ON-LINE COMPUTERS FOR CUSTODY TRANSFER

Class # 3140-1

Peter P. Jakubenas
Installed Product Services Manager
FMC Technologies Measurement Solutions
3402 River Bend Drive
Rosenberg, TX 77471 USA

HISTORY

Until the use and acceptance of the turbine meter and pipe provers in the 1960's, very few electronic devices were used for the measurement of oil or gas. The turning shaft of positive displacement meters powered a number of accessories including counters, printers, mechanical temperature and gravity compensators and meter factor calibrators. The ATG is a wheel and disc mechanical integrator that is still commonly used in gathering system pipeline locations for automatic temperature and gravity compensation of meter totals where electric power may not be available. Gas measurement was accomplished using mechanical circular chart recorders. Total amount of flow was determined by integrating the area under the graph of differential pressure using a planimeter.

Manual reading and recording of meter counts, temperatures and pressures was routinely done. Early provers used counters with the fastest moving two least significant digits being read out by "nixie" tubes, as the electromechanical counters available were limited to about 30 Hz. Computations were all done by hand, as electronic calculators were not even available at that time. The first hand held calculators came in 1967 from TI. They were about $1000. Desk calculators that could add, subtract, multiply and divide were very expensive.

Imagine doing a five run meter proving, collecting the raw data, and then sitting down for 2-3 hours with a calculator to see if the results were repeatable. If they were not, the process had to be repeated. Or manually writing down data every hour or shift or day for a pipeline station and then using raw data and tables to hand calculate net meter tickets. Note that for different operators doing the calculations with the same data, the same answer was expected. To accomplish this, rigorous rules for rounding, truncating, and discrimination levels of data were prescribed by API. These same rules apply to the computer calculations done by software today.

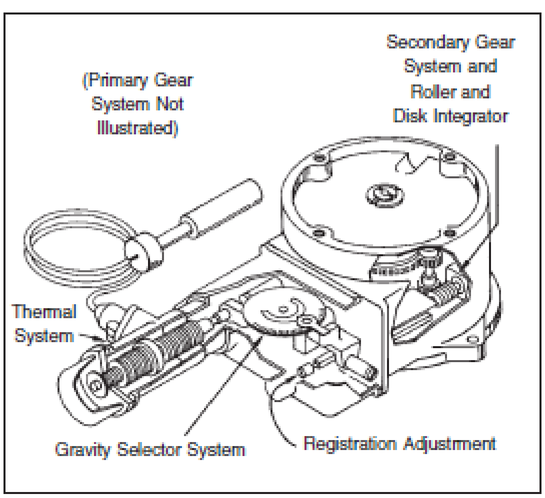


Figure 1

An Early Oilfield Computer (ATG)

A Nixie Tube

With the advent of the turbine meter, electronics became a necessity, as some early turbine meters with bevel gears and shaft outputs were inaccurate because of the gland and accessory load imposed on the rotor.

Proving meters with pipe provers required high speed counting of high resolution meter pulses. Instruments to accumulate pulses, factor counts to read out in engineering units and add counts from multiple meters filled a shower stall size cabinet, consumed a lot of power, and required cooling fans.

Integrated circuits and core memory developed in the 1970's made possible more sophisticated instruments, but most were Stone Age by today's standards.

The big break through came with fast and low cost processors and solid state memory. Early memory used ferrite doughnut shaped cores about 1/8th of an inch in diameter; 1K **bits** costing $1300. Today we can buy a terabyte for less than $100.

Flow computers were first developed with the coming of microprocessors and mini-computers in the 80's, followed by the personal computer. Today's newest flow computers are 8th generation devices.

The concept for ultrasonic meters and Coriolis meters is very old, but they have not become practical devices for custody transfer measurement until the high power calculation ability of relatively low cost computers became available in the last 15 years or so.

As electronic hardware has become less costly and software has become more sophisticated; many advanced features have been added to flow computers, however they still must perform the rudimentary functions of the original counters, i.e., to perform meter ticket calculations and proving calculations .

SPECIFICATIONS AND STANDARDS

The API Manual of Petroleum Measurement Standards Chapter 21."Flow Measurement Using Electronic Metering Systems" defines performance criteria for liquid and gas flow computers. In addition there are various country specific and international standards for this equipment including OIML (International Organization of Legal Metrology) R-117-1 for liquid equipment and EN (European Standard) 12405-1 for gas measuring equipment.

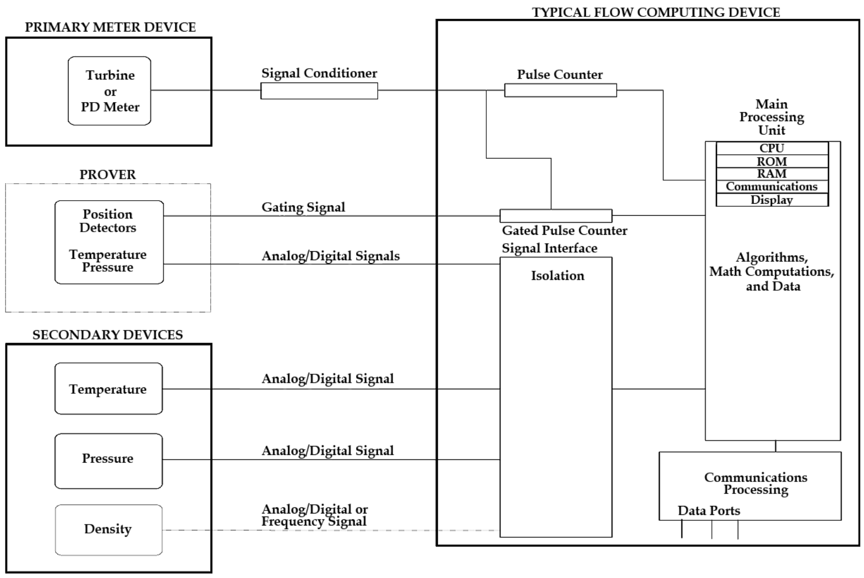
- API liquid measurement standards
  - Chapter 11.1, 2004/2007
  - Chapter 11.1, 1980
  - 1952 Historical Tables (Crude Oil)
  - LPG and NGL per GPA TP-25
- API/AGA/ISO/GPA gas measurement standards
  - Orifice:
    - AGA3
    - ISO5167
  - Turbine or USM
    - AGA7ISO
  - Heating/Calorific Value
    - AGA5
    - ISO 6976
  - VOS
    - AGA10

CONSTRUCTION AND FUNCTIONS

Parts common to all flow computers are:

- ☐ CPU or processor
- ☐ Memory
- ☐ Software
    - o Operating System
    - o Flow Computer Specific Tasks
    - o Algorithms
    - o Computation
    - o Communication Control
- ☐ Input/Output Modules
    - o Pulse Inputs
    - o Pulse Outputs
    - o Digital Inputs
    - o Digital Outputs
    - o Analog Inputs
    - o Analog Outputs
- ☐ HMI (Human Machine Interface)
    - o Display
    - o Touch screen
    - o Keypad
    - o Mouse
- ☐ Communication Ports and Protocols
    - o EIA RS 232
    - o EIA RS 422/485 Modbus
    - o Ethernet
- ☐ Power Supply

Block Diagram of Flow Computer



In addition to calculations, modern flow computers are capable of doing a number of control functions and produce many different reports.

Flow Computer Functions

- ☐ Control Access at Various Levels with Passwords
- ☐ Receive Hardware and Software Inputs
- ☐ Perform Computations, Comparisons, and Logical Functions
- ☐ Raise Alarms When Appropriate.
- ☐ Produce Hardware and Software Outputs
- ☐ Communicate Output
- ☐ Communicate to Report Printer
- ☐ Accommodate Single, Dual, or Multiple Runs
- ☐ Accumulate Pulses
- ☐ Calculate Volume Weighted Averages for Live Data
- ☐ Do Comparison for Pulse Integrity Check IP or API level A or B
- ☐ Compare Live Data With Ranges Preset
- ☐ Raise Alarms for Out of Limit Values
- ☐ Keep Track of Batch Progress
- ☐ Store Past Batch Data
- ☐ Store Future Batch Data
- ☐ Communicate to Upper Level Supervisory Computers

Flow Computer Hardware Inputs

- ☐ Meter Pulses
- ☐ Temperature - Meter and Prover
- ☐ Pressure - Meter and Prover
- ☐ Strainer Differential Pressure
- ☐ Prover 4- Way valve status
- ☐ Density
- ☐ Viscosity
- ☐ Sampler can level or weight
- ☐ BS&W
- ☐ Valve Status

Flow Computer Hardware Outputs

- ☐ Flow Control Signal to Flow Control Valve
- ☐ Display Data
- ☐ Communication to Peers
- ☐ Communication to Higher Level (SCADA) Computer
- ☐ Communicate Reports to Printers
- ☐ Drive External Counters
- ☐ Drive Combinator i.e. Counter that Combines Totals for Multiple Meters
- ☐ Drive Hardware Alarms
- ☐ Pace Sampler
- ☐ Control Prover 4- Way valve

Software Inputs

- ☐ Product data
- ☐ Unit information i.e. metric, English etc.
- ☐ Reference data
- ☐ Batch data
- ☐ Limit and default data
- ☐ Calibration data
- ☐ Communication data
    - To Peer
    - To Upper level
    - Protocol details
- ☐ Report formats
- ☐ Receive data via communications ports

Software Outputs

- ☐ Provide live meter data, net, gross, and mass
- ☐ Batch data, past, present, and future
- ☐ Previously entered data
- ☐ Raise alarms
- ☐ Store data in data base
- ☐ Drive Printers
- ☐ Drive communication ports- send data

Computation Features

- ☐ Temperature, Density and Pressure Compensation
  - 4 Wire 100 ohm Probe or 4-20 mA Transducer Compensates to the Following API Tables Using Reference Density
    - 6 A,B,C,D; Old 24; 24 A,B,D; Old 54; 54 A,B,C,D
  - Compensates Using the Following API Tables to Calculate a Reference Density When an on line Densitometer Is Installed
    - 5 A,B,D; 23 A,B,D; 53 A,B,D
  - Pressure Compensation Using a 4-20 mA Transducer Compensates per API Tables 11.2.1 and 11.2.2 or per GPA Tables

FEATURES OF THE NEWEST FLOW COMPUTERS

The newest flow computers are capable of handling multiple meter runs metering liquid or gas or a combination of the two in one instrument. In addition they can accommodate provers and quality instruments, such as samplers, densitometers, viscometers, chromatographs, dew point analyzers and BS&W analyzers. When multi-meter run instruments are used, they are quite often supplied in redundant pairs.

Flow computers are usually not a stand alone device, but an integral part of a measurement system that receives inputs from the field and transmits information to an upper level or supervisory computer.

Modern flow computers are designed with what we call a “split architecture”. With this feature the field connections can be made to the input/output (I/O) modules either close to the process, ie on the meter or prover skid, or in an intermediate marshalling box closer to the control room, or in the console adjacent to the HMI. The I/O module communicates to the display and read out module using a two wire communication bus. The display or HMI unit communicates with the field unit to collect process information over an Ethernet Control Network (ECN). For very large systems, remote I/O can save much wiring material and labor. The typical fully instrumented meter run uses about 15 pair of wires, so if this can be reduced to less than one pair a savings can be made of cable, cable tray, glands etc. If remote I/O is used, it must be housed in a box appropriate for the area in which it is located, ie, it may be in a hazardous area where special explosion proof and weather proof enclosures are required.

The flow computer will monitor connected process inputs, such as, temperature, pressure, density and meter pulses and compute compensated flow rates and accumulated volumes and mass. The unit can trend all process inputs and will generate high and low process alarms based on the operator entered limits and is capable of condition based monitoring. It will also provide output signals such as, flow control or flow echo. Additionally, the units generate periodic, as well as prove and batch reports.

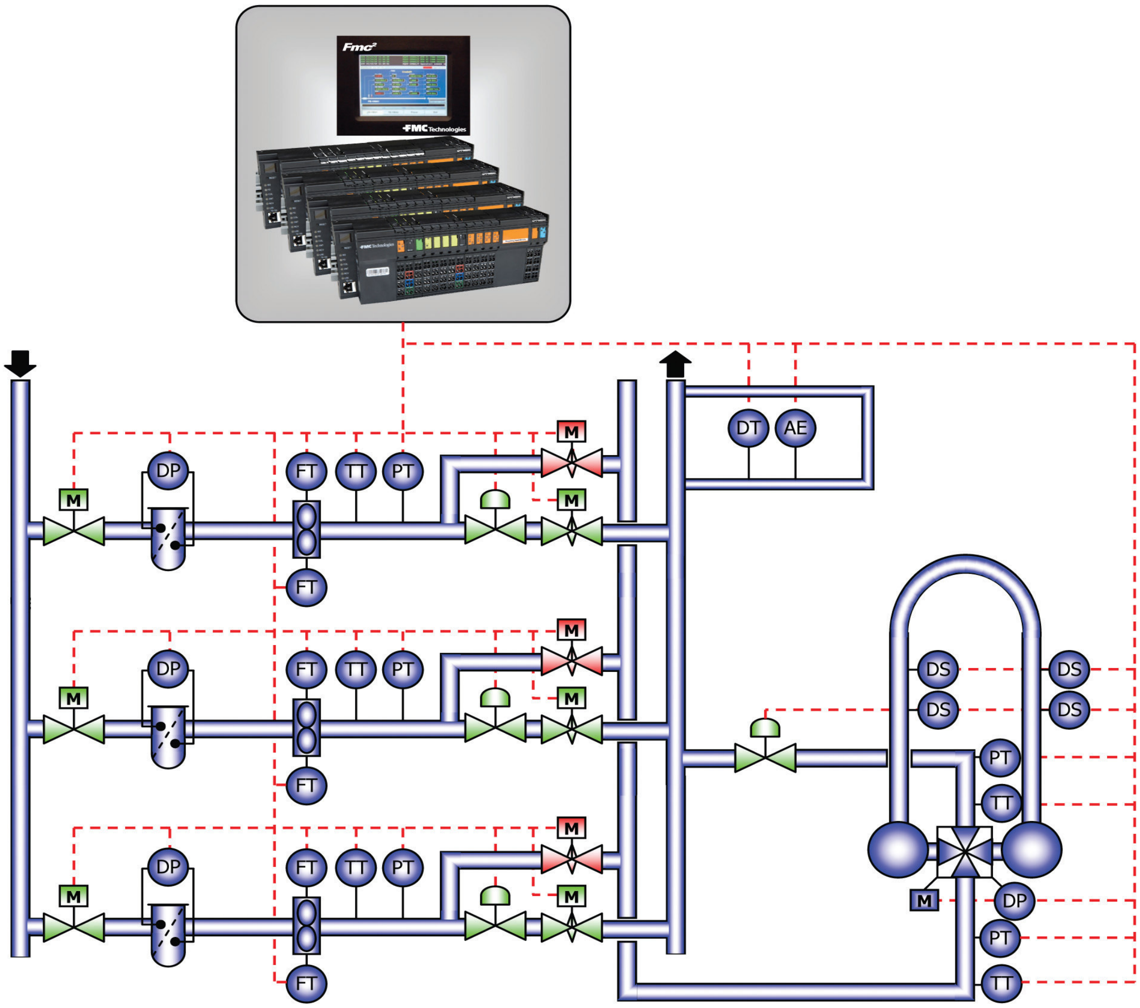
A separate flow computer is not usually required for the meter prover or the quality units as their signals are paralleled to each meter’s flow computer.

The Display Unit is a Panel Mounted PC, with a touch screen, running the operating system. The display will have full color graphics ability with intuitive, graphical user interface.

Flow computers are equipped with Ethernet and serial ports. The communication ports can be configured as Modbus (Slave) ports for interfacing to upper level SCADA computer(s) and Modbus (Masters) for retrieving data from Gas Chromatographs, Viscosity Computers, other flow computers, or any Modbus Slave device.

Below is a depiction of fully instrumented meter system and I/O to the flow computer. Also some sample flow computer screens are shown.

Typical Signals from a Meter Run Connecting to the Field I/O Blocks.



Notes:

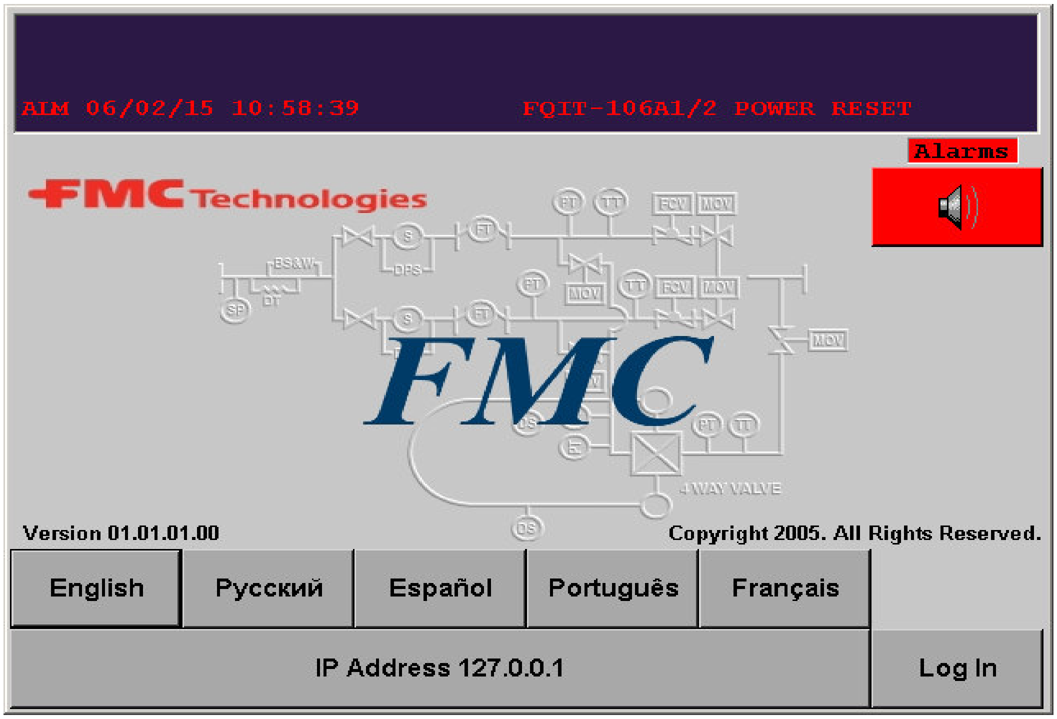
1: "DP" = Differential Pressure; may be a transmitter or switch for strainers, switch for 4-way seal

2: "DT" = Densitometer (frequency or analog)

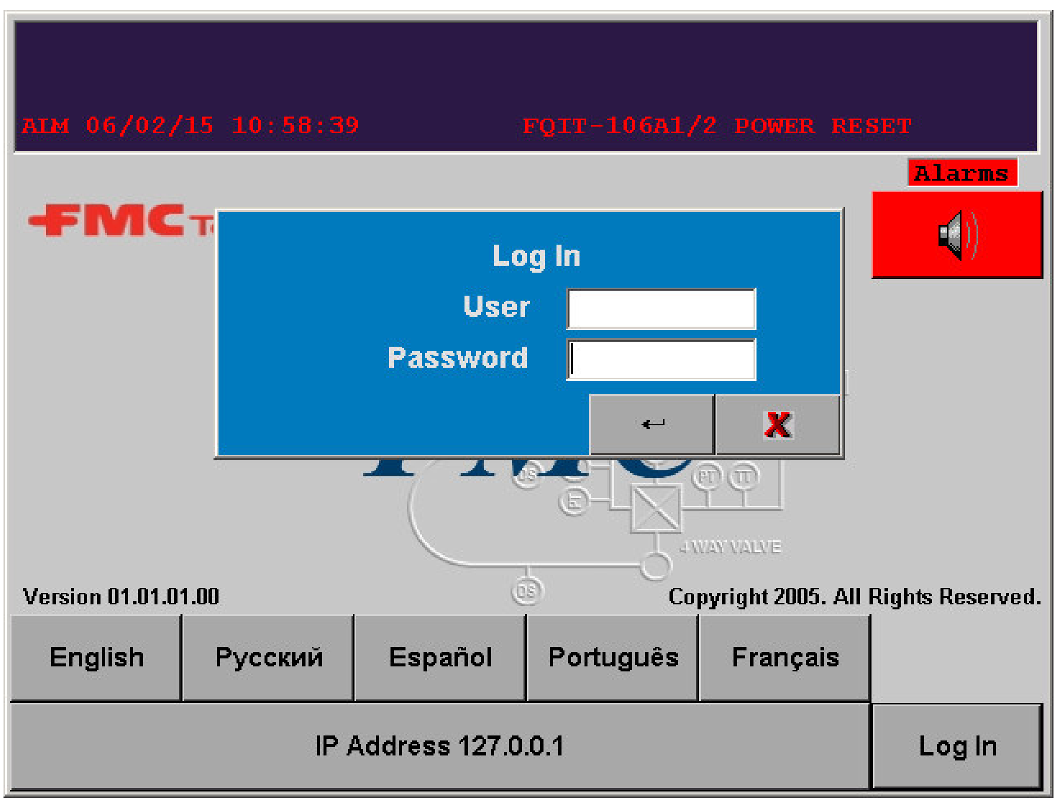
3: "AE" = Analyzer Element (S&W)

4: Sample Controller may be driven by integrated pulse output on the Frequency Module

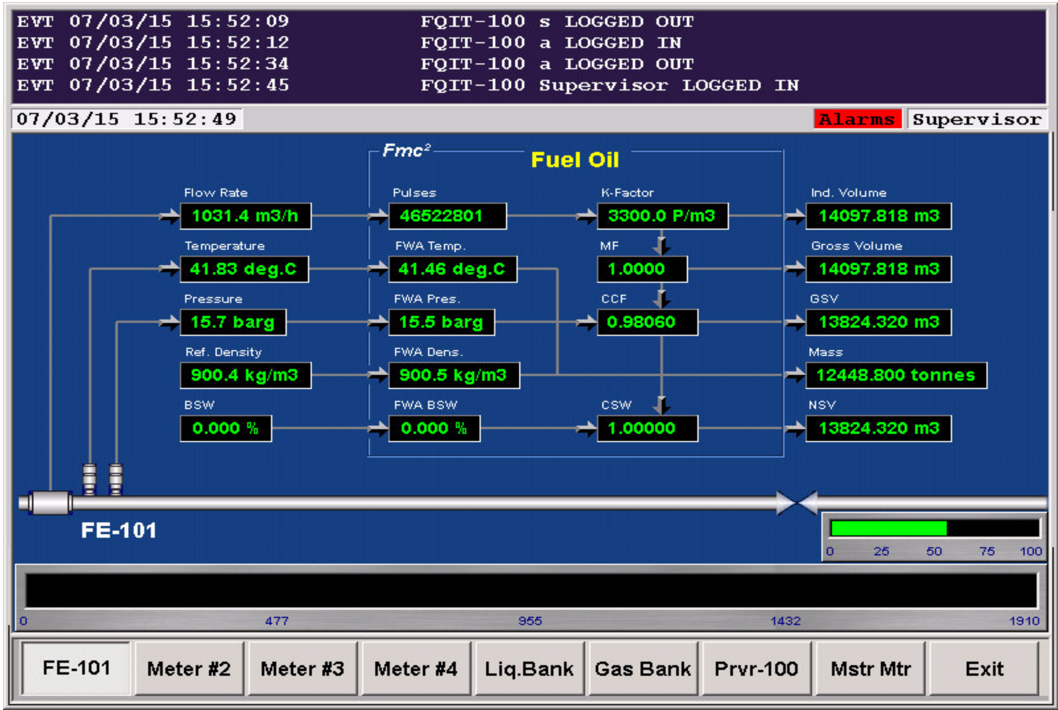
Power Up Screen Note Multiple Language Capability



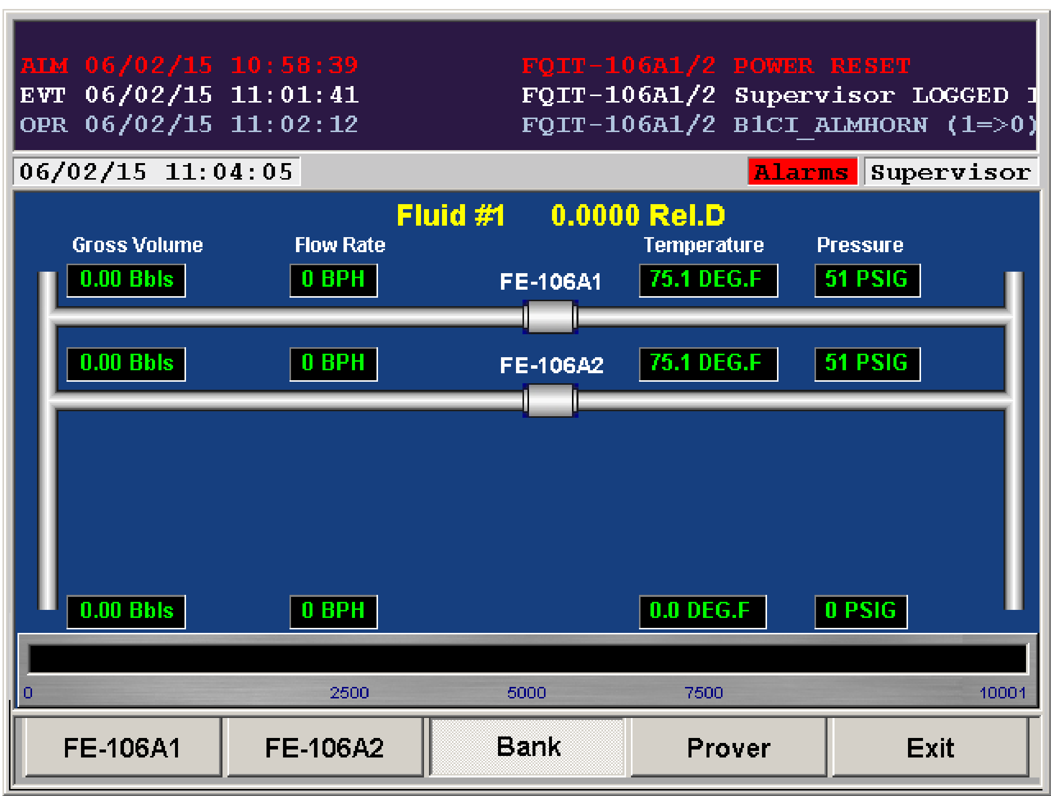
Log in Screen – Multiple Levels of Access



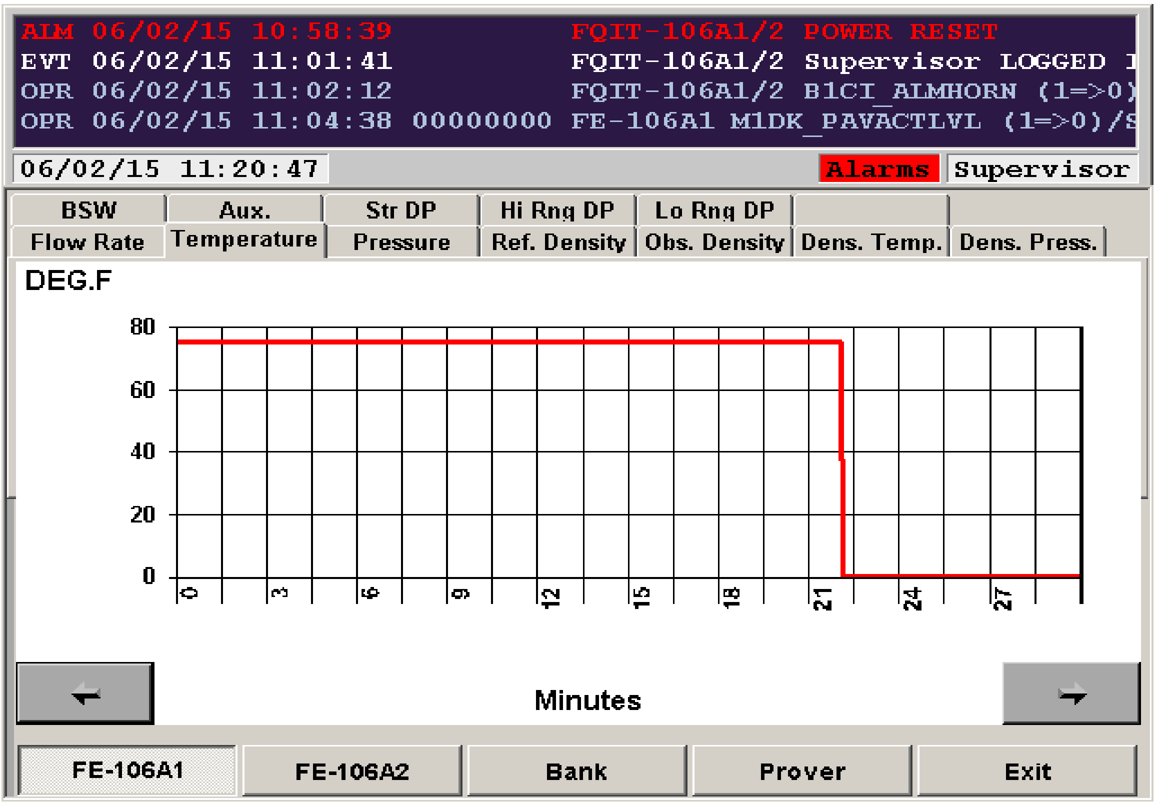
Meter Run Data Screen



Meter Bank Data Screen



Data Trending Screen



Some of the more advanced features of newer flow computers perform analysis of the computed data to assist with operator decisions. Examples are shown below:

User Selected options for determination of acceptance of proving results:

Trip Selection Method - The available repeatability tests may be chosen by selecting the following:

- 0 - Any Trips - any “required number” of trips in which the 100*(Max-Min)/Min is minimized and less than or equal to the Max Repeatability (%).
- 1 - Consecutive Trips - the first consecutive “required number” of trips in which the 100*(Max-Min)/Min is less than or equal to the Max Repeatability (%).
- 2 - All Except Outlier - the root mean square of the deviation from the average of the “required number” of trips excluding a possible Outlier based on a t distribution of 0.95 must be less or equal to the Max Repeatability (%).
- 3 - Std. Deviation Any Trips - any “required number” trips in which the 100*Standard Deviation/Average is minimized and less than or equal to the Max Repeatability (%).
- 4 - Std. Deviation Consecutive Trips - the first consecutive “required number” of trips in which the 100*Standard Deviation/Average is less than or equal to the Max Repeatability (%).
- 5 - Uncertainty Consecutive Trips- the first consecutive trips of at least the “required number” and at most the “maximum number” in which the uncertainty of the average is less than or equal to the maximum allowed repeatability (uncertainty), usually 0.027%. This test is typically used when proving Ultrasonic Meters. **Note: Method 1) can be used instead, if preferred, with reference to Table B-1 of *API Chapter 5 (Metering) - Section 8 - Measurement of Liquid Hydrocarbons by Ultrasonic Flow Meters Using Transit Time Technology***

User selected options for acceptance of new meter factors based on various criteria such as:

- The new MF is always acceptable.
- The new MF must pass "Test 1". Test 1 passes if the new MF deviates from the ***current*** MF by less than the user entered Test 1 percent deviation limit. Usually 0.25%.
- The new MF must pass "Test 2" to be acceptable. Test 2 passes if the new MF deviates from the ***average*** of historical MFs by less than the user entered Test 2 percent deviation limit. Usually 0.1%.
- The new MF must pass "Test 1" and "Test 2" to be acceptable.
- The new MF must lie within the X% confidence range around the average of the historical MFs in order to be acceptable. X may be 80,90,95 or 99.
- The new MF is never acceptable.

CONCLUSIONS

- Today's flow computers and systems for use in custody transfer liquid measurement are far superior to what they have ever been in every aspect
- The ultimate in meter performance can be achieved by surrounding it with high performance readout equipment
- With the latest more powerful flow computer hardware and software; implementation of low uncertainty measurement becomes easier for system operators
- Proving becomes more convenient.
- Condition based monitoring is possible.
- Maintenance costs can be reduced as the diagnostics available in the flow computer can reduce routine intervals for inspection, calibration etc.
- Specification and selection of the equipment is probably more complex than it has ever been
- People selected to specify, operate and maintain the equipment need to work with competent and dependable system suppliers to select the appropriate field proven equipment for the application.
- Operator and Maintenance Training is Important

ACKNOWLEDGEMENT

The author thanks FMC Technologies for permission to prepare and present this paper at the 2011 International School of Hydrocarbon Measurement. He also thanks his colleagues for material for the paper.