



## TRENDS IN FISCAL ELECTRONIC MEASUREMENT SYSTEMS

By **Kenneth D. Elliott**  
**OMNI Flow Computers, Inc.**  
**10701 Corporate Drive, Suite 300**  
**Stafford, Texas 77477, U.S.A.**  
**Ph: 1-281-240-6161**  
**E-Mail: [info@omniflow.com](mailto:info@omniflow.com)**  
**Web Site: <http://www.omniflow.com>**

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### INTRODUCTION

This presentation deals with equipment redundancy, and discusses trends in hardware and software technologies impacting on electronic metering systems, including the use of Ethernet & OPC.

Trend *noun*      1: a general direction taken (as by a stream or mountain range)  
                         2: a prevailing tendency  
                         3: a current style or preference

The above definitions are taken from The Webster Office Dictionary. A trend is more about 'what is', rather than 'what will be'. Most of this paper is devoted to 'what is'. In business, as needs become evident, options are investigated and debated, and hopefully sound engineering decisions are made. In the petroleum business, the 'mountain range' analogy, hopefully, better suits PETRONAS, than the analogy of a meandering stream!

Some of the current trends being applied to fiscal measurement systems by Saudi Aramco are discussed here - these same issues may apply to other regional oil companies. An explanation of emerging supervisory systems communications standards, important to all measurement professionals, is also included:

- Reliance on Redundant Electronic System Components
- Meter Factor Linearization using Flow Rate and Viscosity
- Ethernet / TCP/IP connectivity and Open Process Control (OPC)

### REDUNDANT ELECTRONIC SYSTEM COMPONENTS

Given the typical high delivery volumes of crude oil and refined products taking place within the Kingdom of Saudi Arabia, it is imperative that equipment failure should not impact the ability of Aramco to be able to deliver and correctly measure its various petroleum products at all times with minimal error and downtime.

1) A fiscal electronic measurement system must be able to quickly detect a failure of an electronic flow measurement device such as flow computers and automatically continue measurement operations using a redundant device without introducing unacceptable measurement errors.

2) Failures of mechanical components such as turbine flowmeters are handled by employing redundant meter runs. A failure in this case requires diverting flow from the damaged meter run to a backup meter run equipped with its own measurement electronics.

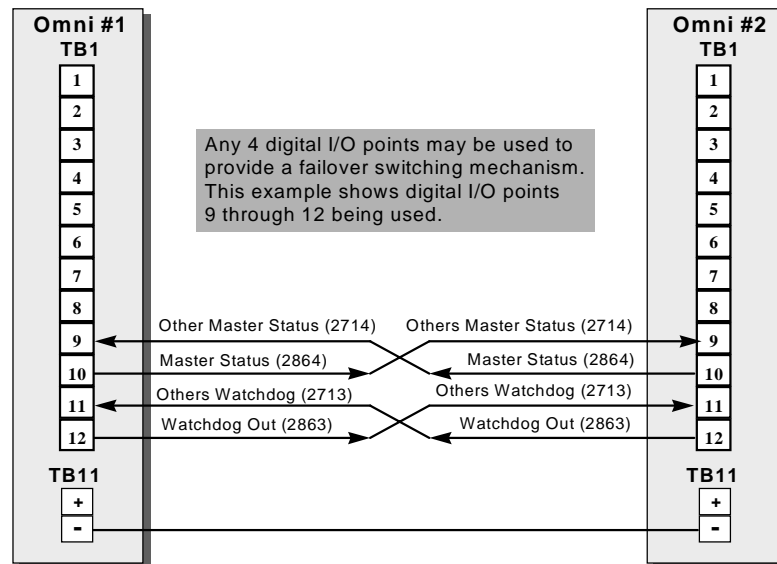
In reality, a failure of type (1) is probably easier to accommodate and adjust to, because it is possible to make the changeover of flow computers almost transparent to the user and his data collection system. Failures of type (2) require much more effort on the part of the user. In this case, not only must the flow be diverted, the user must piece together partial delivery ticket data from two different flow computer systems unless the system is multi-stream.

### Implementing Redundant Flow Computers in Practice

Let's look at the basic requirements needed to provide meaningful redundancy as it applies to flow computers in a Saudi Aramco system

- 1) Failures must be detected and alarmed, and equipment switchover must occur automatically.

Failures can be detected by having each flow computer continuously monitor the others watchdog status. In the systems employing Omni 6000s, this is accomplished by crossing digital I/O points between the units as shown in the diagram below.



An additional set of crossed digital I/O points provide the ability to promote or demote a flow computer from secondary status to primary status or vice versa. The MMI/SCADA system normally controls the primary/secondary status of the flow computers by a serial data write to either the primary or secondary computer. This would be necessary for instance if the MMI/SCADA host lost communication with the primary flow computer. In this case there is no detectable failure of the primary unit and therefore no watchdog activity, someone may simply have disconnected the wrong wire while troubleshooting another unrelated problem.

**2) Switch Over of all batch totalizing, PID control and proving functions**

Switchover of functions such as batch totalizing, PID control, and proving functions work as follows: all measurement I/O such as temperatures, pressures, densities and flow meters are wired in parallel to both the primary and secondary flow computers. In effect, at all times the secondary flow computer is seeing all of the same input parameters and is performing all of the same calculations that the primary flow computer is performing.

The secondary unit is therefore always ready to assume the duties of the primary unit and serves as a truly redundant device. No attempt is made to transfer totalizer values between primary and secondary units thus eliminating any chance that a failing primary flow computer could corrupt the totalizers of a healthy secondary computer. Experience shows that many failures are not clean catastrophic failures but gradual performance deterioration.

PID control valve signals originating from each of the redundant flow computers are usually isolated via dry relay contacts. Control of the relay is by way of the master/slave status that is output via the flow computer's digital I/O.

Prover control and status signals and detector switch signals are simply wired in parallel to the primary and secondary flow computers.

**3) Synchronization of critical variables and historical data must be maintained between the primary and secondary flow computers.**

In the event of a failure, the secondary flow computer must be ready to assume all measurement and control functions. This is accomplished by continuously exchanging critical data over a peer to peer data link between the primary and secondary flow computer. Data transmitted includes: PID setpoints, control valve positions, meter factors, and prove result data needed to maintain the data base containing the results of the last ten provings.

**4) Communication to the MMI and/or SCADA host must be maintained at all times.**

In many instances redundant communication links are provided to each of the redundant flow computers. The designer of the MMI/SCADA system usually wants the serial data interface to look like there is only one device present. Polling only the primary device eliminates the need to configure duplicate databases in the MMI/SCADA host, a significant savings in resources and effort. This is accomplished automatically by control logic within the primary and secondary flow computers which swaps unit ID numbers. In this way the MMI/SCADA system is always talking to the 'current' master who is always addressed as unit ID number one. The switch over between flow computers is virtually instantaneous and could go unnoticed unless the MMI/SCADA system monitors a unique identifying data field within the current primary flow computer and/or the various flow computer status bits indicating that an event took place.

**5) Automatic switch back to primary status is not allowed.**

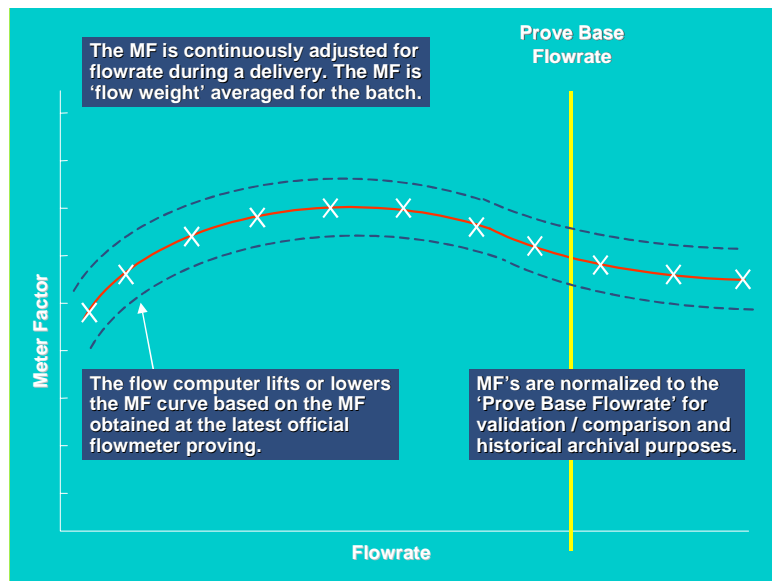
Should a fail-over occur, the data in the new primary computer should be used until the end of the current batch or transaction. If the original primary computer is repaired and placed back in service it should not automatically promote itself to primary status. This could cause flow to be undercounted. The Omni 6000 logic requires the user to manually

promote the repaired flow computer to primary status, usually at the end of the current batch in progress.

### METER FACTOR LINEARIZATION USING FLOW RATE AND VISCOSITY

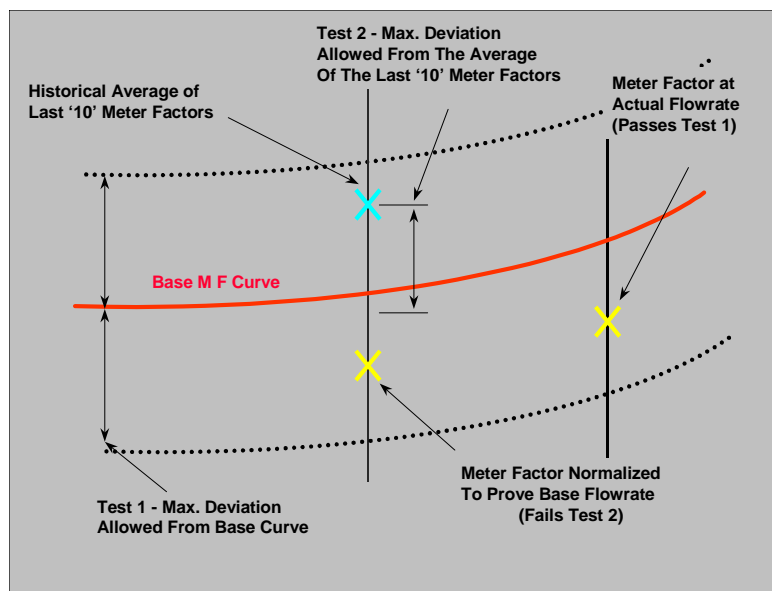
A trend towards using flowmeter linearization has been observed, especially in crude oil systems required to measure crude oils spanning a wide viscosity range. Increasingly users are employing 12-point meter factor linearization curves for multiple crude oil grades and products. The author believes that the first use of a 12-point curve was in the Kingdom of Saudi Arabia!

The meter factor curve for each flowmeter and product combination is determined empirically when the flowmeter is first installed. Minor shifts in flowmeter performance are corrected for when the flow computer lifts or lowers the meter factor curve, based on the meter factor obtained at the latest official flowmeter proving. During a batch delivery, the meter factor is continuously adjusted for flowrate. The reported meter factor for a batch delivery is the 'flow weighted' average meter factor.



Proving meters at various flowrates, in combination with a historical meter factor curve provides a challenge. How can the measurement engineer compare results from the last proving, with the results of the past ten provings which may have been performed at different flowrates? One method is to normalize each meter factor obtained by proving at various flowrates, back to a reference 'Prove Base Flowrate'. This normalized factor is compared to the average of a number of historical meter factors normalized to the same reference flowrate.

To be automatically implemented after the prove sequence, the prove meter factor must pass two tests. Test one (1) checks that the new meter factor has not strayed too far from the original meter factor base curve. Test two (2) verifies that the prove meter factor is within





some acceptable deviation from the historical average of the last ten meter factors.

**Flow / Viscosity Polynomial Equations**

Flow/viscosity polynomials can also be used for some types of pulse producing meters such as helical and positive displacement meters, in lieu of the meter factor linearization method described above. This method does not require the same level of data maintenance, but instead relies on the viscosity changes as indicated by an in-line viscometer. Some users have predetermined the viscosity of various grades of crude oils being transferred under certain conditions and have applied a fixed viscosity value.

The resultant LCF is a function of flowrate and viscosity; both measured in real time.

For a Helical Turbine Meter

$$LCF = a + b/x + c/x^2 + d/x^3 + e/x^4 + f/x^5 + g/x^6$$

For a Positive Displacement Meter

$$LCF = a + (x^c) / b$$

Where:

*x = Flowrate / Viscosity*

*Coefficients a through g are usually provided by the flowmeter manufacturer.*

**ETHERNET-TCP/IP CONNECTIVITY**

Fiscal Electronic Measurement systems employ many electronic devices such as PLCs, flow computers, and MMI/SCADA hosts. The common thread that binds together all of these devices, is the need to exchange relatively large amounts of data as quickly as possible. The trend today is to use the established Ethernet/TCP/IP network technology to efficiently move this data between these devices, moving it up the information chain to the enterprise server infrastructure and higher level software applications.

A very short layman’s tutorial on the basics of Ethernet and TCP/IP (Transmission Control Protocol/Internet Protocol) is in order to fully understand the advantages, and also highlight one or two of the challenges faced, when taking this approach.

Ethernet - TCP/IP as we know it in industry is a four-layer protocol comprising:

- Physical Connection or Link Layer: Ethernet (IEEE 802.3)
- Network Layer: IP
- Transport Layer: TCP, UDP
- Application Layer: FTP, SMTP, TELNET, OPC etc.

**Physical Connection or Link Layer - Ethernet (IEEE802.3)**

Ethernet comes in several flavors, the most well known being 10BaseT, 100BaseT and Thin Coax. These refer to the familiar hardware infrastructure of cables, network hubs, and NICs (Network Interface Cards) that connect our PCs and make up the office LAN (Local Area Networks) or WAN (Wide Area Networks). Ethernet 10BaseT hardware for example, is theoretically capable of moving 10 million bits of information around every second, 100BaseT, 100 million bits of information every 1 second. As usual, in reality these figures are high, because

data collisions occur when you connect lots of devices to the same network, and they try to send data at the same time. The IEEE 802.3 Ethernet standard specifies the rules that the NIC hardware has to follow to recover from data collisions, and ensure maximum throughput of data. Network hubs simply connect together devices and echo or repeat the same data out of all ports. The network is enlarged when hubs are connected together via a communication backbone connection. In this case, data traffic emanating from any device appears on the backbone regardless of whom it is directed at. Intelligent hubs, called network switches, can actually reduce traffic on the main system backbone connection by examining the data traffic coming into each of its local ports, by routing these messages internally the network switch can free up bandwidth on the backbone for other traffic. Gateway routers expand the LAN out of the office and on to WANs and to the Internet beyond.

### **The Network Layer – IP (Internet Protocol)**

The job of the network layer is to send data packets or blocks of data from one point to another using the Ethernet link layer. IP is a connectionless protocol that has no concept of a job or session. Every data packet or block is treated like a separate entity in itself. IP is like a postal worker sorting packages one at a time. IP is not concerned whether a packet is one of a group, it just routes them one at a time on to the next location on the delivery route. IP is also unconcerned with whether a packet reaches its final destination or that the packets are in the original order that they were sent. The mechanism used to ensure delivery and correct data packet order is provided by the higher-level protocols in the TCP/IP suite.

### **The Transport Layer – UDP, TCP**

These two protocols; UDP (User Datagram Protocol) and TCP (Transmission Control Protocol) are used directly by applications such as FTP (File Transfer Protocol) and OPC (OLE for Process Control). The transport protocols UDP and TCP must know a little more about what is in the data packet, they need to know what application in the server and client owns the data in the packet so that they can deliver the data to the correct host application.

UDP is a simple unreliable ‘connectionless’ protocol that adds little functionality to the lower level IP. You do not need to establish a connection with a host device before exchanging data using UDP, and there is no mechanism for ensuring that data sent is eventually received. Although unreliable, UDP is still an appropriate choice for many ‘real time’ applications where the application software takes care of missing or unanswered messages by re-trying the transmission. In some applications like audio streaming you are probably better off ignoring missing data anyway.

TCP is a reliable ‘connection’ oriented protocol. This means that the two host devices, client and server, must first establish a connection before any application data can be transferred between them. An application that uses TCP knows that the data that it sends is received at the host at the other end.

### **TCP/IP Port Numbers**

The concept of port numbers is common to both UDP and TCP. The port numbers are not hardware ports but software ports. They identify which protocol module sent the data, or is to receive the data. Most protocols have predefined standard ports numbers such as:

File Transfer Protocol (FTP):	20/21
Telnet Protocol:	22

Simple Mail Transfer Protocol (SMTP):	25
Modbus/TCP Protocol:	502
WWW-HTTP	80
Omni Multiplexed Modbus Protocol	3001

### **Multiple TCP/IP Connections**

Most host devices allow multiple ‘virtual’ connections to services or applications running within the host device. It is possible for example, to have multiple Modbus/TCP connections, while also being connected and using FTP to download a file from the host.

This is a significant advantage, which ‘theoretically’, allows multiple Modbus masters to simultaneously send requests for data to the same Modbus slave device. I say ‘theoretically’ because, while the TCP/IP protocol will allow multiple connections and virtually simultaneous poll requests for data, there is no guarantee that the Modbus slave will be able to manage these requests and steer the correct poll response to the correct TCP/IP connection!

### **The Terminal Server and its Limitations**

Terminal Servers are hardware devices that look something like a modem. They have Ethernet connections and are also equipped with one or more serial data ports such as RS232 or RS485. The terminal server’s function is to transfer data between the Ethernet/TCP/IP connection, and the serial port connections. Terminal servers allow Ethernet equipped devices to interface with non-Ethernet equipped devices. Most terminal servers have limitations though; they usually do not support multiple TCP/IP connections to the same serial port connection. Each TCP/IP connection made is a virtual direct wire connection to a unique serial data port on the terminal server. Terminal servers with four ports will allow four TCP/IP connections to be made, those with one port, only one connection.

### **Modbus Bridge Multiplexers**

Bridge Muxes are stand alone devices which come in a variety of flavors. Some devices have Ethernet/TCP/IP connections supporting Modbus Plus and/or Modbus/TCP. They are equipped with serial data ports that can support Modbus RTU and ASCII protocols. Each of these serial data ports can be connected to either a Modbus slave or master device. The mux manages all of the data traffic coming in through it’s various ports. It ensures that each slave receives one Modbus poll at a time. Simultaneous polls to a slave are handled by making one of the masters wait until the first master has received its response.

### **Ethernet/TCP/IP Capable Flow Computers**

Some Ethernet equipped flow computers can make the TCP/IP interface easy, eliminating the need for extra terminal servers and Modbus Mux devices. This is especially true if redundant communication links to the measurement system components is desired. Thinking of the Ethernet link as simply a very fast serial port can be a mistake. The flow computer may respond with data quickly, but the data may be ‘stale’ i.e. most flow computer devices calculate and update the data in their database on a regular calculation period. You should verify that it does support multiple virtual connections via the TCP/IP link, and that it has the ability to service more than one poll request at a time. Is it possible to adjust the configuration parameters without interrupting the polls for real time data by the SCADA for example? Can the pipeline integrity application running on the system LAN get the information that it requires, while the PLC, MMI and SCADA are sending and receiving data?



The addition of Ethernet/TCP/IP into the fiscal measurement system opens up all sorts of possibilities:

- Multiple virtual connections via a infinitely scalable enterprise network
- Configuration access of equipment from the desks of authorized personnel
- Browser access to pre-configured web pages within the flow computer
- Automatic distribution of flow computer reports via email to selected recipients
- Automatic email alerts of critical alarm occurrences
- Ability to download historical archive files, alarm logs, audit trail logs and text reports using FTP. No modbus transactions involved.

### **OLE FOR PROCESS CONTROL (OPC)**

OLE (Object Linking and Embedding) for Process Control or OPC, is a result of collaboration between Microsoft and many industry leaders in process control. OPC in some ways can eliminate the need for multiple data connections to the field devices if all of the applications requiring data are OPC clients.

The concept is a novel one; install an OPC server on the system network and concentrate the end device I/O communication drivers and protocols into this device. OPC 'clients' such as the MMI, SCADA, Leak Detection, and Accounting systems simply ask the OPC server to supply the data that they require. If the data is already available in the server, the request is completed immediately. If the data is not available, the OPC server retrieves the required data from the appropriate end device and passes it on. The advantage of this system is twofold:

1. The MMI, SCADA, Leak Detection and Accounting systems no longer have to be concerned about Modbus, Allen Bradley DF1, or any other low level protocol. They simply request the data using well documented OPC calls which are well supported by the operating system of the server and clients.
2. Applications such as MMI, SCADA, and Leak Detection systems require many of the same data points. The OPC server reads this data only once on some pre-configured scan period. The client applications are provided with the most recent updates of this data.

The OPC server connects to the field devices using whatever combination of data links as are required. These may include: TCP/IP, direct connection, dial-up, wireless and lease-line connections. The OPC server can be configured to directly populate just about any database; SQL, Oracle, Access etc., with data retrieved from field devices. The database can reside anywhere on the enterprise's network.

For simple applications, some OPC servers also provide DDE (Dynamic Data Exchange) support allowing DDE clients such as Microsoft Excel to present live data in spreadsheet format. Redundant OPC servers, each with redundant TCP/IP links to the field equipment can easily be employed in mission critical systems such as those found in fiscal metering.

## **SUMMARY AND CONCLUSIONS**

Among the trends in fiscal measurement observed by the author, none are deemed more important by the end user than the ability to employ the principle of redundancy in the design of the measurement system at all critical levels. This includes the flow computer, MMI, PLCs, and communication links that interface them. Any advance in equipment or technology that makes this redundancy easier to implement and less complicated to operate and understand, will be gladly welcomed by the designers and users of the measurement system.

Aramco's experience shows that it is possible to optimize and monitor the performance of turbine meters operating over a wide range of flowrates by implementing meter factor linearizing using a base meter factor curve. In addition to performing real time linearization of the flowmeter, the flow computer also monitors the ongoing performance of the meter as it wears. The flow computer refers to the meter's base meter factor curve each time a prove is performed. While slow shifts in performance due to gradual wear are acceptable over a preset range, any sudden change in performance when compared against the last ten provings, is automatically flagged.

The common thread that ties together all of the critical instruments of the fiscal measurement system is proving to be Ethernet/TCP/IP. This ubiquitous network protocol capable of transporting and supporting many simultaneous messages and protocols at high speed, provides many advantages, some of which are; scalability, remote access and configuration, and interoperability between devices. Ethernet/TCP/IP equipped flow computer devices which support multiple Modbus masters without resorting to an external bridge mux are available. This can lead to significant savings and simplification of the communication network design. OPC eliminates the need for many higher level applications to poll the field devices for data by defining a common, high performance interface that permits this work to be done once, and then easily reused by HMI, SCADA, Control and custom applications. Redundant OPC servers can be employed providing system redundancy all of the way up to the higher enterprise level databases.