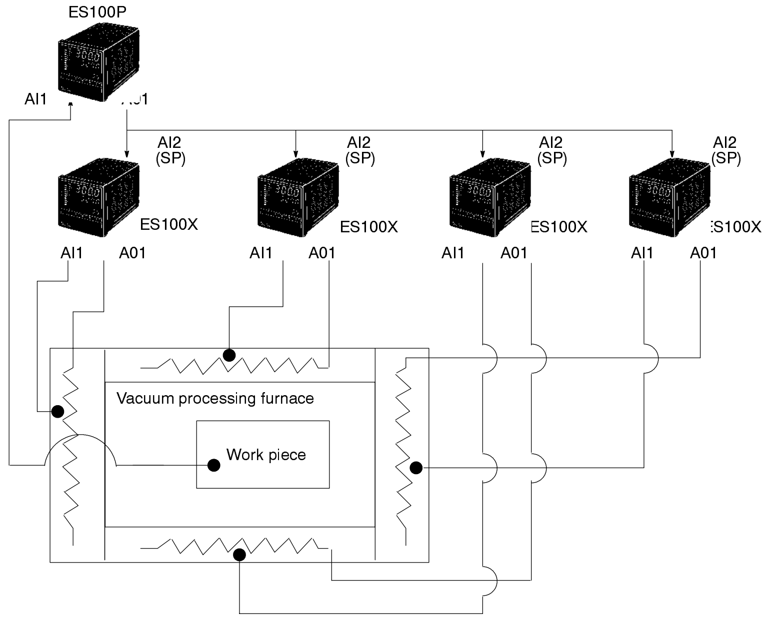

**Process Requirements**

1. Speed up process.
2. Tightly control temperature of the furnace

**Model Selection**

1. With a combination of Cascade Control and an increase of Fuzzy intensity to 70%, the ES100 reduced the time required for a work piece to go through the process from 90 to 12 minutes.

## 1-4-4 Vacuum Processing Furnace




**Process Requirements**

1. Accurately control the temperature of a vacuum furnace with a Ramp Soak Profile.
2. Workpiece temperature may be slightly different than heater temperature throughout the profile.

**Model Selection**

1. By using a primary and secondary set-up, it is possible to provide a Ramp Soak profile to ES100X. The ES100X uses the profile as an RSP, and is configured in the Cascade Control strategy.
2. ES\TOOLS provided easy set-up and maintenance.
3. The Ramp Soak model (ES100P) provided an accurate and steady profile to the ES100X's via the transmission output.

# SECTION 2
# Position Proportional Control

# 2-1 What is Position Proportional Control

Position Proportional Control is a feature of the ES100 which is used to control steam, cooling water, or some fluid/gas substance by controlling valve positioning. It is used in conjunction with a PID algorithm that produces a manipulated variable which is used by the controller to position the valve. There are two types of position proportional control: closed and floating.

## 2-1-1 Closed Control

A Position Proportional Control using a potentiometer incorporated into a control valve is called a CLOSED CONTROL LOOP. In this system, the valve opening is converted into a resistance value that is fed back into the controller. Then the valve is rotated forward or reverse until the opening (in degrees) matches the value output with the manipulated variable.

In the following example, the temperature in a furnace is controlled by adjusting the fuel flow to the furnace.

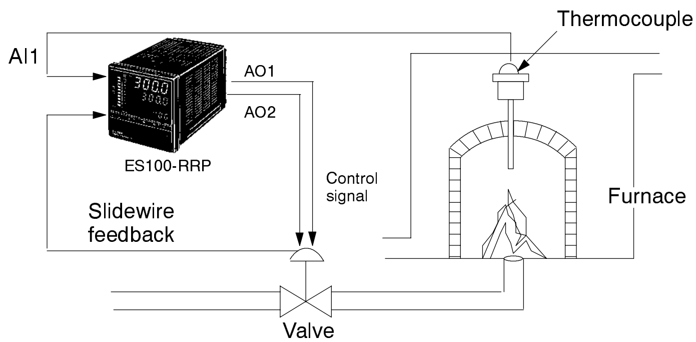



Figure 1

In (Figure 1) we are reading the temperature from a thermocouple in the furnace. We are also reading the exact position of the valve using a potentiometer (slidewire feedback). Using the two relays in the ES100, the controller will send OPEN or CLOSE signals to adjust the valve. The potentiometer feed back lets the ES100 know exactly how wide the valve is open and prevents damage to the valve from over travel.

## 2-1-2 Floating Control

In a floating control loop, the valve is controlled without using a potentiometer and there is no mechanical feedback from the valve to provide the controller with its exact position (Figure 2).

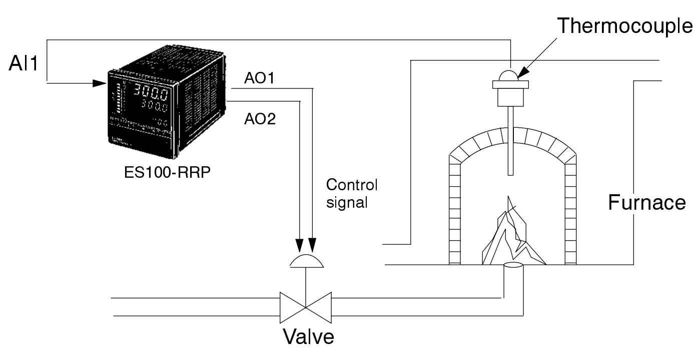



Figure 2

The ES100 operates by sending a signal for the valve to OPEN. Based upon the elapsed time that the valve was energized, the ES100 will estimate the actual position of the valve. The Floating Control Loop functions by converting the elapsed time the valve was open or closed into a value that the ES100 can use to determine the position of the valve (Figure 3).

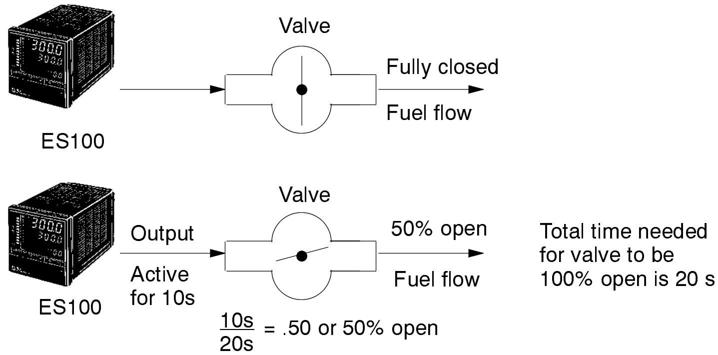



Figure 3

There are several advantages to using Floating Control Loops over that of Closed Control Loops:

1. The control performance is not affected by potentiometer wear and contact failure.
2. Floating Control Loops are more resistive to noise which improves reliability and the safety of the system.
3. Floating Control Loops eliminate the need for potentiometer wiring. Saves control valve costs by eliminating the potentiometer.

The disadvantages of Floating Control Loops when compared to a Closed Control Loop are:

1. There is no proportional action in the control loop.
2. There is no Manipulated Variable limiter.

**Note:** With floating control, the MV upper and lower limits are disabled. When they are required, you must provide the limiting operation directly to the valve.

## 2–1–3 Start-Up Procedure

**Note:** For the following procedures the ES100 should be powered up and connected to the correct port of the computer running ES/TOOLS via the RS-232 cable.

For Position Proportional Control, use ES100X or ES100P with the suffix “RRP”. (ES100_-RRP_ _ _ _ _).

1. Position Proportional Control cannot be performed if any other ES100 model number is used.
2. Since the control output module E53-R is installed in the unit, there is no need to purchase another output module unless replacement is required.

In order to get the controller up and running the quickest way, we will only program selected items. There will not be a need to do any advanced programming at this time.

Figure 4 shows an ES100-RRP using a K type thermocouple as Analog Input 1, and both outputs are being used to control the position of the valve (Analog Out 1, 2). The position of the valve is known from a potentiometer feedback.

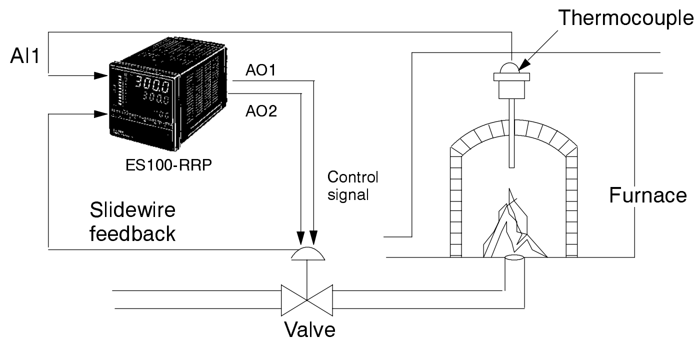



Figure 4

## ES100 Wiring Diagram

For closed control, a potentiometer is required. If no potentiometer is connected to the ES100 when it is configured for closed control, an error code will be displayed and control of the process cannot continue. The Manipulated Variable or MV, will go to a default value (Figure 5).

A potentiometer with a resistance value in the 100Ω - 2.5 KΩ range should be used. For floating control, no potentiometer is required.

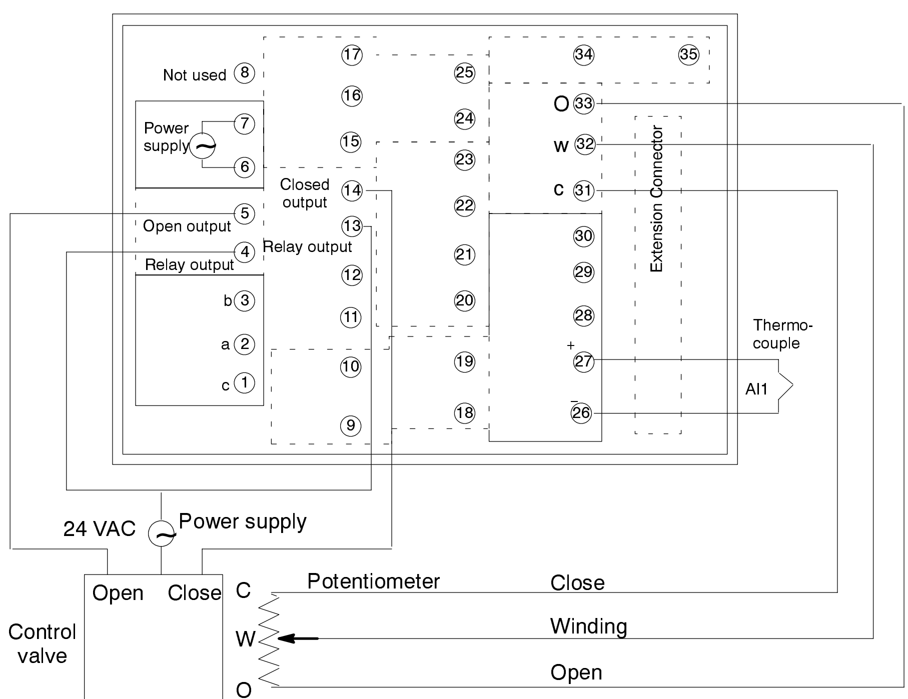



Figure 5

## 2–2 Operation and Tuning

Before you can tune the controller you must first set it up. Proceed in the order of the listed operations.

- Operation and Process Value Error
- Valve Hysteresis and Dead Band
- Configuring the Front Panel
- Motor Calibration and Travel Time
- Travel Time with Floating Control

### 2–2–1 Operation at Process Value Error

The operation at process value error, is used to determine what the controllers action will be. For example, if the potentiometer wire breaks and the control loop becomes open, what action do you wish the controller to take? (Options include fully opening the valve, fully closing the valve, or holding its present position).

1. From the main menu select **Setting Menu <Offline>**.
2. From the **Setting Menu <Offline>**, select **Operation at PV error**.
3. Select **MV at PV error (posi-prop)** for valve positioning controllers (Figure 6).

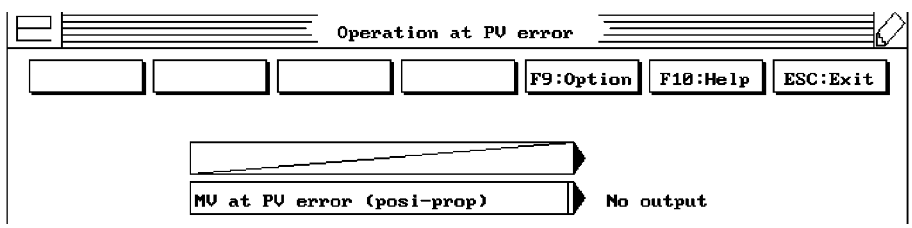



Figure 6

4. Select the desired action from the pop-up menu in Figure 7.
5. Select **ESC:Cancel**.
6. Select **ESC:Cancel**.

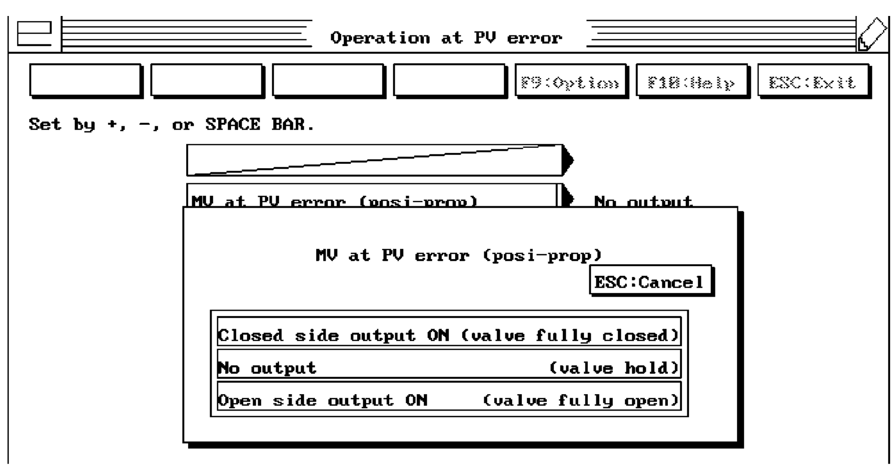



Figure 7

## 2-2-2 Valve Hysteresis and Dead Band

A dead band is a place in the process where no control action is desired (Figure 8).

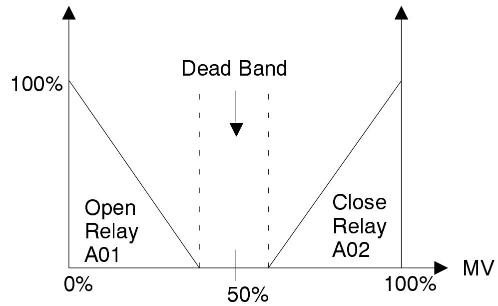



Figure 8

Hysteresis results in the activating point being different from the release point. Typically, this value is expressed as a percentage of the output or alarm setting value. It identifies the distance between the activation point and the release point resulting from the PV approaching or moving away from the activation point.

To set the dead band and hysteresis for the valve proceed as follows:

1. From the **Setting Menu <Offline>**, select **Posi-prop** (Figure 9).

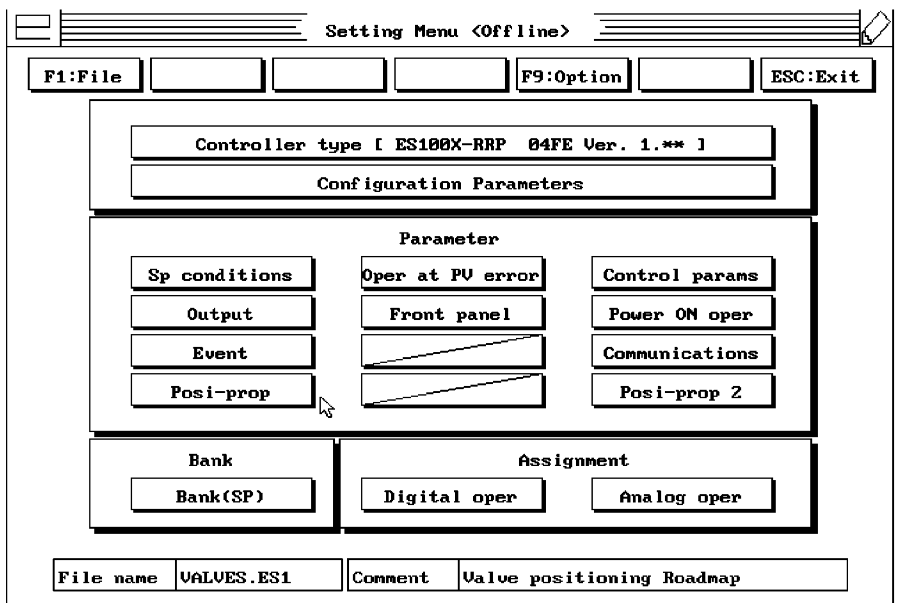



Figure 9

2. Select **Posi-prop dead band** Figure 10. Insert a dead band between the OPEN and CLOSE action of the valve. The default value is 2%.

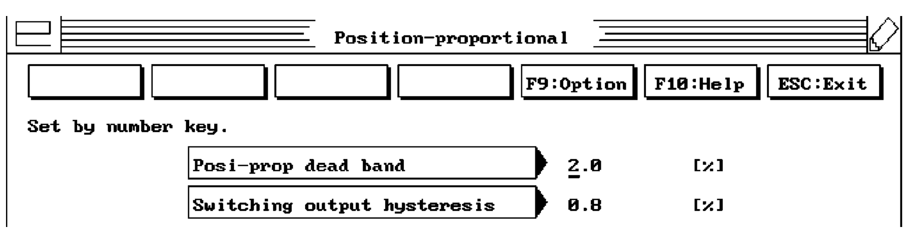



Figure 10

3. Select Switching output hysteresis. This setting adjusts the hysteresis to protect your valve/process from too quick of a reaction from the controller, which could result in a fluttering effect from the output relay if the hysteresis is too small. The default is 0.8%.
4. Double-click on ESC:Cancel.

## 2–2–3 Configuring the ES100 Front Panel

In this section you will learn how to use ES/TOOLS to configure the front panel of the ES100 to display the process parameters of your choice (PID, PV, SP, MV). However, you may elect not to make any changes to the front panel. In this case proceed to Motor Calibration and Travel Time in this section.

There will be differences in the software setup of the controller between slide wire feedback and floating control. If you are using floating control, some operational parameters will not be displayed in ES/TOOLS.

1. From **Setting Menu <Offline>** select **Front Panel**. A pop-up menu appears. Double-click on the **PF Key** (Figure 11).

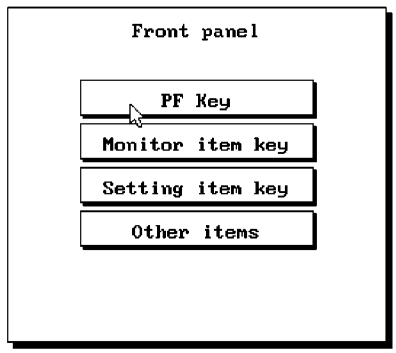



Figure 11

2. A PF key menu appears (Figure 12).

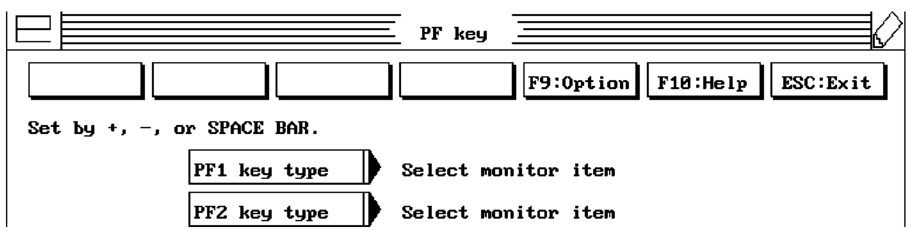



Figure 12

3. Double-click on the PF1 key type button which brings up the PF1 key type pop-up menu.
4. Select Select monitor item (Figure 13). The screen will disappear after selecting.
5. Now select PF2 key type.
6. This will bring you to a pop-up menu which you can select Run/reset (stop) inversion. The screen will disappear after selecting.

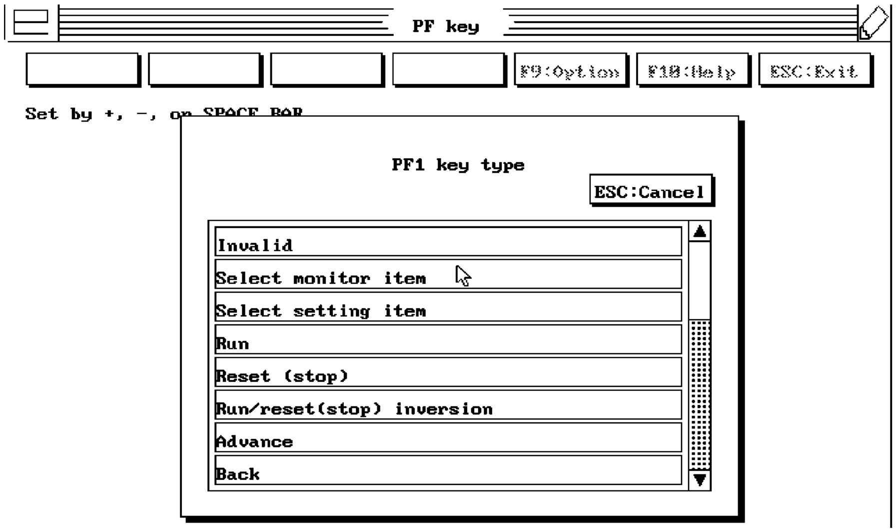



Figure 13

7. Select the ESC:Cancel button twice to return to the **Front Panel** menu.
8. Select Monitor item key. The monitor item selection key menu will appear (Figure 14).

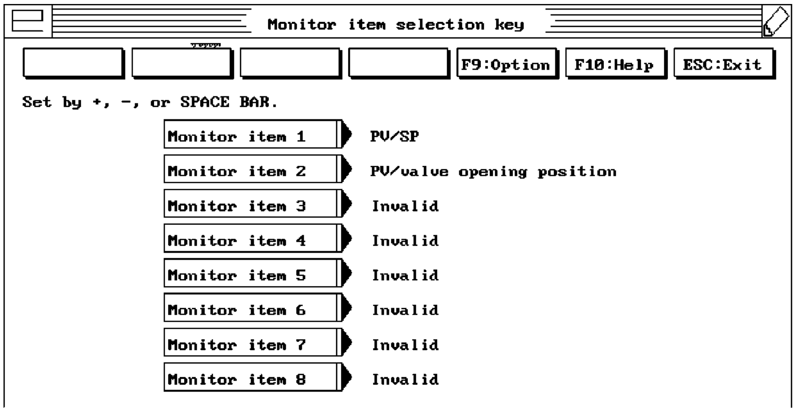
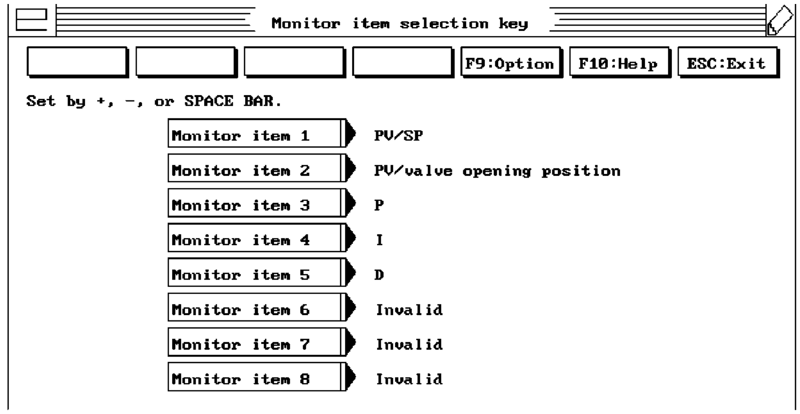



Figure 14

**Note:** From here you may modify which items are to be displayed on the front panel of the ES100. For example, you may display your P, I, and D values by modifying Monitor items 3, 4 and 5 as shown in Figure 15.




9. From the monitor item selection key menu, select Monitor item 3. A pop-up menu appears.
10. Select the item you which to monitor from the list.

## 2–2–4 Motor Calibration and Travel Time

In order for the ES100 to accurately control your process, precise information will have to be obtained on valve reaction speed and the time required to go from fully OPEN to fully CLOSED. **Motor calibration cannot be performed with ES/TOOLS.** It only can be executed from the front panel of the ES100.

Performing Motor Calibration – (Parameter C051 in the ES100 Setting Level 2). Refer to your ES100 User Manual.

**Note:** **If you are using floating control, you do not need to perform this operation. Skip to section 2-2-5. You do need to perform the travel time setup steps in the section following Motor Calibration.**

This operation is required only when operating a closed control loop or slide wire feed back. Motor Calibration is required by the ES100 because it uses the electrical resistance of the valve to determine the valve's position. By performing motor calibration you allow the ES100 to scale the resistance values into a range, from fully closed to fully open.

1. You must to have the controller completely connected to your process (a power source and the valve it will be controlling, slidewire feedback, etc.).
2. Slide the ES100 controller out of the plastic housing and locate Switch 1 and Switch 2 on the top of the controller near the face plate. Make sure that SW1, SW2-1 and SW2-2 are turned ON. SW2-3 and SW2-4 should be turned OFF. See Figure 16.

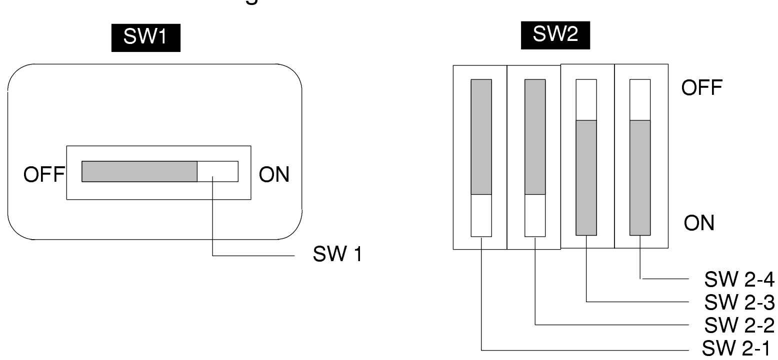



Figure 16

3. Plug the ES100 back into its case. The LED display should show C001 on the PV display. With the UP and DOWN arrows, scroll through the menu until you see C051 on the PV indicator.
4. Push the **ENT** (Enter) key. This will start the ES100 calculating your valve's motor calibration and travel time.
5. After completing this task, return the internal dip switches to their standard or running position (Figure 17).

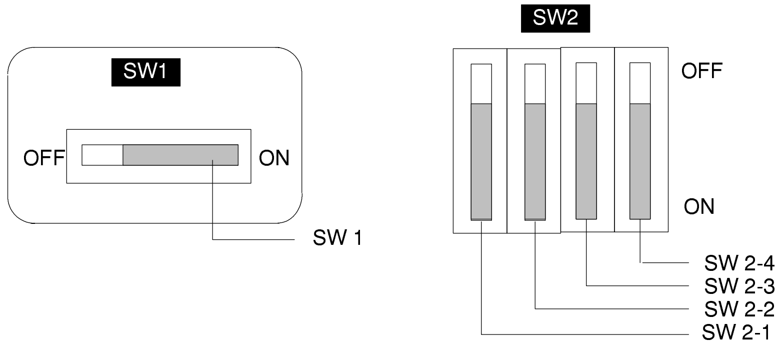



Figure 17

## 2–2–5 Travel Time with Floating Control

Travel time is the time, in seconds, that the value takes in changing from fully OPEN to fully CLOSED. Most control valves will have this time in their specification sheets. This value must be entered manually through ES/TOOLS. To set Travel time proceed as follows.

1. From the **Setting Menu <Offline>** select Posi-prop 2 (Figure 18).

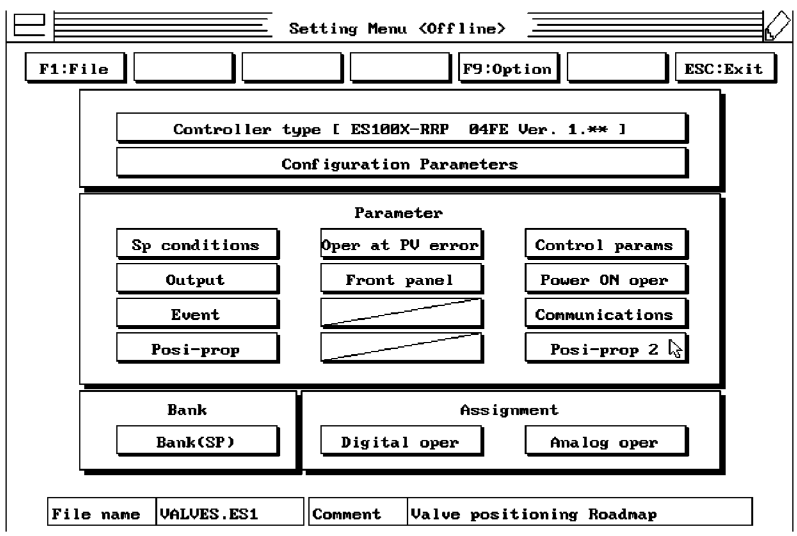
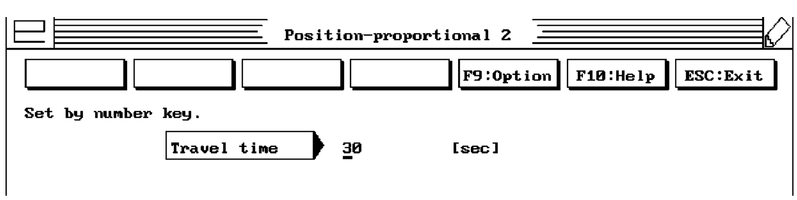



Figure 18

2. Travel time will now appear in the screen (Figure 19).
3. Insert the travel time (in seconds) in this field. The default is 30.




4. Select **ESC:Cancel**.

5. Select ESC:Cancel again to return to the main menu.

To tune your control loop, proceed to Autotuning.

## 2–2–6 Autotuning

Autotuning can be used with valve positioning ES100 controllers. The autotune feature uses a method of tuning similar to a limit cycle, which is more fully described in Section 1, Cascade Control. When autotuning is activated it will be indicated by a blinking yellow LED on the front panel of the ES100.

**Note:** The ES100 must be powered-up and connected to the computer running ES/TOOLS via an RS-232 cable.

1. From the **ES/TOOLS MENU** select **Check Control**.
2. Select F1:Run from the **Check control menu**.
3. Select Run from the **Check control Unit No. 00** menu.
4. Now select ESC:Cancel to get back to the **Check control menu**.
5. Select Exec A.T. by double-clicking.
6. A new pop-up window will appear (Figure 20). Select which PID bank you wish to autotune.
7. Double-click on ENT:OK.

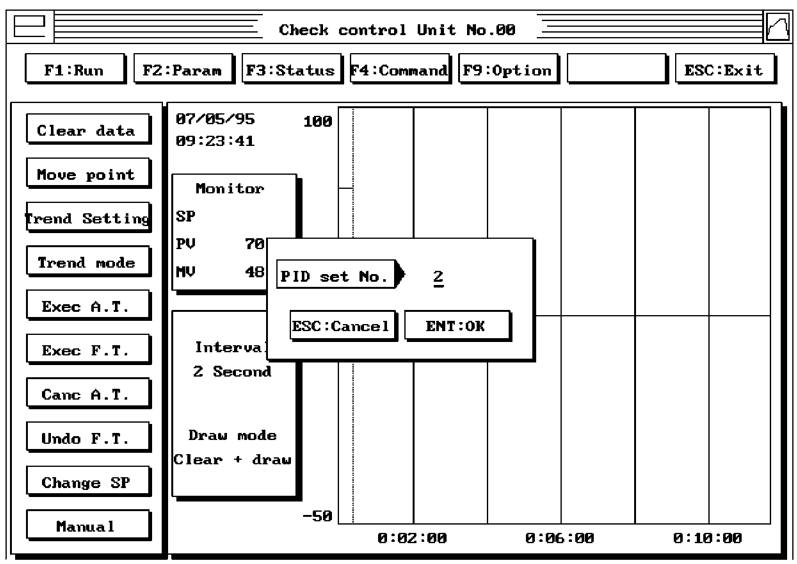



Figure 20

8. The controller will now autotune itself. Do not interrupt or stop this process otherwise the process will not be completed. The controller will have completed autotuning when the yellow “AT” light stops blinking.

## Run Mode

**Place the ES100 into RUN Mode using the Check control menu**

1. Go to the **Check control** menu from the Main Menu in ES/TOOLS.
2. Select F1:Run.
3. From the new vertical menu on the left side of your screen, select Run.
4. Select ESC:Cancel to return to the **Check control** menu.

## 2–2–7 Fuzzy Logic Fine Tuning

If the performance of the controller is not satisfactory after autotuning, you may improve the performance of the ES100 by using the Fuzzy Logic Fine Tune. Follow these steps to get to the Fine Tune portion of the ES/TOOLS program.

**Note:** The ES100 must be powered-up and connected to the computer running ES/TOOLS via an RS-232 cable.

1. From the **ES/TOOLS MENU** select the **Check control** icon.
2. Select **Exec F. T.** from the **Check control** menu (Figure 21).

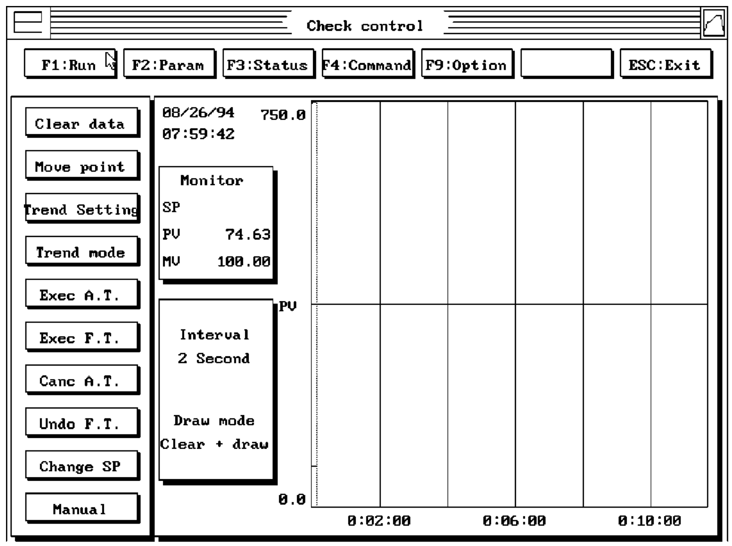



Figure 21

3. A pop-up window appears to confirm the PID set that you are using (Figure 22). Enter the appropriate PID set number and select **ENT:OK**.

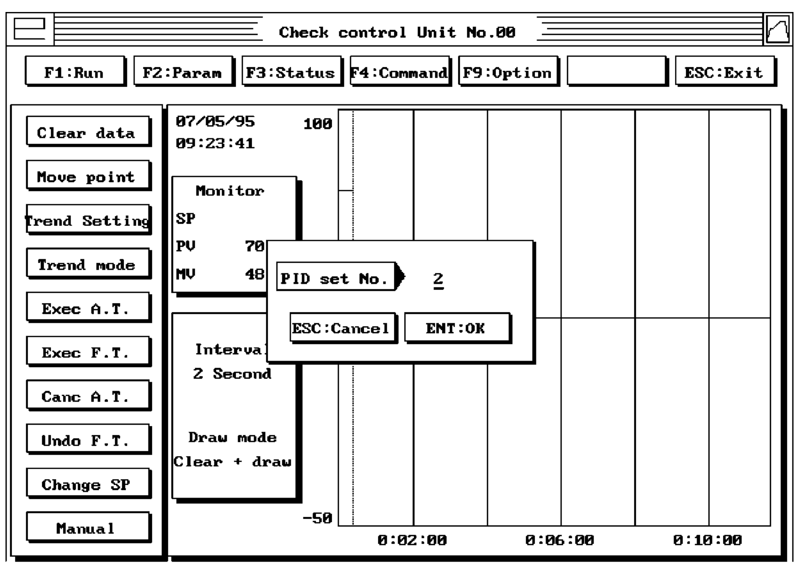



Figure 22

4. Another pop-menu appears which allows you to set fuzzy logic fine tuning (Figure 23).

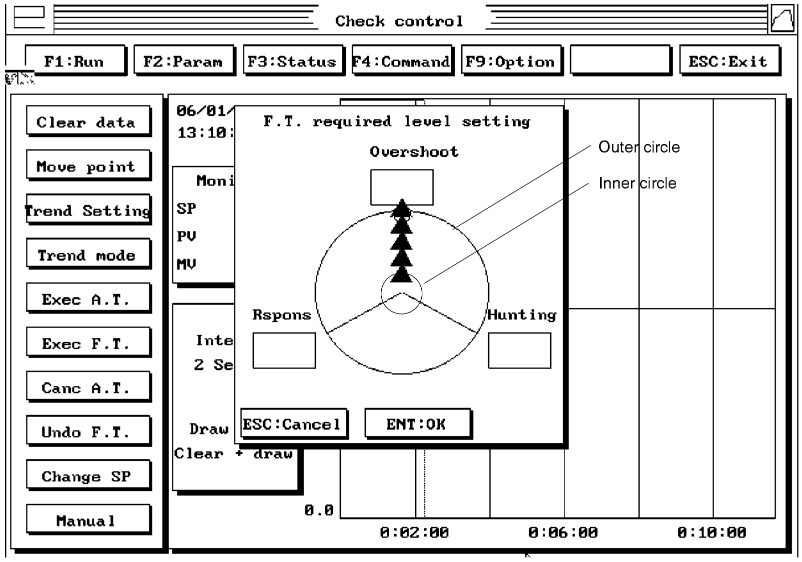



Figure 23

5. There are five different levels of response that you can initiate using Fuzzy Logic Fine Tuning. Each triangle represents one level of strength. The more triangles you select the greater the reaction will be from the Fine Tuning effect of Fuzzy Logic. You can select one parameter (as is shown) or a maximum of two parameters, such as Response/Hunting, or Overshoot/Hunting. Use the keyboard cursor controls to move the red inner circle around the inside of the outer circle. The arrowheads will automatically fill in based on the position of the red circle.

6. Select ENT: OK after you have selected the level of corrective action you require.

7. ES/TOOLS will prompt you to execute fine tuning, select ENT:OK. Repeat Fuzzy Logic Fine Tuning as necessary to achieve optimum performance.

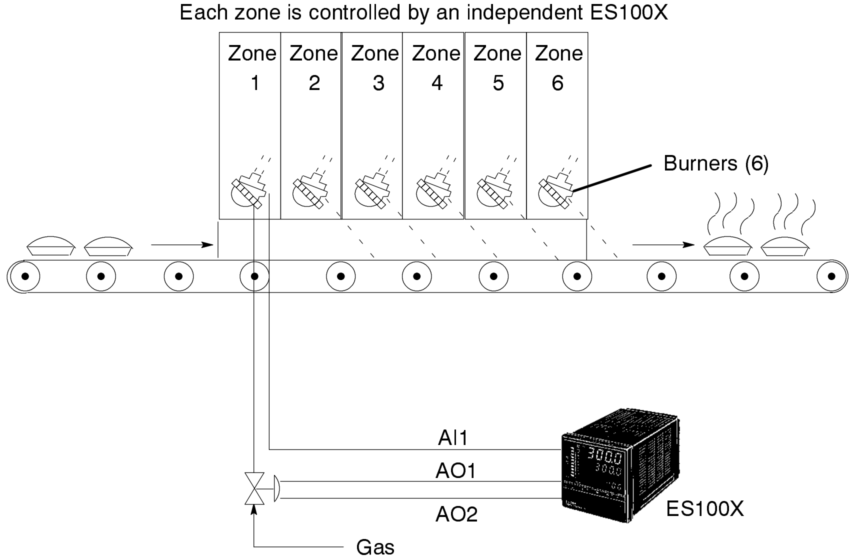
**You have now completed tuning your Position-Proportional Control Loop.**

# 2–3 Applications

## 2–3–1 Bread Baking Oven

**ES100X**

The ES100 was selected for this process because of operability and 6 identical controllers.




**Process Requirements**

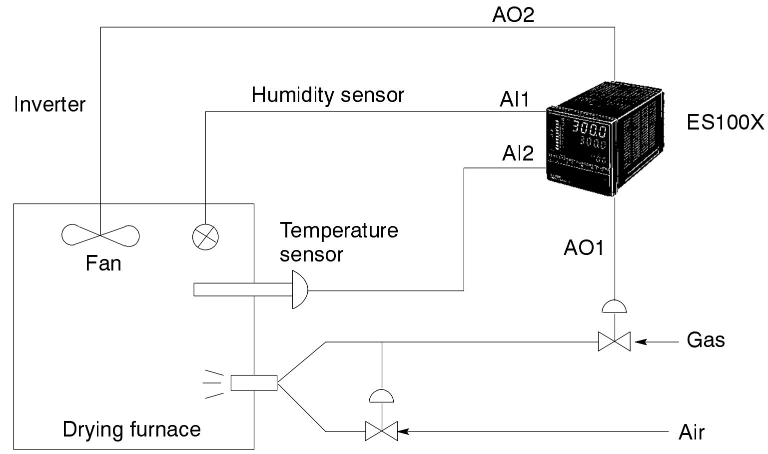
1. Accurate control of each zone to assist in increased throughput.
2. Each zone will have different temperature requirements.
3. Gas flow will be controlled by valves.

**Model Selection**

1. The ES100X-RRP is able to accurately control each zone without being affected by a neighboring zone.
2. Using the –RRP valve positioning models, control accuracy is increased while increasing valve life using the hysteresis and deadband setting.

## 2–3–2 Drying Furnace

**ES100P-RRP01FE**




**Process Requirements**

1. Control humidity and temperature of drying furnace.
2. Dry object with resulting heated air.
3. Control the humidity by adjusting air flow.
4. Use less fuel for more efficient drying.

**Model Selection**

1. By using a –RRP version, the ES100 is able to control temperature and humidity.
2. With the ES100 controlling both variables, a high efficiency was obtained and the clothes were dryed in the same amount of time with less fuel used.

# SECTION 3
# Heat/Cool Control

# 3–1 Definition of Heat/Cool Control

A heat/cool control strategy is used when the process that you are controlling is an exothermic process, or a process that is capable of generating its own heat. An example of this would be in the plastics industry where extruders are used (Figure 1).

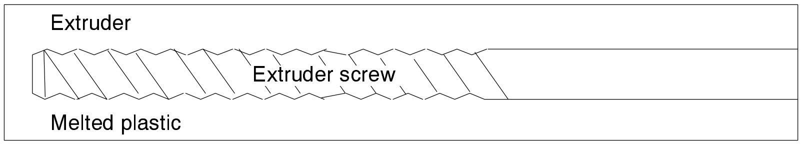



Figure 1

As the screw turns in the extruder forcing the plastic into the mold, the friction of the screw generates heat. This process needs a cooling source in order to stop the temperature from exceeding the set point, yet it needs a heating source to melt the plastic when the process first starts.

Another example of an exothermic process is a chemical reaction in an autoclave (Figure 2).

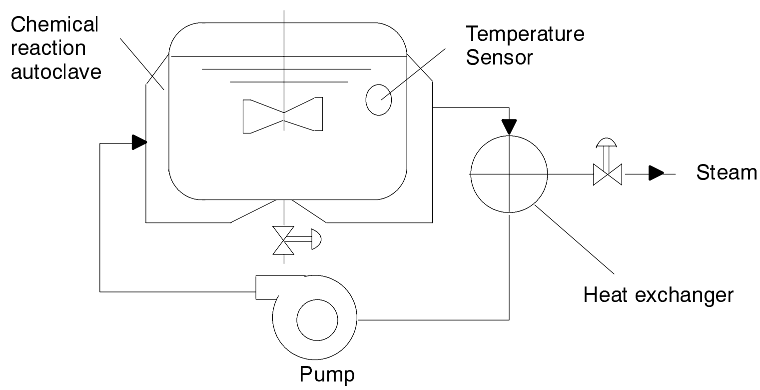



Figure 2

The temperature inside the autoclave continues to rise due to the chemical reaction of the process. Even if the controller's output (manipulated variable or MV) is off, the temperature will continue to increase beyond the setpoint. For this reason, a cooling source is required to keep the temperature constant. In Figure 3 we show an exothermic process with a zone indicated where the MV has been reduced to zero (heating source shut off). However, because of the heat generated from the chemical reaction, the Process Variable (PV) continues on an uncontrolled rise.

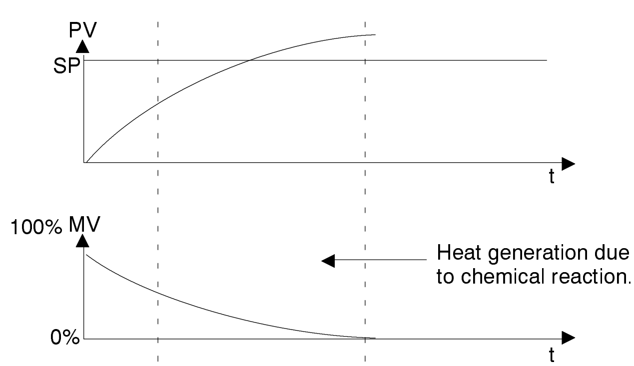



Figure 3

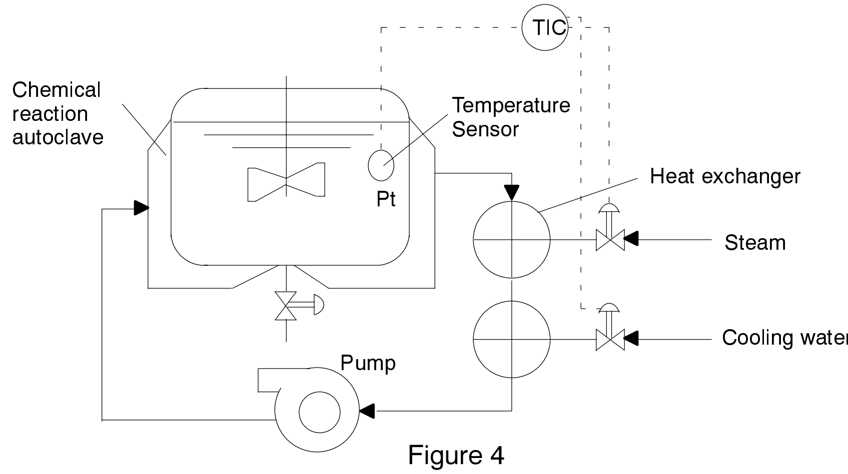



Figure 4

When using the heat/cool control method (Figure 4), a cooling source controls the process during the exothermic reaction.

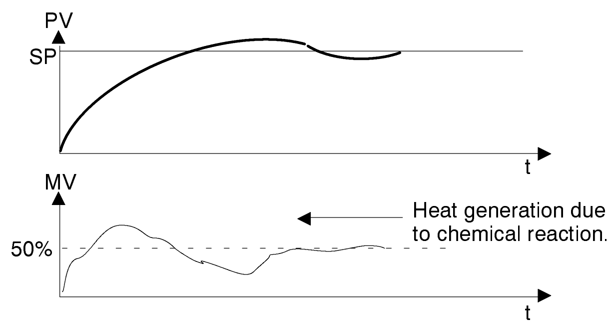



Figure 5

With a cooling source, the exothermic properties of the chemical reaction can be controlled. Figure 5 shows the cooling source in use. As the Process Value rises above setpoint the cooling source activates and returns the process temperature to setpoint.

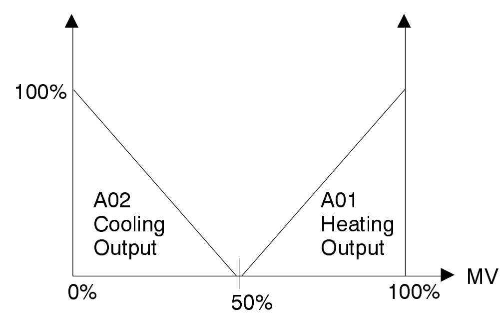



Figure 6

The MV (Manipulated Variable) functions differently in a heat **and** cool control method than either a reverse heating method **or** a direct cooling method. The difference is that a singular MV controls **both** the heat source and the cooling source. At certain points during the process the MV will change from a heating source to a cooling source (Figure 6).

In our example, when neither the cooling or heating output is active, the actual MV will read 50%. The cooling output will be active only when the MV is between 0-50% and the heating output will be active only when the MV is between 50-100%. At a certain point in the above example, the process will require either a heating or cooling source, and our MV will change accordingly.

## 3–1–1 Dead Band and Overlap Bands

A dead band can be defined as a range of temperature in which there is no controlling action taken by the temperature controller.

In other words, for a predefined temperature range, neither the cooling output nor the heating output will be activated. You can modify the ES100 so that its output characteristics reflects Figure 7. An advantage of the dead band is that it helps save on energy costs.

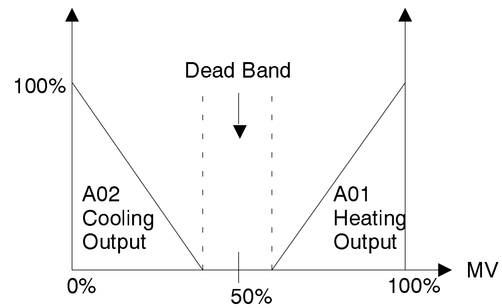



Figure 7

**OVERLAP BAND**

Greater stability and control of the process can be achieved by providing an overlapping band as shown below. In this example, the controller will be actively controlling the temperature of your process at all times. This method of control will require more energy/material to control your process. Because of the overlap band control the accuracy of the controller on the process can be improved (Figure 8).

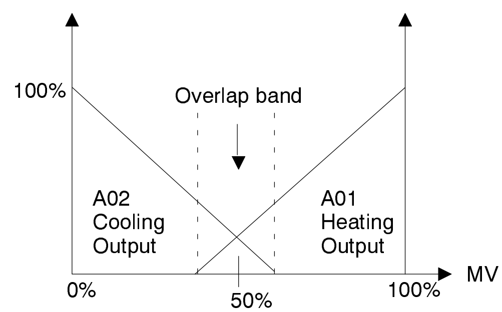



Figure 8

## 3–1–2 Start Up Procedure

**Note:** Heat/cool control can be performed with all standard models of the ES100 except the Valve Positioning (ES100_-RRP- - - -) models.

## 3–1–3 System Configuration

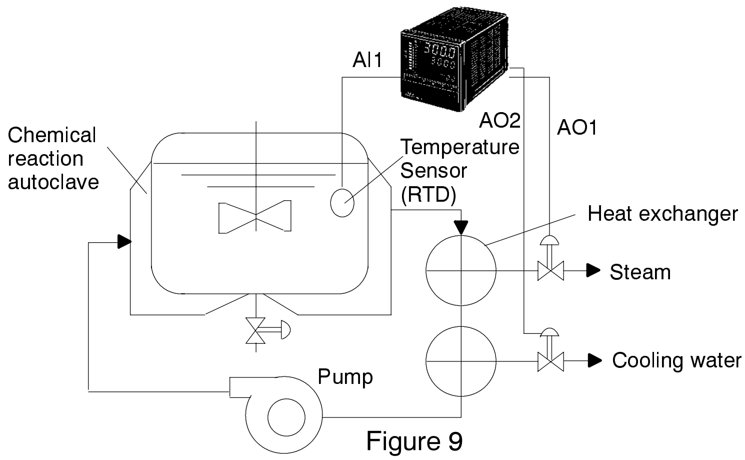



Figure 9

Figure 9 depicts how an ES100 connected in a typical heat/cool application, in this example a chemical reaction autoclave. The valves for heating and cooling are being controlled by 4-20 mA signals from the ES100. A Platinum Resistance Thermometer is being used to measure the temperature within the autoclave itself. Analog Output 1 is the heating output and Analog Output 2 is the cooling output.

After completing the basic wiring, you need to program the ES100 to operate the heat/cool process.

# 3–2 Setting Manipulated Variable for Process Operation

Before you can tune the controller you must first enter parameters for the operations listed. Proceed in the order of the listed operations.

- Setting the Dead Band
- Setting the Overlap Band
- Setting Cooling Coefficient

## 3-2-1 Setting a Dead Band

1. From the ES/TOOLS menu, select the **Setting <Offline>** icon. The **Setting Menu Offline** appears.
2. Select the [Analog oper] button. The **Analog operation assignment** menu appears.
3. From within the **Analog operation assignment** menu (Figure 10), select [F1: Details]. The **Set Analog Operation Details** pop-up menu appears.

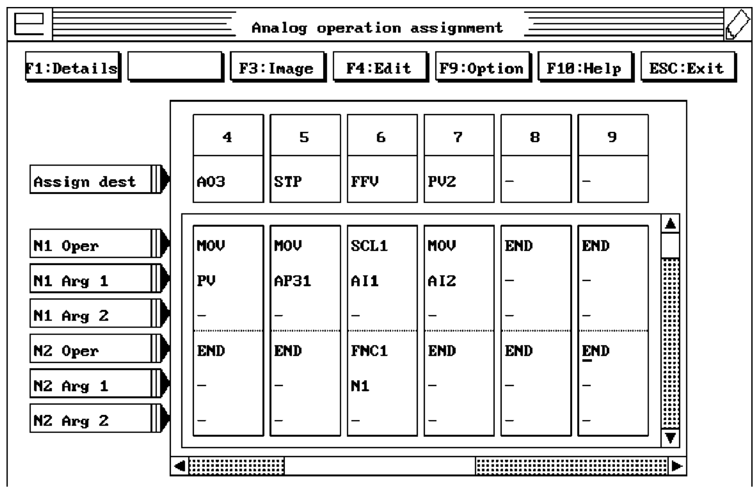



Figure 10

4. From the **Set Analog Operation Details** pop-up menu, select **AP1 to AP32 (Analog Operation Parameters)** in Figure 11.

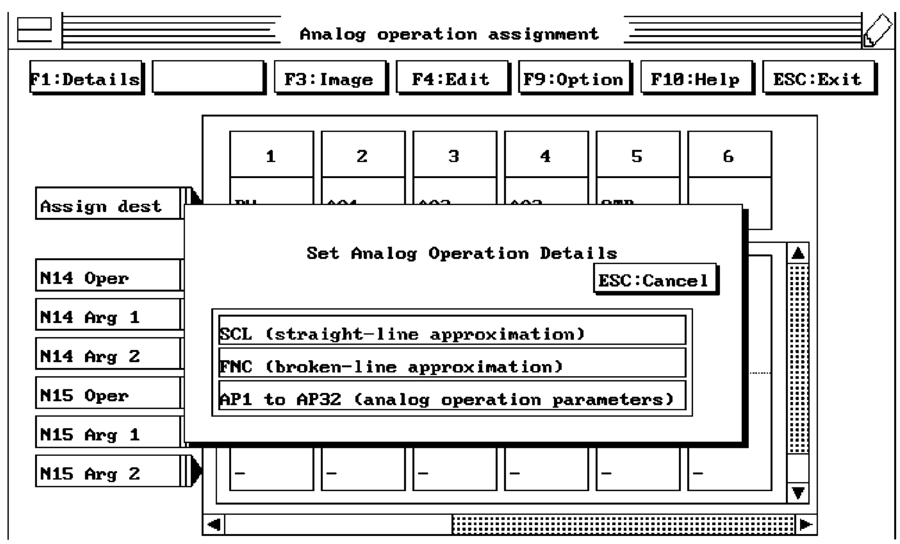



Figure 11

5. From the **Analog operation parameters** menu (Figure 12), scroll down until you see [Anlog oper param 32] and select it. Enter the deadband value as a percent of full scale. For example, if you would like a 10% dead band, key in a value of 0.100. This will make a 10% of full scale deadband in your process (Figure 13).

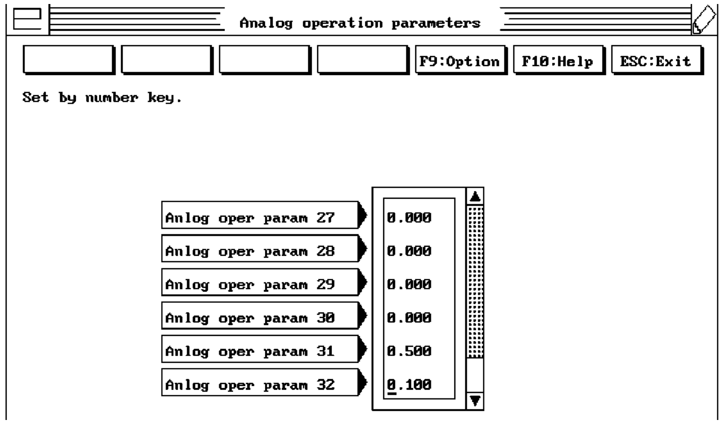



Figure 13

## 3–2–2 Setting an Overlap Band

To set up your controller with the overlap band simply place a (–) symbol in front of the percentage of overlap needed in the **Analog operation parameters** menu. To this follow the steps below.

1. From the ES/TOOLS menu, select the **Setting <Offline>** icon. The **Setting Menu Offline** appears.
2. Select the [Analog oper] button. The **Analog operation assignment** menu appears.
3. From within the **Analog operation assignment** menu, select [F1: Details]. The **Set Analog Operation Details** pop-up menu appears.
4. From the **Set Analog Operation Details** pop-up menu, select **AP1 to AP32 (Analog Operation Parameters)**.
5. From the **Analog operation parameters** menu, scroll down until you see [Anlog oper param 32] and select it. Enter the overlap band value as a negative (–) percent of full scale. For example, if you would like a 10% overlap band, key in a value of –0.100 (Figure 14).

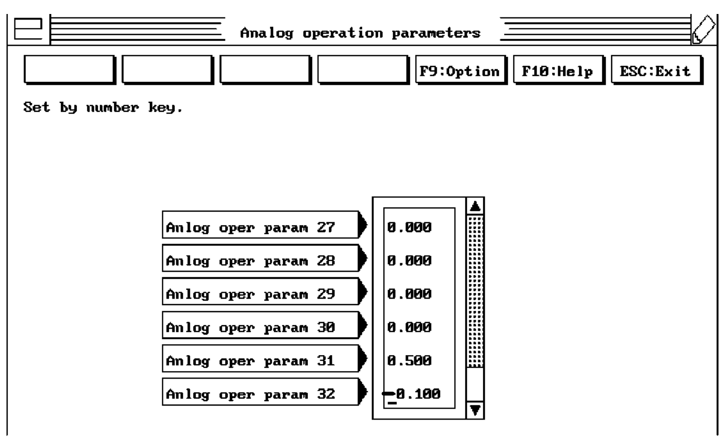



Figure 14

## 3–2–3 Setting the Cooling Coefficient

The cooling coefficient enables the controller to compensate for differences between the heating and cooling capabilities of a system. In heat/cool control, the cooling process is controlled by changing only the proportional band. The proportional band is defined as the range of temperature values above and below the setpoint, where control action is fully ON below the band, and fully OFF above the band and proportional within the band (Figure 15).

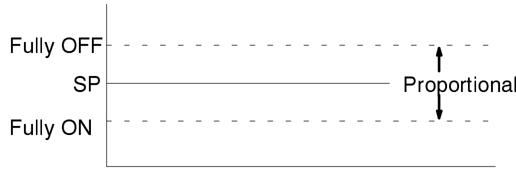



Figure 15

You should adjust the cooling coefficient when there is a difference between the heating and cooling characteristics of the process. If the cooler is more powerful than the heater, set the cooling coefficient to less than 1 (from 0.99 to 0.01). If the heater is more powerful than the cooler, set the cooling coefficient to greater than 1 (to a maximum of 99.99). If both are about equal, no change is necessary to the cooling coefficient.

In the ES100 the cooling coefficient is set at the factory to a default of 1. With the cooling coefficient set to 1 the proportional band of the cooling output is exactly the same value as the heating output proportional band.

1. To set the cooling coefficient, from the **Setting Menu <Offline>** select the **Control params** button. The pop-up menu **Control parameters** appears (Figure 16).
2. From the **Control parameters** menu, select **Other items**.

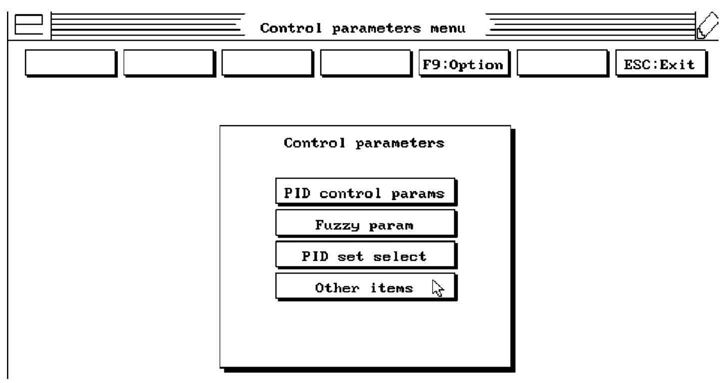



Figure 16

3. From the **Other items of control** menu, select **Cooling coefficn't** and key in the appropriate value for your system (Figure 17).

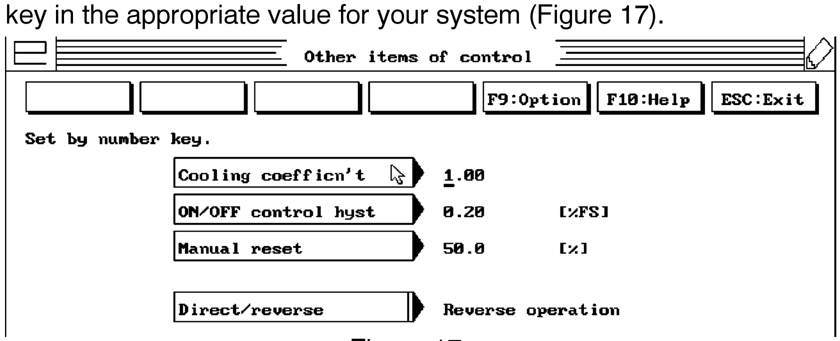



Figure 17

# 3-3 Setting Manipulated Variable for Process Completion

Before you can tune the controller you must set it up for how you want the manipulated variable or controller output to respond when the process it is controlling has been completed or when you take the controller out of RUN mode and need to halt any control action from the controller. How you set the controller up depends on whether or not you desire no output or continued output when the process is complete.

## 3-3-1 Manipulated Variable When NO OUTPUT is Desired

The process for setting the manipulated variable at operation stop is different for dead band and overlap band settings. Refer to the appropriate procedure below.

### When Using a Dead Band

**VERSION 1 CONTROLLERS**

**Note:** The setup for **NO OUTPUT** on process stop is different depending on whether you have an ES100 Version 1 (the part number of Version 1 Controllers ends with the letter "–E") or Version 2.

Because the factory default setting for Version 1 is 0% (heating OFF; cooling ON 100%) you must change this setting to set the controller for NO OUTPUT at process stop (Figure 18).

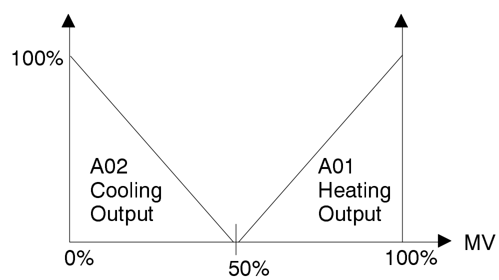



Figure 18

1. From the **Setting menu <Offline>**select the **Analog oper** button. The **Analog operation assignment** menu appears.
2. From the **Analog operation assignment** menu, select **F1: Details**. From the new pop-up menu, select **AP1 to AP32 (analog operation parameters)**.
3. From the Analog operation parameters menu, scroll down to **Anlog oper param 31** and select it. If you have not changed the default dead band value, then key in 0.500. If you have changed the default dead band value, then key in the mid-point value of the dead band expressed in terms of a percent. For example, if the mid-point of your dead band is 40%, key in 0.400.
4. Select **ESC: Exit**. You will be returned to the **Analog operation assignment** menu.
5. In the **Analog operation assignment** menu, scroll down so that the N11 Oper button appears at the top of the table (Figure 19).

6. In the Analog operation assignment menu (Figure 20), you must enter the values exactly as shown in columns 1 and 2 starting at **N11 Oper** and continuing through to **N14 Arg 2** (shaded columns).
7. When all values have been entered, select **ESC: Exit**. Now proceed to Autotuning in this section.

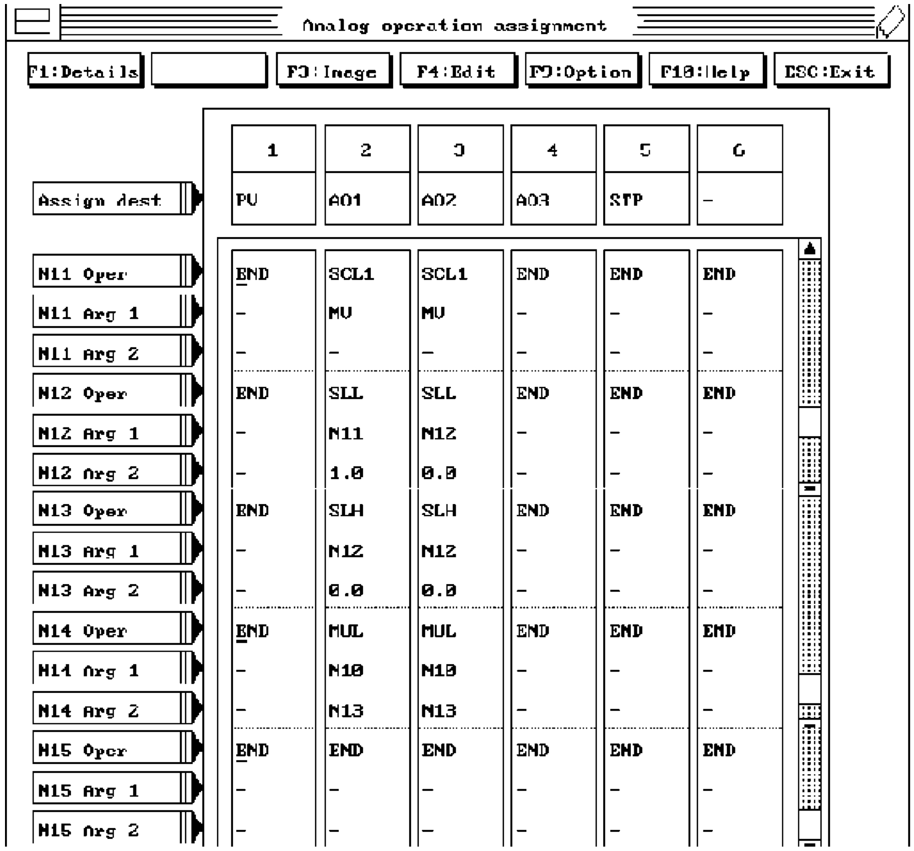



Figure 20

### FOR VERSION 2 CONTROLLERS

**Note:** The setup for **NO OUTPUT** on process stop is different depending on whether you have an ES100 Version 1 (the part number of Version 1 Controllers ends with the letter "–E") or Version 2.

The factory default setting for Version 2 Controllers is 50%. If you have not made any changes to the default dead band no changes are necessary. If you have changed the dead band settings, follow the steps below.

1. From the **Setting menu <Offline>**select the **Analog oper** button. The **Analog operation assignment** menu appears.
2. From the **Analog operation assignment** menu, select **F1: Details**. From the new pop-up menu, select **AP1 to AP32 (analog operation parameters)**.
3. From the Analog operation parameters menu, scroll down to **Anlog oper param 31** and select it. Key in the mid-point value of your dead band expressed in terms of a percent. For example, if the mid-point of your dead band is 40%, key in 0.400.
4. Select **ESC: Exit**. Now proceed to Autotuning in this section.

## When Using a Overlap Band

If you have programmed an overlap band into the controller, and you want all heating and cooling action turned OFF at the completion of your process, you must make the following changes to the ES100 program.

**Note:** If you want to maintain some heating or cooling action at the completion of your process, refer to Maintaining Control Action at Operation Stop later in this section.

**VERSION 1 CONTROLLERS**

**Note:** The setup for **NO OUTPUT** on process stop is different depending on whether you have an ES100 Version 1 (the part number of Version 1 Controllers ends with the letter “–E”) or Version 2.

1. From the **Setting menu <Offline>**select the **Analog oper** button. The **Analog operation assignment** menu appears.
2. From the **Analog operation assignment** menu, select **F1: Details**. From the new pop-up menu, select **AP1 to AP32 (analog operation parameters)**.
3. From the Analog operation parameters menu (Figure 21), scroll down to **Anlog oper param 31** and select it. Key in the value –1.000.

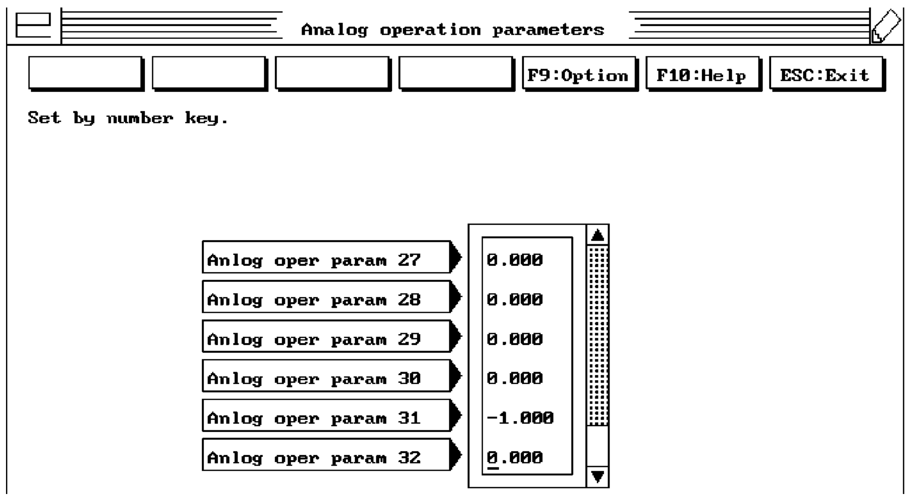



Figure 21

4. Select **ESC: Exit** to return to the Analog operation assignment menu.

5. In the Analog operation assignment menu (Figure 22), you must enter the values exactly as shown in columns 1 and 2 starting at N11 Oper and continuing through to N14 Arg 2 (shaded columns).

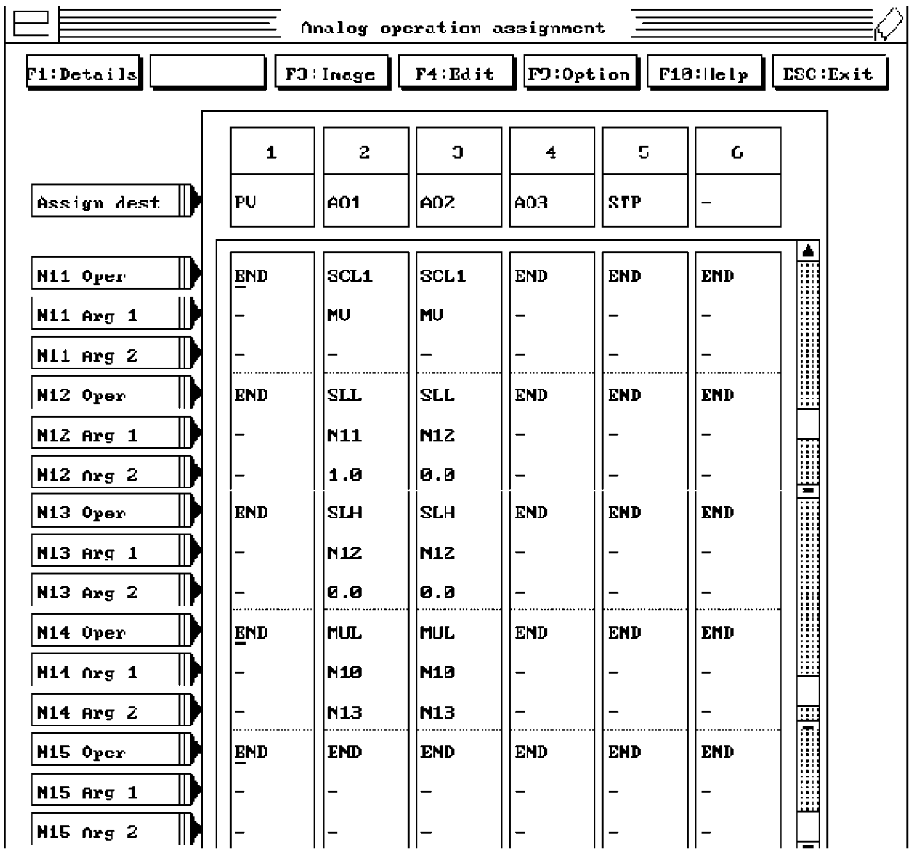



Figure 22

6. When all the values have been entered as shown select ESC: Exit.

7. Select F1: Details. From the pop-up menu select **SCL (straight-line approximation),** Figure 23.

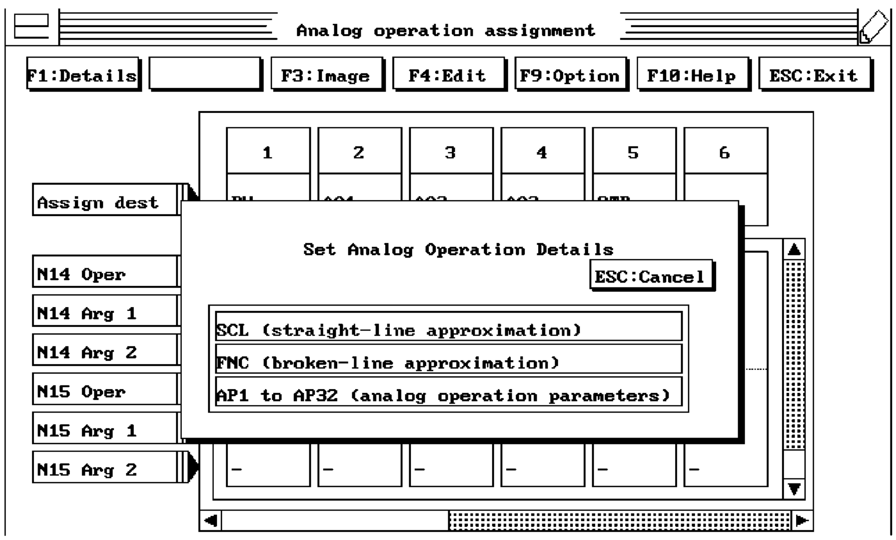



Figure 23

8. Select the **Input 1** button (Figure 24). In column one enter the value –0.001.

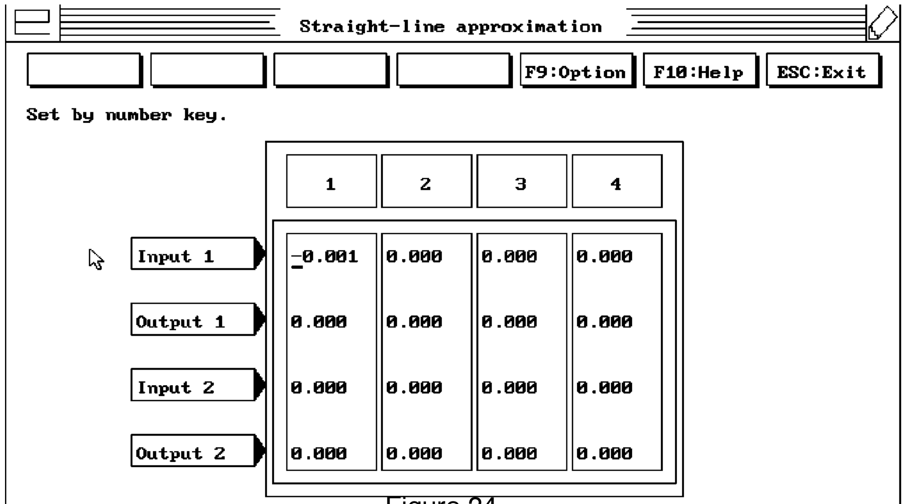



Figure 24

9. Select **ESC: Exit**.

You have now completed the steps necessary to configure your ES100 for NO OUTPUT at process completion. You may now proceed to Autotuning.

**VERSION 2 CONTROLLERS**

**Note:** The setup for **NO OUTPUT** on process stop is different depending on whether you have an ES100 Version 1 (the part number of Version 1 Controllers ends with the letter "–E") or Version 2.

1. From the **Setting menu <Offline>**select the **Analog oper** button. The **Analog operation assignment** menu appears.
2. From the **Analog operation assignment** menu, select **F1: Details**. From the new pop-up menu, select **AP1 to AP32 (analog operation parameters)**.
3. From the Analog operation parameters menu (Figure 25), scroll down to **Anlog oper param 31** and select it. Key in the value –1.000.

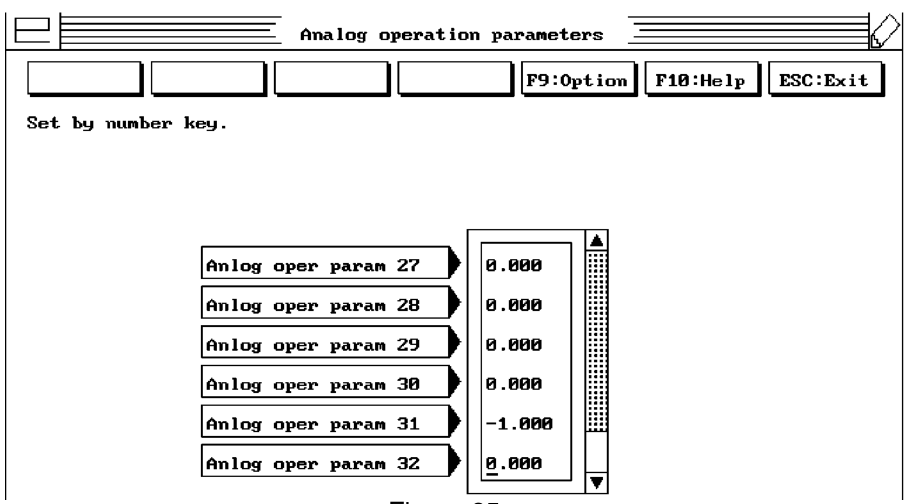



Figure 25

4. Select **ESC: Exit** to return to the Analog operation assignment menu.

You have now completed the steps necessary to configure your ES100 for NO OUTPUT at process completion. You may now proceed to Autotuning.

## 3-3-2 When Continued Control Output is Desired

If appropriate for your process, you can configure the ES100 to maintain a heating or cooling output after the process has completed. The procedures are the same for dead band and overlap band control processing.

**Note:** If you wish to maintain a fixed set point at operation stop, refer to Fixed Set Point in your ES100 operations manual (H069 and H070).

1. From the **Setting menu <Offline>**select the **Analog oper** button. The **Analog operation assignment** menu appears.
2. From the **Analog operation assignment** menu, select **F1:Details** (Figure 26). This will bring you to a selection of three options.

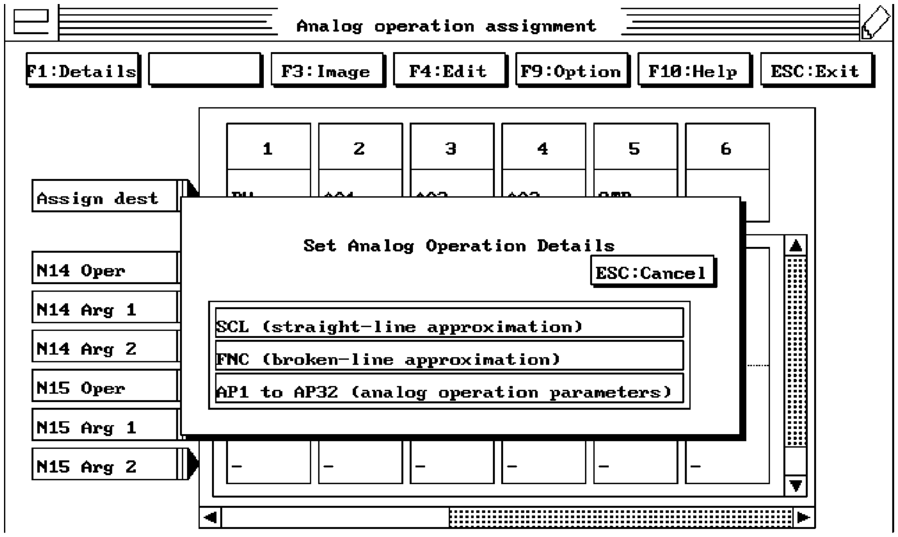



Figure 26

3. Select AP1 to AP32 (Analog Operation Parameters). Using the arrow keys, scroll down to **Anlog oper param 31** and select it (Figure 27).

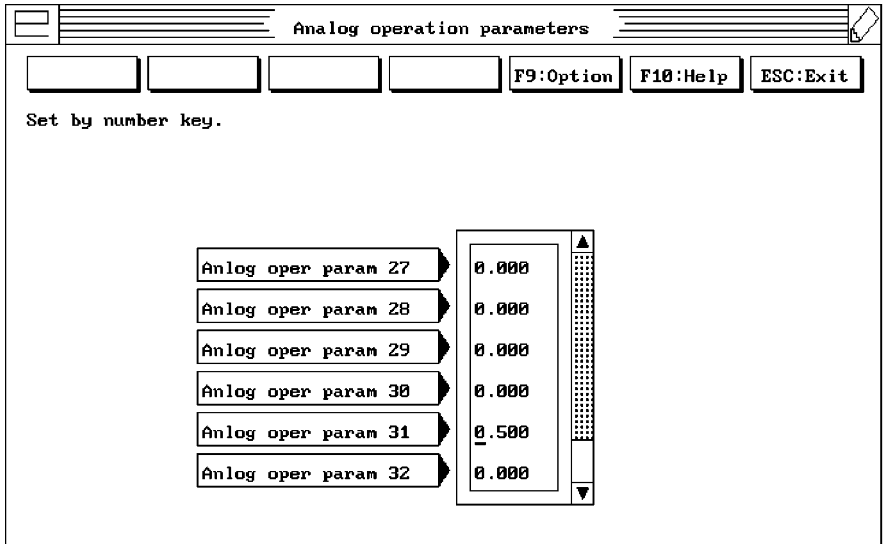



Figure 27

If you want to maintain some cooling action after the process is complete, set AP 31 from 0.000 to 0.500. At zero the cooling action will be 100%, at 50% the cooling action will be off. The action declines in a linear fashion from 0 to 50%.

If you want to maintain some heating action after the process is complete, set AP 31 from 0.500 to 1.000. The action increases in a linear fashion from 50% to 100%. Depending on the size of your overlap band, you may have both heating and cooling action on at the same time (Figure 28).

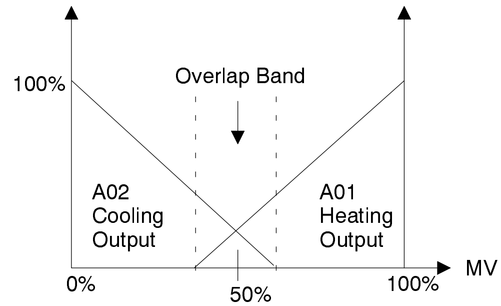



Figure 28

By following these procedures, you have completed the basic programming requirements of the ES100 for a Heat/Cool Control Method. To tune your control loop, please refer to Autotuning.

# 3–4 Autotuning

Autotuning can be used with all Heat/Cool Control strategies. The autotune feature uses a method of tuning similar to a limit cycle, which is described in Section 1, Cascade Control. When autotuning is activated it will be indicated by a blinking yellow LED on the front panel of the ES100.

1. From the ES/TOOLS menu, select the **Check Control** icon.
2. Select **F1:Run** from the **Check control** menu (Figure 29).

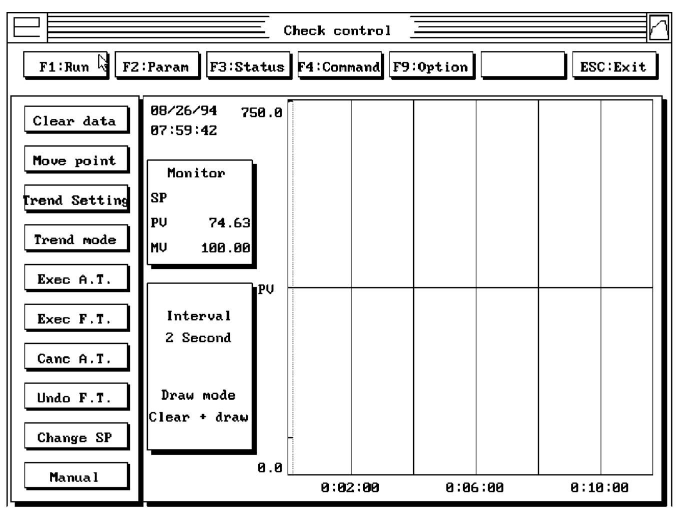



Figure 29

3. Select **Run** from the new vertical menu on the left side of the screen (Figure 30).

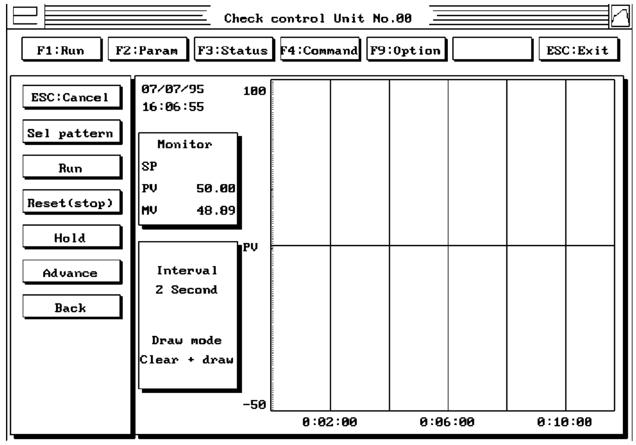



Figure 30

4. Select **ESC: Cancel** to return to the **Check control** menu.

5. From the vertical menu on the left side of the screen, select **Exec A.T.**.

6. A new pop-up window will appear (Figure 31). Enter the number of the PID bank you wish to Autotune.

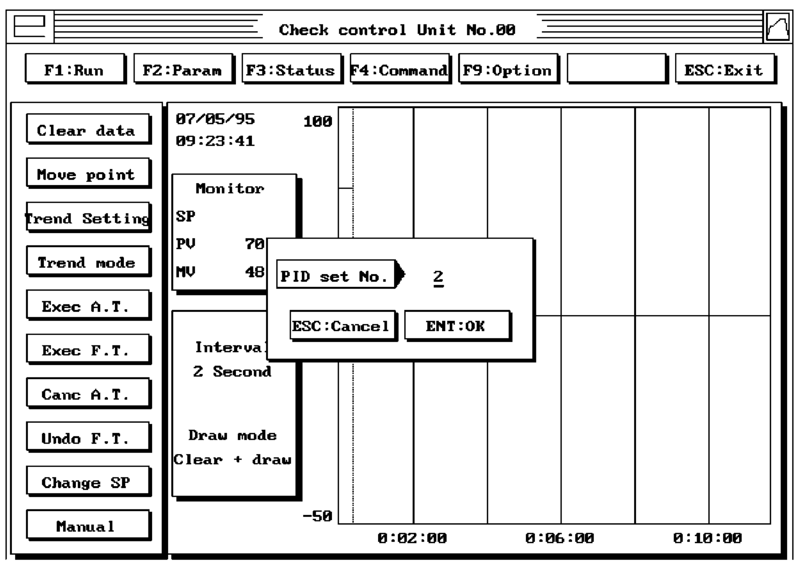



Figure 31

7. Select **ENT: OK**. The controller will now autotune. Do Not interrupt or stop this process. The controller will have completed autotuning when the yellow 'AT' light stops blinking on the front panel of the ES100.

## 3-4-1 Fuzzy Logic Fine Tuning

Start controlling your process with the ES100 by placing it in the RUN mode.

1. From the ES/TOOLS menu, select the **Check control** icon.

2. From the **Check control** menu, select **F1:Run**.

3. From the vertical menu on the left side of the screen, select **RUN**

If the performance of the controller is not satisfactory after autotuning, you may improve the performance of the ES100 by using the Fuzzy Logic Fine Tune. Follow these steps to get to the Fine Tune portion of the ES/TOOLS program.

1. From the ES/TOOLS Menu select the **Check control** icon.
2. Select **Exec. F.T.** from the menu on the left side of the screen (Figure 32).

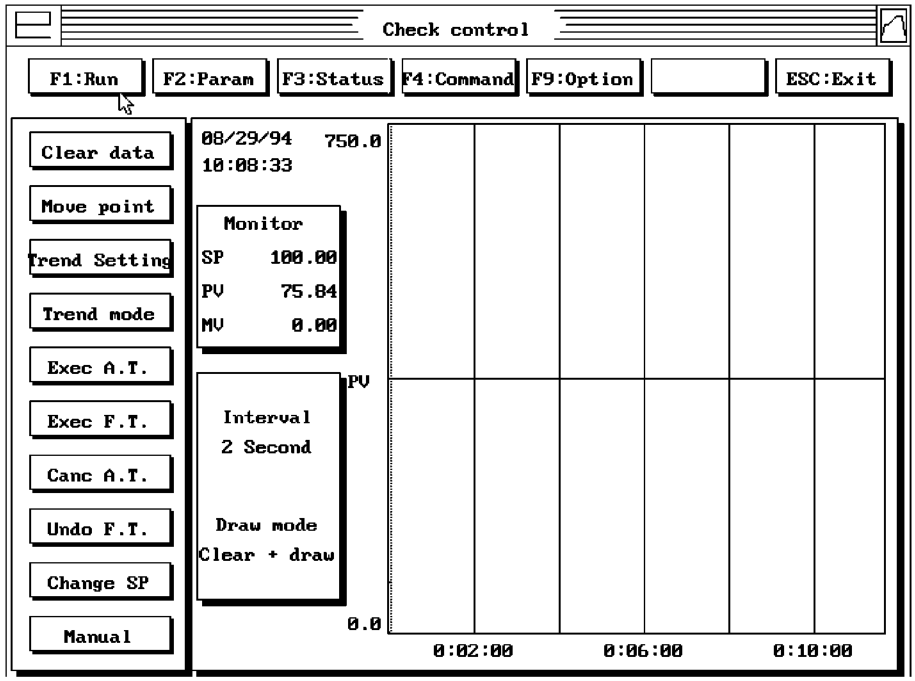



Figure 32

3. A Pop-Up window will appear to confirm the PID set that you are using.
4. Enter the appropriate PID set number and select **ENT: OK**. A new pop-up window will appear Figure 33.

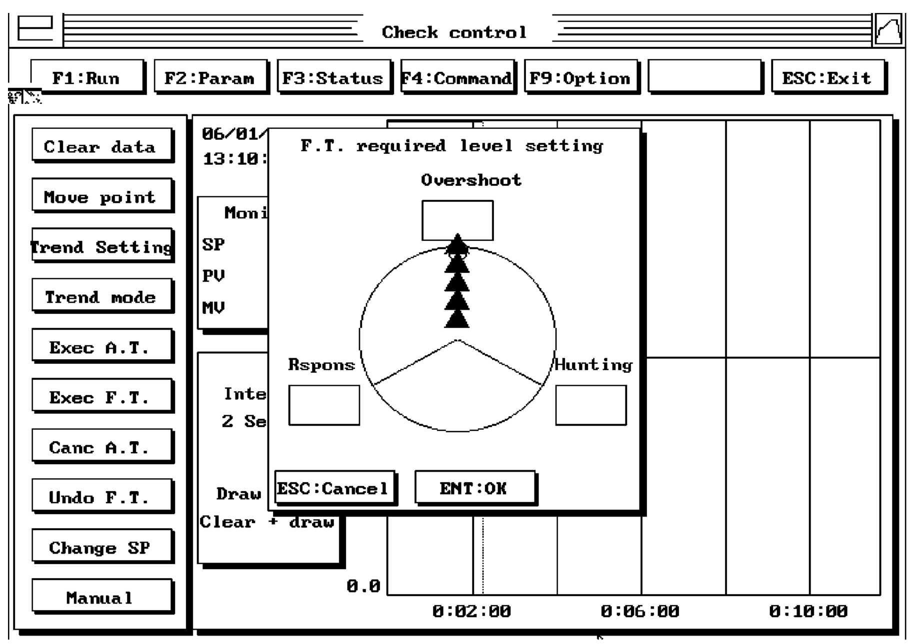



Figure 33

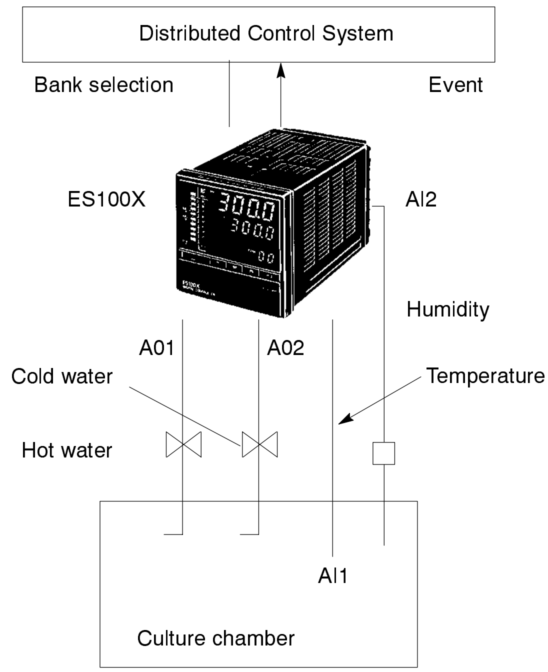
5. There are five different levels of response that you can initiate using Fuzzy Logic Fine Tuning. Each triangle represents one level of strength. The more triangles you select the greater the reaction will be from the Fine Tuning effect of Fuzzy Logic. You can select one parameter (as is shown) or a maximum of two parameters, such as Response/Hunting, or Overshoot/Hunting. Use the keyboard cursor controls to move the red inner circle around the inside of the outer circle. The arrowheads will automatically fill in based on the position of the red circle.
6. Select **ENT: OK** after you have selected the level of corrective action you require.
7. ES/TOOLS will prompt you to execute fine tuning, select **ENT:OK**. Repeat Fuzzy Logic Fine Tuning as necessary to achieve optimum performance.

**You have now completed tuning your ES100 for Heat/Cool Control.**

# 3–5 Applications

## 3–5–1 Culture Chamber

**ES100 used: ES100X-AAWHFE**




**Process Requirements**

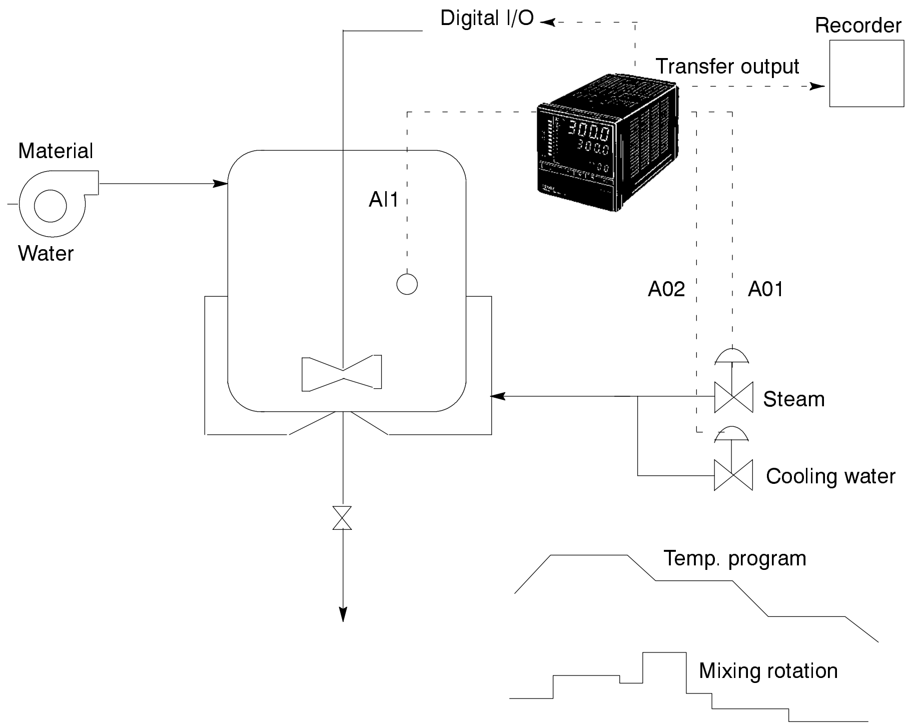
1. Temperature and humidity must be very consistant and at the precise levels.
2. Separate outputs for heating and cooling.
3. Heat/cool should be performed by one controller, not two.
4. Needs to have control information about more than one type of product for quick changeover (while minimizing thr requirement for frequent autotuning that can cause product damage).

**Model Selection**

1. The ES100 controlled more steadily and accurately with Fuzzy Logic, insuring a high return.
2. Heat/cool is accomplished with ES100 with separate outputs.
3. With the eight banks of PID in the ES100X series setpoints, PID setting could be stored making changeover easier while eliminating the need to autotune each time.

## 3-5-2 Shampoo Manufacturing Machine

**ES100 used: ES100P-AAHFE**




### Application

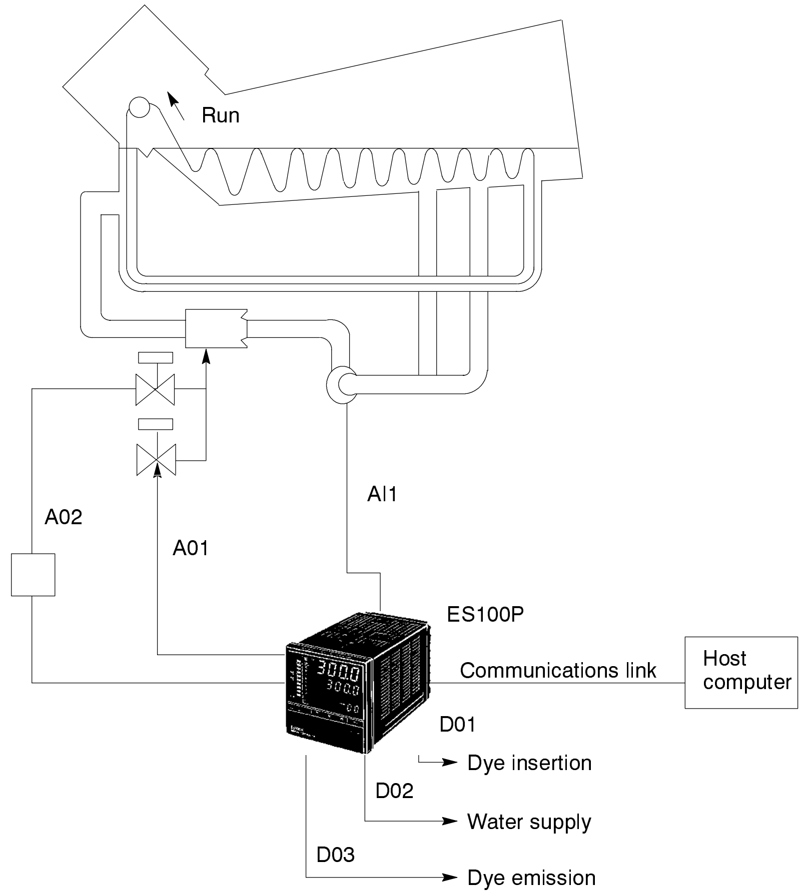
1. The controller must have the ability to store several different pattern profiles.
2. Mixing speed will be different in almost every step.
3. A chart recorder will be used to provide a temperature history.
4. Must provide heat/cool capability

### Model Selection

1. The ES100P series provides up to 99 different program profiles.
2. It is possible to use a combination of internal timers and outputs to provide different mixing speeds.
3. The transfer output was connected directly to the chart recorder.
4. Even the ramp/soak ES100 can perform heat/cool control.

## 3-5-3 Drying Machine

**ES100 used: ES100P-AAH01FE**




**Process Requirements**

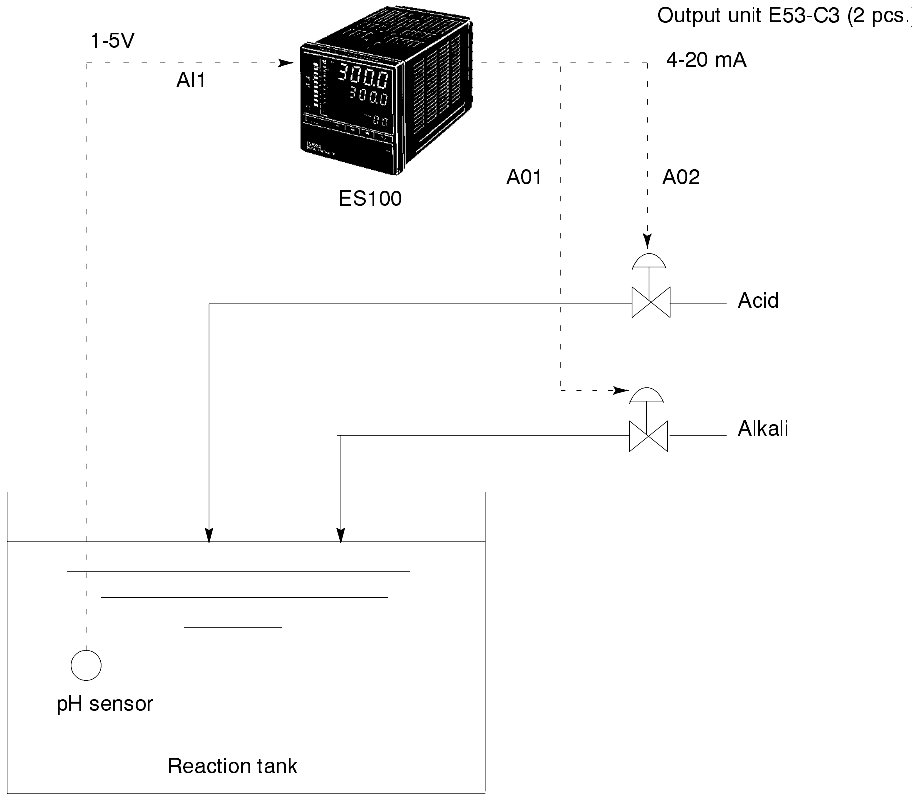
1. The controller must be able to store different profiles.
2. Temperature must rise slowly to insure proper finish correct/even coloring.
3. Use a host computer to control the ES100.

**Model Selection**

1. The ES100P provides 99 different program profiles.
2. The ES100P is capable of having a rise time measured in seconds or in hours.
3. By using ESTOOLS, the customer was able to select the correct pattern and monitor the process as well.

## 3–5–4 Water Purifying Machine

**ES100 used: ES100X-AAH**




**Process Requirements**

1. Control pH of water purifying machine to national standards.
2. Control pH by using 2 valves with a 4-20 mA signal.

**Model Selection**

1. The ES100 provided control of the process so that the national standards were achieved easily.
2. Heat/cool control was used because the output signal was 4-20 mA.

# SECTION 4
# Ratio Control

# 4–1 What is Ratio Control

Ratio control usually involves the mixture of two or more ingredients using a very specific mixture (or ratio) where the flow of one ingredient into a process is controlled based on a flow of a second, uncontrolled ingredient. The variable input is generated directly from an external input, or remote set point (RSP).

For example, in a grout color mixing application the two main ingredients, sand and dye, must be mixed in an exact ratio of 100 parts sand to 5 parts dye or a 20:1 ratio. In the example, the sand is the uncontrolled variable (RSP) and flows freely into the process. The dye in turn is delivered to the process in a 20:1 ratio based on the amount of sand entering the system (Figure 1).

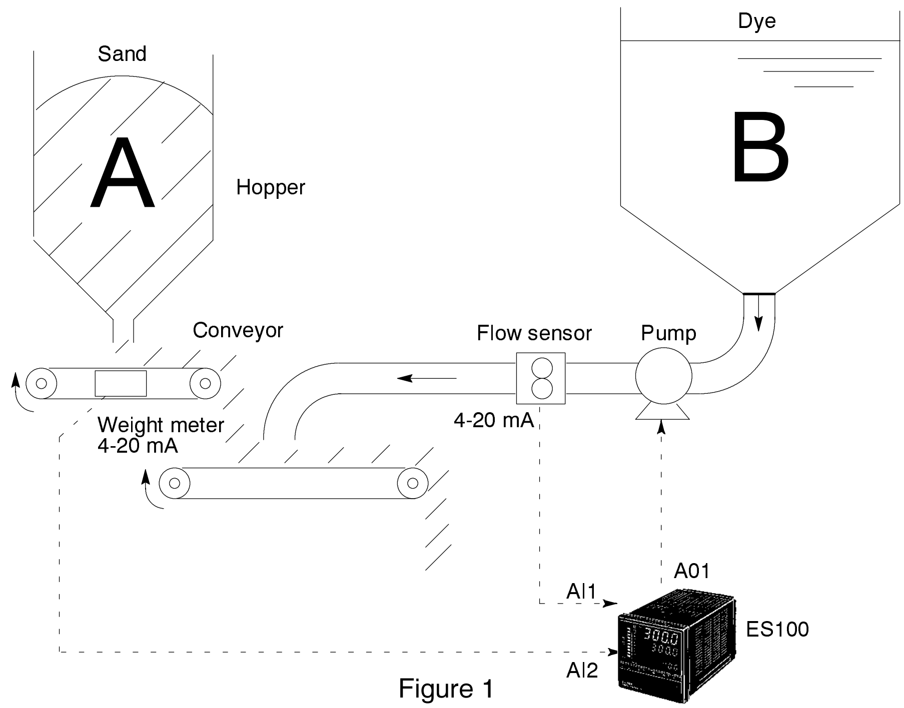



Figure 1

In the grout example above, the input to the ES100 from the remote setpoint (AI2) is a 4-20 mA signal generated from a weight meter. To maintain tight control of the mixture to avoid over or under-dyeing, the controller's primary input is a 4-20 mA signal from a flowmeter (AI1) in the dye injection tube. It is also the PV for the flow of the dye. The control output is directed to a dye flow control pump (AO1).

The system operates by taking the remote setpoint value and comparing it to a preprogrammed ratio (Figure 2). The ratioed value is then use to adjust the output to precisely control the flow of dye to maintain grout color consistency.

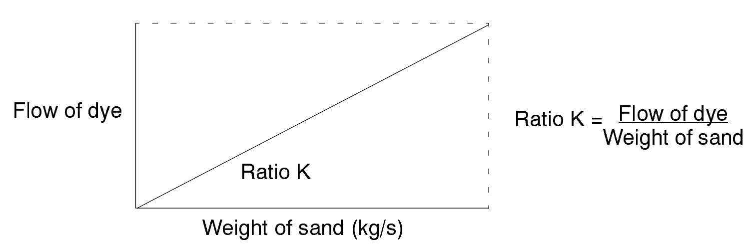



Figure 2

# 4–2 Start-Up Procedure

The ES100 selected for Ratio control applications must have an optional second input installed. The part number should look like: ES100X-_ _ W_ _ _ _

## 4–2–1 Wiring

A wiring diagram for the grout mixing applications appears below (Figure 3). It is typical of most ratio control applications. In our example there are three connections to be made: the dye flow sensor (AI1), the sand scale (AI2), and the dye flow pump AO1).

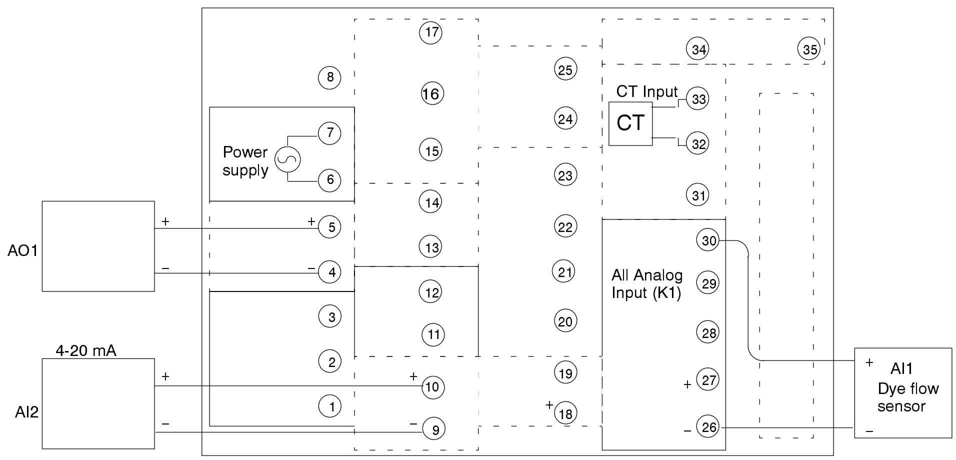



Figure 3

# 4–3 Operation and Tuning

The first step in setting up a ratio control application is to scale the control inputs. The second step is to input the desired control ratio.

### Scaling the Control Inputs

In this example we will set up the controller to scale 4-20 mA signals for each input (AI, AI2). The full scale of the sand scale (AI2) is 0-500 kg/min, the full scale of the dye flow sensor (AI1) is 0-25 kg/min. As an aid to organizing information that will be programmed into the ES100, use the table below.

| Input | Item | Low End | High End |
|---|---|---|---|
| **AI1** | Input from Sensor | 4 | 20 |
| | Value to be displayed on Front panel of the ES100 | 0 | 500 |
| **AI2** | Input from Sensor | 4 | 20 |
| | Value to be displayed on Front panel of the ES100 | 0 | 25 |

Program the ES100 as follows:

1. From the ES/TOOLS menu, click on the **Setting <offline>** icon.
2. From the **Setting menu <offline>** select the **Analog oper** button.

3. Select F1:Details from the **Analog operation assignment** menu. A pop-up menu appears (Figure 4).

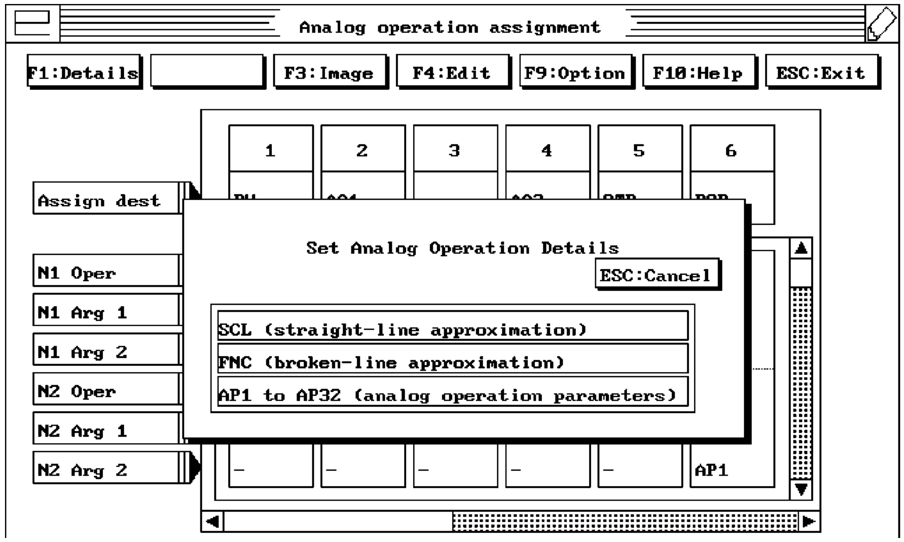



Figure 4

4. Select SCL (straight-line approximation) button. The **Straight-line approximation** menu (Figure 5) will appear. For the grout coloring example, you must complete the table exactly as shown.

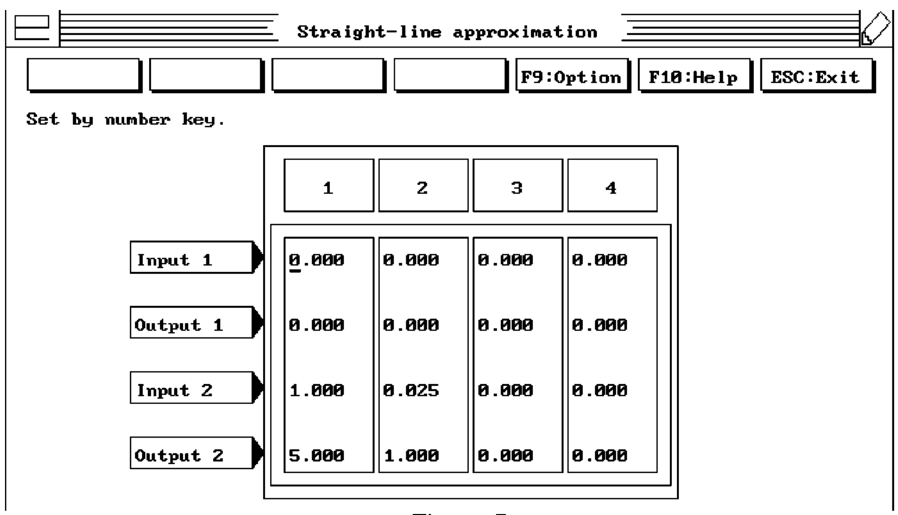



Figure 5

**Note:** The ES100 uses a Normalizing process to scale low end and high end values from the actual sensor input to the controller. This internal process uses 0-1 as the full scale. As a result, it is necessary to input 0 for the low end and 1 for the high end of the sensor output scales, not 4 and 20 (the actual output range).

Columns 1 and 2 are used for scaling AI2 for display and renormalization after it (AI2) has been ratioed. To enter the values, simply click the cursor on the value in the appropriate place in the table. For this example the table should appear exactly as shown above.

**Note:** Read the following button definitions.

Input 1 Low end value of the actual sensor input to the controller.

Output 1 Low end value to be displayed on the front panel of the ES100.

Input 2 High end value of the actual sensor input to the controller.

Output 2 High end value to be displayed on the front panel of the ES100.

5. Select ESC: Exit to return to the **Analog operation parameters** menu.

**Setting the Control Ratio**

The next step in setting up a ratio control application is to input the control ratio. The mixing ratio must be predetermined by the user. In the grout coloring example, the appropriate ratio is 100 parts of sand to 5 parts dye or 20:1. Follow the steps below to program the controller with the control ratio.

1. From the **Analog operation assignment** menu, select F1:Details. From the pop-up menu, select **AP1 to AP32 (Analog operation parameters)**.
2. Click on the value across from Analog oper param 1 and enter 0.050. The table should look like Figure 6.

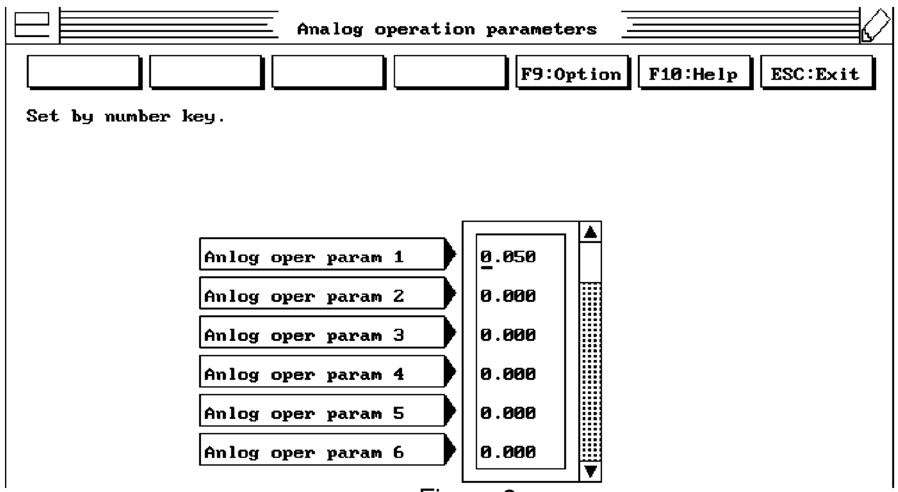



Figure 6

3. Select ESC: Exit to escape back to the **Analog operation assignment** menu.

### Linking the Control Ratio Program to ES100 Operation

Now that the ration programming is complete. It is necessary to link it to the core program of the ES100 using the **Analog operation assignment** table. To do this, follow the procedures below.

1. From the **Setting menu <offline>**menu, select **Analog Oper** (Figure 7).

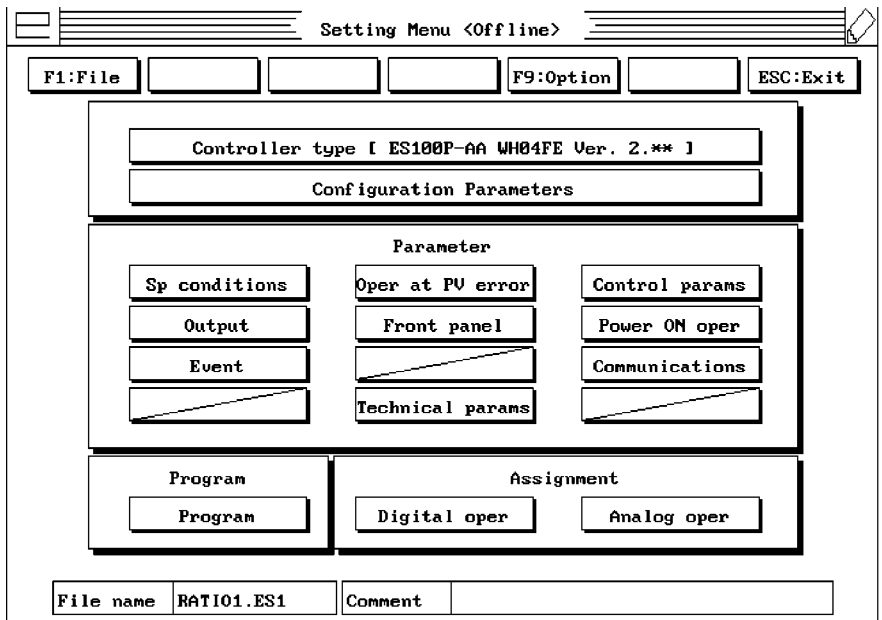



Figure 7

2. From the **Analog operation assignment** table, double-click on the area intersected by **Assign dest** and column 6. A pop-up menu appears. Scroll through the menu and double-click on **RSP (Remote Setpoint)**.
3. Double-click on the N1 Oper/column 6 intersection. Scroll through the pop-up menu and select **SCL1 (Straight-line approximation)**.
4. Double-click on the N1 Arg1/column 6 intersection. Double-click on **AI2 (Analog Input 2)**.
5. Double-click on the N2 Oper/column 6 intersection. Select **MUL (Multiply)** from the pop-up menu.
6. Double-click on the N2 Arg 1/column 6 intersection. Select **N1 (Argument Result)** from the pop-up menu.
7. Double-click on the N1 Arg 2/column 6 intersection. Select **AP1 (Analog Parameter 1)** from the pop-up menu.
8. Double-click on the N3 Oper/column 6 intersection. Select **SCL2 (Straight-line approximation)** from the pop-up menu.
9. Double-click on the N3 Arg 1/column 6 intersection. Select **N2 (Argument Result** from the pop-up menu.

For this example, column 6 should look exactly like the one shown in Figure 8.

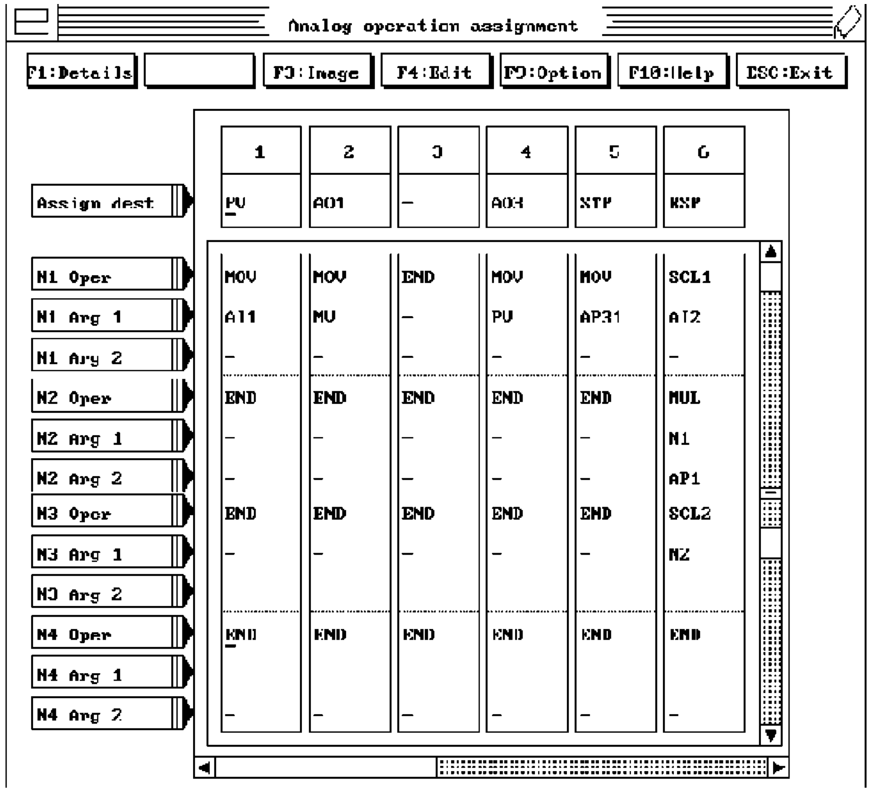



Figure 8

The programming in column 6 reflects the connection of the basic ratio program to the core of the ES100. By performing the steps above, you have accomplished the following:

- Scaling AI1 to SCL (Straight-line approximation, column 1), 0-500 Kg/s (N1).
- AI2 (weight of the sand) is multiplied by the ration (20:1) in AP1 (N2).
- In the final operand (N3) AI2 was scaled to provide a useable number for display on the front panel of the ES100. However, in order for the ES100 to use the data that AI2 provides, AI2 must be rescaled, or normalized to 0-1. This value is then transferred into the Remote Setpoint function of the ES100 (Figure 9).

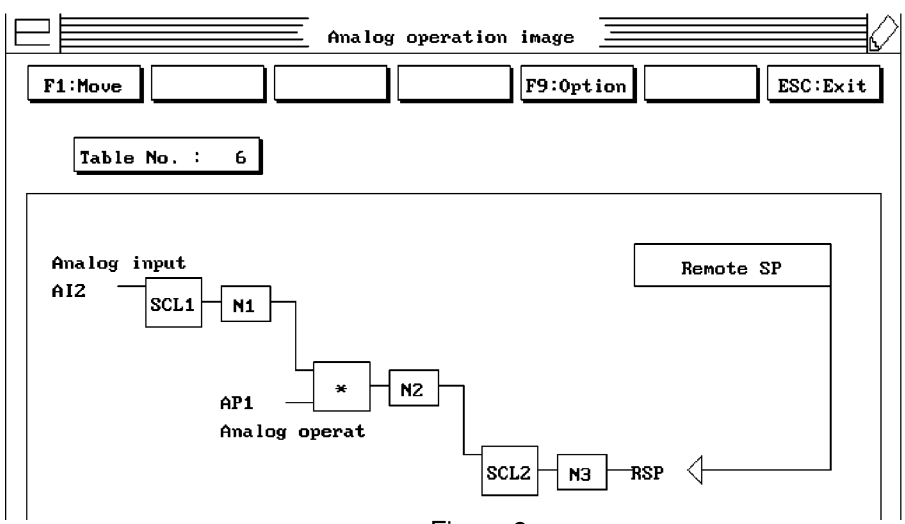



Figure 9

AI2 is normalized after the ratio has been applied to the input. The normalized ratio is then used as the Remote Setpoint for the ES100 so that it can mix the proper amount of dye with the sand.

You have now completed all programming for ratio control process. Proceed to Autotuning.

# 4-4 Autotuning

**Note:** The ES100 must be connected.

The autotune feature uses a method of tuning similar to a limit cycle, which is described in Section 1, Cascade Control. When autotuning is activated it will be indicated by a blinking yellow LED on the front panel of the ES100.

1. From the ES/TOOLS menu, select the **Check Control** icon.
2. Select **F1:Run** from the **Check control** menu (Figure 10).

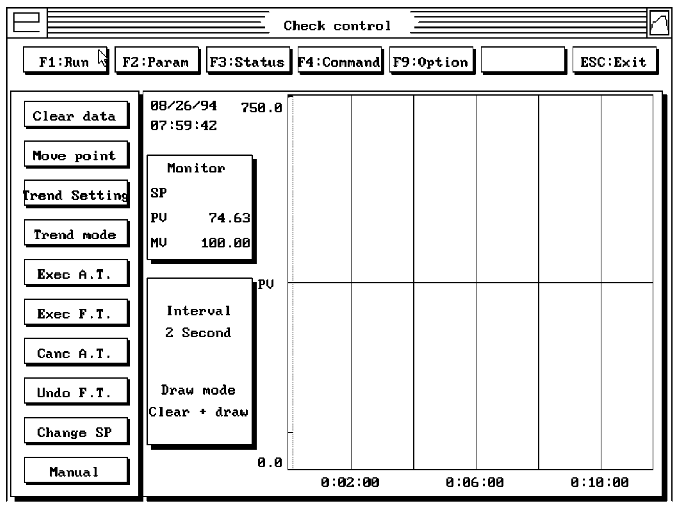



Figure 10

3. Select **Run** from the new vertical menu on the left side of the screen (Figure 11).

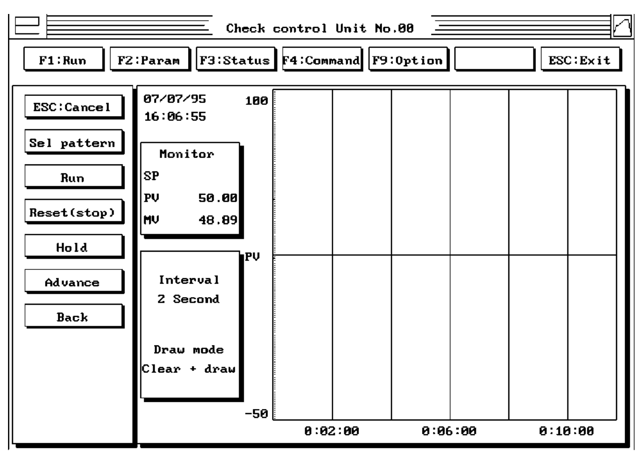



Figure 11

4. Select **ESC: Cancel** to return to the **Check control** menu.
5. From the vertical menu on the left side of the screen, select **Exec A.T.**.
6. A new pop-up window will appear (Figure 12). Enter the number of the PID bank you wish to Autotune.

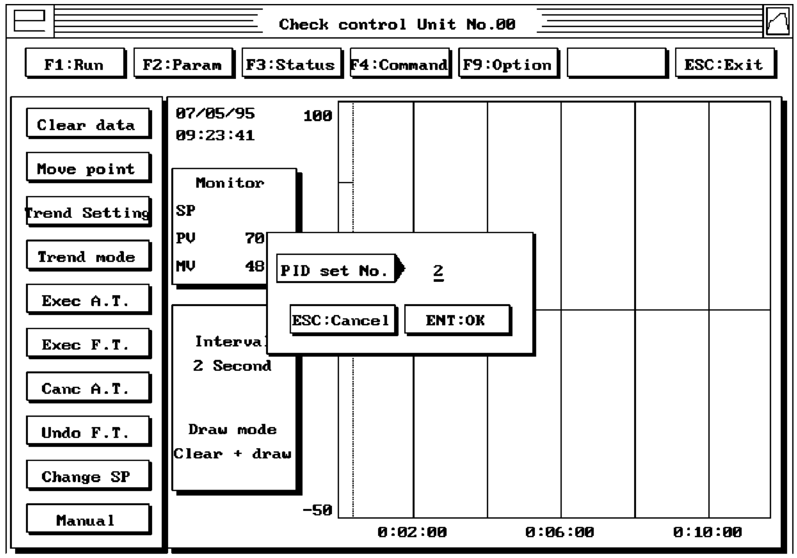



Figure 12

7. Select ENT: OK. The controller will now autotune. Do Not interrupt or stop this process. The controller will have completed autotuning when the yellow ‘AT’ light stops blinking on the front panel of the ES100.

## 4–4–1 Fuzzy Logic Fine Tuning

If the performance of the controller is not satisfactory after autotuning, you may improve the performance of the ES100 by using the Fuzzy Logic Fine Tune. Follow these steps to get to the Fine Tune portion of the ES/TOOLS program.

Start controlling your process with the ES100 by placing it in the RUN mode.

1. From the ES/TOOLS menu, select the **Check control** icon.
2. From the **Check control** menu, select F1:Run.
3. From the vertical menu on the left side of the screen, select RUN
1. From the ES/TOOLS Menu select the **Check control** icon.

2. Select Exec. F.T. from the menu on the left side of the screen (Figure 13).

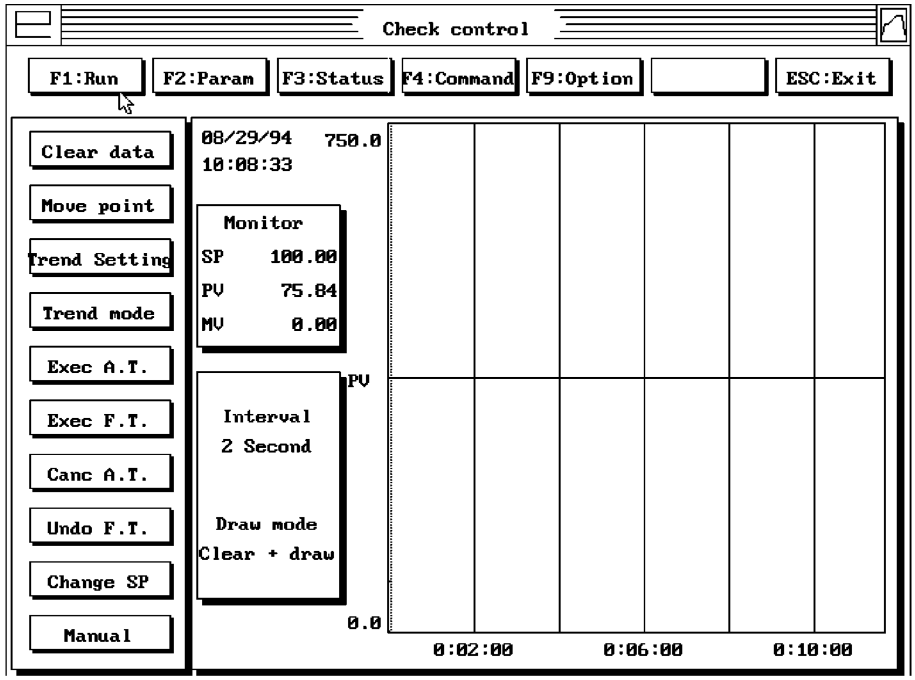



Figure 13

3. A Pop-Up window will appear to confirm the PID set that you are using.

4. Enter the appropriate PID set number and select ENT: OK. A new pop-up window will appear Figure 14.

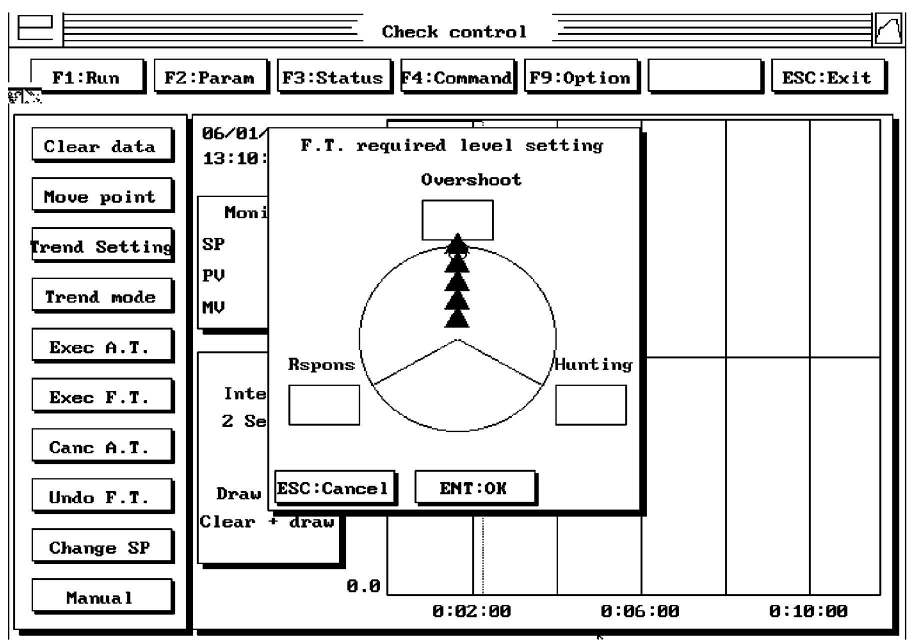



Figure 14

5. There are five different levels of response that you can initiate using Fuzzy Logic Fine Tuning. Each triangle represents one level of strength. The more triangles you select the greater the reaction will be from the Fine Tuning effect of Fuzzy Logic. You can select one parameter (as is shown) or a maximum of two parameters, such as Response/Hunting, or Overshoot/Hunting. Use the keyboard cursor controls to move the red

inner circle around the inside of the outer circle. The arrowheads will automatically fill in based on the position of the red circle.

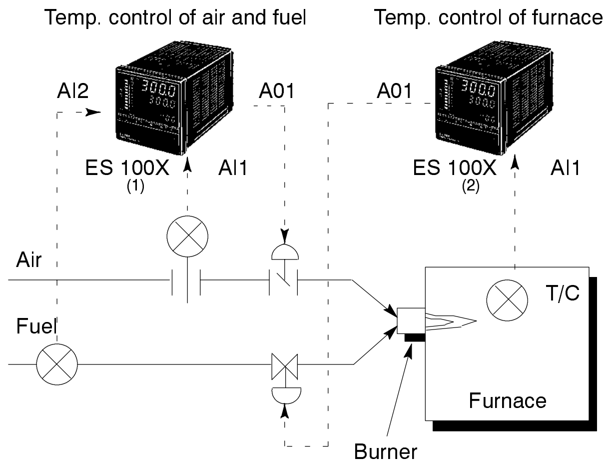
6. Select **ENT: OK** after you have selected the level of corrective action you require.
7. ES/TOOLS will prompt you to execute fine tuning, select **ENT:OK**. Repeat Fuzzy Logic Fine Tuning as necessary to achieve optimum performance.

**You have now completed tuning your ES100 for Ratio Control.**

# 4–5 Applications

## 4–5–1 Heating Furnace

**ES 100 used: ES 100X-AAWHFE**




**Process Requirements**

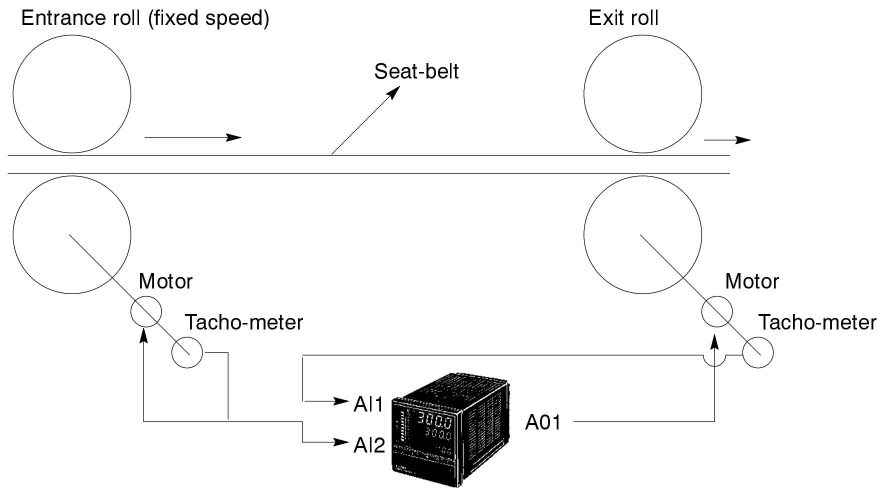
1. Improve combustion efficiency by reducing the amount of air required to burn the metal in the process.
2. Ensure complete combustion of gas in furnace by controlling the ration of fuel to air.

**Model Selection**

1. The first ES100 is controlling the ratio of fuel to air. By having an ES100 do this using Fuzzy Logic, very tight control was obtained on the mix, allowing complete combustion of the gas used in the process.
2. The second ES100 was used to achieve tight control of the temperature of the furnace. By having an ES100 doing this, the amount of air required for complete combustion was reduced. Another benefit was less pollution created by the process.

## 4–5–2 Seat Belt Manufacturing

**ES 100 used: ES 100X-AAWHFE**




**Process Requirements**

Control the length of the seat belt by changing the rotation speed of the entrance and exit rolls.

**Model Selection**

1. The ratio ability allowed the ES100 to take the uncontrolled speed of the entrance and match the exit roll speed at the appropriate ratio thereby maintaining the desired length of the seat belt.
2. The use of multiple AP registers provides for many different seat-belt lengths.

# SECTION 5
# Feed Forward Control

# 5–1 What is Feed Forward Control

Feed Forward control is a feature of the ES100 process controller which is used to anticipate a process and minimize its effect on the process. After the controller detects the disturbance, it adjusts its Manipulated Variable (MV) so it will be able to offset the estimated change in the process. It is able to do this by using two sensors; one placed within the process, the other to measure the value of a process ingredient before it arrives where the process is controlled.

An example of this is food sterilization by steam. The flow of food into the sterilization chamber is not continuous, and the temperature in the chamber has to be precisely controlled to avoid scalding the food or insufficiently sterilizing it.

**Standard Control**

With standard control strategies (i.e. one feed back loop only), the process cannot be controlled accurately because of the variable flow of food into the system (Figure 1). By controlling the amount of steam pressure around the chamber, the temperature of sterilization chamber can be accurately controlled.

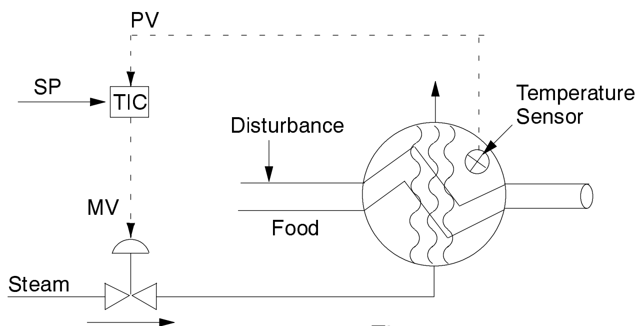



Figure 1

Figure 2 shows an example of the process trend without feed forward control. When the flow of food into the chamber drop, the temperature increases because there is less food to absorb the heat. As a result, the temperature increase will scald the food.

Further in the time before the controller regains control of the process, all incoming food will be damaged by the excessive heat.

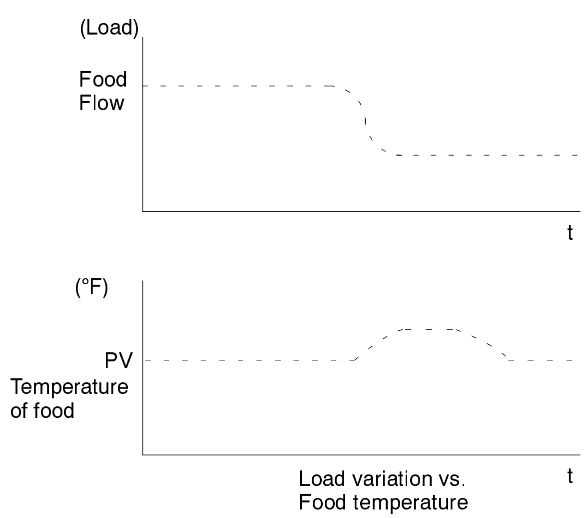



Figure 2

### Feed Forward Control

By placing a second sensor in the path of the food (a flow sensor) the system can now anticipate the flow of food before it enters the chamber and adjust the steam pressure (Figure 3). This is known as a Feed Forward control strategy.

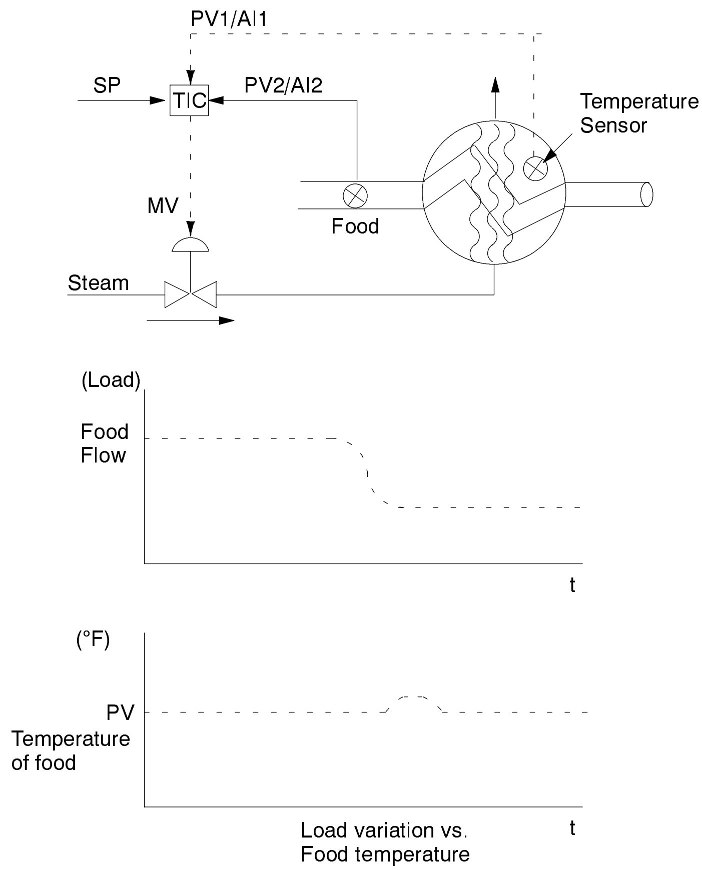



Figure 3

By using the Feed Forward control method, the controller detects the reduced flow of food and can slow down the flow of steam before it scalds the food.

To set up this Feed Forward method in the ES100, the ratio of steam pressure to food flow must be determined and entered into the ES100. That ratio is know as the Feed Forward Variable (FFV).

Once this is accomplished, you will see a considerable improvement in the control performance. This is because the response of the MV to the disturbance is much quicker than with a normal single loop control strategy.

It is important to note that Feed Forward control is used in conjunction with the existing PID algorithm. It is designed as an enhancement to the PID loop.

## 5-1-1 Start-up Procedure

For Feed Forward control, any ES100 with two analog inputs may be used.

The following part number represents an ES100 controller with two analog inputs. ES100_ -_ _W_ _ _ _ _

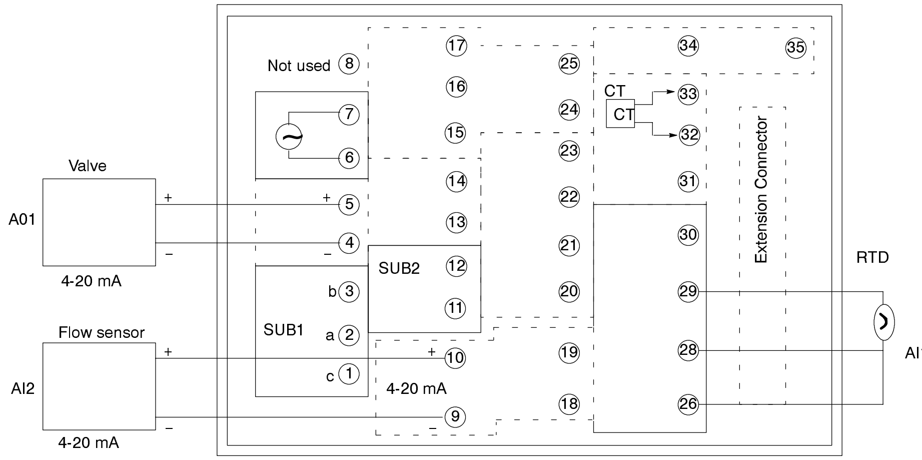



Figure 4

Figure 4 shows a wiring diagram for the food processing example. It is shown in a Feed Forward configuration with the following requirements:

- PV1/AI1 = Platinum RTD (process)
- PV2/AI2 = Flow Sensor 4-20 mA (food flow)
- MV/AO1 = Control Valve 4-20 mA (steam flow)

## 5-1-2 Analog Operation Assignment Table

For Feed Forward Control, delete data in columns 6, 8 and 9 from your Analog operation table. Column 7 is used for Feed Forward Control, while columns 6, 8 and 9 are not (Cascade Control only). Use either the Edit menu or keyboard to delete data in columns 6, 8 and 9.

**Deleting Data Using the Edit menu**

1. From the main menu select the **Setting <offline>** icon.
2. From the **Setting menu <offline>**select [Analog oper] button. The **Analog operation assignment** menu will appear.
3. Select [F4: Edit] and you will see the following screen (Figure 5):

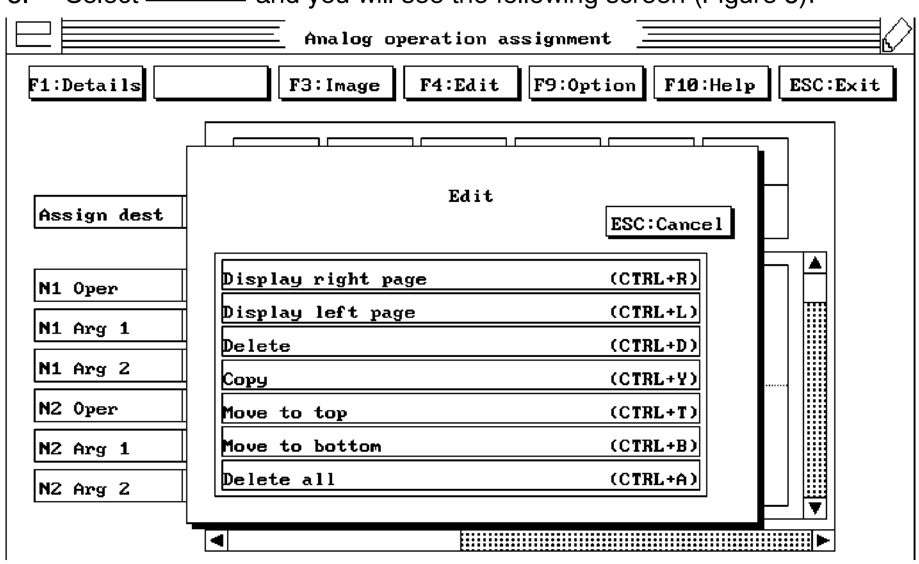



Figure 5

4. Select the **Delete** button.
5. ES/TOOLS prompts you to select a starting point to delete. Select the beginning of column 8 to the end of column 9.
6. Select **ENT: OK** button to delete data within these columns. Repeat steps 4 and 5 to delete data in column 6.
7. Select **ESC: Exit** button.

**Deleting Data Using the Keyboard**

1. Press the <CTRL> and <D> keys at the same time.
2. ES/TOOLS prompts you to select a starting point to delete. Select the beginning of column 8 to the end of column 9.
3. To delete data within these columns, press the <ENTER> key.

Your Analog Operation Table should look like Figure 6.

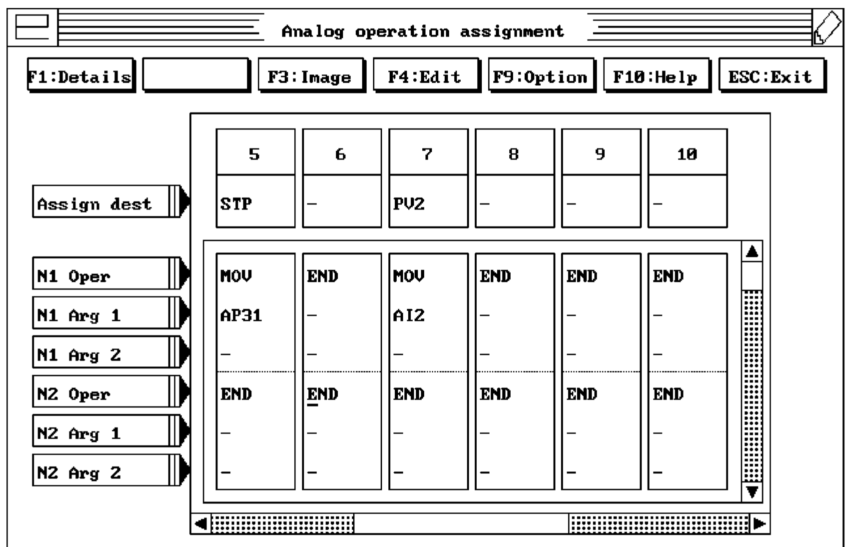



Figure 6

# 5–2 Operation and Tuning

The first step in setting up a Feed Forward control application is to scale the control inputs.

**Scaling the Control Inputs**

In this example we will set up the controller to scale 4-20 mA signal for input AI2. The full scale of the food flow (AI2) is 0-500 kg/min. As an aid to organizing information that will be programmed into the ES100, use the table below.

| Input | Item | Low End | High End |
|---|---|---|---|
| **AI2** | Input from Sensor | 4 | 20 |
| | Value to be displayed on Front panel of the ES100 | 0 | 25 |

Program the ES100 as follows:

1. From the ES/TOOLS menu, click on the **Setting <offline>** icon.
2. From the **Setting menu <offline>** select the **Analog oper** button.

3. Select **F1:Details** from the **Analog operation assignment** menu. A pop-up menu appears (Figure 7).

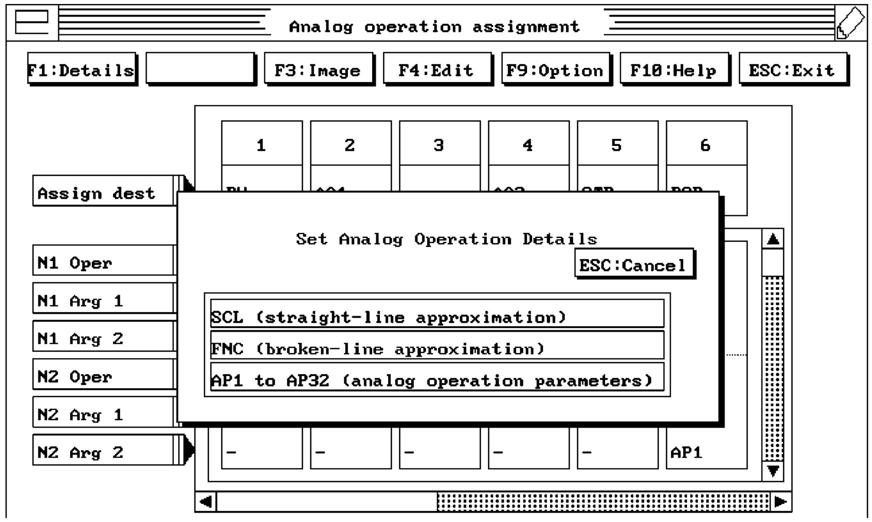
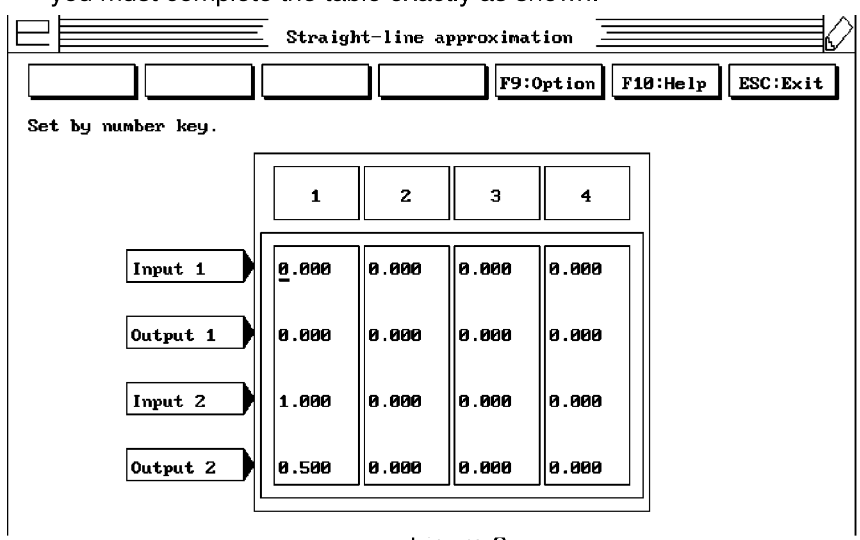



Figure 7

4. Select **SCL (straight-line approximation)** button. The **Straight-line approximation** menu (Figure 8) will appear. For the food sterilization example, you must complete the table exactly as shown.




| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Input 1 | 0.000 | 0.000 | 0.000 | 0.000 |
| Output 1 | 0.000 | 0.000 | 0.000 | 0.000 |
| Input 2 | 1.000 | 0.000 | 0.000 | 0.000 |
| Output 2 | 0.500 | 0.000 | 0.000 | 0.000 |

Figure 8

**Note** The ES100 uses a Normalizing process to scale low end and high end values from the actual sensor input to the controller. This internal process uses 0-1 as the full scale. As a result, it is necessary to input 0 for the low end and 1 for the high end of the sensor output scales, not 4 and 20 (the actual output range).

Column 1 is used to scale AI2 for display and normalization after it (AI2) has been ratioed. To enter the values, simply click the cursor on the value in the appropriate place in the table. For this example the table should appear exactly as shown above.

**Note** Read the following button definitions.

**Input 1** Low end value of the actual sensor input to the controller.

**Output 1** Low end value to be displayed on the front panel of the ES100.

**Input 2** High end value of the actual sensor input to the controller.

Output 2 High end value to be displayed on the front panel of the ES100.

5. Select ESC: Exit to return to the **Analog operation parameters** menu.

**Linking the Control Ratio Program to ES100 Operation**

Now that the ration programming is complete. It is necessary to link it to the core program of the ES100 using the **Analog operation assignment** table. To do this, follow the procedures below.

1. From the **Setting menu <offline>**menu, select Analog Oper (Figure 9).

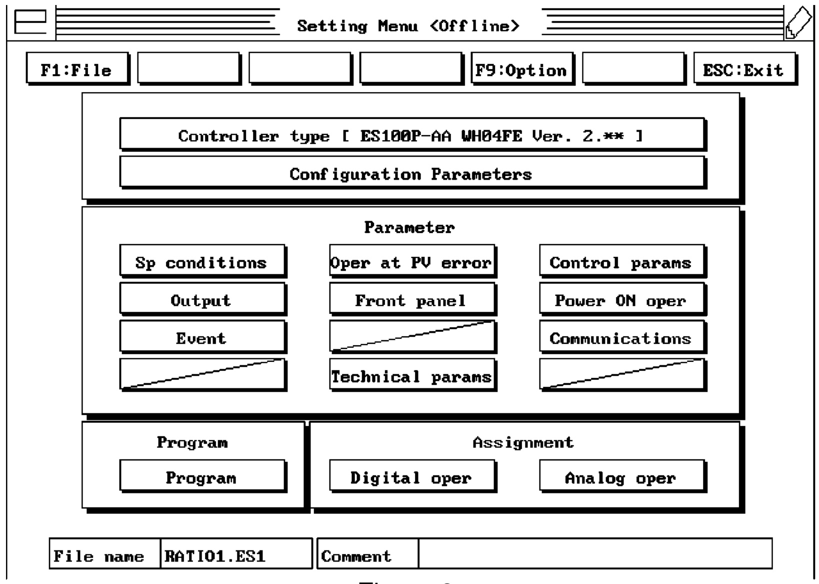



Figure 9

2. From the **Analog operation assignment** table, double-click on the area intersected by **Assign dest** and column 6. A pop-up menu appears. Scroll through the menu and double-click on **FFV (Feed Forward amount)**.
3. Double-click on the N1 Oper/column 6 intersection. Scroll through the pop-up menu and select **SCL1 (Straight-line approximation)**.
4. Double-click on the N1 Arg1/column 6 intersection. Double-click on **AI2 (Analog Input 2)**.

For this example, column 6 should look exactly like the one shown in Figure 10.

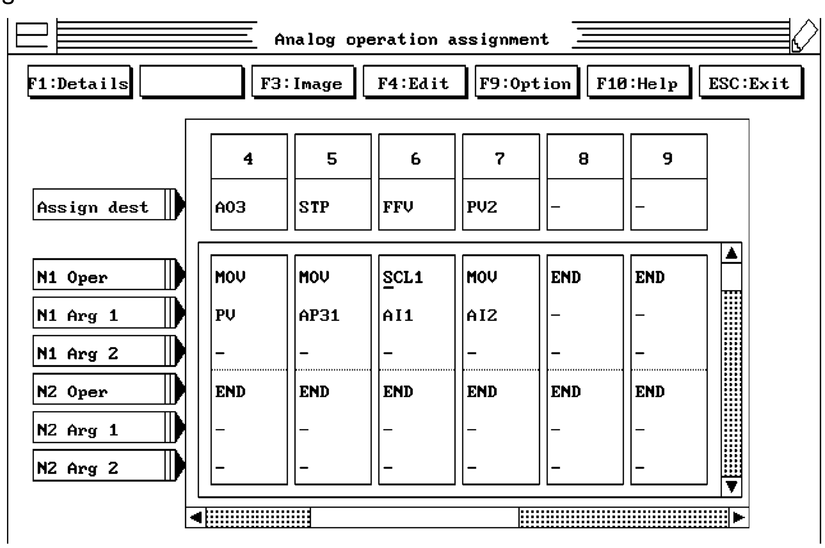



Figure 10

The programming in column 6 reflects the connection of the basic Feed Forward program to the core of the ES100.

You have completed programming the ES100 to operate in a Feed Forward control mode. Now link this data into the operating program of the ES100. To do this proceed as follows.

1. Position your cursor in column 6, in line with Assign dest which is located on the left side of the Analog operation assignment menu, then click into the top of the column. A pop-up menu will appear for the Assign dest selection. In the pop-up menu, select FFV (Feed-forward amount). FFV now appears at the top of column 6. Repeat this procedure for N1 oper, N1 Arg 1, N1 Arg 2...etc.
2. From the N1 Oper pop-up menu, select SCL1 (Straight Line Approximation).
3. From the column N1 Arg 1 pop-up menu, select AI2 (Analog Input 2).

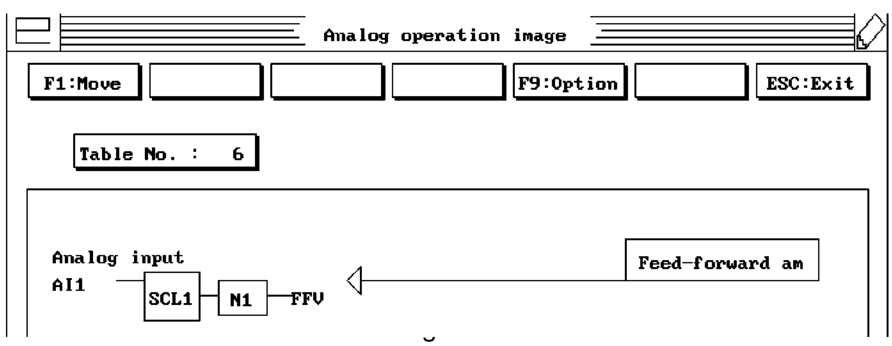
You have now programmed the ES100 to accept AI2 as its Feed Forward input. The information from this input will be placed into the calculation that the ES100 will use to determine the Manipulated Variable (MV).

By programming the ES100 for Feed Forward as we have demonstrated, you have accomplished the following:

- Analog Input 2 signal of 4-20 mA was converted to 0-1.
- Use of the FFV (Feed Forward Variable) to calculate the proper output variable so that the ratio of food to steam would be consistent throughout our process.
- Scaling to SCL (Straight-line approximation, column 1), 0-500 Kg/s (N1).

The ES100 is calculating the Feed Forward variable from the food flow of 0-500 kg/s. The food flow is then used to calculate the Feed Forward Variable.

For a graphic view of the program; select **F3:Image**. Make sure you have column 6 highlighted. It will look like Figure 11.



# 5–3 Autotuning

Autotuning can be used with all Feed Forward control strategies. The autotune feature uses a method of tuning similar to a limit cycle, which is described in Section 1, Cascade Control. When autotuning is activated it will be indicated by a blinking yellow LED on the front panel of the ES100.

**Note** The ES100 must be connected.

1. From the ES/TOOLS menu, select the **Check Control** icon.
2. Select **F1:Run** from the **Check control** menu (Figure 12).

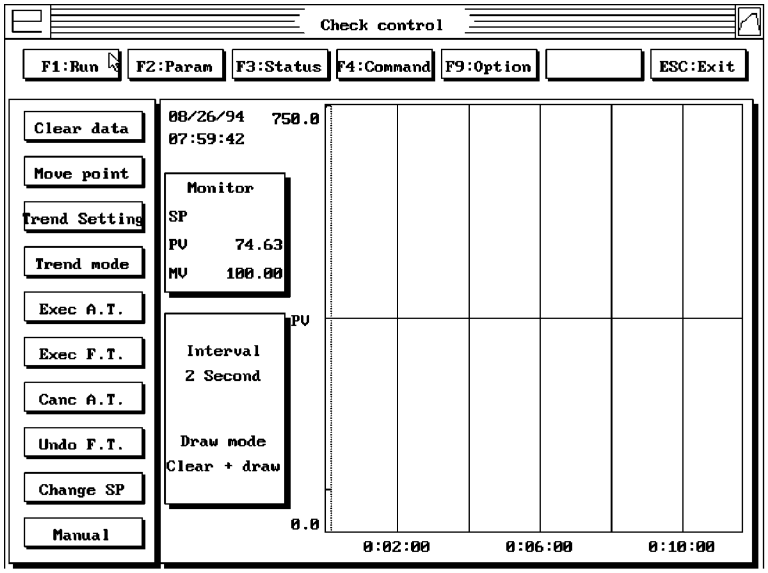



Figure 12

3. Select **Run** from the new vertical menu on the left side of the screen (Figure 13).

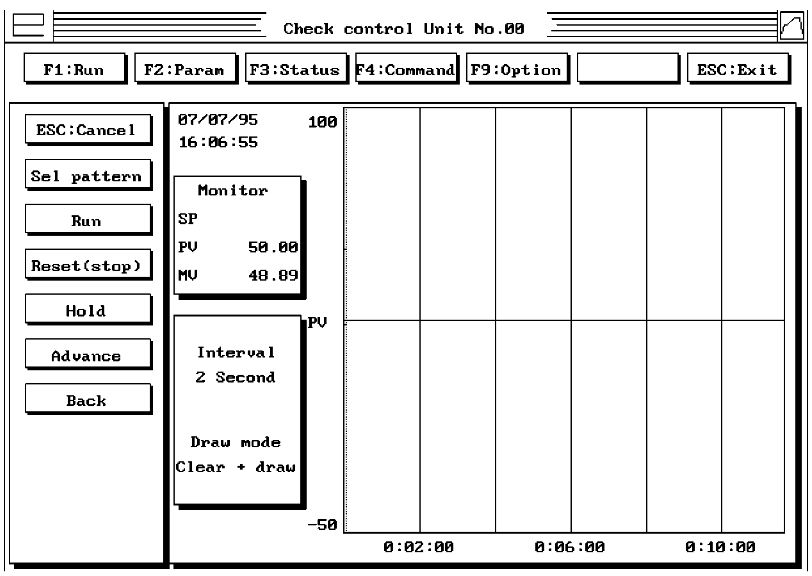



Figure 13

4. Select **ESC: Cancel** to return to the **Check control** menu.
5. From the vertical menu on the left side of the screen, select **Exec A.T.**.

6. A new pop-up window will appear (Figure 14). Enter the number of the PID bank you wish to Autotune.

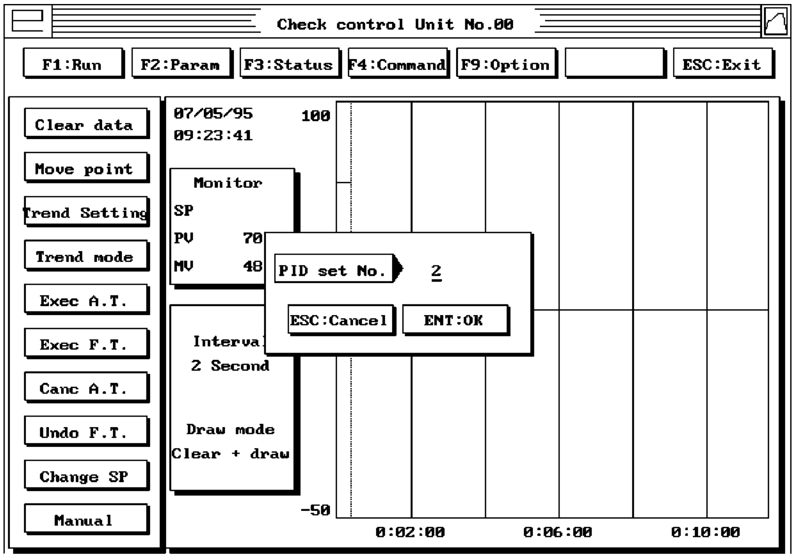



Figure 14

7. Select **ENT: OK**. The controller will now autotune. Do Not interrupt or stop this process. The controller will have completed autotuning when the yellow 'AT' light stops blinking on the front panel of the ES100.

## 5-3-1 Fuzzy Logic Fine Tuning

Start controlling your process with the ES100 by placing it in the RUN mode.

1. From the ES/TOOLS menu, select the **Check control** icon.
2. From the **Check control** menu, select F1:Run.
3. From the vertical menu on the left side of the screen, select RUN

If the performance of the controller is not satisfactory after autotuning, you may improve the performance of the ES100 by using the Fuzzy Logic Fine Tune. Follow these steps to get to the Fine Tune portion of the ES/TOOLS program.

1. From the ES/TOOLS Menu select the **Check control** icon.
2. Select Exec. F.T. from the menu on the left side of the screen (Figure 15).

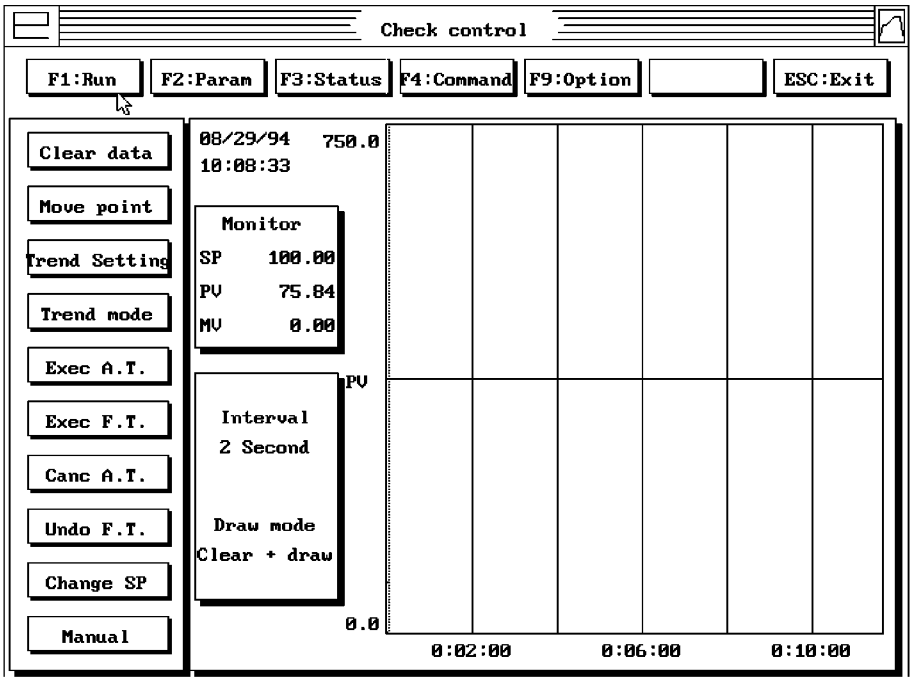



Figure 15

3. A Pop-Up window will appear to confirm the PID set that you are using.

4. Enter the appropriate PID set number and select ENT: OK. A new pop-up window will appear Figure 16.

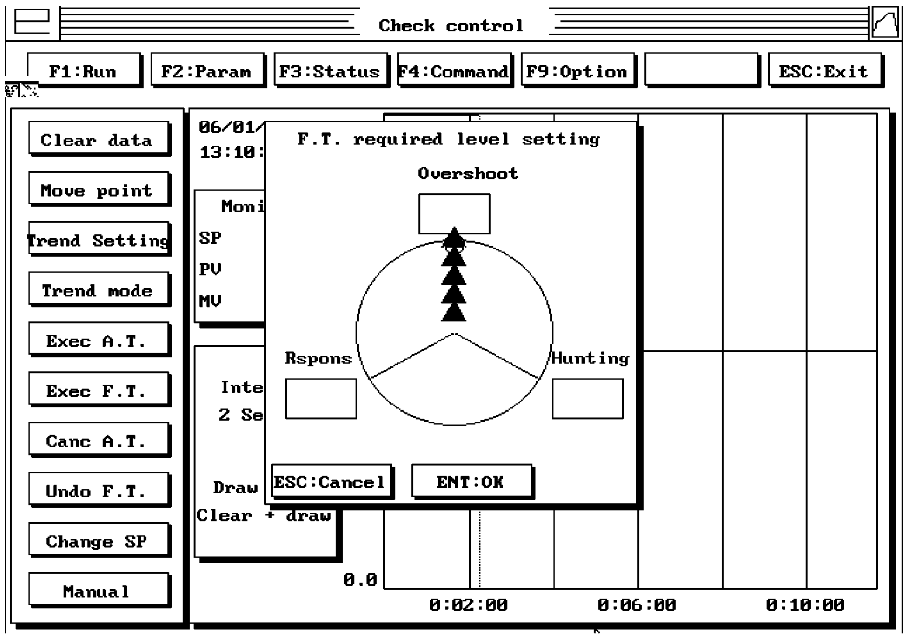



Figure 16

5. There are five different levels of response that you can initiate using Fuzzy Logic Fine Tuning. Each triangle represents one level of strength. The more triangles you select the greater the reaction will be from the Fine Tuning effect of Fuzzy Logic. You can select one parameter (as is shown) or a maximum of two parameters, such as Response/Hunting, or Overshoot/Hunting. Use the keyboard cursor controls to move the red inner circle around the inside of the outer circle. The arrowheads will automatically fill in based on the position of the red circle.

6. Select ENT: OK after you have selected the level of corrective action you require.

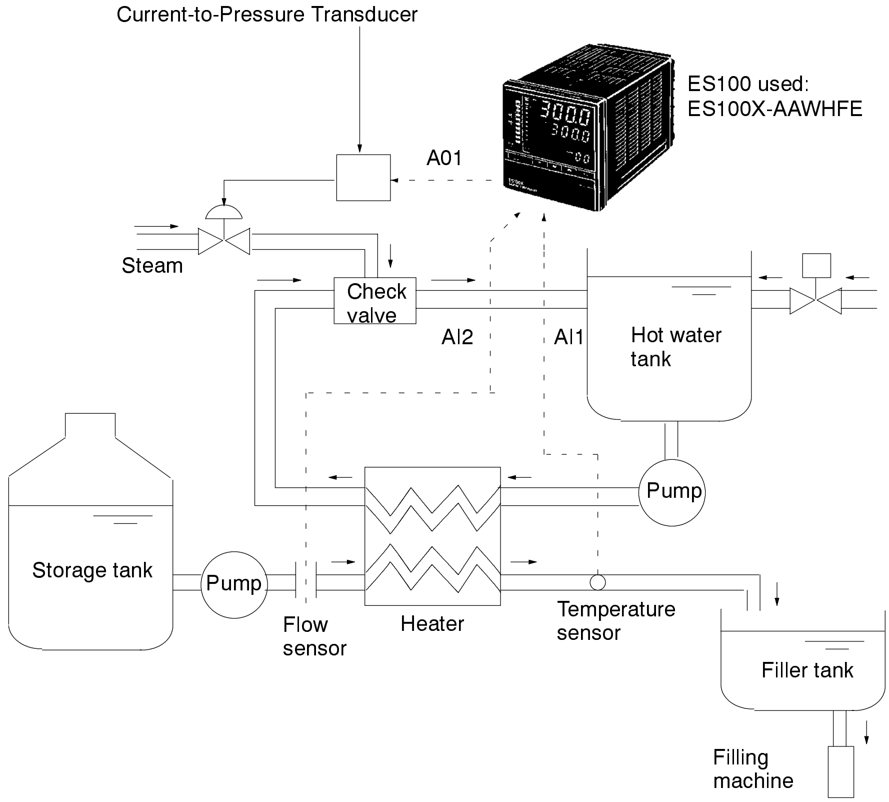
7. ES/TOOLS will prompt you to execute fine tuning, select ENT:OK. Repeat Fuzzy Logic Fine Tuning as necessary to achieve optimum performance.

**You have now completed tuning your ES100 for Feed Forward control.**

# 5-4 Application

The following is a typical example illustrating how ES100 is used in Feed Forward control.

**Alcohol Sterilizing System**




### Process Requirements

The system is comprised of 2 separate loops. The first loop is water heated by steam, stored in a hot water tank, and sent through a "heater" to sterilize the liquor (controlled flow).

1. The process was being controlled by holding the hot water tank at a specific temperature. This did not allow for changes in the flow of the liquor. Customer wanted to control the temperature of the alcohol directly.
2. Process needed to be very accurate because over/under temperature could cause sterilization and/or flavor differences.

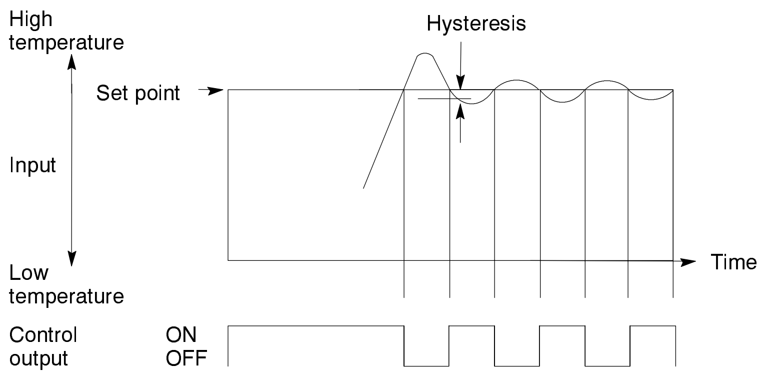
### Model Selection

With Feed Forward control, the temperature of the alcohol can be directly controlled using the flow of alcohol as the Feed Forward variable. By controlling the process this way we were able to better maintain SP resulting in greater production and lower product damage.

# Appendix A
# Control Modes

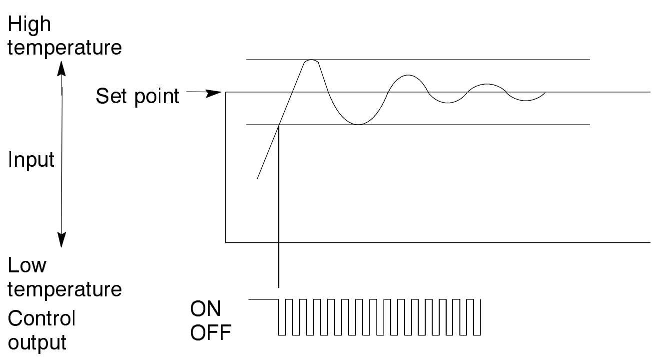
## ■ ON/OFF CONTROL

The output remains ON when the controlled variable (CV) is below the set point (in heating mode). When the CV reaches the set point the output turns OFF. The output will not turn on again until the CV has dropped a specified amount below the set point. The difference between the point at which the output will turn OFF and the point at which it will turn ON is called hysteresis. ON/OFF control is simple but imprecise since the CV will never stabilize.



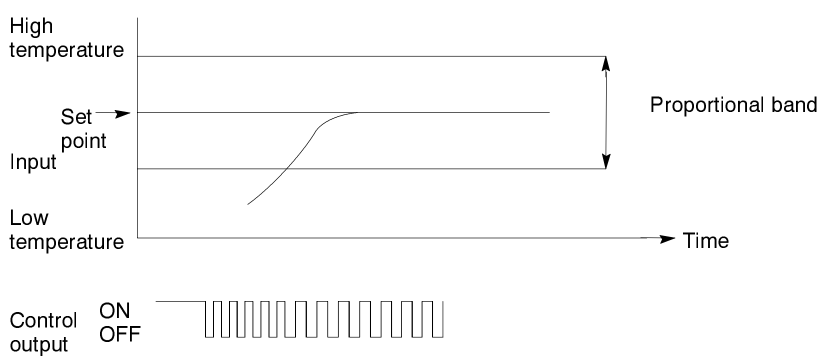

## ■ PROPORTIONAL-DERIVATIVE (PD) CONTROL

In proportional action the percentage of output is based on the amount of deviation from set point. Anywhere below the proportional (P) band, the output is full ON. As the Controlled Variable (CV) moves through the band, the output percentage decreases in a linear fashion until the output is totally OFF at the top end of the P band. When derivative action (D) is added, the controller has the ability to respond to a process disturbance by increasing or decreasing the output percentage based on the rate of change of the CV.




## ■ PROPORTIONAL-INTEGRAL-DERIVATIVE (PID) CONTROL

Choose PID control action when tight control is required. The proportional action (P) varies the output percentage based on the amount of deviation from set point. But proportional control alone can only maintain the set point if the system is designed so that the required output at set point is 50%. Since few systems meet this requirement exactly, an offset often occurs. Integral action (I) checks for this offset, and eliminates it by shifting the proportional band up or down. Derivative action (D) give the controller the ability to respond to a process disturbance by increasing or decreasing the output variable based on the rate of change of the controlled variable.



# Appendix B
## PID Conversions

In Process Control, PID is sometimes referred to as GAIN, RESET, and RATE opposed to PROPORTIONAL BAND, INTEGRAL, and DERIVATIVE. The following conversions should be used as necessary:

$$\text{PROPORTIONAL BAND (\%)} = \frac{100}{\text{GAIN}}$$

$$\text{INTEGRAL TIME (sec)} = \frac{60}{\text{RESET(repeats/min)}}$$

$$\text{DERIVATIVE TIME (sec)} = \frac{60}{\text{RATE(repeats/min)}}$$

The following algorithm formula is set by ISA standards and is called Non-Interacting PID Algorithm based on the fact that the Integral and Derivative are non-interacting with each other. See equation below:

$$m(t) = Kc\left[e(t) + \frac{1}{Ti}\int e(t)dt + Td\frac{de(t)}{dt}\right]$$

m(t) = Controller Output
Kc = Gain (i.e. 100/PB)
Ti = Integral or Reset time
Td = Derivative or Rate Time
e(t) = Error signal

Most of OMRON's controller E5X – – ES 100 series use a form of the equation above.

# Index

## Symbols



## Numbers



## A



## B



## C



## D



## E



## F



## G

## H



## I



## L



## M



## O



## P



## R



## S



## T



## U



## V



## W

# Revision History

A manual revision code appears as a suffix to the catalog number on the front cover of the manual.

**Model ES100 Process Controller**
**ESTOOLS Software Programming Manual**
**and Application Road Map**

Cat. No. H03OAA1

Revision code

The following table outlines the changes made to the manual during each revision. Page numbers refer to the previous version.

| Revision code | Date | Revised content |
|---|---|---|
| H03OAA1 | January 1996 | Original production |

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