USER MANUAL

PITOPS-TFI VER. 6.1

(PROCESS IDENTIFICATION & CONTROLLER TUNING OPTIMIZER SIMULATOR)

TFI

TRANSFER FUNCTION IDENTIFICATION

INDUSTRIAL PROCESS CONTROL SOFTWARE FOR DCS/PLC PID TUNING AND ADVANCED PROCESS CONTROL DESIGN & OPTIMIZATION

PICONTROL SOLUTIONS COMPANY

PART A: **SOFTWARE INSTALLATION AND GETTING STARTED**

CONTENTS

PART A: **SOFTWARE INSTALLATION AND GETTING STARTED**

1.0 INTRODUCTION

Part A specifies the hardware required to run Pitops™-TFI. It also explains software installation procedure and how to start and use Pitops™-TFI.

2.0 SOFTWARE REQUIREMENTS AND INSTALLATION

Pitops™-TFI runs on Windows XP, Windows NT, and Windows 98/2000 operating systems. Microsoft® Excel software is essential for running Pitops™-TFI.

To install Pitops™-TFI, download program installation setup exe file from the picontrolsolutions website (www.picontrolsolutions.com).

To start installation, double-click **PITOPS_TFI_SETUP.exe** file. To complete installation, follow all the step-by-step installation instructions on the screen. All Pitops™-TFI files will be installed to the specified program folder. A program Group "PITOPS-TFI" will be created with program icons "PITOPS TFI, Readme First, Help and License Agreement.

3.0 SIMPLICITY OF PITOPS™ AND RELATED PRODUCTS

Pitops™ is very simple to use for any plant operator, control engineer, DCS/PLC technician or researcher. Pitops™ works entirely in the time-domain (seconds, minutes, etc.) It does not use the more complicated "***s***" (Laplace) or the "***Z***" (discrete) domains.

Use of Pitops™ does not require deep academic knowledge of process control theory. This manual does not cover details of process control theory and fundamentals. For mastering process control theory and fundamentals, please see PiControl's Process Control CBT (computer-based training) module. This CBT is rich with powerful ideas and concepts on practical process control designed for the control room environment.

The users are also referred to Simcet^{TM}, Apromon^{TM} and Tadpole^{TM} products, all designed to help you improve process control at your plant in many new and innovative ways.

Simcet^{TM} is a real-time dynamic simulator that provides a real-plant like PID tuning environment. It lets you practice PID tuning and then take online real-time tests to test your PID tuning skills.

Apromon^{TM} is a PID/advanced controller health monitoring and diagnostics software that helps to identify poorly performing controllers and then provides a structured methodology to improve the controller performance.

Tadpole ^{TM} is equipped with revolutionary, novel mathematics to reliably detect process oscillations and provide adaptive control.

For more information on all these products, visit the website www.picontrolsolutions.com.

4.0 GETTING STARTED ON USING PITOPS^{TM}-TFI

Pitops^{TM} software consists of two modules- Pitops^{TM}-TFI and Pitops^{TM}-PID.

TFI stands for *Transfer Function Identification*. TFI module identifies transfer functions using time-series plant data. This document covers the TFI module only. Another separate document covers the PID module.

To start the TFI module, double-click on its icon (Pitops-TFI). After start-up, an initial information screen is displayed, showing product and registration information. This screen is cleared after a few seconds.

Now continue to Part B for step-by-step procedures on how to use Pitops-TFI software.

PART B: **EXAMPLES ON TRANSFER FUNCTION IDENTIFICATION**

CONTENTS

PART B: **EXAMPLES ON TRANSFER FUNCTION IDENTIFICATION**

1.0 INTRODUCTION

This part helps the user to get started on how to identify transfer functions with Pitops. Several examples are provided on how to configure Pitops to identify transfer functions based on trend data. Detailed step by step instructions are provided on each example.

Example #1 shows how to identify a first order transfer function with time delay. Example #2 shows how to identify a second order transfer function with time delay. Example #3 shows how to identify three transfer functions with time delays simultaneously using closed-loop data. Example #4 shows how to identify control valve stiction. Example #5 shows how to fit transfer function models to step response coefficients. After configuring these examples, the user will be able to use Pitops-TFI for new applications.

2.0 EXAMPLE #1 - IDENTIFY FIRST ORDER WITH DELAY TRANSFER FUNCTION

This example illustrates how to identify a single first order transfer function. This example shows reactor temperature control. If steam flow is increased, reactor temperature increases (transfer function gain is positive). The steam flow is the input signal to the transfer function and the temperature is the output signal from the transfer function. See Figure 1.

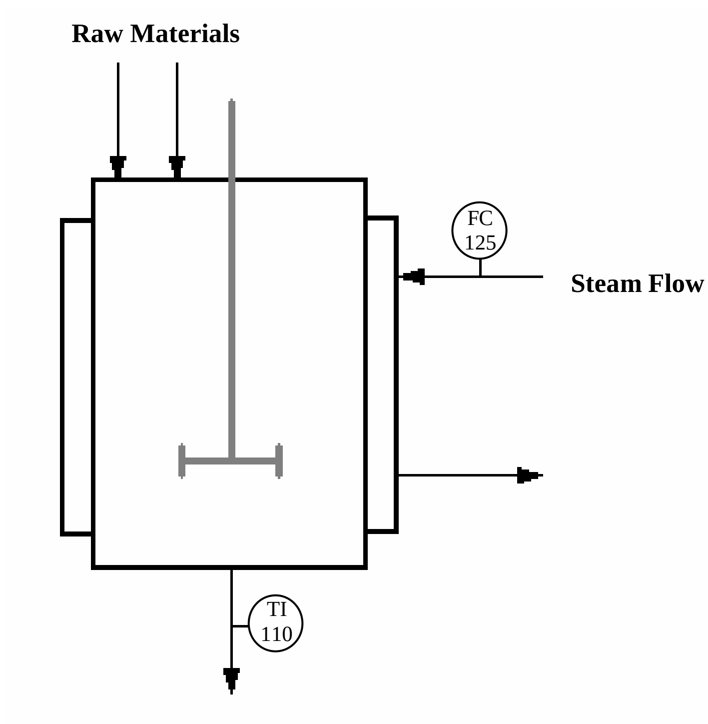
We want to identify the transfer function between steam flow and temperature based on trend data on these two variables. The tagname of the steam flow PID in the DCS or PLC is FC125 and the tagname for the temperature is TI110.

The DCS or PLC data extraction software needs to create an Excel file EX1 PLANT DATA.xls. This file is supplied with the Pitops-TFI software to show the file format and structure. The second column contains temperature data (DCS tagname

TI110). The third column contains the steam flow setpoint data (DCS tagname FC125). The two trends are shown in Figure 2. Note that the first column in the file EX1 PLANT DATA.xls is ignored but this column is required since at start time of Pitops-TFI, we specified that data starts in column #2.

The procedure for configuring Pitops to identify the transfer function is given below:

Figure 1. Temperature Control Example



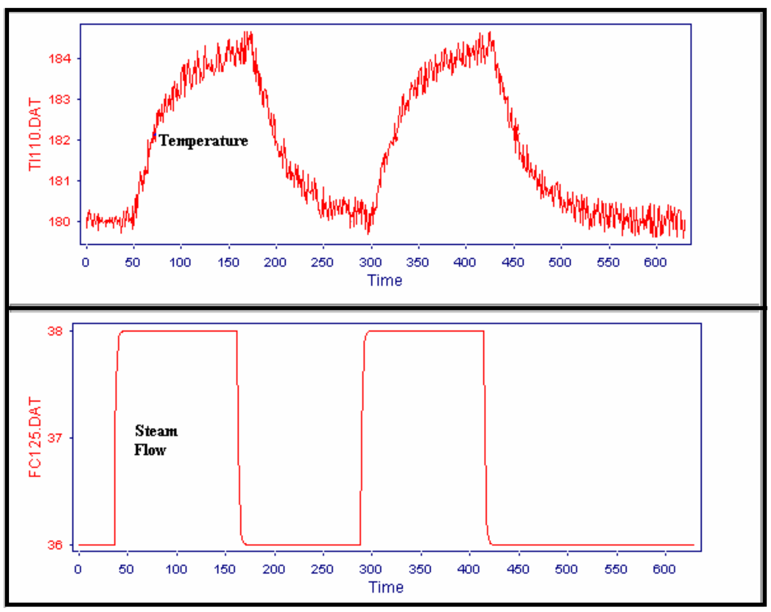
Step #1: **Plant Data Files**

Go to the Pitops directory, where all Pitops files are located. Open and examine the file EX1 PLANT DATA.xls.

The first row contains tagname labels. Sample time is one minute in this case, but can be anything - 1 sec, 10 sec, 30 sec, 1 min, 5 min, etc. (the user needs to know the sample time, but Pitops-TFI does not need to know the sample time). Pitops-TFI assumes unit time, where one time unit can be anything). Note that all time-dependent units entered by the user, e.g., the transfer function parameters (delay and time constants) must be specified in the same time units consistent with the sample time unit used in the file.

The second and third rows in the file are blanks and can be used to specify tagname descriptor and engineering units (these two rows are optional and may be kept blank). This file format can be changed as necessary; the procedure is explained in Part C, Section 3.4.

Figure 2. Steam versus Temperature Data



The actual process data values start from the fourth line onwards and go until the end of the file.

Go to the end of the file. Note that the number of data points in all columns must be the same. Maximum number of data points cannot exceed 20000.

In this example, we have only one MV (steam flow). Pitops-TFI can process up to three MVs.

Now start the Pitops-TFI by double clicking on the icon.

Step #2: **Specify Filenames**

Click on File, click New Case File or click on the icon. Click Yes inside the popup window. Loading New Case File erases data from any previous work prepares for a new case.

Click on File / Plant Data File or the icon and click on the small box with three dots under Select Plant Data File. Select EX1 PLANT DATA.xls. Click on Read Data File; click Close.

Notice that the temperature data can be seen in the topmost plot (red colored trend). The plot is labeled Output (CV) on the left side.

The steam flow setpoint data can be seen in the bottom window (also in red color). The plot is labeled Input1 (MV1) on the left side.

Step #3: **Start Time and End Time**

At the bottom of the screen, note that the Start Time is 0 and End Time is 634. This is because we have 634 data points in the data file EX1 PLANT DATA.xls. If we keep the 0 - 634 settings, this means we want to use the entire window of data (0-634) for analysis. If portions of the data were bad, or we wanted to use smaller piece of the total data set, then we can change the Start Time and End Time to something else.

Step #4: **Transfer Function Parameters**

Pitops-TFI provides powerful zooming feature. With left mouse, click in the topmost plot window somewhere around time = 30 and temperature (CV) = 182. Keep the left mouse key pressed and draw a rectangle towards the second coordinate close to time = about 60 and temperature (CV) about 179.5 and then release the mouse key. The rectangle is now nicely zoomed. Now click and hold the right mouse key and move the mouse up, down, right, left at any angle to scroll the screen.

Zoom also similarly for the steam flow plot. Zooming like this helps to visually estimate the process dead time (time delay). Based on visual inspection, the delay appears to be 5 - 12 minutes. We can also see that the time constant (Tau1) is about 20 minutes. Also notice that for the 2.0 change in steam flow (MV1), the temperature (CV) changes by approximately 4.0. This means that the process gain is approximately 4.0/2.0 = 2.0.

On the right side of the screen, inside the Transfer Function #1 box, set initial guess for Delay = 5 minutes, Gain = 1.5 and Tau1 = 20. We need to specify some reasonable initial approximate values for all four transfer function parameters. Leave Tau2 at zero, since here we are assuming a first order transfer function.

Step #5: **Run Simulation**

Click on Run / Simulate or click on the icon . Notice that the blue trend (in the topmost plot) which was a flat line before now is somewhat similar to the red trend. The blue trend is the temperature signal (CV) prediction in response to the steam flow (MV1) input signal and the transfer function parameters.

The blue trend is also called Model Prediction. Pitops reads steam flow data (MV1), temperature data (CV) and transfer function parameters to generate the model prediction. Note the value of Error located near the bottom right corner of the screen. This is the difference between the blue and the red colored trends summed at every sample time (one minute in this case). If the blue and red signals were identical (superimposed on top of each other) then Error would be zero.

Step #6: **Check Guessed Transfer Function Parameters**

Try different values of Transfer Function #1 parameters. For example, set Gain = 5 while keeping other parameters unchanged. Click on Run / Simulate . Notice that the blue colored trend expands significantly compared to the red. Obviously, we made the transfer function fit worse. Try different values for Delay, Gain and Tau1 and study the impact on the simulation.

Step #7: **Identify Transfer Function**

Re-set the initial guess to: Delay = 5, Gain = 1.5, Tau1 = 20. Click on Run / Simulate . Note the value of Error near the bottom right corner of the screen.

Click on Run / Identify or the icon to trigger the optimizer (the optimizer identifies the transfer function parameters). Near the bottom left corner of the screen, a message appears: "*Optimization calculations in progress, please wait*". After a short time, a message "*Optimization Complete, Improved Transfer Function Parameters*" appears. Click on OK.

Notice the new and improved Transfer Function #1 parameters determined by the Pitops-TFI optimizer. The Error value is lower than the previous case.

Notice that the blue colored trend (model prediction) in the top window now closely matches the temperature CV data (red colored trend). The transfer function parameters: Delay = 14, Gain = 2.1 and Tau1 = 31 fit the process dynamics well for this MV, CV pair of variables.

The Pitops-TFI optimizer consists of an identification algorithm that searches for the best transfer function parameters based on their starting values which we had specified earlier.

Try different values of initial transfer function parameters and click on Run / Identify again. The identification algorithm may converge to slightly different values based on convergence tolerance. If the initial values are very far from the optimum values, then the identification algorithm may not be able to identify good transfer function parameters and will display the message "*Optimization Complete, No Improvement Made*". In this case, change the transfer function parameters and click on Run / Identify again.

Step #8: **Save Case File**

Now we can save all identified transfer function parameters and the plant data filename to a case file for future re-runs and continued analysis.

Click on File / Save As. Enter any desired filename to save, with "TF" as filename extension (example, TEST1.TF). The "TF" filename extension is an abbreviation for "Transfer Function". Click on Save. Now a file with that name will be created. By saving the file, one can restore the complete example later conveniently.

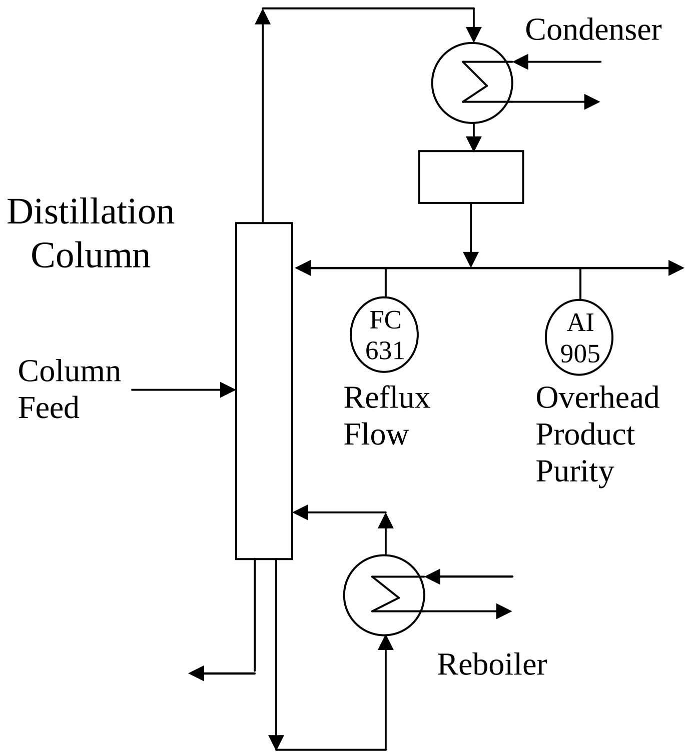
A case file named EX1.TF has been provided with the Pitops software. This is a case file with all configuration data from this example. To bring up this example, click on File / Open Case File or click on the icon and then select EX1.TF.

3.0 EXAMPLE #2 - IDENTIFY SECOND ORDER WITH DELAY TRANSFER FUNCTION

This example illustrates how to identify a single second order transfer function. This example illustrates distillation column product purity control. If reflux flow is increased, overhead product purity increases and vice versa. The reflux flow is the input signal to the transfer function and the overhead product purity is the output signal from the transfer function. See Figure 3 below.

We want to identify the transfer function between reflux flow and overhead product purity based on trend data on these two variables. The tagname of the reflux flow PID is FC631 and the tagname for the product purity is AI905.

Figure 3. Reflux versus Overhead Purity Data



The DCS or PLC data extraction software needs to create an Excel file EX2 PLANT DATA.xls. This file is supplied with the Pitops-TFI software to show the file format and structure. The second column contains product purity data (DCS tagname AI905). The third column contains the reflux flow setpoint data (DCS tagname FC631). The two trends are shown in Figure 4. Note that the first column in the file EX2 PLANT DATA.xls is ignored but this column is required since at start time of Pitops-TFI, we specified that data starts in column #2.

The procedure for configuring Pitops to identify the transfer function is given below:

Step #1: Plant Data Files

Go to the Pitops directory, where all Pitops files are located. Open and examine the file EX2 PLANT DATA.xls.

The first row contains tagname labels. Sample time is one minute in this case, but can be anything - 1 sec, 10 sec, 30 sec, 1 min, 5 min, etc. (the user needs to know the sample time, but Pitops-TFI does not need to know the sample time). Pitops-TFI assumes unit time, where one time unit can be anything).

Note that all time-dependent units entered by the user, e.g., the transfer function parameters (delay and time constants) must be specified in the same time units consistent with the sample time unit used in the file.

The second and third rows in the file are blanks and can be used to specify tagname descriptor and engineering units (these two rows are optional and may be kept blank).

The actual process data values start from the fourth line onwards and go until the end of the file.

Go to the end of the file. Note that the number of data points in all columns must be the same. Maximum number of data points cannot exceed 20000.

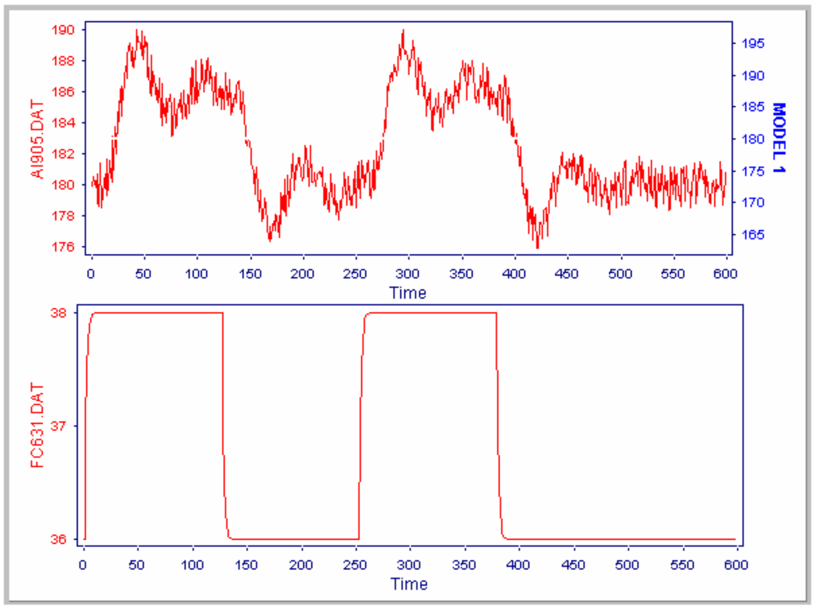
In this example, we have only one MV (reflux flow). Pitops-TFI can process up to three MVs.

Now start Pitops-TFI by double-clicking on its icon.

Step #2: Specify Filenames

Click on File / New Case File or click on the icon and then click Yes inside the popup window. This erases data from any previous work prepares for a new case.

Figure 4. Reflux versus Product Purity Data



Click on File / Plant Data File or the icon  and click on the small box with three dots under Select Plant Data File. Select EX2 PLANT DATA.xls. Then click on Read Data File; click Close.

Notice that the product purity data can be seen in the topmost plot (red colored trend). The plot is labeled Output (CV) on the left side.

The reflux flow setpoint data can be seen in the bottom window (also in red color). The plot is labeled Input1 (MV1) on the left side.

Step #3: Start Time and End Time

At the bottom of the screen, note that the Start Time is 0 and End Time is 599. This is because we have 599 data points in the data file EX2 PLANT DATA.xls. If we keep the 0 - 599 settings, this means we want to use the entire window of data

(0 - 599) for analysis. If portions of the data were bad, or we wanted to use smaller piece of the total data set, then we can change the Start Time and End Time to something else.

Step #4: Transfer Function Parameters

Pitops-TFI provides powerful zooming feature. With left mouse, click in the topmost plot window somewhere around time = 0 and product purity (CV) = 184. Keep the left mouse key pressed and draw a rectangle towards the second coordinate close to time = about 40 and product purity (CV) about 178 and then release the mouse key. The rectangle is now nicely zoomed. Now click and hold the right mouse key and move the mouse up, down, right, left at any angle to scroll the screen.

Zoom also similarly for the reflux flow plot. Zooming like this helps to visually estimate the process dead time (time delay). Based on visual inspection, the delay appears to be 5-12 minutes. We can also see that the settling time is about 120 minutes. Also notice that for the 2.0 change in the reflux flow (MV) the product purity (CV) changes by approximately 5.0. This means that the process gain is approximately 5.0/2.0 = 2.5.

Inside the Transfer Function #1 box, set initial guess for Delay = 5 minutes, Gain = 2, Tau1 = 15 and Tau2 = 15. We need to specify some reasonable initial approximate values for all four transfer function parameters. These transfer function parameters are initial guesses based on approximate knowledge of the process dynamics.

Step #5: Run Simulation

Click on Run / Simulate . Notice that the blue trend (in the topmost plot) which was a flat line before now is somewhat similar to the red trend. The blue trend is the prediction of the product purity based on the reflux flow input signal and the transfer function parameters.

The blue trend is also called Model Prediction. Pitops reads the product purity, reflux flow data from the Excel file, the transfer function parameters and generates the model prediction. Note the value of Error located near the bottom right corner of the screen. This is the difference between the blue and the red colored trends summed at every sample time (one minute in this case). If the blue and red signals were identical (superimposed on top of each other) then Error would be zero.

Step #6: Analyze Transfer Function Parameters

Try different values of transfer function #1 parameters. For example, set Gain = 5 while keeping other parameters unchanged. Click on Run / Simulate. Notice that the blue colored trend expands significantly compared to the red. Obviously, we made the transfer function fit worse. Try different values for Delay, Gain, Tau1 and Tau2 to study the impact on the simulation.

Step #7: Identify Transfer Function

Re-set the initial guess to: Delay = 5, Gain = 2, Tau1 = 15 and Tau2 = 15. Click on Run / Simulate. Note the value of Error.

Click on Run / Identify or the icon to trigger the optimizer (the optimizer identifies the transfer function parameters). Near the bottom left corner of the screen, a message appears: "*Optimization calculations in progress, please wait*". After a short time, a message "*Optimization Complete, Improved Transfer Function Parameters*" appears. Click on OK.

The Pitops-TFI identification algorithm searches for the best transfer function parameter fit based on their starting values entered earlier.

Notice the new and improved Transfer Function #1 parameters determined by the Pitops-TFI optimizer. The Error value is lower than the previous case.

Try different initial transfer function parameters and then click on Run / Identify again. If the initial transfer function parameters are too far from the optimum, then you may see the message: "*Optimization Complete, No Improvement Made*".

After clicking on Run / Identify, and after Pitops has determined new (optimum) transfer function parameters, if you click Run / Identify again, you will see a message “Calculations Complete”. The Identify function will not re-run unless you change one or more of the transfer function parameters and then click on Identify again.

Notice that the blue colored trend (model prediction) in the top window now closely matches the product purity CV data (red colored trend). The transfer function parameters: Delay = 10, Gain = 3.0 and Tau1 = 96 and Tau2 = 4 represent the process dynamics fairly well.

Step #8: Save Case File

Now we can save all identified transfer function parameters and the plant data filename to a case file for future re-runs and continued analysis, if necessary.

Click on File / Save As. Enter any desired filename to save, with “TF” as filename extension (example, TEST1.TF). The “TF” filename extension is an abbreviation for “Transfer Function”. Click on Save. Now a file with that name will be created. By saving the file, one can restore the complete example later conveniently.

A case file named EX2.TF has been provided with the Pitops software. This is a case file with all configuration data from this example. To bring up this example, click on File / Open Case File or click on the icon and then select EX2.TF.

4.0 EXAMPLE #3 - IDENTIFY MULTIVARIABLE TRANSFER FUNCTIONS USING CLOSED-LOOP PLANT DATA

This example illustrates the simultaneous identification of three transfer functions. This example is based on a typical distillation column with one feed stream, one reboiler and one reflux stream.

The process dynamics are such that if the reflux flow is increased then, the overhead product impurity decreases and vice versa. If either feed or reboiler flows are increased, the overhead product impurity increases.

This is a three-input example comprising of three independent transfer functions. The three transfer functions are:

- Reflux Flow to Overhead Product Impurity
- Feed Flow to Overhead Product Impurity
- Reboiler Steam Flow to Overhead Product Impurity

Pitops identifies the three transfer functions simultaneously. See Figure 5.

The reflux flow PID tagname is FC211, feed flow tagname is FC311 and the reboil steam flow tagname is FC411. The product impurity tagname is AI715.

The procedure for configuring Pitops to identify the three transfer functions simultaneously is given below.

The Excel file named EX3 PLANT DATA.xls contains one-minute sampled data. This file is provided with the Pitops-TFI software. The user can open this file and see the various columns containing the data for tags AI715, FC211, FC311 and FC411. The file data trends are shown in Figure 6.

Figure 5. Multivariable Identification for Distillation Column

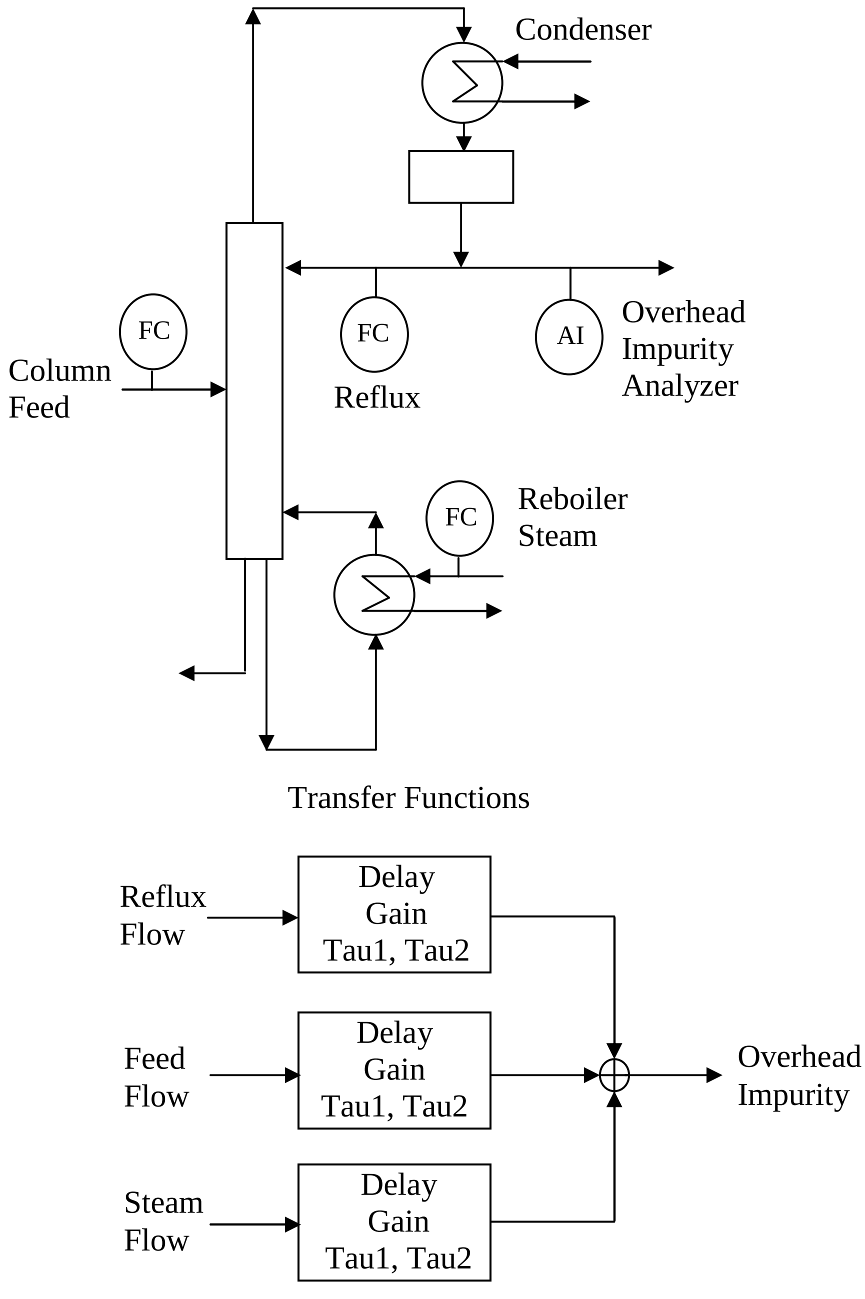
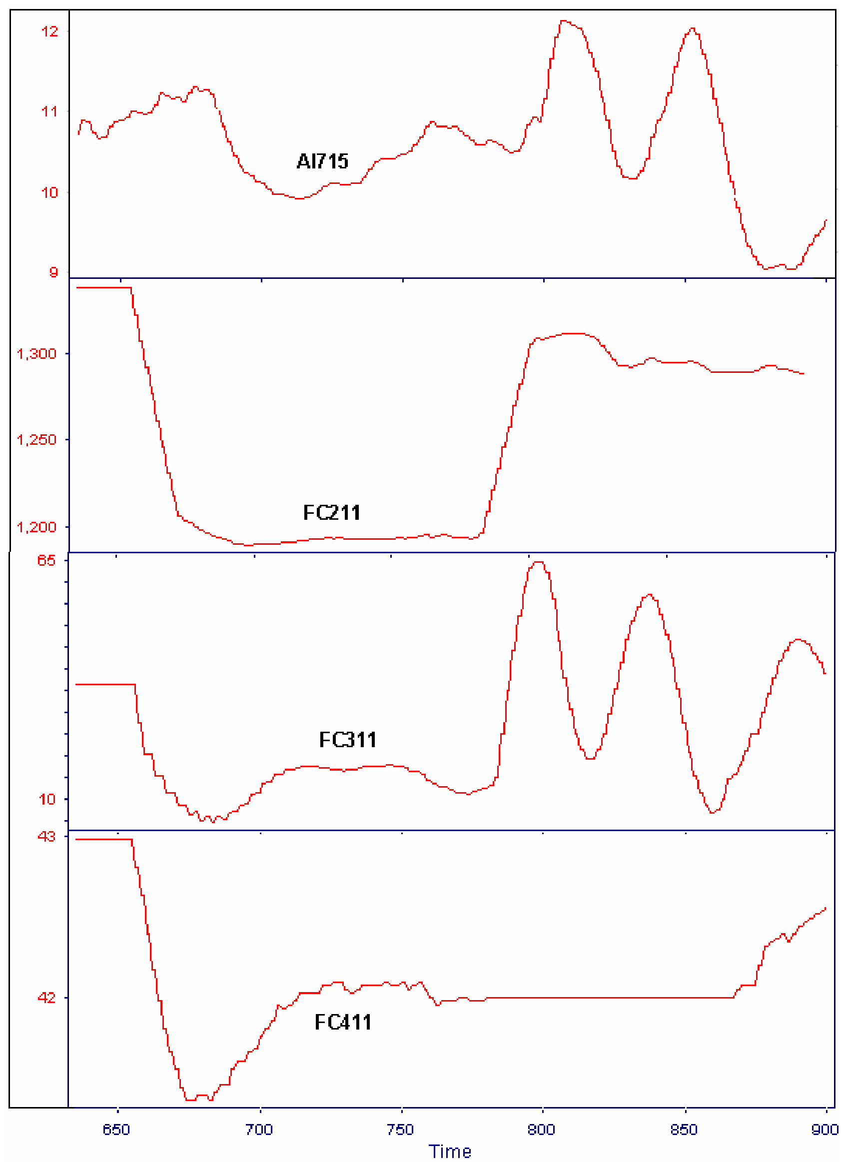


Figure 6. Overhead Impurity versus Reflux, Feed and Steam



Step #1: Plant Data Files

Examine the file EX3 PLANT DATA.xls. This file is created by the DCS data generating software at the plant. Sample time is one minute. The left-most column "Time" is required but the data in this column is not read by Pitops-TFI.

Now start Pitops-TFI by double-clicking on its icon.

Step #2: **Specify Filenames**

Click on File / New Case File or and click Yes. This erases data from any previous work prepares for a new case.

Click on File / Plant Data File or the icon and click on the small box with three dots under Select Plant Data File. Select EX3 PLANT DATA.xls. Then click on Read Data File; click Close.

The topmost plot (red colored trend) displays the overhead product impurity data (CV). The second plot (also red colored trend) shows the reflux flow setpoint data (MV1). The third plot (also red colored trend) shows the feed flow setpoint data (MV2). The bottom-most plot shows the reboiler steam flow setpoint data (MV3).

Note that the CV is also the combined ***Output*** from the three transfer functions. Also note that the three MVs are the three ***Inputs*** to their three respective transfer functions shown on the right side of the screen.

Step #3: Start Time and End Time

Portions of file data may be bad because of instrumentation problems, data collection errors or other reasons. To illustrate the problem, we will only use the good data in this example and ignore the rest of the data that are bad (unusable).

Notice that for MV2 (FC311), data are bad between time = 0 and 256. All four variables appear to be definitely good between time = 635 and 900.

Near bottom left corner of the screen, click on Start Time and set it to 635. Near bottom right corner, set End Time to 900. This means that we wish to analyze data only between time = 635 and time = 900. All other data (before 635 and after 900 are ignored).

Step #4: **Transfer Function Parameters**

Some approximate, initial values for transfer function parameters need to be specified. These may be determined by conducting plant tests or consulting experienced control room operators. These guesses need to be only approximate.

Initial guesses are provided below. Type in the following initial guesses for Transfer Function Parameters for the three transfer functions:

	TF #1	TF #2	TF #3
Delay	2	2	2
Gain	-1.0	1.0	1.0
Tau1	50	50	50
Tau2	50	50	50

It is important that the ***sign*** of the gain (positive or negative) is correctly entered.

By setting Tau2 (Time Const. #2) to a non-zero number, Pitops-TFI will identify a second order transfer function fit. If Tau2 is set to zero, then Pitops-TFI will identify Tau1 (Time Const. #1) only.

Step #5: **Run Simulation**

Click on Run / Simulate  to run the simulation. Pitops reads the data from the EX3 PLANT DATA.xls file, the transfer function parameters and generates a model prediction, shown as the blue trend in the top window. The Error is shown near the bottom right corner of the screen. This is the difference between the blue (transfer function predicted) and the red (actual product impurity) trends summed at every sample time of one minute.

Step #6: **Identify Transfer Function**

Note that the blue trend seen after clicking on Run / Simulate  is the combined prediction based on all three inputs (MV1, MV2 and MV3). If the model prediction (blue line) is almost superimposed on the red (CV), this is an indication of good transfer function parameters. With the initial guesses of transfer function parameters entered above, there is a significant difference between the model prediction (blue trend) and the product impurity (red trend).

Pitops-TFI can identify improved transfer function parameters. The initial (guessed) transfer function parameters must be reasonably correct. If the initial parameters are very different from the actual ones, then Pitops may not be able to determine improved parameters.

For example, if the actual dead time is 10 minutes, then values of 2-15 are reasonable starting guess; but guesses of 30 or more are poor. If the process gain is -1.0, then guesses of -0.1 to -10.0 are reasonable. If actual Tau1 or Tau2 are 30, then guesses of 5 to 50 are reasonable initial guesses.

The user should select initial guesses based on process and dynamics knowledge and then run the Pitops simulation to check the prediction. The prediction should be at least directionally correct as seen in the plots (red and blue trends).

Make sure that the transfer function parameters are as specified in the table above. The Optimize boxes must be checked for all parameters. This means that we want Pitops to identify all parameters. If any box is unchecked, that parameter will be held fixed at the guessed value. All checked parameters will be changed while trying to search for an improved model prediction. Keep the Optimize box for Valve Stiction ***unchecked*** and its value at the default value of ***zero***. Click on Run / Identify . This step may take several seconds. During the identification, Pitops searches for the best fitting transfer function parameters. On completion, a success message box appears, indicating that new and improved transfer function parameters were determined. Click on OK. Observe the updated blue trend showing the new model prediction. Notice that the blue and the red trends are almost superimposed now, better than before. Note the improved transfer function parameters identified by Pitops. The Error is reduced compared to before clicking the Run / Identify button.

Different initial guesses may lead to a different final best set of identified transfer function parameters. It is recommended that different guesses be tried followed by clicking the Run / Identify button to explore possibly different results.

Knowledge of the process and user discretion must be used in selection of the final best set of transfer function parameters.

Step #7: **Save Case File**

Now you can save all identified transfer function parameters and the plant data filename to a case file for future re-runs and continued analysis, if necessary.

Click on File / Save As. Enter any desired filename to save, with "TF" as filename extension and then click on Save. Now a file with that name will be created. By saving the file, one can restore the complete example later conveniently.

A case file named EX3.TF has been provided with the Pitops software. This is a case file with all configuration data from this example. To bring up this example, click on File / Open Case File or click on the icon and then select EX3.TF.

5.0 EXAMPLE #4 - IDENTIFY VALVE STICTION AND TRANSFER FUNCTIONS SIMULTANEOUSLY

Control valves can be defective and exhibit stiction problems. Valve Stiction is explained in Part C, Section 8 below. Please read that section before proceeding further below.

Pitops-TFI provides a novel and revolutionary technique of identifying valve stiction using plant data. The data can be closed-loop, open-loop or a mixture of both. Up to three transfer functions can be identified simultaneously in addition to identifying control valve stiction. This example illustrates how to identify valve stiction using plant data.

Step #1: Open Case File

Click on Open Case File, select the file Ex4.tf, click on Open (the file Ex4.tf is provided with Pitops software). This example has two transfer functions. See initial guesses for transfer functions and valve stiction on right side of the screen.

Step #2: Examine Plant Data File

Click on Plant Data File; you will see the Excel filename EX4 Plant Data.xls (this file is also supplied with Pitops software). The MV1 and MV2 columns are the two inputs and the CV is the output. Note that this example data are from a simulation and are not real plant data.

Step #3: Understand Control Schematic

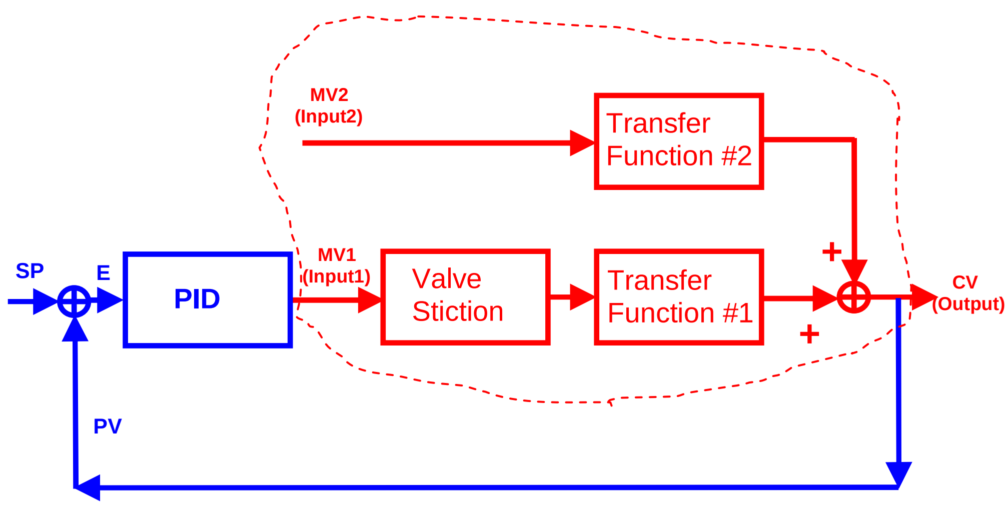
Figure 7 shows a control schematic. Stiction exists between the MV1 (Input1) signal and the input to the Transfer Function #1. The MV2 signal passes through the Transfer Function #2. The outputs from the two transfer functions are summed to comprise the CV signal. Note that the scope of this example is all inside the red envelope with all the red colored elements.

Now examine all the blue colored elements. Notice that the MV1 (Input1) could be the output from a PID and the CV

(Output) signal could be the PV signal going to the PID. So this could be a PID controller with valve stiction.

The MV2 signal could be a disturbance signal. However, our goal in this example is to make use of the MV1, MV2 and CV data and then identify simultaneously both transfer function parameters and valve stiction.

Figure 7. Valve Stiction Identification



Step #4: Identify Stiction and Transfer Function Parameters

Note the initial transfer function parameters and the stiction value. Now click on Identify. Pitops-TFI identifies all six parameters for both first order transfer functions and the valve stiction. Compare the values before and after clicking on Identify. Note that Pitops-TFI changes the initial guessed value of Stiction from 5 to 14. Notice that the blue trend (transfer function model prediction) and the red trend (CV data from the Excel file) in the top window are completely superimposed on each other indicating an excellent fit.

6.0 EXAMPLE #5 - IDENTIFY TRANSFER FUNCTIONS FROM STEP RESPONSE COEFFICIENTS

Pitops-TFI can convert step response coefficients into equivalent transfer functions. Three examples in this section illustrate this feature.

Step #1: Study Format of Step Response Model File

Using Notepad or any text editor, open the file EX5.mdl (this file is supplied with the Pitops software). The file contains vector coefficients characterizing the dynamic response due to a unit step change in the input signal. The input signal is not part of the file. Only the CV response data are shown. Pitops-TFI reads the data starting with the first row, reading from left to right. When all data in the first row are completely read, then it proceeds to the second row and then the third, etc. till all columns are completely read.

Step #2: Identify Transfer Function

Click on Plant Data File . Click on the small box with three dots inside the box. Change the option Files of Type (bottom option inside the popup box) to Step Response Files (*.mdl). Click on Ex5.mdl (this file is supplied with Pitops) and click Open. Click on Read Data File and click on Close. Click OK when you see the "*Optimization Complete*" message. See the identified transfer function parameters on the right side of the screen. The bottom plot labeled "Input1 (MV1)" shows a unit step change. The red trend in the top window is the data from the Ex5.mdl file and the blue trend in the top window shows the transfer function prediction based on the identified transfer function parameters show on the right side of the screen.

Step #3: Fixing Known Parameters to Improve Transfer Function Fit

In most cases, one or more transfer function parameters are already well known. In such cases, you can fix the known parameters and allow Pitops-TFI to identify the others. To illustrate this, click on Plant Data File. Click on the small box with three dots inside the box. Make sure that the option Files of Type (bottom option inside the popup box) is Step Response Files (*.mdl). Click on Ex6.mdl (this file is supplied with Pitops) and click Open. Click on Read Data File and click on Close. Click OK when you see the "*Optimization Complete*" message.

Notice that this model has a small inverse response. To improve the fit, under Transfer Function #1, set Delay to 3 and ***uncheck*** the Optimize box on the far right next to Delay. This fixes the Transfer Function #1 Delay to 3. Based on the red trend in the top plot, we can visually see that only after time = 3, the red trend starts to really change. Set ***both*** Tau1 and Tau2 to 25 (these are just some approximate starting values for the time constants). So here, we want to fit a second order fit. Make sure that the Optimize boxes against Tau1 and Tau2 are checked (we want Pitops-TFI to identify Tau1 and Tau2). Click on Identify. Notice now Pitops-TFI generates a better fit with a second order transfer function model with delay set fixed at 3.

Step #4: Fitting a Zero-Order Transfer Function

Now we will illustrate how to fit a zero-order transfer function to step response coefficients. Zero-order is also called "ramp" or "integrating" type of transfer function.

Click on Plant Data File. Click on the small box with three dots inside the box. Make sure that the option Files of Type (bottom option inside the popup box) is Step Response Files (*.mdl). Click on Ex7.mdl (this file is supplied with Pitops) and click Open. Click on Read Data File and click on Close. Click OK when you see the "*Optimization Complete*" message.

Notice that this model is a ramp (it does not reach steady state, but keeps ramping in response to the step change).

To improve the fit, under Transfer Function #1, set Delay to 1 and ***uncheck*** the Optimize box on the far right next to Delay.

This fixes the Transfer Function #1 Delay to 1. Based on the red trend in the top plot, we can visually see that there is very little time delay (1 or less than 1). Click on Identify. Notice now Pitops-TFI fits a first order transfer function with delay set fixed at 1.

Now let's fit a zero-order transfer function with ramp rate only. Make sure Delay = 1 and that its Optimize box on the far right is ***unchecked***. Set Tau1 = 0. Click on Identify. Notice that now Pitops-TFI fits a zero order transfer function with delay set fixed at 1. The zero order transfer function has only delay and gain (both Tau1 and Tau2 are zero). Many processes with very slow dynamics can be well characterized by zero order transfer functions.

You can click on the File / Save or Save As options to save all these cases for later use.

7.0 GUIDELINES AND RECOMMENDATIONS

Some guidelines and recommendations on how to identify transfer functions are given below. These will help the user in achieving successful results with Pitops and also clarify some common questions.

1. **Need for Cause-and-Effect Relationship between MV and CV**

   The plant data used for transfer function identification must contain some dynamic information in order to be useful. The window of data used in Pitops must be carefully selected. The data must contain some meaningful MV-CV dynamic information. This means that MV changes must cause CV changes in order to have useful plant data. Data where unknown disturbances first caused the CV to deviate followed by feedback corrective action by the MV are useless.

2. Closed-loop Data or Open-loop Data

With open-loop tests, primary PID setpoints are changed (pulsed up and down) based on a recommended move plan. Where ever possible, open-loop tests should be conducted.

However, if an existing advanced control strategy is manipulating the primary PID setpoints, these data can also be used for transfer function identification. Such data are called closed-loop data. Examples #1 and #2 described above are based on open-loop data and example #3 is based on closed-loop data. Notice the box type pulses for input variables in examples #1 and 2 (characteristic of open-loop tests). Input signals in example #3 are not "clean" pulses, but were moved by an advanced control system, which was adjusting their setpoints every minute.

Pitops can identify transfer function parameters successfully using any of the three cases:

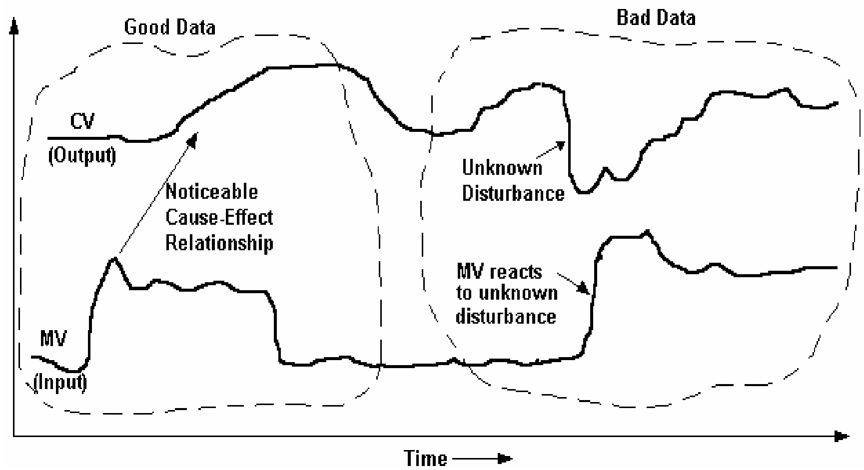
- Open-loop data
- Closed-loop data
- Mixture of both Open-loop and Closed-loop data

In all cases, it is important that the process is at steady state at the start time of the data window.

Closed-loop data are not useful if the inputs were changed by the advanced control system or a human being in response to an unknown or unmeasured disturbance. This concept is illustrated in Figure 8.

The MV increase near the left causes a noticeable CV increase (inside the region marked "**Good Data**"). Here there is a distinct cause-and-effect relationship. The increase in MV causes the increase in CV with some noticeable dynamics (delay and time constant). This action may be achieved by a setpoint change on the CV with an advanced control system.

Figure 8. Good and Bad Data



However, inside the region marked "**Bad Data**", an unknown disturbance causes a dip in the CV. The control system responds by increasing the MV, but this is not a cause-and-effect relationship. The MV responds to an unknown disturbance and in this case, there is not enough information to identify dynamics from the "bad" section. Such data windows must not be used for identification of the transfer function.

3. **Initial Guesses for Transfer Function Parameters**

Before clicking on <u>Run</u> / <u>Identify</u>, approximate transfer function parameters must be specified. Consultation with plant operators or engineers familiar with the process is recommended. Based on process and dynamics knowledge, it is fairly easy to estimate approximate values of transfer function parameters.

For example, if the real dead time in a process is 10 minutes, an initial estimate of 2-15 minutes is a good initial guess. Similarly, if the real process gain is 5.0, then initial guesses of 0.1-10 are good starts. Similar guidelines apply to time constants. If good initial estimates are not available, then various different values can be tried and the simulation plots examined to help determining good guesses. If initial guesses are very poor, Pitops may not always be able to determine improved parameters.

4. **Number of Input Signals**

Most chemical and industrial processes are accompanied with noise, unknown disturbances and some nonlinearities. Also, it is often difficult to conduct long duration open-loop plant tests. Pitops is designed to identify transfer function parameters with short duration data. Uncertainty in the accuracy of identification is high if there are many changing input signals.

Experience has shown that dynamics identification with short duration real plant data with more than three inputs leads to some uncertainty in the final transfer function parameters. Different sets of transfer function parameters may appear to fit the data almost equally well. Pitops is designed to work with a maximum of three inputs and the longest time window of 20000 time units.

5. **Optimize Check Box**

In addition to specifying the initial transfer function parameters, the Optimize check box must be either checked or unchecked for each transfer function parameter. The Optimize check box is located near the right side of the screen. The purpose of this option is to allow the user to fix certain parameters if they are already accurately known.

For example, if the delay is known to be definitely 10 minutes, the user can enter 10 for dead time and uncheck the Optimize box for delay. In this case, Pitops will set the delay fixed at 10 minutes while searching for other parameters (gain and time constants). One or more parameters can be unchecked (set constant), if the user is certain about their accurate values. By fixing known parameters, uncertainty of the problem can be further reduced thereby increasing the chances of accurately determining other unknown parameters.

6. **Sample Time**

The sample time between the data samples in the plant data files is assumed to be one time unit (seconds, minutes, hours, milliseconds or other units - 10 sec, 15 sec, etc.). Pitops-TFI does not need to know the sample time in the data file. The user only needs to know what the sample time is. All time-dependent transfer function parameters (Delay, Tau1 and Tau2) will be calculated in those time units. E.g., let's say sample time is 15 seconds. Then each value in the Excel plant data file will be 15 seconds apart. If the final optimized Delay from Pitops-TFI calculations is 20 then this means that the real Delay is 20 * 15 sec = 300 seconds or 5 minutes.

7. **Setting Some Parameters to Zero**

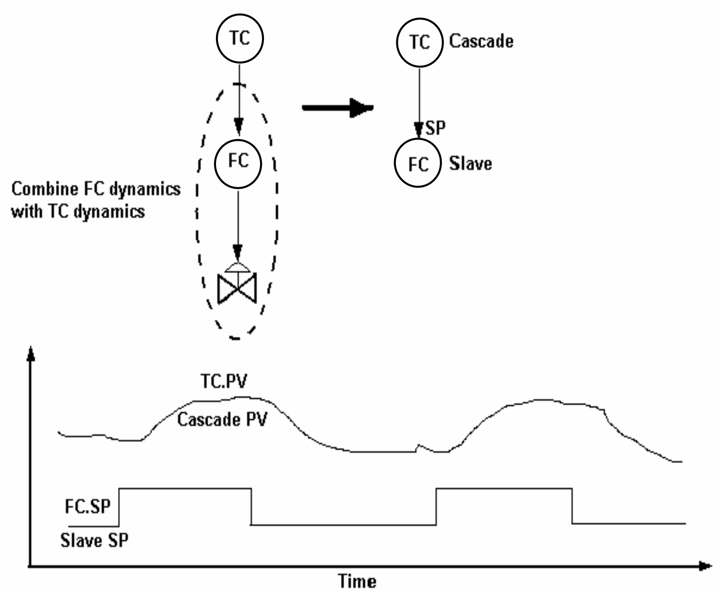
If a transfer function parameter is set to zero, it will be left fixed at zero by Pitops. The Run / Identify  function will not change the value from zero.

8. **Dynamics of the Primary Control Loop**

It is important to remember that in case of cascade loops, the slave loop dynamics are a part of the cascade transfer function.

Consider the example where a temperature PID (TC) is manipulating the setpoint of a steam flow PID (FC) to control a temperature. The MV is steam flow and the CV is temperature. This is a cascade loop (TC is master and FC is slave). See Figure 9 below.

Figure 9. Cascade PID with Fast Slave Dynamics



It is important to optimally tune the slave loops first before attempting to identify the master loop dynamics.

In the above case, the FC needs to be tuned first optimally. Then, the dynamics between the FC setpoint and the temperature (CV) need to be identified. Note that in this case, the MV is really the FC **setpoint** and **not the actual flow**. The data read by Pitops will be for temperature (CV) and for the steam FC setpoint.

If the FC is tuned optimally first before conducting any pulse tests on the FC setpoint, then the flow dynamics will be included in the transfer function between temperature and FC setpoint. If the FC tuning is too slow, this will increase the dead time and time constant for the temperature also.

This completes your training on the use of Pitops-TFI.

PART C: **PITOPS-TFI SCREENS AND MENU OPTIONS**

CONTENTS

PART C: **PITOPS-TFI SCREENS AND MENU OPTIONS**

Part C explains all Pitops pop-up, pull-down menus and screen options. The user should configure the sample examples provided in Part B and familiarize with Pitops before applying Pitops to new problems. Part C can be used to clarify specific queries on any of the menus and screen options that may arise while configuring new problems.

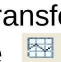
1.0 TRANSFER FUNCTION IDENTIFICATION

The Transfer Function Identification (TFI) module is used to identify transfer function parameters based on historical plant data. To use this option, historical plant data in the form of Excel files are required. Pitops reads the historical data and then identifies the transfer function parameters (process gain, dead time and time constants). An approximate starting guess for each of the transfer function parameters must be supplied before the identification process can be started.

Part B in this manual provides step-by-step examples on how to use the various transfer function identification features. The user may proceed directly to Part B and step through the examples and simultaneously refer to detailed explanations in this section.

2.0 TRANSFER FUNCTION PARAMETERS

You will see the transfer function parameters on the right side of the screen: Delay, Gain (Process Gain), Tau1 and Tau2 (first order and second order time constants). You must enter some reasonable initial values for these transfer function parameters.

After entering the transfer function parameters, you can click on Run / Simulate  to see the model prediction (blue colored trend) in the top plot window. The blue trend shows the transfer function model prediction based on your entered transfer function parameters and the data from the Input Files.

Each transfer function parameter is provided with an Optimize option check box. If the box is checked, then the variable will be changed (improved) when the Run / Identify option is clicked. If the box is unchecked, then the variable will be set fixed at the value specified.

Note that the Optimize check boxes are relevant only to the Identify function and have no effect on the Simulate function. The Simulate function shows the transfer function model predictions based on the transfer function parameters seen on the right side of the screen, whereas the Identify function determines improved parameters.

The Optimize check box is provided to allow fixing known transfer function parameters. In some cases, based on process knowledge and experience, certain parameters may be accurately known. E.g.: if the delay is known to be 10 minutes, then we can set the delay fixed to 10 minutes (uncheck the box for Delay). Then Pitops will identify the process gain and first/second order time constants only, while keeping the delay fixed at 10 minutes. Similarly, the gain or time constants may be fixed if they are accurately known.

If all parameters are set to fixed values (all boxes unchecked), then the Identify function will result in no changes to the initial transfer function parameters provided by the user.

If zero is entered for any parameter, that parameter will be set fixed at zero by the Identify function.

2.1 TRANSFER FUNCTION #1

Use this option to specify transfer function parameters for the first transfer function.

The Simulate function simulates the transfer function response based on the specified transfer function parameters (Delay, Gain, Tau1 and Tau2).

The Identify function reads the initial specified transfer function parameters and then changes (improves) them based on the trend data read from the data files.

2.2 DELAY

Enter the best guess for delay in the selected time units. If you want Pitops to determine the dead time, the Optimize box must be checked. If you are sure that the entered value is the correct dead time, then the box must be unchecked. With an unchecked box, the Delay will be set fixed at the specified value.

Typical starting values are 1 – 20.

2.3 PROCESS GAIN

Enter the process gain in engineering units. For example, consider the case of temperature control by manipulating steam flow. Let's say that changing the steam flow by 5.0 ton/hour results in 4°C change in temperature. Then the process gain can be calculated as = (4.0 / 5.0) = 0.8 °C / (ton/hour). Note the units for the process gain in this example: delta temperature (°C) / delta steam flow (ton/hour). Generically stating, the process gain is the change in the output variable per unit change in the input variable.

Note that Pitops will identify the process gain during the optimization run when the Identify function is clicked. The initial gain entered by the user needs to be only an approximate guess. For example, if the process gain is 0.8, then values such as 0.01 to 5 (say) are reasonable starting values. It is important to specify the correct sign for the gain (positive or negative). If increasing the input variable (MV) causes the output variable (CV) to decrease, then the process gain is negative and a negative gain must be entered. If the initial guess is rather poor, then the Identify function may not be able to find the best fit for the transfer function parameters.

Typical starting values are -20 to 20, but they really depend on the process and can vary a lot. Consult plant operations or study historical data to determine a reasonably good guess.

2.4 TAU1 (TIME CONSTANT #1)

Enter the best guess for the first order time constant in the selected time units.

If you want Pitops to determine the first order time constant, check the <u>Optimize</u> box. If zero is specified for Tau1, this is interpreted as a zero order transfer function. Pitops will then try to fit a zero order transfer function (with both Tau1 and Tau2 set to zero).

Typical starting values are 5 – 100.

2.5 TAU2 (TIME CONSTANT #2)

Use this option only for second order transfer functions. If you wish to fit a first order transfer function, set this parameter to zero.

If you wish to fit a second order transfer function, enter the best guess for the second order time constant in the selected time units in this field.

If you want Pitops to determine the second order time constant, the <u>Optimize</u> box must be checked.

Typical starting values are 5 – 100.

2.6 TRANSFER FUNCTION EQUATION

On the right side of the screen, the Process Transfer Function equation format is displayed, as shown below:

$$G(s) = \frac{\text{Gain}\ e^{-\theta s}}{\tau_2 s^2 + \tau_1 s + 1}$$

Note that the <u>Tau1</u> and <u>Tau2</u> (time constants) displayed under the Process Transfer Function box are the denominator τ_1 and τ_2 shown in the above equation. Note that Pitops-TFI uses the polynomial form and not the factorial form for the denominator of the above transfer function equation.

2.7 TRANSFER FUNCTION #2

In most industrial processes, a controlled variable is affected by more than one input. In the case of a distillation column, the product purity is typically affected by reflux flow, reboil flow and column feed flow. Ideally, if only one of the three input variables can be changed while the other two are fixed, the dynamics identification would be relatively simple, since this would be a single input/ single output (SISO) situation. But in practice, it may not be possible to allow only one of the inputs to change while the rest are fixed. Typically, several variables may be changing at various times. Pitops allows up to three input signals to be analyzed simultaneously.

If your identification problem needs a second MV (input), then under Transfer Function #2, enter the transfer function parameters for the second transfer function. Data for the second MV is required in the Excel plant data file (column #4).

If your identification problem is a single input problem, set all four parameters (Delay, Gain, Tau1 and Tau2) under Transfer Function #2 to zero.

2.8 TRANSFER FUNCTION #3

If your identification problem needs a third MV (input), then under Transfer Function #3, enter the transfer function parameters for the third transfer function. Data for the third MV is required in the Excel plant data file (column #5).

If your identification problem is a one or two input problem, set all four parameters (Delay, Gain, Tau1 and Tau2) under Transfer Function #3 to zero.

3.0 FILE

The File pull-down menu button is located near the top left corner of the screen. It is used to read and save Pitops-TFI simulation case files. After a simulation is configured in Pitops-TFI, the whole data set can be saved conveniently to a file for later use. The File pull-down menu button provides the following file operations for opening and saving files. It also is used to generate vector files (explained below) and also to print plots and reports:

3.1 NEW CASE FILE

New Case File erases all current data and initializes with default values (mostly zeros). This is a convenient way to start a new run. Data from the previous run is erased and the simulator is ready for a new case. The icon is also denotes New Case File.

3.2 OPEN CASE FILE

Open Case File function allows reading a previously saved case file (case files are described in a later section below). The icon also denotes Open_Case Files. The case file contains all configured data: transfer function parameters, stiction value and plant data filename. This is a convenient means of restarting the case at a later time.

When you exit Pitops, all information is automatically saved to a special start-up case file. This file is automatically read after Pitops is restarted at a later time. Thus, you can conveniently exit and re-start from where you left.

To open an existing case file, click on Open Case File and then select the appropriate file from the window and click on Open.

It is recommended that case files in the TFI module should be given filename extension "***.TF*** ". This is not a requirement, but a good naming convention to follow. The Open Case File function expects case filename extensions to be "***.TF*** ". If different extensions are used, then *File Type* should be changed to *All Types* (*.*) to view the case files.

3.3 SAVE, SAVE AS

The File / Save function saves all current information to the existing file name on the hard disk for future use. All transfer function parameters and plant data filename are saved to the current simulation case file. The icon is also denotes Save.

This case file can be restored at a later time by using the Open Case File option described above.

To save the current configuration data to a file with a different name, click on File / Save As and then specify the new case file name as desired.

3.4 PLANT DATA FILE

Click on File / Plant Data File or the icon to specify the plant data filename. Click on the small box with three dots inside to select the filename. Pitops-TFI can read files in either Excel format or in Text format. See the option Files of Type at the bottom inside the Select Plant Data File box. Using the down arrow, you can chose from two options: ***Plant Data Files (*xlr, *.xls)*** or ***Step Response Files (*.mdl)***.

The default option is the Plant Data Files option and is explained below:

1. Plant Data Files (*.xlr, *.xls)

Pitops identifies transfer function parameters based on historical plant data in Excel format.

This section explains the naming convention of the files and the file format expected by Pitops-TFI.

As an example, open the file EX3 PLANT DATA.xls provided with the Pitops-TFI software. The first column contains time stamps (this column is ignored by Pitops-TFI, but this column is required). The actual plant data begin in the second column and fourth row (this is defined in the file ***default.ini*** and is explained below).

The first row contains tagnames for the CV and MVs. The second and third rows may be left blank or used to specify some tag descriptors and engineering units. Data begins from fourth row onwards.

All the rows in the file consist of data spaced apart at unit sample time.

The second column must contain data for the CV (Controlled Variable) data.

The third column must contain MV#1 (Manipulated Variable #1).

The fourth column contains MV#2 (Manipulated Variable #2). If there is no MV2, then this column can be blank (see data file named EX1 PLANT DATA.xls).

The fifth column contains MV#3 (Manipulated Variable #3). If there is no MV3, then this column can be blank (see data file named EX1 PLANT DATA.xls).

The file structure (column and row number where the actual plant data start) can be changed. For all supplied files and examples, plant data started in Row# = 4 and Column# = 2. If your plant data generating system generates files with a different column or row number, then the Pitops file reading format can be changed also.

To change the plant data file structure to suit your plant, open file ***Default.ini*** supplied with the Pitops-TFI software. Then, using Notepad editor modify the Row# and Col# as needed and save the file. Exit and re-start Pitops-TFI for the changes to take effect.

For complete details and examples on how to use plant data files in Excel format, see Sections 2, 3, 4 and 5 in Part B.

2. Step Response Files (*.mdl)

Pitops can read step response files in text format and then fit transfer function parameters. For complete details and examples on how to use step response files, see Section 6 in Part B.

3.5 PRINT

Click on Files / Print or the icon  to print the transfer function prediction plot.

3.6 EXIT

To exit Pitops-TFI, either click on File and Exit, or click on the Windows "X" icon on the top right corner of the screen. Exit is used to exit the Pitops-TFI module. A "Yes" or "No" confirmation is prompted. If No is selected, exit is cancelled. If Yes is selected, Pitops-TFI module exits. Before exiting, all configuration data at time of exit are saved to a configuration file. This file is opened and all data are restored when the Pitops-TFI program is started again later. This allows the user to conveniently continue the last run after exiting the program.

4.0 SIMULATE

Click on Run / Simulate  to run the Pitops simulator. The simulator reads the transfer function parameters entered by the user and the plant data file. The model prediction based on the transfer function parameters entered is displayed as a blue colored trend. The data from the plant data file is displayed as a red colored trend.

5.0 IDENTIFY

Click on Run / Identify  to find improved transfer function parameters that match the Output file data better than the initial set of transfer function parameters.

Pitops reads the initial (guessed) transfer function parameters entered by the user and then runs an optimization algorithm to minimize the error between the measured output signal (specified in the trend data file) and the model predicted signal. The model predicted signal (output) is based on the transfer function parameters and the input signal. The optimization algorithm starts with the initial transfer function parameters provided by the user and searches for an improved set.

5.1 SUCCESS MESSAGE

If the optimization results in an improvement in transfer function parameters, a message is displayed stating that transfer function parameters were improved. This means that the integrated error between the measured and the predicted signals was reduced.

5.2 FAIL MESSAGE

If the optimizer could not find improved transfer function parameters, a message is displayed stating that no improvement was made. This means that either the transfer function parameters are already very close to the best (optimum), or that the starting guess for the transfer function parameters was poor. The user may modify the transfer function guesses and then restart optimizer by clicking on Run / Identify .

5.3 LOCAL MINIMA

Different combinations of initial transfer function parameters may result in several local minima. It may be desirable to start with different sets of initial transfer function parameters and then examine the optimized parameters for each case. Optimum results from different initial guesses for the transfer function parameters combined with knowledge about the process will help in narrowing down the range of values for the transfer function parameters.

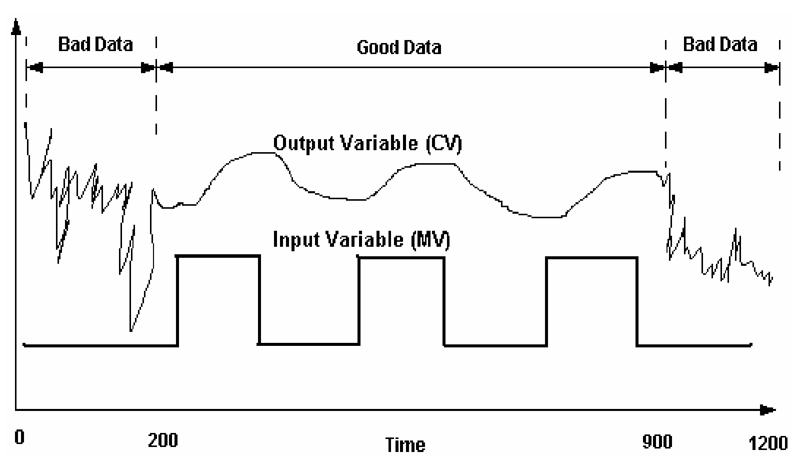
Note that in some cases, changing the initial transfer function parameters and clicking again on the Run / Identify button can generate further improved transfer function parameters. It is a good practice to try different sets of initial guesses for the transfer function parameters and clicking on Run / Identify button.

6.0 START TIME AND END TIME

The Start Time and End Time fields are located near the bottom of the screen.

The Start Time specifies the start time to start processing the data. For example, the files described above may contain some window of bad data because of (say) failed instrument signal or some abnormal process upset. E.g., if the file had 1200 data points (at 1 minute sample time) and if the data from time = 0 to time = 200 are bad, then type 200 as the start time. See Figure 10 below.

Figure 10: Define Start Time and End Time



The End Time specifies the last sample point to use. For example, as shown in Figure 10, data between 900 and 1200 are bad because of a failed instrument signal or some abnormal process upset. In this case, type 900 as the end time.

Based on the specified start and end times, data points between 200 and 900 only will be used for transfer function identification. Data between 0-200 and 900-1200 will be ignored. The start and end times thus allow taking out bad or undesirable data from the problem definition.

7.0 ERROR

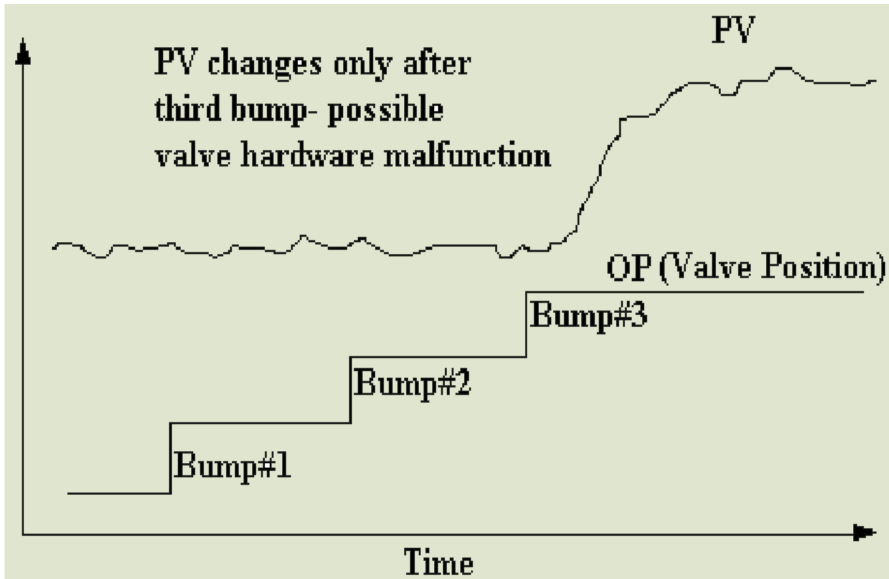
The Error field is displayed near the bottom right corner of the screen. This is a calculated field and cannot be modified by the user. The error is the difference between the model prediction and the output file data calculated at every time unit between the specified time window. In other words, error is the difference between the red and blue trends on the model prediction plot. When the <u>Run</u> / <u>Identify</u> button is clicked, Pitops tries to minimize the Error value.

8.0 VALVE STICTION

Control valves can stick, have “loose-play” or “deadband” in their hardware linkages. As the PID OP changes, the valve may not move at all until the PID OP has changed by certain minimum threshold limit. This limit is called ***Stiction***. The stiction problem can be because of valve sticking or loose linkages. Stiction is often seen in compressor turbine nozzles, old control valves not maintained in a long time, valves servicing corrosive, abrasive materials or with poor valve hardware. Figure 11 illustrates a control valve problem.

Only when the valve is bumped up three times, a noticeable change in flow is finally seen. This is clear proof of valve stiction. If there was no stiction, then the flow (PV) should have increased for the first two valve bumps also.

Figure 11. Pulse Disturbance Signal



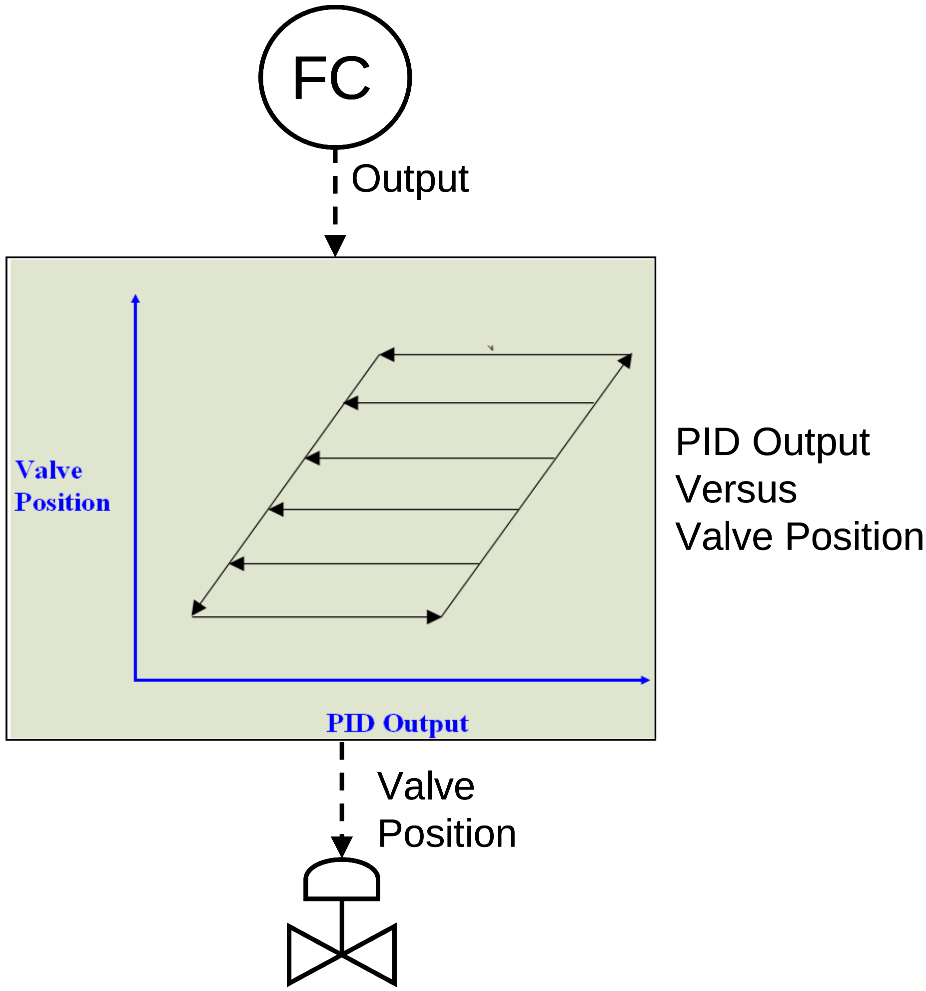
A typical relationship between the PID output and the actual valve position is shown in Figure 12.

Notice that once the PID OP has moved enough to overcome the stiction deadband, then the valve moves in accordance to the PID OP.

If the direction of the PID OP changes, then the valve will not move until the stiction deadband is traversed again.

Pitops-TFI software simulates valve stiction. See the field labeled Valve Stiction located near the bottom right corner of the screen. Typical values of valve stiction are 0.5% to 25%. Valve stiction of over 10% is on the high side.

Figure 12. Stiction Plot showing
PID OP versus Valve Position



Pitops-TFI identifies valve stiction and the transfer function of the control loop using plant data. Data can be closed-loop, open-loop or a mixture of both. Refer to a complete step-by-step example on PID simulation and optimization in the presence of valve stiction described in Part B, Section 5.

9.0 HELP

Click on Help / Help Topics in the top tool bar or click on the icon  to open the Pitops-TFI User Manual.

Click on Help / About in the top tool bar to see information on the Pitops-TFI software product.

TECHNICAL HELP AND CONTACT INFORMATION

For free technical help and support, please contact the PiControl Solutions technical team at info@picontrolsolutions.com or visit our website at www.picontrolsolutions.com.