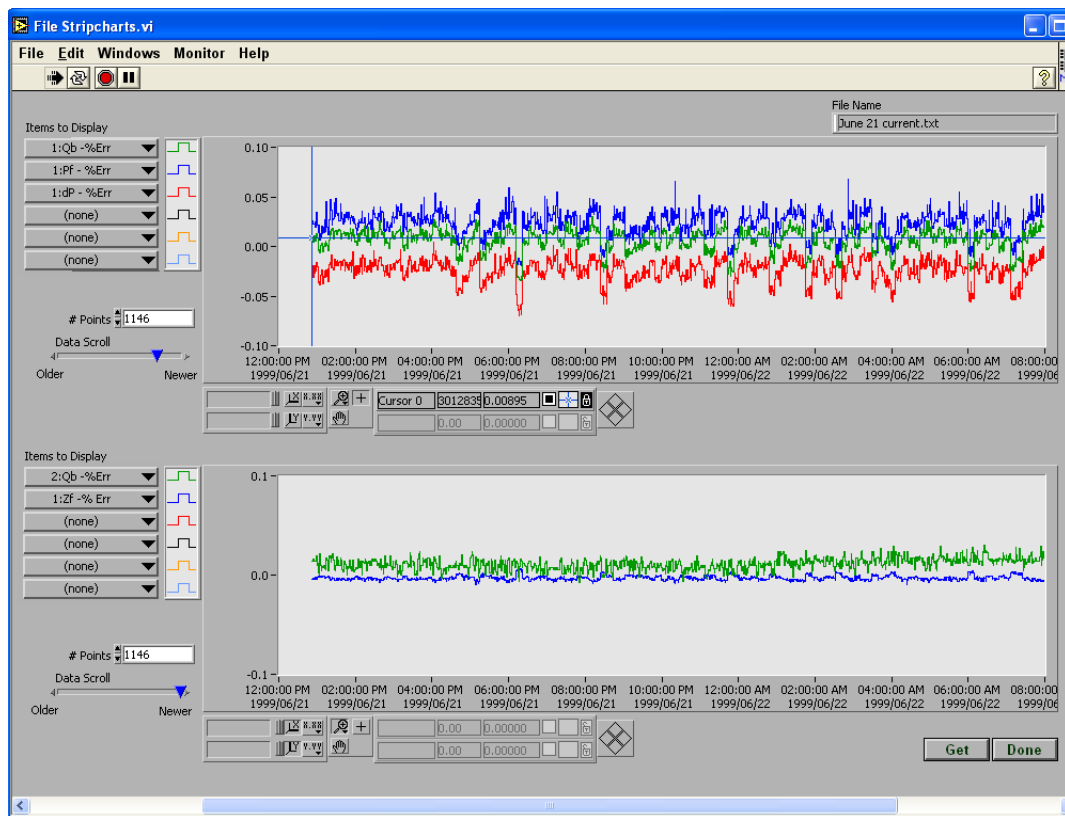


# EFM Test Bench



## User's Guide

# EFM Test Bench

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## User's Guide

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# About EFM Test Bench...

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EFM Test Bench is the industry's best tool for testing electronic flow measurement computers. It is designed for systematic end-to-end testing of every aspect of flow measurement performance, including analog inputs, calibrations, internal calculations, historical record storage, and information retrieval by a measurement host.

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## Features

- Tests the analog input system
- Tests calibrations
- Tests handling of static pressure compensation
- Tests handling of k-factor tables, and Reynolds number tables
- Tests calculations: AGA-3 (92, 2010); AGA-5 (92, 2009), AGA-8 (94)
- Tests GC polling — simulate almost any Modbus Gas Chromatograph.
- Tests handling of any line conditions
- Tests host polling
- Generates comprehensive reports
- Convenient spreadsheet-oriented import & export
- Tests different analog assignments without rewiring
- Easy pass/fail test reporting, with detailed information of error conditions
- Calculates the theoretical flow rates and volumes for a test, and compare them in real-time with the results obtained by a flow computer being tested. Theoretical values are calculated using your choice of AGA standard calculations.
- Flow computers can be monitored using ADEPT (ScanCom) or Modbus.

# Overview

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The EFM Test Bench is designed for systematic end-to-end testing of electronic flow computers.

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## Analog Inputs

The hardware component of the EFM Test Bench simulates the analog transmitters in a natural gas measurement flow run. You can choose hardware which sources 4..20 mA current loops, creates 0..5 V signals, or which simulates 3 and 4 wire resistive RTDs.

National Instruments makes several devices that simulate 4..20 mA transmitters. The easiest to use is probably the CompactDAQ chassis, with individual modules that can source four 4..20 mA current loops. This lets you conveniently wire one hardware module to each flow run you wish to test in a flow computer. The analog outputs can accurately simulate static pressure effects on differential pressure transducers.

At the time of this writing, the most cost effective RTD simulator seemed to be manufactured by Pickering Instruments.

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## Pulse Inputs

You can also simulate various flow measurement devices that emit pulses to indicate flow measurement. The EFM Test Bench can simulate k-factor tables, and Reynolds number corrections, so that you can see if these functions are working properly in the flow computer under test.

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## Calculations

The EFM Test Bench includes a variety of equations of state, and flow calculations.

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## GC Simulation

You can simulate arbitrary gas chromatographs.

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## Host Polling

The Test Bench monitors flow computers during tests. You can compare current process variables with the expected values, using flexible strip charts and spreadsheet reports. You can also compare accumulated volume and energy, as well as the API-21 *Integral Value*, and average input values.

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## Reporting

Each test run produces easy to read spreadsheet reports, highlighting any items that fall outside of the test tolerances.

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## Easy Operation

It's easy for relatively untrained people to run test suites, and check for compliance.

# Creating Effective Tests

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Most software manuals concentrate on how to use the software, and this one is no exception. However, before we look at the mechanics of using the software, this introduction looks at the kinds of things that the EFM Test Bench can test, and at what makes a test effective.

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## Regulatory Compliance

One of the obvious things that you can use the EFM Test Bench for, is to ensure that a flow computer complies with whatever published standards apply in the jurisdiction in which they will be used.

In North America, some of the tests that apply are:

- AGA test cases  
Each of the AGA standards contains expected values at specified conditions. In general, the AGA tests are all quite static. It's quite easy to simply have a test that includes every published AGA test case.
- API chapter 21  
As of this writing, API is in the process of approving a new version of Chapter 21 of the standard: *Flow Measurement Using Electronic Metering Systems*. The API-21 tests are also very straightforward, as they only specify a limited number of test conditions. API-21 adds a new *Integral Value* calculation, and the requirement that it be included in custody transfer logs, so it is necessary for the API-21 tests to run long enough to verify that the correct accumulations and averages are performed.

---

## Past Experience

Every flow computer user accumulates a wealth of troubleshooting information over time. Many past experiences are worth capturing, and adding to the test case library.

As an example, one of the first things we used the EFM Test Bench for, was to test something that the measurement technicians had begun to suspect, but had never been able to prove. It seemed that the hourly volumes were a bit too high in the springtime. The suspicion was that very gradual temperature drifts didn't trigger a full calculation cycle.

We generated a test with the EFM Test Bench in which the temperature increased very gradually over a period of several days. Sure enough, the volumes were over-reported, and the degree to which they were over-reported gradually increased as the line temperature went up.

At this point, we asked the flow computer manufacturer to see if a very gradual temperature drift could cause the gas property calculation to be skipped. Sure enough, there was a loop in the code that checked to see if the previous temperature value had changed more than a certain threshold. On a loop to loop basis, the change was always too low for the calculation to be triggered. The one-line-of-code solution was to avoid replacing the previous value in the code with the current value every time through the loop.



---

## Specific Conditions

When gas custody transfer measurements involve large dollar values, questions and challenges are almost inevitable.

Some of these challenges have historically been quite complex. In one case, a producer argued that the AGA standards under-reported the energy in their gas. It takes more than the EFM Test Bench to address issues regarding gas physics, although it is easy to compare the effects of different equations of state.

Fortunately, most custody transfer questions are fairly easy to address. One of the common questions in gas measurement is whether particular a pulsation pattern will affect the measured gas volume. Here, addressing the concern is a simple matter of measuring the actual line conditions over some period of time, and using the recorded conditions as the line conditions in an EFM Test Bench test. Since the EFM Test Bench calculates expected values as the discrete integral of each set of input conditions, it is not affected by pulsation. Determining whether a particular flow computer miscalculates the volume and energy is straightforward, allowing sensible measurement decisions to be made. In some cases, it is possible to safely use a less sophisticated flow computer at a location with pulsation.

Gas stream mixing can raise questions regarding energy calculations. Again, it is quite straightforward to determine whether specific stream mixture changes lead to measurement errors.

Most gas chromatographs suffer from a limited ability to distinguish between molecules with high molecular weights. It is easy to test various simulated gas chromatographs to see if the aggregation of certain molecules leads to incorrect energy calculations. The EFM Test Bench uses the 29 component AGA-5 gas slate for its energy calculations.

It's also possible to explore operational questions, such as whether stacked differential pressure measurement would improve flow and volume measurements. While it is quite easy to explore the effect of operating extremes on the calculated flow and volume, it is worth remembering that the EFM Test Bench does not test the validity of the basic orifice plate calculations — only whether they have been correctly applied by a flow computer!

# The Main Menu

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When you start the EFM Test Bench, the main menu window appears:

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## The Menu Window

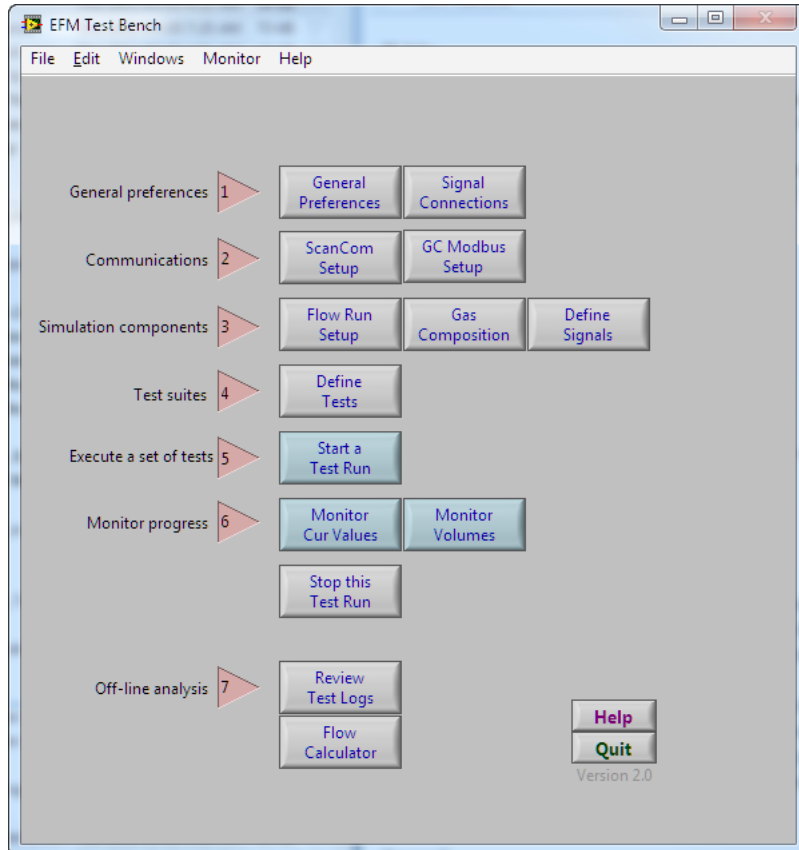


Figure 1 — The Main Menu

While the cursor is in the main part of a window, it is in the shape of a pointing hand. You select a function by clicking the appropriate button.

When you select a function, its window appears. This panel will usually have a “Done” button on it somewhere. When you’re finished using a window, click its Done button to return to this menu. You can have several windows active at a time.

In general, the workflow goes from top to bottom, following the numbered steps. Once the EFM Test Bench has been set up, operators should only need to use the green buttons to run test sequences.

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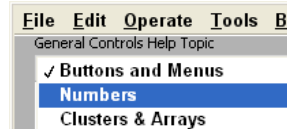
## Getting Help

You probably shouldn’t throw this manual away, but the software has an on-line help system. Here’s how to use it:

Most panels contain a “Help...” button. Clicking it displays general information about using that panel (you can usually press the F1 function key instead of clicking

the Help button), or select from the Help menu. The help panel may contain buttons to display related information.

There may also be a pop-up menu in the upper left hand corner of the help window, which lets you select from a variety of help topics



Every panel also has a “Done” button — click it to return to the previous panel (or press the Enter key).

---

### Floating Help Window

You can also display a “floating” help window, which will give you specific information about almost any object on the screen. To show it, either select “Show Help” from the Help menu, or press the letter “H” while holding down the Control key. When the cursor is over a screen object, the help window displays information about that object.

Select “Hide Help Window” from the Help menu to remove the Help window.

# Step by Step

Let's quickly go through the process of testing a flow computer. We'll go through the steps on the main menu in order. Each row of items depends on the rows above it:

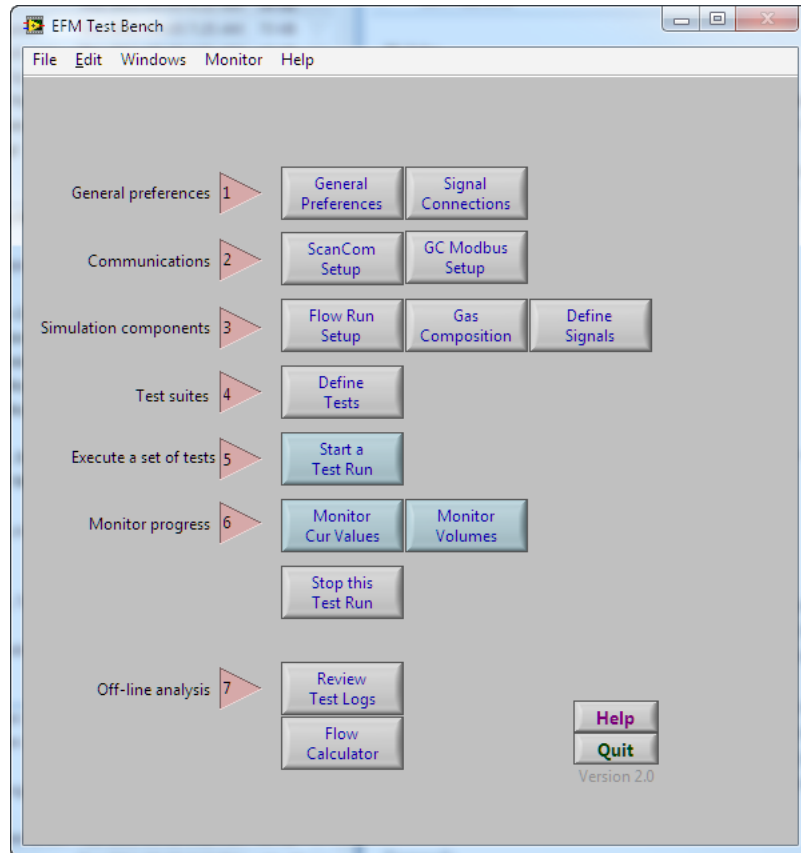


Figure 2 — Workflow order

## Quick Start

Here's a quick overview of the process. You'll find more detail on each of these steps in the following sections of the Guide.

### 1. General Preferences

If this is the first time you are using the system, you should tell the system where you would like to store files, and which communications ports you will use.

You also need to tell the system about your wiring setup. In most cases, you will probably re-use a standard wiring harness.

### 2. Communications

You also need to tell the software about the network protocols you might be using: ScanCom and Modbus.

### 3. Simulation Components

Here you specify the run geometry and transducers to simulate for the flow runs you wish to simulate. You can also test the calibration procedure in your flow computers. If you will be monitoring a Cameron/Barton/Bristol flow computer using ADEPT, you can get flow run information from the flow computer, and set the flow computer's clock

You also specify the line conditions to test, and the gas compositions you wish to use. These can both be imported from spreadsheets.

### 4. Tests

This is where you build up a library of tests. The Test Bench comes with tests for common operations such as API-21 compliance, but you will probably want to define your own tests as well. For each test, you specify the signals and gas compositions to use, and the allowable pass/fail tolerances.

### 5. Start a Test Run

Once you've defined your tests, you bring them together when you start a test run. You can quick-save various test combinations, making it easy for test operators to start a series of standardized tests.

### 6. Monitor Progress

During a test, you can view strip charts to show deviations from the expected values in either the current process variables, or the periodic accumulations of volume, mass, and energy.

After each test completes, you can view summary and detail reports for the test.

# Preferences

The first time that you use the system, you should tell the EFM Test Bench where you'd like to store your data files. Do this by clicking the *Preferences* button on the main menu. The Preferences window appears:

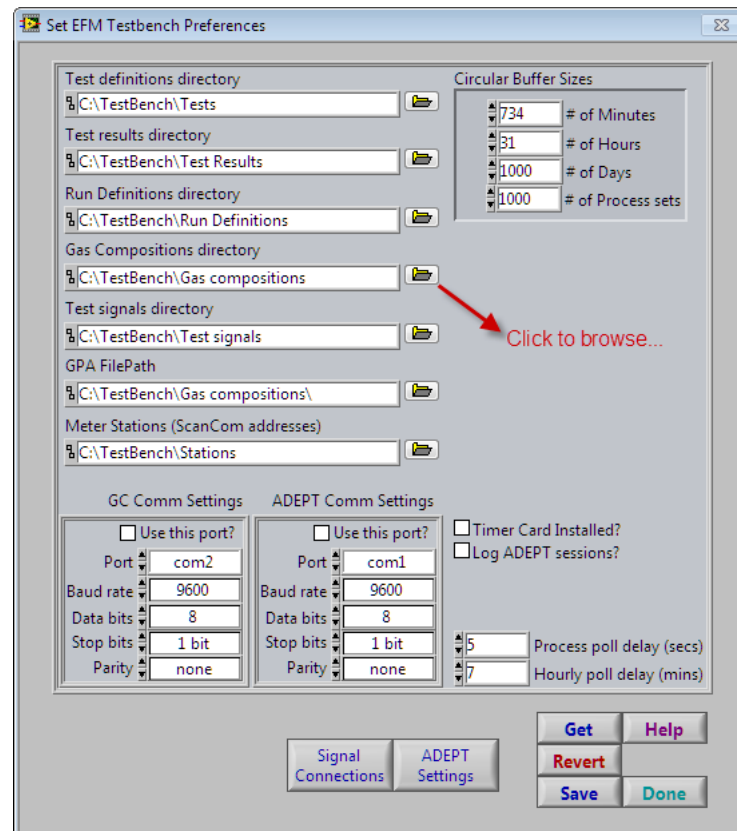


Figure 3 — Preferences

## File Locations

The EFM Test Bench helps to keep you organized by storing different kinds of files in their own directories. For each of these files types, enter the *path* to a folder on your hard disk where you'd like to store them. When you retrieve or save a file, the file dialog will start at this location (but you can always specify a file located somewhere else).

There are a couple of shortcuts you can use instead of typing in the full path names:

- Drag and drop a folder from the Windows Explorer.
- Click the little folder icon at the right of the path name to browse for a file or directory
- Copy and paste.

Click “Save” to save your file preferences in a file called *Prefs.dat*, which will be located in the same folder as the EFM Test Bench application. You cannot change the name or location of the file (if you could, how would the Test Bench find it?).

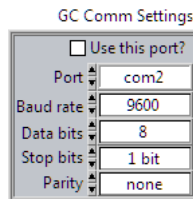
“Revert” restores the values that were in *Prefs.dat* the last time you saved them.

“Done” allows you to use these path names for the remainder of this session, but does not save them permanently.

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## Serial Ports

The EFM Test Bench uses serial ports to simulate a Modbus Gas Chromatograph, and to communicate with the flow computers under test. Specify the port to use for the Gas Chromatograph, and the port settings here:



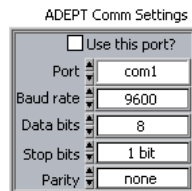
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## ScanCom

If you are testing a Cameron/Barton or Bristol flow computer, the EFM Test Bench can communicate with the flow computer using ADEPT (ScanCom) over a serial port.

This lets you compare the measurements made with the flow computer with the theoretical values calculated by the EFM Test Bench.

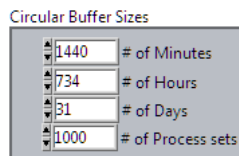
You can select any unused communication port on the simulation computer.



---

## In-memory buffer sizes

While a test is running, a certain number of data sets are kept in memory, so that you can display them using the strip charts. You specify how many data sets should be kept in memory here:



You can set these values fairly high if your system has sufficient memory.

# Wiring

There are a number of cables that tie everything together: signal cables, serial cables, and network cables.

## Signal wiring

In most cases, you will probably select hardware that can source 4..20 mA current loops, as this is the most common wiring method in use for analog transmitters. You can also choose hardware that generates voltages.

The EFM Test Bench can simulate up to eight flow runs, each of which can be either a differential pressure producer (orifice plate, cone, venturi, or pitot), or a pulse (turbine) meter. Each flow run can simulate two stacked differential pressure transmitters.

Click “Signal Connection” from the main menu to display the wiring setup window:

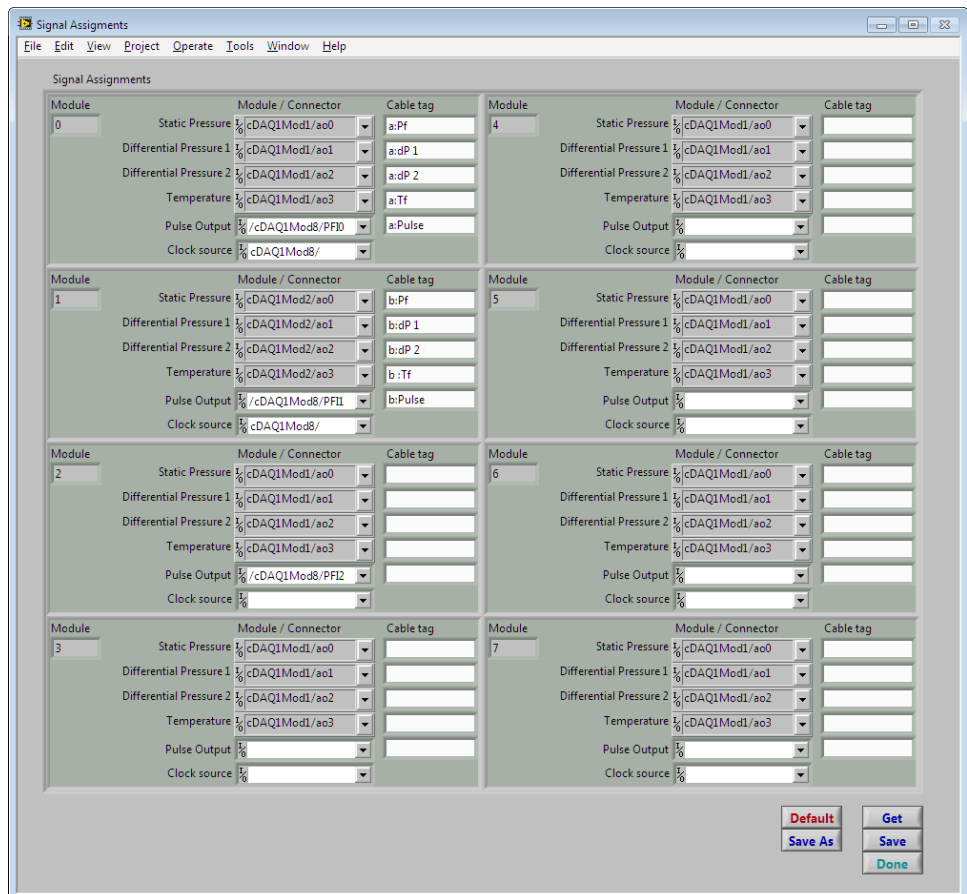


Figure 4 — Signal Assignments

In this example, we are using a National Instruments CompactDAQ USB chassis to generate signals. The eight output modules correspond to the eight flow runs that the EFM Test Bench can simulate.



For each transducer you wish to simulate, click on its pop-up menu to select an output channel on your hardware:

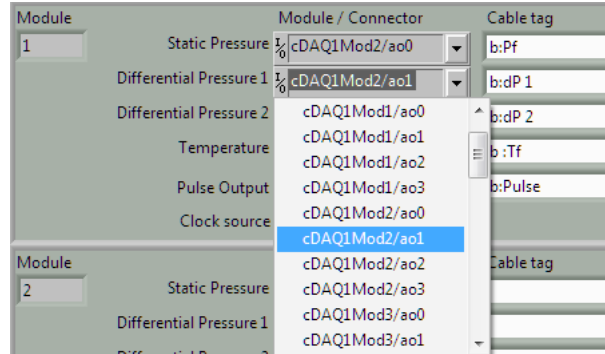


Figure 5 — Assigning a physical output to a signal

There is an open text field next to each hardware assignment, which is intended to record any tagging information on the physical wiring.

Frequency / Pulse outputs are assigned to output terminals in the same way, except that you also need to specify one of the timing clocks in your hardware.

## Wiring Harnesses

The system is designed to let you create re-usable wiring harnesses to connect to the flow computers under test.

The analog output reassignment pop-up menus let you send an analog signal to any physical terminal you wish. If you then configure the flow computer to read the transducer signal from the new terminal location, you can change the meaning of terminals on the flow computer without having to make wiring changes.

Once you've set up the wiring assignments, you can save them. Clicking "Default" loads a wiring assignment file called "Default.wiring". You can change the default settings by saving whatever you want as "Default.wiring".

We can supply pre-wired wiring harnesses for the National Instruments hardware options, or you can wire your own.

## Current loop wiring

In most cases, you will probably select hardware which can source 4..20 mA current loops, as this is the most common wiring method in use for analog transmitters.

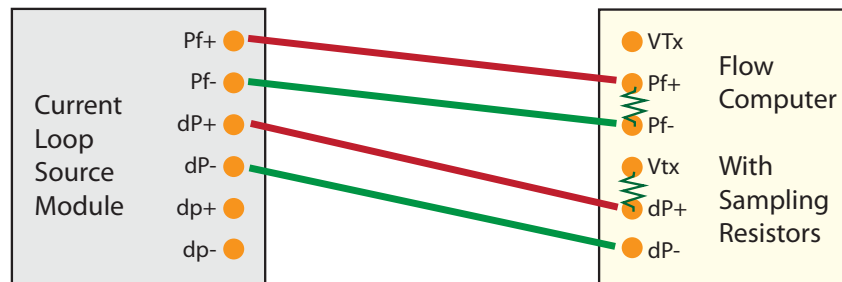


Figure 6 — Connecting a current loop source to differential inputs

Some older current loop cards can only sink current loops. In this case, the simulator card sinks the current loop to ground<sup>1</sup>:

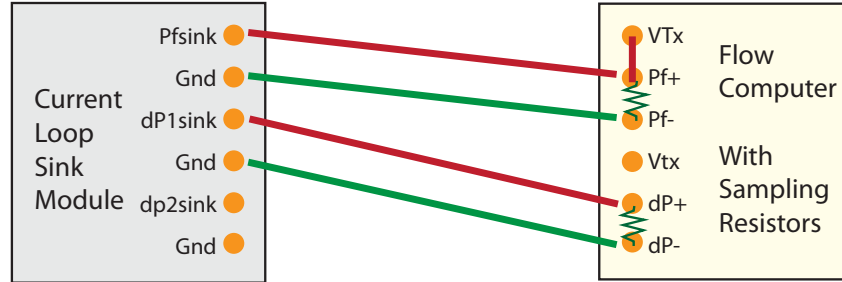


Figure 7 — Connecting a single-ended current loop sink to differential inputs

### Voltage signal wiring

You can also choose hardware that generates voltages. You will need to remove or switch out the 250Ω or 50Ω sampling resistors on the flow computer’s input line(s).

In general, the connections for voltage outputs look like this:

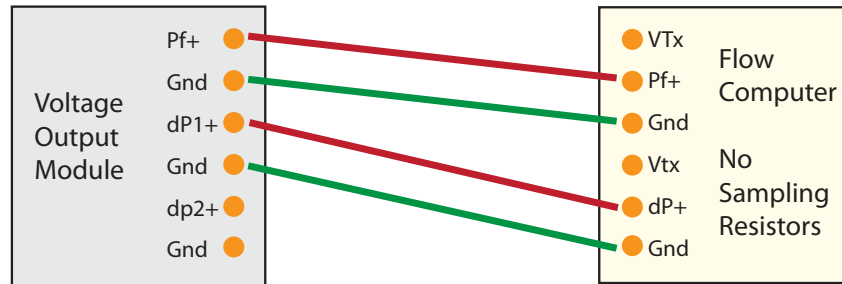


Figure 8 — Connecting a voltage source to single-ended inputs

Note: Don’t connect a flow computer VTx terminal to your test signal generation hardware, as it will likely be damaged as a result.

### Simulation Signals — Frequencies

As of this writing, the hardware for generating current loop sources generally does not have the ability to also generate pulse outputs. Some hardware can generate both voltages and frequencies, but usually only one or two frequencies. Since current loops are more common, we usually end up using a separate card or module to generate pulse signals (a typical module would generate 8 pulse outputs, which allows eight turbine-type runs to be simulated).

In most cases, the frequency signals we can generate will be single-ended TTL signals (they share a single analog ground).

### Simulation Signals — Temperature

Three and four wire RTDs are commonly used in flow measurement but are notoriously difficult to simulate accurately. As of this writing, the Pickering

<sup>1</sup> This wiring option has not been tested, and may be wrong (sink-only hardware is generally obsolete)!

Instruments modules shown in Appendix 1 seem to be a good choice for simulating them.

It's possible to wire in fixed resistances, but they often suffer from poor accuracy, and fail to test RTD measurements at more than one temperature. Decade boxes are sometimes used, but may not be switchable under program control.

Thermocouples are less commonly used in flow measurement applications than RTDs, but can be simulated fairly easily. The necessary linearization curve is handled in software.

---

## GC wiring

If you want to have your flow computers poll the simulated gas chromatograph, you will need to connect a serial cable to the EFM Test Bench. In most cases, you will probably want to create a multi-drop serial cable, so that more than one flow computer or flow module can poll the simulated gas chromatograph, in the same way that you would connect to a physical gas chromatograph.

Serial ports stopped being standard equipment on general purpose computers some time ago, but inexpensive USB to serial converters are readily available. Both RS-232 and RS-485 converters are available. We prefer the ones that use the FTDI chipset.

When you set up a test run, you can choose which stream number will be used for each flow run being tested.

---

## Network wiring

If you are using ADEPT (ScanCom) to interrogate the flow computers under test, you will also need a serial cable to connect them. Again, just as with actual field wiring, ADEPT is intended for use with a multi-drop serial cable, so you don't need to dedicate a serial port to each flow computer being tested. On the other hand, you can also just use a standard serial cable to connect to each flow computer. If you go this route, you specify the serial port names in the ADEPT setup page.

# Define Flow Runs

You can simulate up to eight flow runs, which can be any combination of orifice plates and turbine meters:

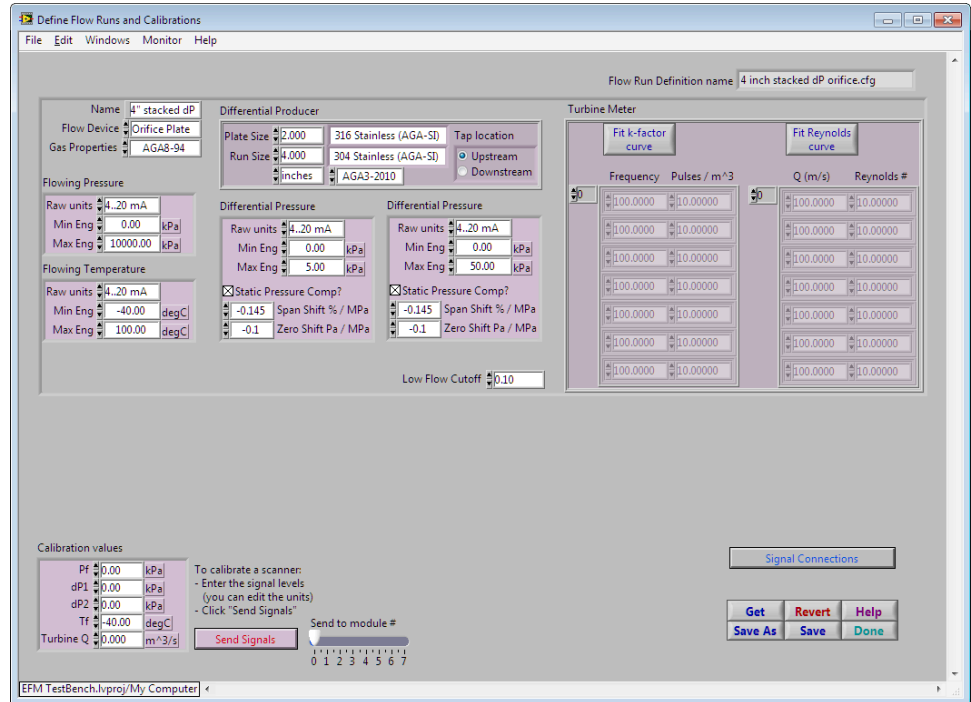
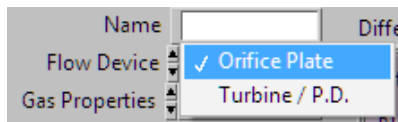


Figure 9 — Define a flow run

When you define a test, you will specify a run definition. Each run definition can be assigned to as many simulated flow runs as you like.

You start by specifying whether the flow device is a orifice plate / cone meter, or a turbine / positive-displacement meter):



You can give the run definition a meaningful name, and specify which gas property equation of state to use<sup>2</sup>.

<sup>2</sup> As of this writing, only AGA-8 (1994) is supported, although our intent is to support GERG-2004 in the future. We have removed support for AGA-8 (1985), as it is rarely used anymore.

You always need to specify the simulated transducer ranges for flowing pressure and temperature:

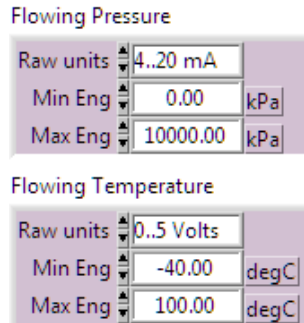
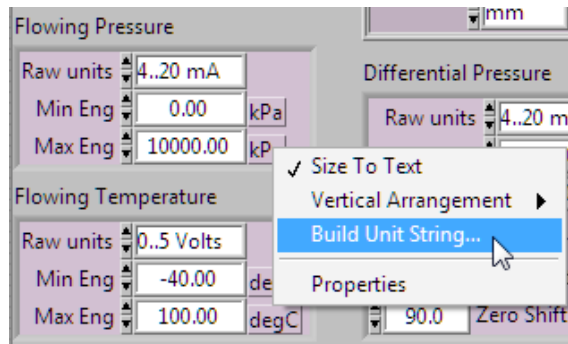


Figure 10 — Simulated transducers

You specify the full-scale calibration in your choice of engineering units. By default, SI units (kPa and degC) are displayed, but you can select from a wide variety of units of measure by right-clicking the unit label, and selecting “Build Unit String”:



... which lets you specify units of measure:

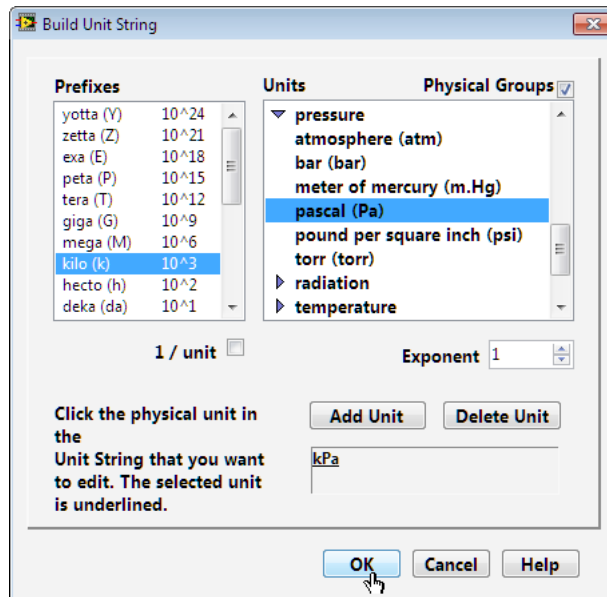


Figure 11 — Specify units of measure

You can also type a valid unit string directly into the unit box. Of course, you have to select a pressure unit of measure to display pressures, and a temperature unit of measure to display temperatures.

The raw units have to match the capabilities of your actual hardware, or you will get errors when you try to generate signals (for example, if you pick raw units of 4..20 mA, but your hardware can only generate voltages):

Raw units

---

## Differential Pressure

For flow runs that are measured using a differential pressure device (orifice plate, cone, etc.), you need to specify the usual things:

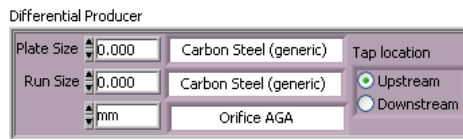


Figure 12 — Specifying a differential pressure measurement

A variety of differential pressure producers are supported:

- Orifice plate
- Orifice cone
- Venturi nozzle
- Pitot annubar

For each differential pressure flow run, you can simulate “stacked” transducers by giving the two simulated differential pressure transducers different ranges (for example, one might be 0..10 kPa, and the other might be 0..50 kPa). If you want to simulate triple-stacked transmitters, you’ll have to configure two otherwise identical flow runs, and put the third differential pressure in the second run specification. Going this route, you could even simulate a quadruple-stacked differential pressure if you wanted to.

This is where you specify the run and plate materials<sup>3</sup>, and which version of the AGA gas flow calculations to use. The tap location is the relative location of the static pressure measurement with respect to the differential pressure producer.

---

## Static Pressure Compensation

Many types of differential pressure transducers change their geometry slightly when they are subjected to operating line pressures (the sensing diaphragm is stretched). This causes two effects: the output per unit of differential pressure is reduced, and the zero point is shifted (in either direction). The effect is illustrated in this diagram, taken from Rosemount technical data sheet #3044:

---

<sup>3</sup> The reason that the material pop-up menus have more than one definition for 300 Stainless Steel goes back to a historical error in the AGA material property tables, which is included for compliance with the published AGA values.

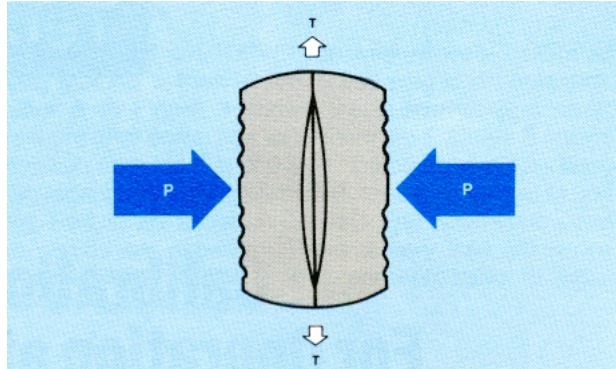


Figure 13 — How static pressure affects differential pressure measurement

These two effects are quite repeatable, and are usually compensated for by a flow computer. If you check the “Static Pressure Comp?” box, the effects of static pressure will be simulated:

Differential Pressure

Raw units	4.20 mA
Min Eng	0.00 kPa
Max Eng	50.00 kPa
<input checked="" type="checkbox"/> Static Pressure Comp?	
	-0.145 Span Shift % / MPa
	900.0 Zero Shift Pa / MPa

Figure 14 — Specifying static pressure effects

You need to specify the span shift as a percentage of the reading per thousand kPa. This information can be found in the manufacturer’s specifications (such as those for the Rosemount 1151DP transmitter):

Range Code	Span Shift % Input per 1000 PSI		
	316L SST	HASTELLOY	MONEL
3	-1.75%	-1.0%	-1.0%
4	-0.87%	-0.60%	-0.50%
5	0.81%	0.70%	0.75%

Figure 15 — Rosemount 1150DP static pressure compensation

You also need to specify a zero shift. This number is not normally published by the manufacturer — typical instructions for a differential transducer are simply to zero the transmitter at line pressure. The physical behavior of the transmitter however, is similar to the span shift, and is a function of the static pressure.

If you wish to reproduce the behavior of a specific transmitter, you will need to know the amount of zero shift at a known line pressure in that transmitter. From this you can easily obtain the shift per 1000 kPa.

If you simply wish to simulate the effect of a typical zero shift, you can enter any positive or negative number you choose into this box.

# Turbine Meters

Turbine meters are specified a little bit differently:

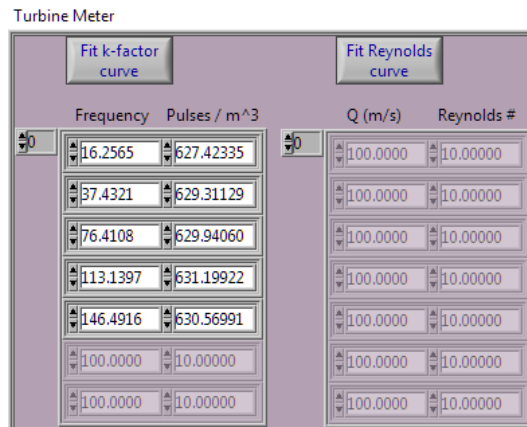


Figure 16 — Specifying k-factors and Reynolds number corrections

A turbine meter (and similar positive-displacement meters such as vortex meters) measures the actual gas flow at line conditions. The meter manufacturer specifies that a certain number of pulses will be generated for each cubic meter of gas that flows through the meter.

At different flow rates, this number may change slightly, so it is typical for the manufacturer to publish a table like this one:

<b>K-Frequency (Hz)</b>	<b>K-Factor (Pulses/m^3)</b>
16.2565	627.42335
37.4321	629.31129
76.4108	629.94060
113.1397	631.19922
146.4916	630.56991

Figure 17 — A typical k-factor table



You can enter this table into the space provided, and then click the “Fit” button. There is only room to display a few entries at a time, but you can scroll by changing the index entry at the upper left-hand corner of the table. You can also just click the “Fit” button to go to a screen that has room to view more table entries at once:

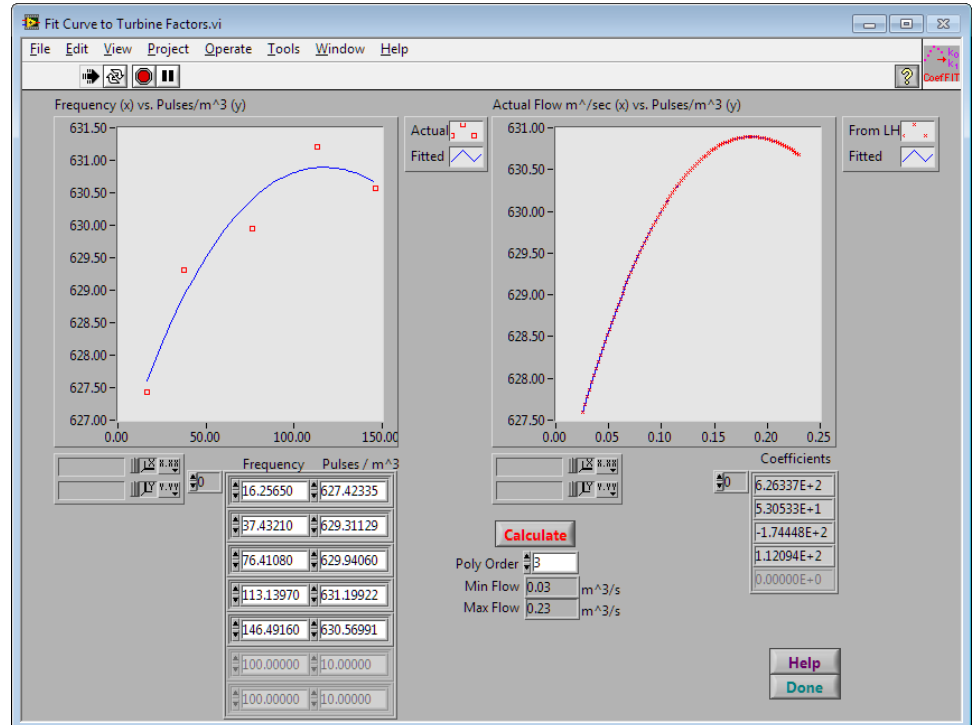
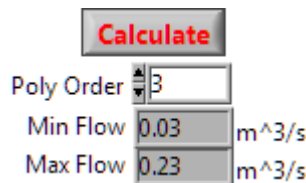


Figure 18 — Characterizing k-factors

This screen lets you fit a smooth polynomial to the turbine K-factor table supplied by a manufacturer. You specify the polynomial order you wish to use, and click the “Calculate” button:



The graph on the left-hand side of this screen lets you see both the points from the table, and a polynomial that has been fitted to them using the least-squares method.

If for some reason you only have a single k-factor, just enter it as the only entry in the k-factor table, and fit a 0<sup>th</sup> order polynomial to it. Otherwise, we suggest fitting either a second or third order polynomial to the table entries (higher order polynomials introduce unwanted inflection points if you extrapolate the table).

This screen has an important purpose for the flow run simulator. When the simulator is generating frequencies, it needs to calculate the k-factor in reverse: unlike a flow computer, which reads a frequency and pick the appropriate k-factor to use, the simulator needs to calculate the number of pulses per cubic meter to use

at a given flow rate. It does that by solving the equation for the curve shown on the right-hand side of the window.

If you plan to use the simulated turbine meter over a larger range than that the one provided by the manufacturer's table, you can specify the range of flows over which the curve on the right-hand side of the screen will be extrapolated:

Min Flow  m<sup>3</sup>/s  
 Max Flow  m<sup>3</sup>/s

Click "Done" to return to the run definition screen.

## Calibrating a flow computer

Once you've defined the characteristics of each of the transducers being simulated, you should go through the calibration sequence for the flow computers that you will be testing.

Go through the flow computer's calibration sequence in the normal way, using the user interface for each flow computer. You can simulate any line conditions you wish – at the points in the calibration process where you would normally inject a pressure, or drop on a weight, you just type the desired pressure into the Calibration values box:

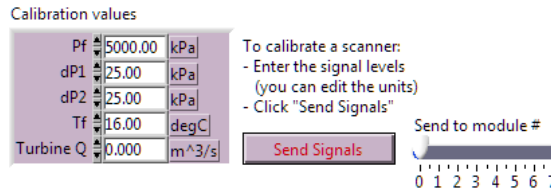


Figure 19 — Sending calibration signals

Click "Send Signals" to send the appropriate electrical signals from the module you specify (the physical terminal outputs are determined by your current wiring setup). While the "Send Signals" button is "depressed", the actual signal levels being sent are displayed:

Signal levels out (mV/mA)	
Pf	12.00
dP1	19.88
dP2	11.94
Tf	10.40
Turbine Q	0.000

This lets you use a voltmeter or ammeter to verify your connections. For your convenience, the connectors and tags of the output module are also displayed.

If you checked "Static Pressure Compensation?", the differential pressure signals will be compensated for the static pressure you specified.

This calibration step is the most time consuming part of a test, but it effectively tests the flow computer's ability to compensate for static pressure effects (differential pressure meters) or meter factors (pulse producers).

# Gas Compositions

You can either enter gas compositions directly, or import them from a spreadsheet. The gas components can be entered as either Mole Fractions or Mole Percentages:

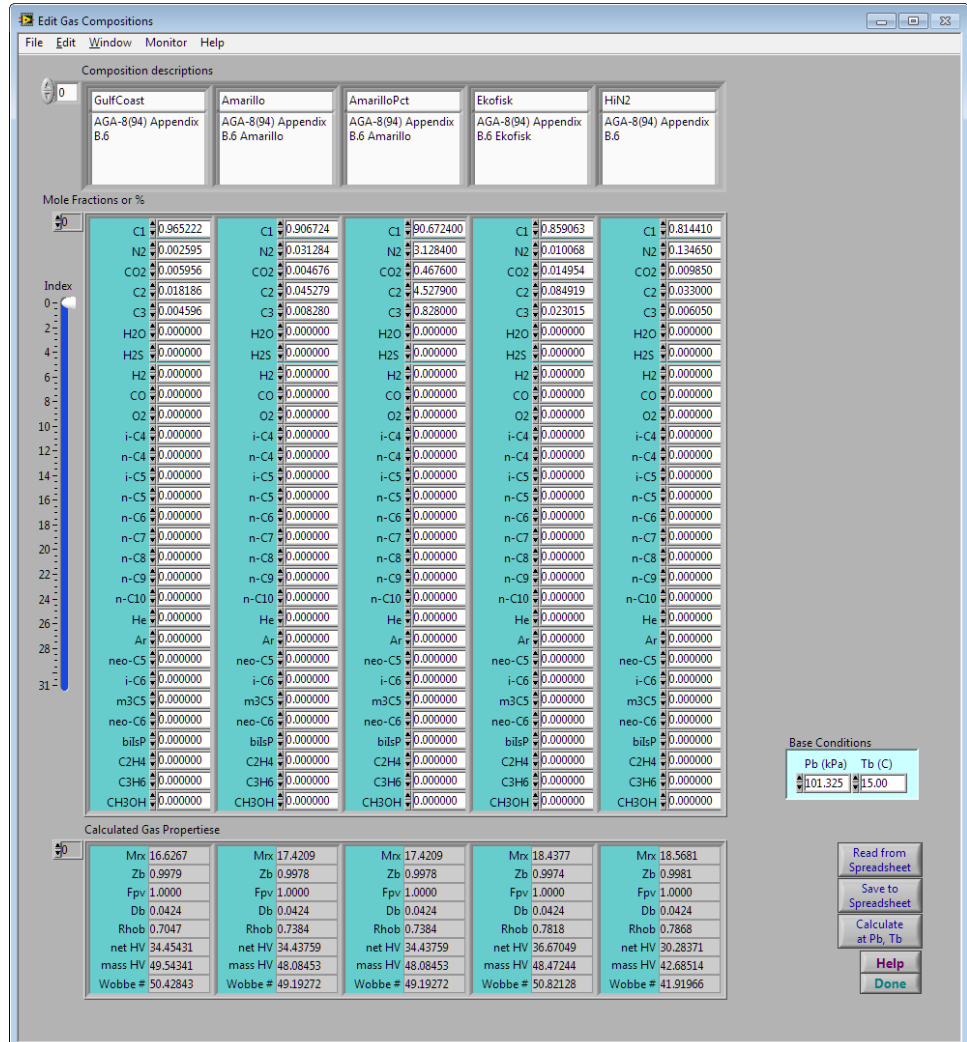
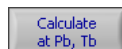


Figure 20 — Gas Composition table

The index scroll bar lets you quickly scroll through as many gas compositions as you have. You can give each gas composition a name and description.

Each test will cycle through the gas compositions at a rate you specify when you create the test.

Click “Calculate @ Pb,Tb” when you’ve entered the gas compositions, or if you want to see if a composition is allowable:



The gas properties are calculated at the base conditions you specify:

Base Conditions

Pb (kPa)	Tb (C)
101.325	15.00

The base gas properties are calculated using the 1994 version of AGA-8 equations for density and compressibility, and the 2009 version of the AGA-5 heating value equations:

Gas Properties at Pb, Tb

Mrx	0.0000
Zb	0.0000
Fpv	0.0000
Db	0.0000
Rhob	0.0000
net HV	0.56174
mass HV	0.56174
Wobbe #	33.63486

A dialog box will appear if any problems are encountered in the AGA calculations. To see which gas composition they relate to, look at the status message:

Calculating gas constants for gas composition at index = 0

The gas properties are also calculated when you click “Done”.

## Importing a Gas Composition

It’s often convenient to create a table of gas compositions in a spreadsheet, and import them into the EFM Test Bench

To do this, create a spreadsheet in which each row is a new gas composition, and each column is a gas component. The first row should contain the component names. The columns can be in any order:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Name	Description	C1	N2	CO2	C2	C3	H2O	H2S	H2	CO	O2	iC4	nC4
2	GulfCoast	AGA-8(94) Appendix B.6	0.965222	0.002595	0.005956	0.018186	0.004596	0	0	0	0	0	0.000977	0.001007
3	Amarillo	AGA-8(94) Appendix B.6 Amarillo	0.906724	0.031284	0.004676	0.045279	0.00828	0	0	0	0	0	0.001037	0.001563
4	AmarilloPct	AGA-8(94) Appendix B.6 Amarillo	90.6724	3.1284	0.4676	4.5279	0.828	0	0	0	0	0	0.1037	0.1563
5	Ekofisk	AGA-8(94) Appendix B.6 Ekofisk	0.859063	0.010068	0.014954	0.084919	0.023015	0	0	0	0	0	0.003486	0.003506
6	HIN2	AGA-8(94) Appendix B.6	0.81441	0.13465	0.00985	0.033	0.00605	0	0	0	0	0	0.001	0.00104
7	HICO2	AGA-8(94) Appendix B.6 High CO2-N2	0.81212	0.05702	0.07585	0.04303	0.00895	0	0	0	0	0	0.00151	0.00152
8	Comp21	AGA-10(2003) page 23	0.8629	0.02	0.005	0.05	0.03	0.0001	0.001	0.0001	0.0001	0.0002	0.011	0.009
9	Comp18	Comp21 modified for use with Gerg-2004	0.8642	0.02	0.005	0.05	0.03	0.0001	0	0.0001	0.0001	0.0002	0.011	0.009

Figure 21 — a gas composition spreadsheet

It doesn't matter how many decimal places you use. You can have columns that aren't gas compositions, if you want. You don't have to include all of the columns. Save the spreadsheet as a comma-delimited text file.

To import the text file, click “Read from Spreadsheet”:



A new panel appears, and you'll be asked to select the text file, using a standard file dialog. In the new panel, you'll see a list of AGA's 29 possible gas components on the screen. Beside each gas component is a pop-up menu that lets you assign any of the column headers in your spreadsheet to a gas component:

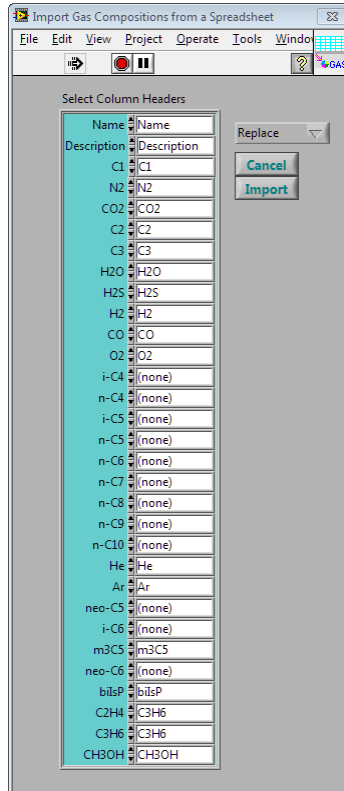


Figure 22 — Importing gas compositions from a spreadsheet

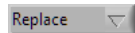
If you used the standard gas component names below, the pop-up menus will be positioned automatically. If you didn't use the standard names, you simply select the column header you used for each gas component from the pop-up menus.

Here are the standard gas component names (they are not case-sensitive):

Name  
Description  
C1  
N2  
CO2  
C2  
C3  
H2O  
H2S  
H2  
CO  
O2  
iC4  
nC4  
iC5  
nC5  
nC6  
nC7

nC8  
nC9  
nC10  
He  
Ar  
neoC5  
iC6  
m3C5  
neoC6  
biIsP  
C2H4  
C3H6  
CH3OH

You can either add new gas compositions to the ones you already have, or else replace your current list:



Click “Import” to add the new gas compositions, or “Cancel” if you change your mind.

You can also save to a spreadsheet file with the same format:



# Simulating a Gas Chromatograph

You can simulate a Modbus Gas Chromatograph, using any register map of your choice<sup>4</sup>. You can assign as many serial ports as you wish to the gas chromatograph. Each flow computer and flow run under test can be assigned its own stream number.

This screen lets you define register maps, and save them for future use:

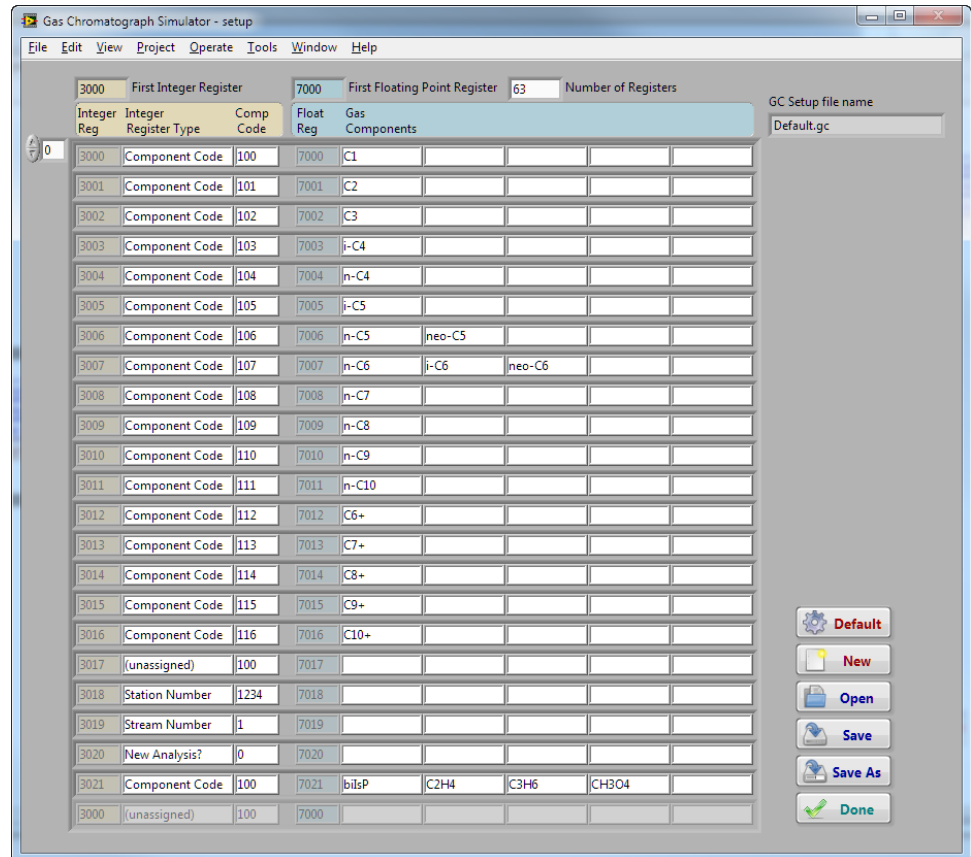


Figure 23 — A Gas Chromatograph register map

You start by specifying the first integer register, the first floating point register, and the size of the register range:

7000 First Floating Point Register

3000 First Integer Register

63 Number of Registers

The registers are arranged in pairs, since it's common (but not necessary) to have an integer component code paired with a floating-point value.

<sup>4</sup> At least, we don't know of any gas chromatograph register map that the simulator can't emulate.

So, in the screen example above, integer register 3000 returns the value 100, which is the component code for Methane (C1). The paired floating-point register 7000 returns the mole percentage of C1.

With a real gas chromatograph, you generally can't return separate values for all 29 AGA gas molecules, so it's common to group some of the higher molecular weights together.

The simulated gas chromatograph is more flexible than a real gas chromatograph, since it isn't constrained by the physical gas properties. So, in the example screen, we've defined registers for more than one grouping of the higher molecular weights, which a real GC generally can't do.

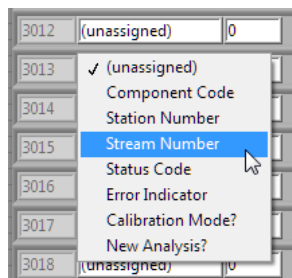
You can group up to five gas molecules for each floating-point register. The mole percentage of each of the components you specify are added together, and their sum is the value of the floating-point registers.

C6+ includes iso and neo molecules with as least the molar mass of C6

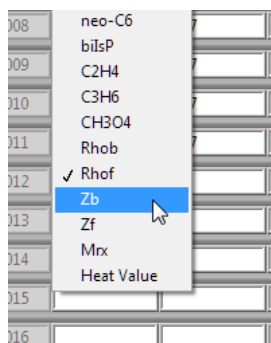
C7+ is the same, but excludes all of the C6 molecules

C8+, C9+, and C10+ are similarly defined.

Some of the registers are not paired, such as the integer registers for station number, stream number, and new analysis. You select the register definition from the pop-up menu for each integer register:



Similarly, you can assign other floating-point values, such as density or heating value to a floating-point register:

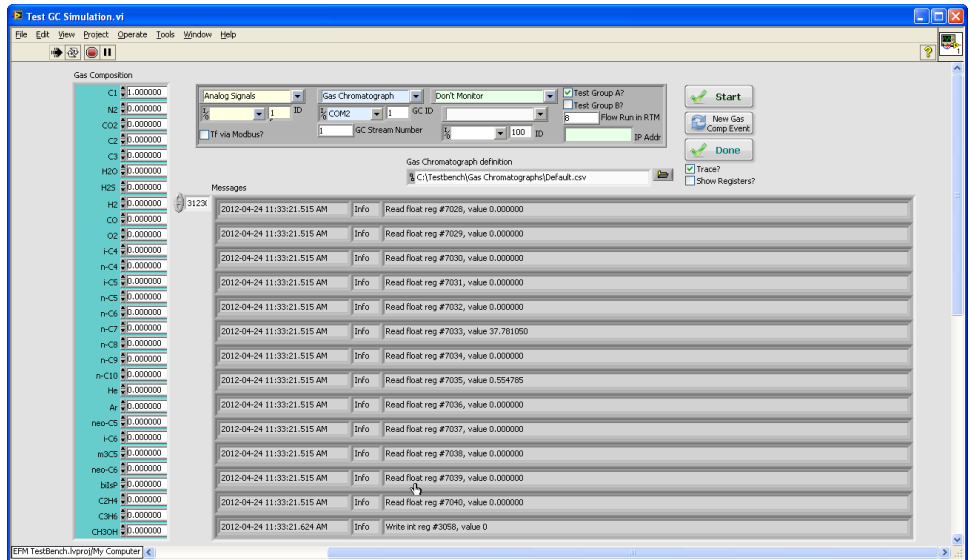


You can save any number of virtual gas chromatograph register maps, although only one can be used during a given test.

The simulated gas chromatograph is defined to have 8 streams: one for each potential flow run simulation. They are streams 1 through 8, and are specified when you start a test run.



You can test the communications between a flow computer and the GC simulator:



# Defining Test Signals

The test signals are intended to simulate line conditions. You can easily simulate line conditions such as pulsation and low flow, as each set of test signals is just a line in a spreadsheet. There is a column for each transducer you wish to simulate.

You can simulate any values you want for flowing temperature and pressure. For differential producers, you also simulate differential pressure. For pulse meters, you simulate the actual flow rate at line conditions.

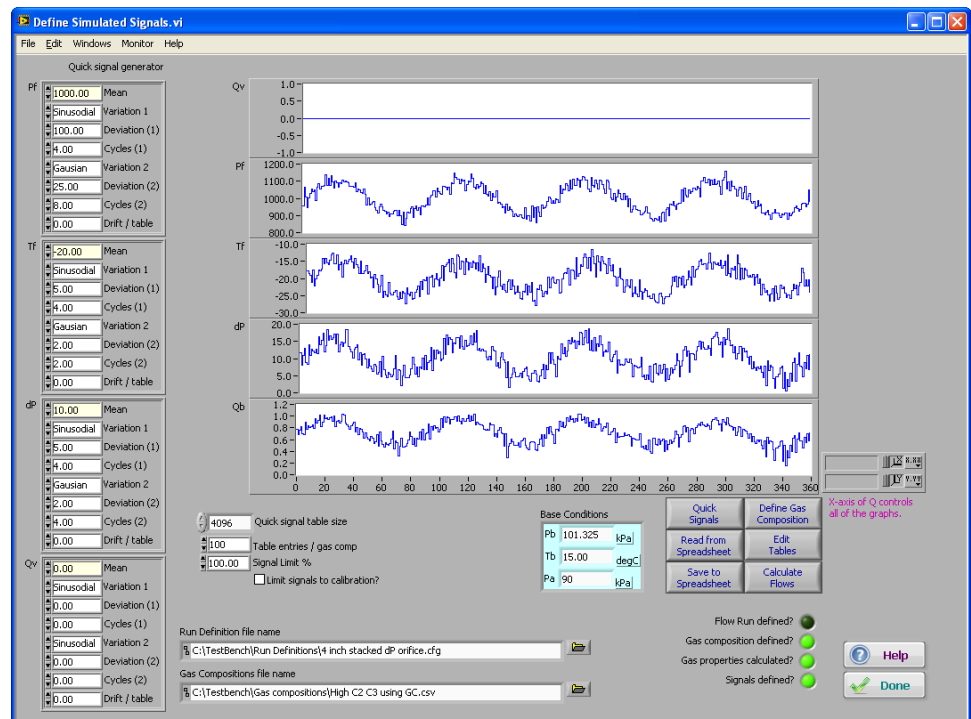


Figure 24 — Quick generation of test signals

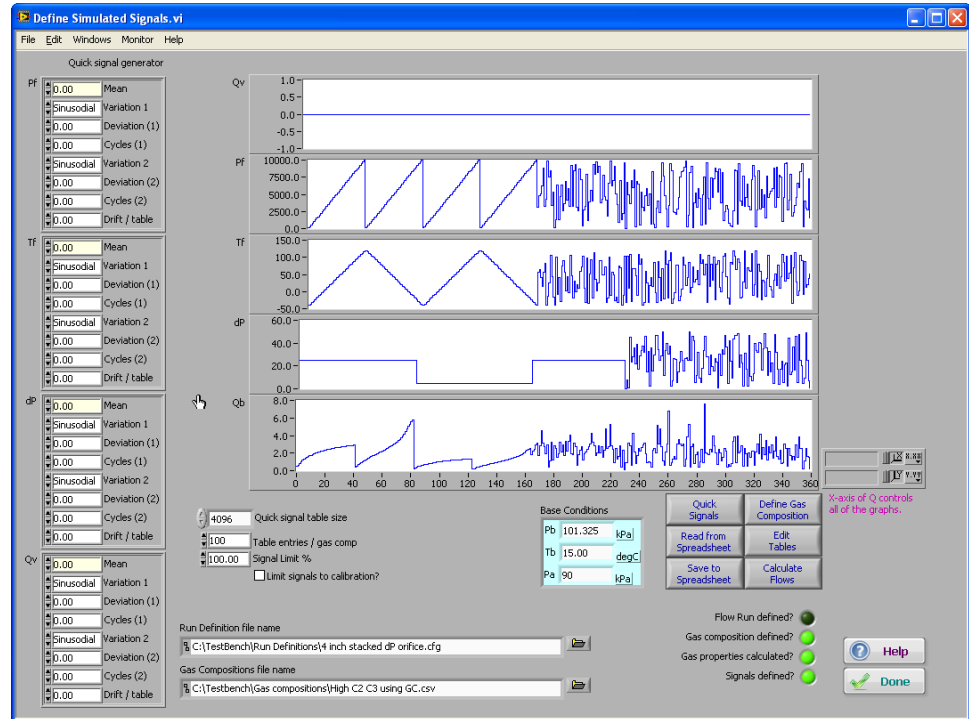


Figure 25 – Signals generated in a spreadsheet

During a test, the values in each table are used, one line at a time, at the rate you specify, until the end of the table is reached. The table is reused as many times as necessary. To prevent a discontinuity between the last value in a table and the first value, you can check “Mirror Tables”:

Mirror Tables?

If this box is checked, the table is traversed forwards to the end, and then backwards to the beginning.

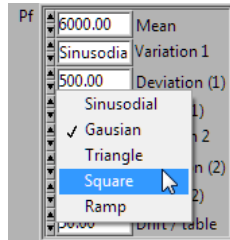
## Quick Signals

If you want to quickly generate test signals without using a spreadsheet, the quick signal generator lets you create the same kinds of signals that an analog signal generator produces.

For each test signal, you specify a mean value, and up to two variation signals that will be added to the mean:

dP	7.75	Mean
	Gaussian	Variation 1
	0.74	Deviation (1)
	0.00	Cycles (1)
	Square	Variation 2
	0.03	Deviation (2)
	12.00	Cycles (2)
	0.00	Drift / table

The following variations are available:



- Sinusoidal  
The positive amplitude of the sine wave is the “Deviation”, and the number of full sine waves in the table is “Cycles”.
- Gaussian  
“Deviation” is one standard deviation. “Cycles” is not used.
- Square  
The positive amplitude is “Deviation”, and the number of square wave patterns is “Cycles”.
- Triangle  
“Deviation” is the maximum variation, and “Cycles” is the number of triangle patterns.
- Ramp  
The signal ramps linearly until it reaches “Deviation” at the end of the table. “Cycles” is not used.
- Drift/table  
You can cause a very gradual ramp in the simulation values by specifying a “Drift” which causes every value in the table to be incremented by the drift value each time the table is repeated.  
For example, if you specify a drift value of 1.5 to the Pf signal, the table will be used as you see it on this screen the first time it is used. When the simulation reaches the end of the table (or when it returns to the beginning of the table if you turned mirroring on), a value of 1.5 kPa is added to every value in the table, and then the table is traversed again. At the end, another 1.5 kPa is added.<sup>5</sup>

Note: in all cases, the maximum signal you can actually generate during a test will be the maximum engineering value you specified in the Calibration screen.

Click “Quick Signals” to generate the signal value tables:



The graphs will be updated to show the new table contents.

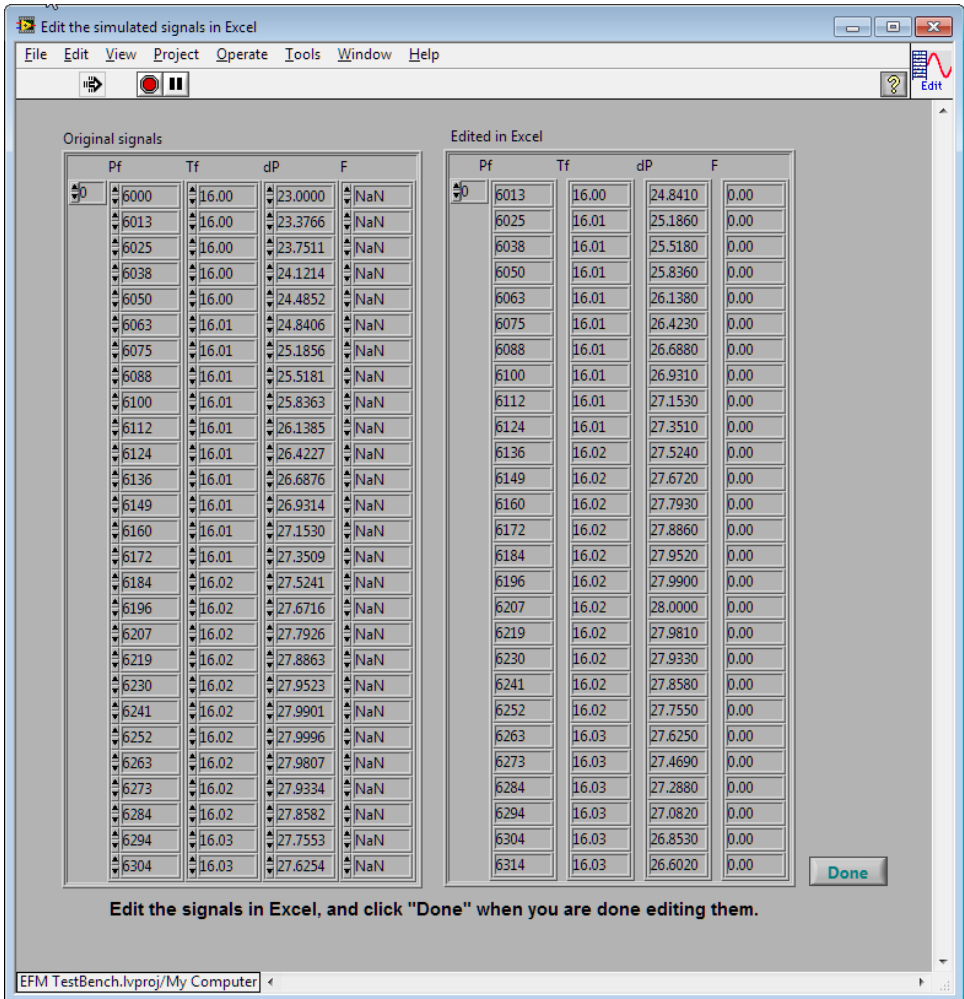
You can manually edit the signal tables if you wish:

---

<sup>5</sup> This feature is currently disabled, because it’s not quite complete.

Edit  
Tables

A screen appears in which you can edit any of the signal values:



At the same time, Excel is launched, so that you can edit the signal values in Excel:

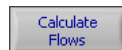
	A	B	C	D
1	Pf	Tf	dP	Qf
2	6000	16	23	NaN
3	6012.565	16.001	23.377	NaN
4	6025.122	16.002	23.751	NaN
5	6037.663	16.003	24.121	NaN
6	6050.181	16.004	24.485	NaN
7	6062.667	16.005	24.841	NaN
8	6075.113	16.006	25.186	NaN
9	6087.512	16.007	25.518	NaN
10	6099.855	16.008	25.836	NaN
11	6112.135	16.009	26.138	NaN
12	6124.345	16.01	26.423	NaN
13	6136.476	16.011	26.688	NaN
14	6148.521	16.012	26.931	NaN
15	6160.472	16.013	27.153	NaN
16	6172.321	16.014	27.351	NaN
17	6184.062	16.015	27.524	NaN
18	6195.687	16.016	27.672	NaN
19	6207.188	16.017	27.793	NaN
20	6218.558	16.018	27.886	NaN
21	6229.79	16.019	27.952	NaN
22	6240.877	16.02	27.99	NaN
23	6251.812	16.021	28	NaN

Figure 26 — Editing signals in Excel

Click “Done” to return to the Define Signals screen.

## Calculating Flows

When you’ve defined the transducer signals, you can calculate the flow values (the flow computer’s calculations will be compared with these reference values):



You need to specify the base conditions used to convert flow to standard flow (ie: flow at base conditions), as well as the ambient pressure (used to convert static pressure gauge to absolute pressure):

Base Conditions

Pb (kPa)	Tb (C)
101.325	15.00

Ambient Conditions

Pa (kPa)
90.000

It can take a few seconds to calculate the flows. A progress indicator lets you know how far along you are:

Calculating Flow for Run 1,  
table entry 37

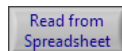
## Reading from a Spreadsheet

You can also create a set of test signals in a spreadsheet, using the same method as for gas compositions. To do this, create a spreadsheet in which each row is a new set of signal values, and each column is for one signal. The first row should contain the signal names. The columns can be in any order:

	A	B	C	D
1	Pf	Tf	dP	Qf
2	6000	16	23	NaN
3	6012.565	16.001	23.377	NaN
4	6025.122	16.002	23.751	NaN
5	6037.663	16.003	24.121	NaN
6	6050.181	16.004	24.485	NaN
7	6062.667	16.005	24.841	NaN
8	6075.113	16.006	25.186	NaN
9	6087.512	16.007	25.518	NaN
10	6099.855	16.008	25.836	NaN
11	6112.135	16.009	26.138	NaN
12	6124.345	16.01	26.423	NaN
13	6136.476	16.011	26.688	NaN
14	6148.521	16.012	26.931	NaN
15	6160.472	16.013	27.153	NaN
16	6172.321	16.014	27.351	NaN
17	6184.062	16.015	27.524	NaN
18	6195.687	16.016	27.672	NaN
19	6207.188	16.017	27.793	NaN
20	6218.558	16.018	27.886	NaN
21	6229.79	16.019	27.952	NaN
22	6240.877	16.02	27.99	NaN
23	6251.812	16.021	28	NaN

It doesn't matter how many decimal places you use. You can have extra columns if you want, and you don't have to include all of the columns. Save the spreadsheet as a tab-delimited text file.

To import the text file, click “Read from Spreadsheet”:



A new panel appears, and you'll be asked to select the text file, using a standard file dialog. In the new panel, you'll see a list of the signals for both flow runs on the screen. Beside each gas component is a pop-up menu which lets you select any of the column headers in your spreadsheet:

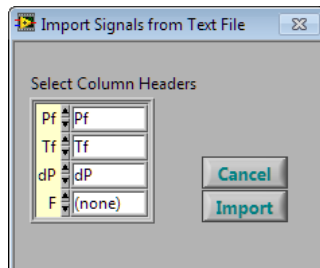


Figure 27 — Importing test signals

If you used standard signal names, the pop-up menus will be positioned automatically. If you didn't use the standard names, you simply select the column header you used for each signal from the pop-up menu.

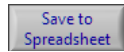
Here are the standard signal names (they are not case-sensitive):

- Pf    Static pressure
- Tf    Temperature
- dP    Differential pressure

Qf Flow rate at line conditions, for turbine meters

Click “Import” to get the signal tables, or “Cancel” if you change your mind.

You can also save the current signal tables as a comma-delimited spreadsheet file (the calculated flows are also saved):





# Using ADEPT

If the flow computer you are testing supports the ADEPT (ScanCom) protocol, the EFM Test Bench can access many of the flow computer's configuration and status values.

To use it, you need to connect a serial port on the flow computer to the EFM Test Bench. You can use any unused communication port on the EFM Test Bench.

When you click "ADEPT setup" on the main menu, the ADEPT configuration screen appears:

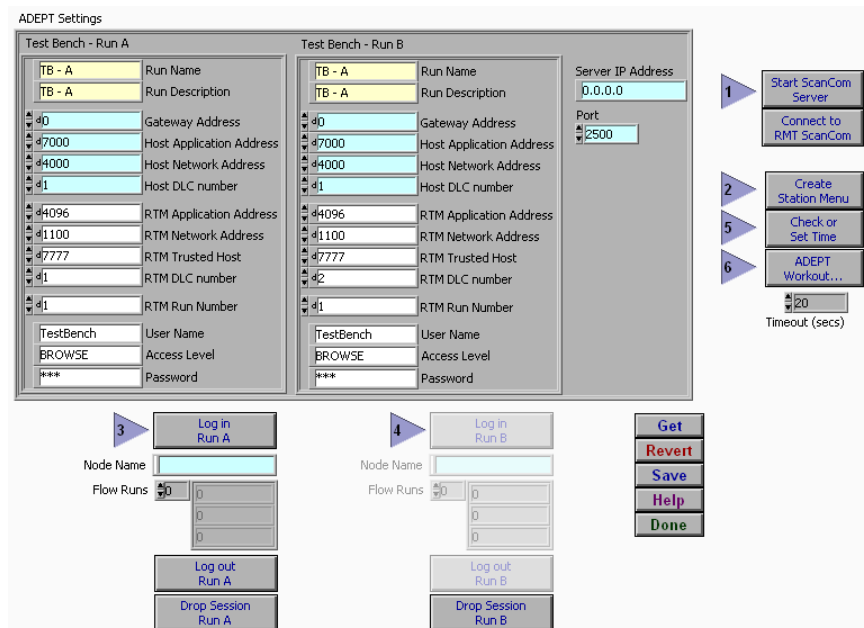


Figure 28 — The ADEPT setup screen

You specify the ADEPT addresses for each flow computer, and the access level you want. If you are using ADEPT to send new gas compositions to the flow computer, you'll need to select an access level which gives you permission to write gas compositions.

Here are the steps you should follow to start the ADEPT process:

1. Start the ADEPT server
2. Log into the flow computers  
After you log in, the name of the station will be shown, along with a list of the configured flow runs.

When you start a test, you will tell the EFM Test Bench what to use ADEPT for:

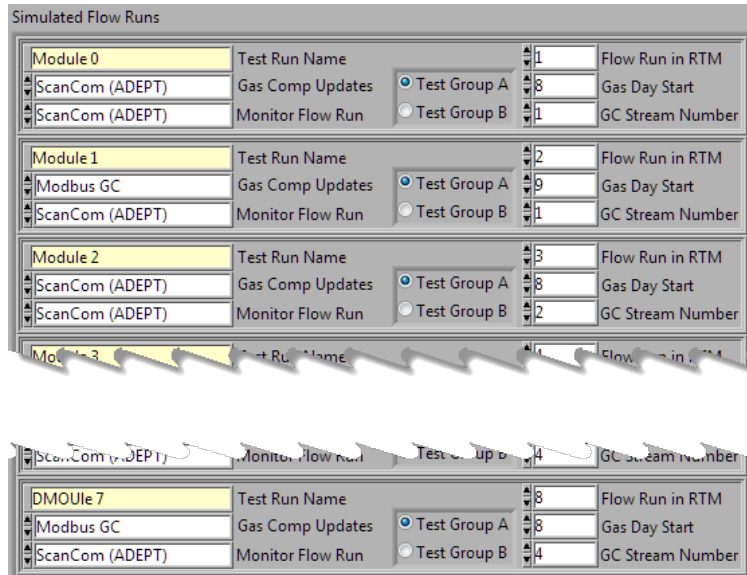


Figure 29 — Telling EFM Test Bench what to use ADEPT for

You can monitor the flow runs using ADEPT, and/or use ADEPT to send gas composition updates.

You need to correlate the flow computer runs with the flow run simulator's run numbers, as shown in the illustration.

You can also compare the time on the PC running the EFM Test Bench software, and the time on the Barton/NuFlow/Cameron flow computer:



If you wish, you can set the flow computer's clock to match the PC's clock. You should be aware that there may be undesirable side-effects of changing the clock in the flow computer<sup>6</sup>.

<sup>6</sup> If the clock changes causes the time to go back to a previous hour, the current hour will be closed, and a new (older) hour record will be started. Commands which reference a range of time may be confused as a result.

# ADEPT (ScanCom) testing

You can exercise the ADEPT protocol implementation on a flow computer:

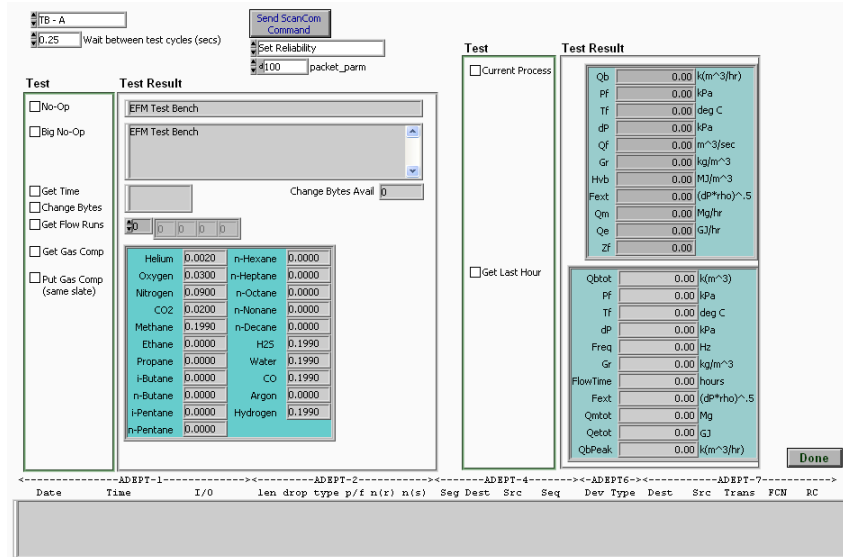


Figure 30 — The ADEPT workout

The selected (checked) ScanCom operations are performed repeatedly.

You can see the ScanCom traffic in the monitor window. Each packet shows the information at each of the OSI layers in the ADEPT protocol.

The testing is non-destructive. If you choose to write gas compositions, the existing gas composition will be read, and then written. Only 21 gas components are read or written, as the current ScanCom specification only provides for 21 components (during a test run, the extended AGA-5 gas slate components are mapped to the 21-component AGA-8 gas slate).

# Using Modbus

If you will be using Modbus to update gas compositions, or to monitor a test, you will need to specify a register map. These are defined in spreadsheet files:

	A	B	C	D	E	F
1	Version	1				
2						
3	Register	Name	Unit	Data Type	Bytes	Regs
4	1	C1	%	FLOAT	4	2
5	3	N2	%	FLOAT	4	2
6	5	CO2	%	FLOAT	4	2
7	7	C2	%	FLOAT	4	2
8	9	C3	%	FLOAT	4	2
9	11	H2O	%	FLOAT	4	2
10	13	H2S	%	FLOAT	4	2
11	15	H2CO	%	FLOAT	4	2
12	17	O2iC4	%	FLOAT	4	2
13	19	nC4	%	FLOAT	4	2
14	21	iC4	%	FLOAT	4	2
15	23	nC5	%	FLOAT	4	2
16	25	nC6	%	FLOAT	4	2
17	27	nC7	%	FLOAT	4	2
18	29	nC8	%	FLOAT	4	2
19	31	nC9	%	FLOAT	4	2
20	33	cC10	%	FLOAT	4	2
21	35	He	%	FLOAT	4	2
22	37	Ar	%	FLOAT	4	2
23	39	neoC5	%	FLOAT	4	2
24	41	iC6	%	FLOAT	4	2
25	43	m3C6	%	FLOAT	4	2
26	45	bilsP	%	FLOAT	4	2
27	47	C2H4	%	FLOAT	4	2
28	49	C3H6	%	FLOAT	4	2
29	51	CH3OH	%	FLOAT	4	2

Figure 31 — Defining a Modbus register map

In this example, the gas slate registers are shown. For each of the items used by the EFM Test Bench, you specify the starting register number, data type, and the number of contiguous registers required to hold the data type.

Every Modbus device you use needs to have a register map, which you specify when you start a test. You can mix register maps in the group of flow computers running a test series. To create a new register map, edit the template *Modbus Registers.xslt*, located in the template directory, and save the register map in .csv format into the same directory.

# Create a Test

The EFM Test Bench is designed to let you create a library of standardized tests. Each test is a combination of:

- A run definition
- A set of gas compositions
- A set of signals
- Test conditions
- Error tolerances

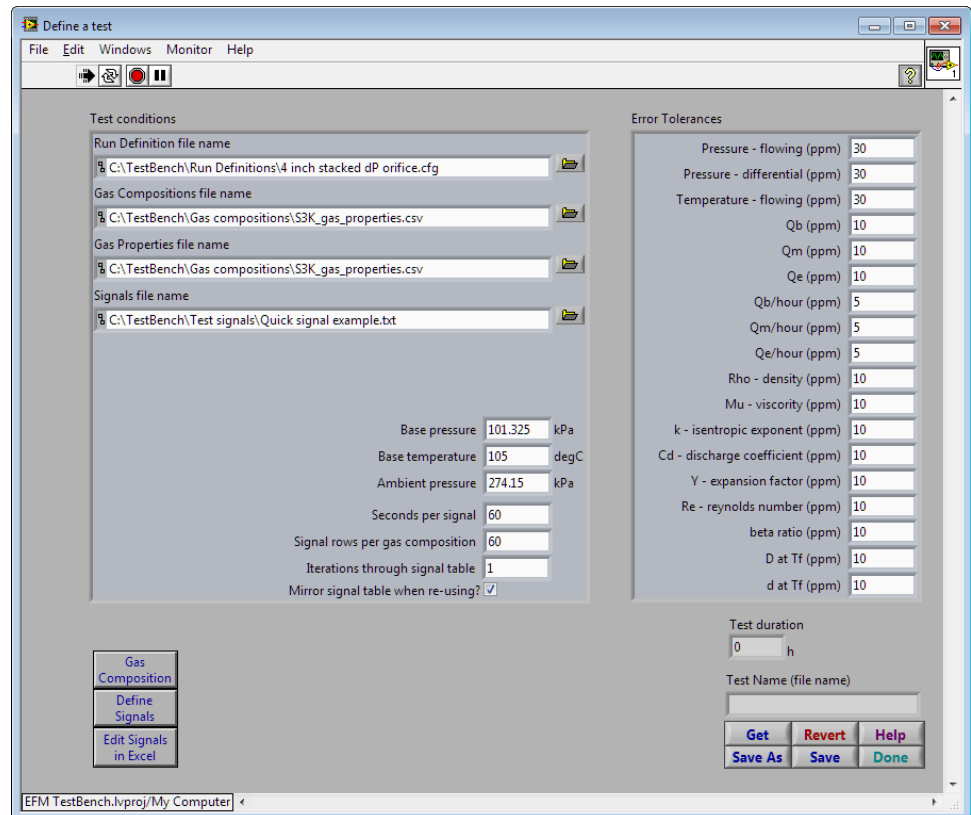


Figure 32 — Defining a reusable test

Optionally, you can also specify a GPA 2145 molecular properties file.

As you use the EFM Test Bench, you should gradually build up a comprehensive library of standardized tests. The software ships with some standard tests, such as the AGA standard tests, and tests to monitor API chapter 21 compliance.

The more work you put into creating good tests, the more you should get out of the EFM Test Bench.

# Starting a Test Run

The EFM Test Bench is designed to make it easy to run sets of tests. Once you have defined a library of tests, you can quickly recall a set of tests, and schedule them for execution:

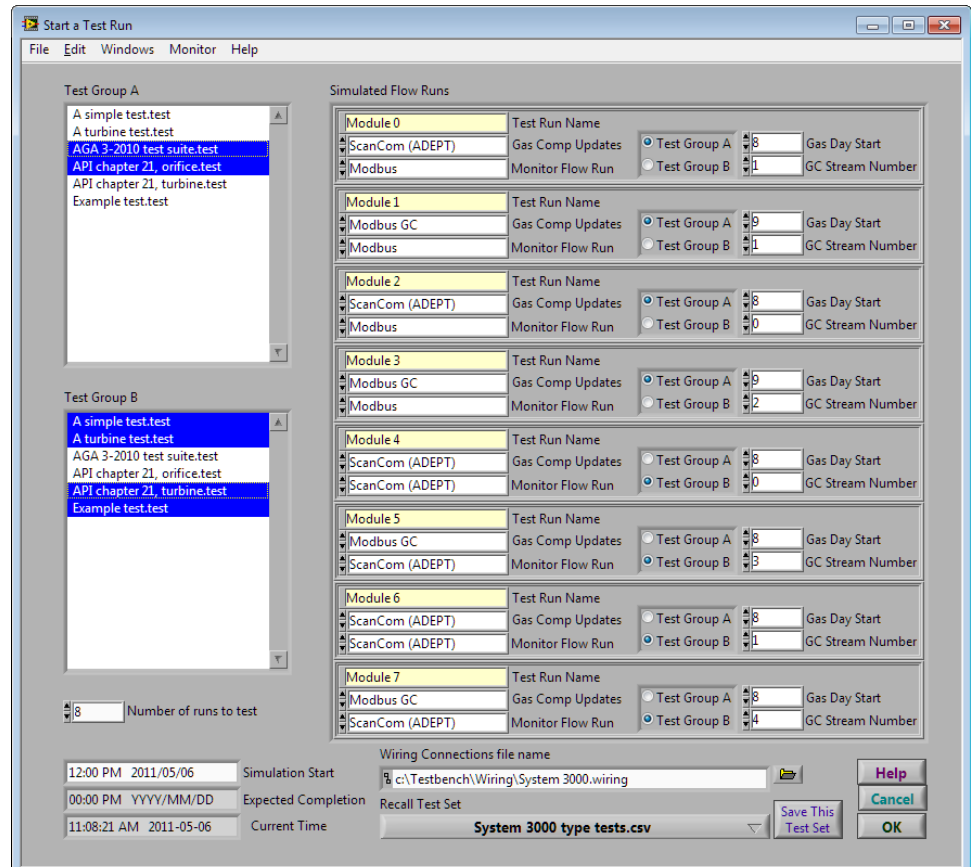
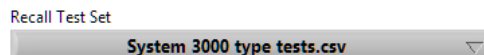


Figure 33 — Starting a test run

Although there is a fair bit on this screen, you can recall a set of saved values by selecting it from the pop-up menu at the bottom of the window:



Click “OK” to schedule the test series for execution. The test will begin just before the start of the next hour.

---

## Test Groups

It’s not necessary to have all of the possible 8 flow runs run the same tests. You can have two groups of tests, and each of the modules under test can be assigned to either of the test groups.

---

## By Module

For each of the flow runs being simulated, you need to tell the EFM Test Bench how to handle gas composition updates, and how to monitor the flow device.

For gas composition updates, the choices are:

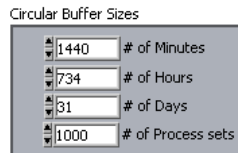
- Ignore gas compositions, and just use what is already on the flow computer
- Send gas compositions via ScanCom or Modbus
- Emulate a Gas Chromatograph, which the flow device will poll (in which case you also need to specify which gas stream will be polled)

---

## Buffers

While a simulation is running, it will log values to several text files. It will also keep a certain amount of information in main memory, to let you view the results of the test as it progresses

This information is kept in circular buffers. In the *Preferences* step, you decided how many entries the buffer should hold. When more values are generated than the buffer can hold, the oldest entries are replaced by new entries (but the log files contain everything):



# Monitoring a Test

After you start a set of tests, the Test Runner shows which tests are scheduled for execution, and their pass/fail status:

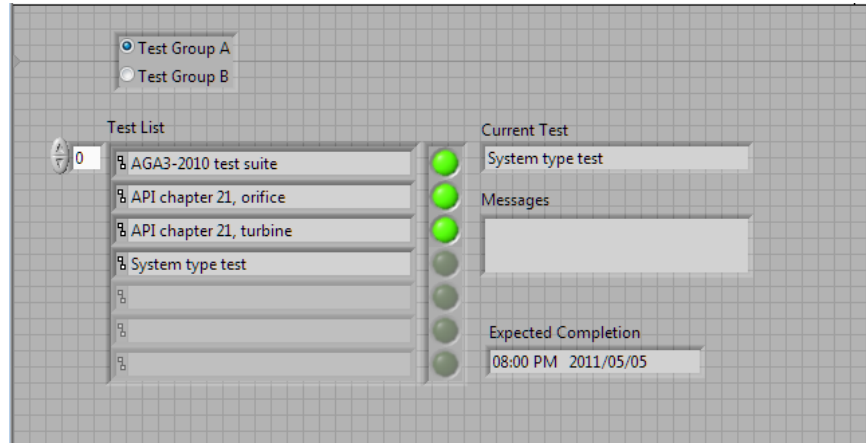


Figure 34 — The test runner window

While each test is running, you can monitor the process variables, and compare the results calculated by the flow computer with the expected values:

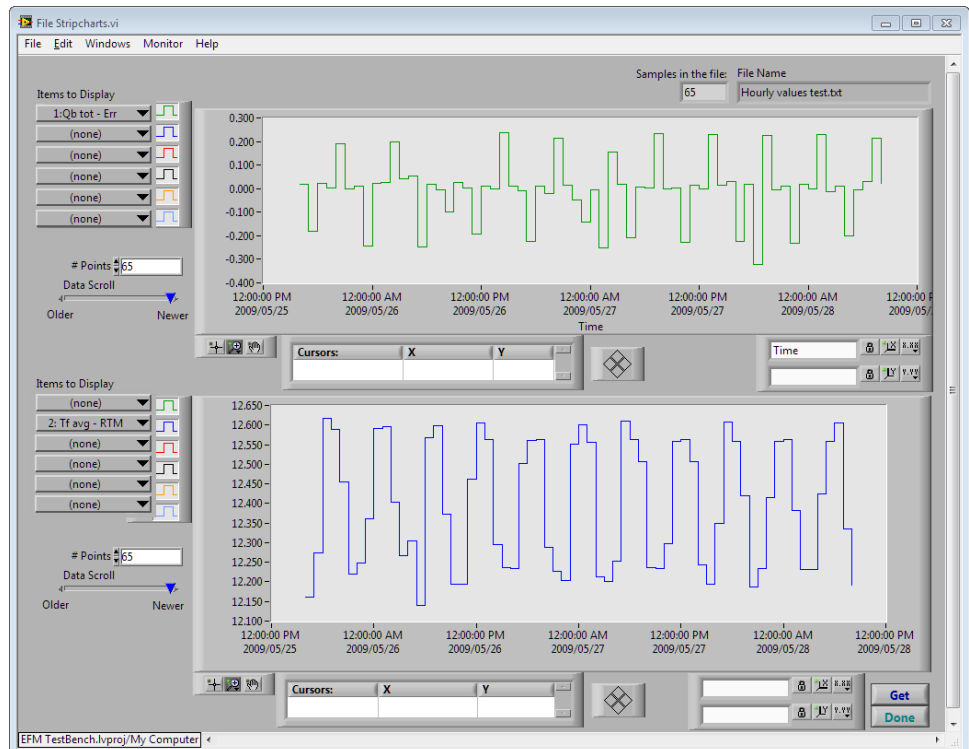


Figure 35 — Strip charts



Both the upper and lower strip charts let you add up to half a dozen traces, each of which can be any process or calculated variable. In the example above, the percentage of error is being graphed for a variety of variables.

# Reports

When each test completes, it will generate a test report for each flow run under test. A summary report shows each module under test:

## EFM Test Bench Test Report

Test start date: 2010-10-13

Test duration: 54 hours

Scanner serial: 123456 4 modules

Module serial: 1234567	Run: 1-P	AGA-8 (1992)	AGA-3 (1992)	Orifice Plate
Module serial: 1234566	Run: 2-P	AGA-8 (1994)	AGA-3 (1992)	Orifice Plate
Module serial: 12344555	Run: 1-C	AGA-8 (1994)	AGA-3 (2011)	Cone
Module serial: 12432354	Run: 2-C	AGA-8 (1994)	AGA-3 (2011)	Cone

<b>Module serial: 1234567</b>	<b>Run: 1-P</b>	<b>AGA-8 (1992)</b>	<b>AGA-3 (1992)</b>	<b>Orifice Plate</b>
Pipe: 102.54 mm	AGA-SI Carbon steel			
Plate: 50.8 mm	AGA-SI Stainless 316			
Taps: upstream flange				

Simulated transducers:

Pf: 4..20 mA	0..8000 kPa	CDaq0_A0		
dP1: 4..20 mA	0..5.000 kPa	CDaq0_A1	Staticshift: -0.052 %/MPa	Zero shift: 90 Pa / Mpa
dP2: 4..20 mA	0..50.000 kPa	CDaq0_A2	Staticshift: -0.145 %/MPa	Zero shift: 210 Pa / Mpa
Tf: n/a	fixed	121 ohm		

Tests run:

Gas pulsation test 123	Pass
dP transition test 12345	Fail <a href="#">(hyperlink to first failure case)</a>
beta ratio boundary test	Fail <a href="#">(hyperlink to first failure case)</a>
API-21 compliance test 1	Pass
API-21 compliance test 2	Pass
Overall status	FAIL

Module serial: 1234566 Run: 2-P AGA-8 (1994) AGA-3 (1992) Orifice Plate

Gas pulsation test 123 Pass

dP transition test 12345 Pass

Figure 36 — Summary report

For each flow module/run under test, a spreadsheet report is produced:

EFM Test Bench Test Report					
Module serial:	1234567				
Module firmware version:	1.01				
Test suite:	API-21 compliance test 1	Fail			
Test start date:	2010-10-13				
Test duration:	54	hours			
Flow run:	1-P				
Gas properties:	AGA-8, 1992				
Gas properties file:	GPA-2145-2010				
Flow calculation:	AGA-3, 1992				
Energy calculation:	AGA-5, 2010				
<b>Differential producer flow meter:</b>					
Flow device:	Orifice plate				
Pipe:	102.54 mm	AGA-SI Carbon steel			
Plate:	50.8 mm	AGA-SI Stainless 316			
Taps:	upstream flange				
<b>Simulated transducers:</b>	type	range	connector	static shift (% / MPa)	zero shift (Pa / Mpa)
Pf:	4..20 mA	0..8000 kPa	CDAQ0_A0		
dP1:	4..20 mA	0..5.000 kPa	CDAQ0_A1	-0.52	90
dP2:	4..20 mA	0..50.000 kPa	CDAQ0_A2	-0.145	210
Tf:	0..5 V	120 deg C	CDAQ7_A0		
<b>Test Conditions:</b>					
Base pressure:	101.325 kPa				
Base temperature:	15 degC				
Seconds per Signal row:	2 secs				
Secs per Gas Composition:	1800 secs				
<b>Error Tolerances:</b>					
Pressure - flowing	0.01 % of full-scale				
Pressure - differential	0.005 % of full-scale				
Temperature - flowing	0.01 % of full-scale				
Qb - flow at base conditions	3 ppm				
Qm - mass flow	4 ppm				
Qe - energy flow	5 ppm				
Mr - molar mass	4 ppm				
Rhof - flowing density	3 ppm				
Rhob - base density	4 ppm				
dF - d at Tf	5 ppm				
Df - D at Tf	4 ppm				
beta - beta ratio	3 ppm				
Cd - Discharge coefficient	4 ppm				
T - Expansion factor	5 ppm				
Rd - Reynolds number	4 ppm				
Total Qb	1.5 ppm				
Total Qm	1.1 ppm				
Total Qe	1.8 ppm				
<b>Test failures:</b>					
(hyperlink to failing case)					

Figure 37 — Flow run summary report

More detailed reports are produced for both current (process) variables, and hourly accumulations:

Date	Time	Status	Pf			Tf			dP			Zf			Qf			Qe		
			Expected kPa	Actual kPa	Error % full-scale	Expected degC	Actual degC	Error % full-scale	Expected kPa	Actual kPa	Error % full-scale	Expected kPa	Actual kPa	Error ppm	Expected m3/sec	Actual m3/sec	Error ppm	Expected J/sec	Actual J/sec	Error ppm
05-May	2:25:33 PM	Pass	5601.325	5600.903499	0.005	22	21.998578	0.001	13.64	13.641463	-0.003362903	6.880598	0	0	0.890525	0.890523	2.2458662	0	0	0
05-May	2:26:07 PM	Pass	5601.325	5601.317222	0.000	22	21.997218	0.002	13.64	13.640965	-0.0033739	6.880598	0	0	0.890525	0.890531	-6.773799	0	0	0
05-May	2:26:59 PM	Pass	5601.325	5600.851429	0.006	22	21.998793	0.003	13.64	13.640827	-0.003031525	6.880598	0	0	0.890525	0.890538	-3.368799	0	0	0
05-May	2:27:59 PM	Pass	5601.325	5600.851429	0.006	22	21.995393	0.004	13.64	13.640329	-0.001208012	6.880598	0	0	0.890525	0.890529	-4.431732	0	0	0
05-May	2:29:13 PM	Pass	5601.325	5600.903499	0.005	22	21.997218	0.002	13.64	13.640965	-0.0033739	6.880598	0	0	0.890525	0.890525	0	0	0	0
05-May	2:30:09 PM	Pass	5601.325	5601.11036	0.003	22	21.998578	0.001	13.64	13.640965	-0.0033739	6.880598	0	0	0.890525	0.890525	0	0	0	0
05-May	2:31:04 PM	Fail	5601.325	5601.11036	0.003	22	21.997218	0.002	13.64	13.641463	-0.003362903	6.880598	0	0	0.890525	0.890523	2.2458662	0	0	0

Figure 38 — Current values detail report

The following process variables are compared:

Pf Flowing pressure

- Tf Flowing Temperature
- dP Differential Pressure
- Zf Compressibility
- Qf Volumetric flow rate at base conditions
- Qe Energy flow rate
- Qm Mass flow rate
- Mr Molecular weight
- Rhof Density at flowing conditions
- Rhob Density at base conditions
- Mu
- k Isentropic exponent
- df Diameter of orifice plate at flowing conditions
- Df Diameter of pipe at flowing conditions
- beta Beta ratio at flowing conditions
- Cd Discharge coefficient
- Y Coefficient of expansion
- Re Reynolds number

Date	Hour start	Hour #	Status	Qf			Qe			Qm			Pf avg			Tf avg		
				Expected E3 m3	Actual E3 m3	Error ppm	Expected kt	Actual kt	Error ppm	Expected kg	Actual kg	Error ppm	Expected kPa	Actual kPa	Error ppm	Expected deg C	Actual deg C	Error ppm
05-May	2:00:00 PM	1	Pass	0.890525	0.890523	-0.000284	0	0	0	5.132366	5.132366	0	6800	6802	294.1176	23.12	23.123	129.7578
05-May	3:00:00 PM	2	Pass	0.890525	0.890531	0.00061	0	0	0	5.132142	5.132142	0	6800	6803	441.1765	23.12	23.123	129.7578
05-May	4:00:00 PM	3	Pass	0.890525	0.890528	0.000286	0	0	0	5.132064	5.132064	0	6800	6804	588.2353	23.12	23.123	129.7578
05-May	5:00:00 PM	4	Pass	0.890525	0.890529	0.000444	0	0	0	5.131837	5.131837	0	6800	6805	735.2941	23.12	23.123	129.7578
05-May	7:00:00 PM	5	Pass	0.890525	0.890525	0.000014	0	0	0	5.132158	5.132158	0	6800	0	0	23.12	23.123	129.7578
05-May	8:00:00 PM	6	Pass	0.890525	0.890525	-0.000012	0	0	0	5.132165	5.132165	0	6800	0	0	23.12	23.123	129.7578
05-May	9:00:00 PM	7	Fail	0.890525	0.890523	-0.000249	0	0	0	5.132224	5.132224	0	6800	0	0	23.12	23.123	129.7578

Figure 39 — Hourly values detail report

The following hourly or daily items are compared:

- Qf Volume at base conditions
- Qe Energy
- Qm Mass
- Pf avg
- Tf avg
- dP avg
- Flowtime (seconds)
- IV API-21 *Integral Value*
- Gr avg
- Hvb

Fext Flow extension

Qb peak

Gas component average value (percentages)

# Flow Calculator

The EFM Test Bench also includes a handy flow calculator:

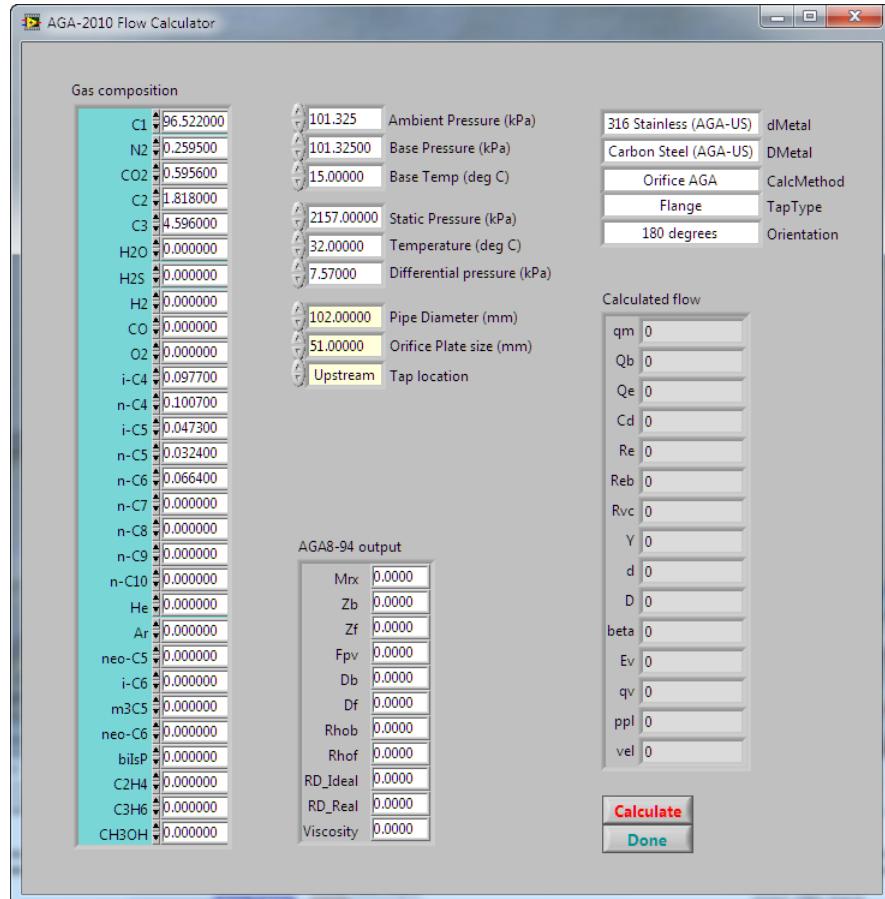


Figure 40 — The Flow Calculator

You can calculate flow and energy for a variety of differential pressure flow devices. The energy calculation is based on AGA-5 (2009), and the flow calculation is based on AGA-3 (2010).

# Appendix I — Getting Started

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## Choosing Hardware

The EFM Test Bench can use just about any analog output hardware that supports the National Instruments Measurement Automation Explorer interface. Here's what you should look for when choosing hardware

- Analog output hardware

Pick hardware that can provide at least 16 bits of accuracy, and which sources your choice of 4..20 mA current loops, or 0..5V outputs.

For PCI bus, the National Instruments NI PCI-6704 analog output board, and the NI PXI-6602 counter/timer card would be appropriate. We can supply wiring harnesses for this configuration.

For USB or Ethernet CompactDAQ, the National Instruments NI 9265 CompactDAQ 4..20 mA output modules can each simulate up to four current loops. The NI 9264 module can source up to 16 voltage outputs. The NI 9401 TTL digital I/O card can simulate up to eight pulse transmitters.

- RTD simulation

If you want to simulate RTDs, the Pickering 40-262 RTD Simulator Module can simulate either 6 or 18 RTDs with what appears to be good accuracy.

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## Installing the Software

The EFM Test Bench installer by default installs everything in directory:  
c:\TestBench

The first time you use the system, you will be asked to create a preference file: *prefs.dat*, which is stored in the same directory as the application. The EFM Test Bench uses this file to remember where you wish your data files to be stored, what the hardware configuration is, and other information such as the IP address of the ScanCom protocol stack.

# Appendix II — Controls

Most of the controls you see in the EFM Test Bench are standard Windows controls, and the windows respond in the usual ways. The strip chart graphs are particularly powerful, so some of the graph controls are shown in this section.

## Graph controls

The strip charts let you pick up to six signals to display at the same time. You select the signals you wish to view from the “Items to display” pop-up menus:

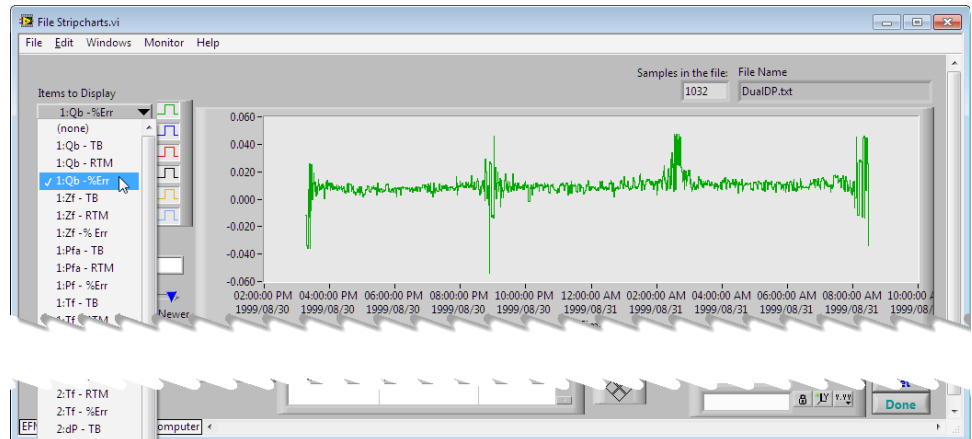
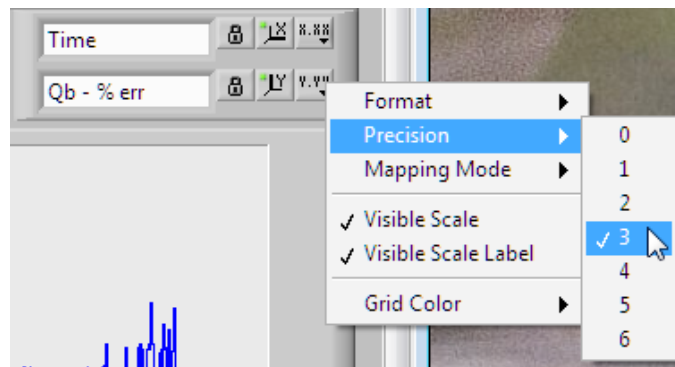


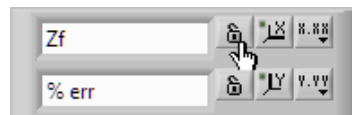
Figure 41 — Selecting strip chart items to display

## Scales

You can change the precision of the graph scales, by selecting a precision from the x or y pop-up menu in the scale legend:



You can manually change the scale range by double-clicking the first or last value in a scale, and typing in a new value. For this to work, you first need to turn auto-scaling off, by clicking the “lock” icon on the scale legend so that the “unlocked” icon is visible:





Click the lock icon again to turn auto-scaling back on.

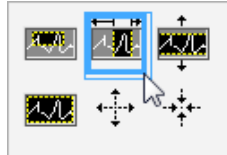
---

## Zooming in

You can zoom in on part of a graph by right-clicking the zoom control from the graph palette:



... and then choosing a zoom mode from the pop-up menu:

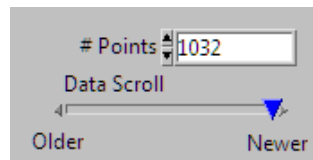


If you select the hand icon, you can push the visible part of the graph around.

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## Scrolling

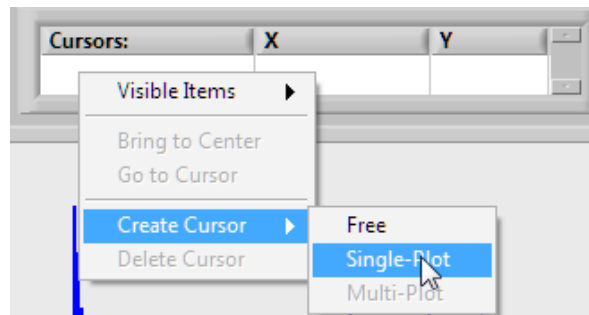
You can also limit the number of points to be displayed, and scroll forward and backward through the circular buffers:



---

## Cursors

The graphs also have a powerful cursor feature. Create a cursor by right-clicking in the cursors legend:



After you have defined a cursor, you can right-click on the cursor legend item to lock it to a particular plot. You can drag the cursors with the mouse, or else move them a point at a time with the cursor arrows:

