New technologies of the future

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analyse the effect of industry downsizing on the quality of tertiary measurement devices and the implementation of new standards and trends.

As the energy industry continues to re-engineer itself through downsizing, rightsizing, and mergers, standardisation of product selection and outsourcing elements of engineering, operations and maintenance are becoming increasingly common. This does not however relieve the user of responsiblity for his own processes and the underlying technologies employed. Consolidation within vendor groups is resulting in product rationalisation and a reduction in the number of expert companies with custody measurement experience and the commitment needed to maintain product excellence and integrity.

Over time, our perception of what constitutes a typical tertiary device (e.g. flow computers) will change. It has already been established that they are capable of multiple uses. Current and emerging technologies will have a profound effect on their ultimate role in the future of measurement, control, and data acquisition systems.

Software and hardware

Software is a key ingredient in virtually every aspect of our environment. In custody transfer, the software implementation and certification of API standards for several generations of microprocessor based devices has always been a subject of debate for a number of users. The expert knowledge required both by the manufacturers and users, contrary to expectation, is more important today than it was a decade ago due to the reasons discussed above. However, one cannot consider software development independent of hardware architecture design.

Microprocessors/maths coprocessors

Flow computers today include powerful microprocessors, which enable them to easily perform calculation intensive tasks. At the same time, related control and communication functions can also be undertaken with minimal processing impact.

By using 32 bit processing power, flow computers perform simultaneous tasks by operating in a multi tasked, interrupt driven mode. This means that time dependent functions have their own processing allotment. Tasks may run every 10 msec, 50 msec, 100 msec, or 500 msec. Other, less time dependent tasks, such as formatting a report for printing, can be performed in a background mode, so as not to waste CPU processing time.

Because the primary function of a flow computer is to undertake number crunching, a maths co-processor chip can significantly speed up maths processing. Dedicated floating point maths hardware chips will always outperform comparable software solutions.

This does not mean that the hardware and software maths methods will produce differing results, it simply means that more processor time will be available for other tasks. Because ‘same chip family’ parts are used, there is usually a tight integration between CPU and the maths co-processor chip. This combination can provide a substantial improvement in performance with very little added programming complexity. Another way of increasing processing throughput is to operate with multiple processors that execute assigned tasks. Using a separate microprocessor as a communications controller, for example, requires the programmer to write two separate programs that have to be able to access the same database without concern for data synchronisation.

There also remains a significant difference in requirements between flow computers that calculate in near real time and solar powered systems with continuous I/O sampling (e.g. every second but with a one minute calculation cycle). These solar powered systems in gas measurement are the norm due to the absence or potential loss of continuous power, and are designed to replace clockwork chart recorders!

There are distinct differences between microprocessor families or classes. For example, 32 bit Intel based PC chipset modules are primarily designed for a personal computer, but are being used for industrial applications. Another class of 32 bit microprocessor was designed to be embedded into the system. These microprocessors are specifically designed from the fundamentals by the manufacturer, ensuring a tight coupling between I/O hardware

Using a field mounted transmitter as a secondary transducer to the primary flow meter.

and application software. The latter approach is used in the majority of industrial applications, including DCS systems.

The memory addressing capability of processors can differ significantly. As an example, compare Intel's original 64K segmented architecture addressing constraints to Motorola's linear addressing capability. This can have a major impact on the programmer's ability to write efficient code.

Programming language selection has a direct impact on the memory requirements for software code. Optimised code written in assembler language may operate more efficiently than higher level languages using compilers. The software within the flow computer is mainly produced using high level compilers, with critical sections of code, usually low level driver code, programmed in the assembly language.

Application software

There is a lot more that goes into the development of a flow computer than the calculations. In fact, that is usually the easiest part of the development. Other auxiliary functions such as PID control, meter proving, valve and sampler control, archiving, batch processing and data communications are more challenging. These tasks are broken into modules for easier maintenance (Omni's current software coding standard limits modules to a maximum of 1000 source code lines).

Separate executable sections ease debugging and allow code to be upgraded a section at a time. Several programmers must be able to work on sections of a product's code without interfering with one another's memory space.

Moving memory allocation and usage around without proper planning can cause unnecessary delays in the programming cycle. Getting the most out of memory requires a well considered design and careful coding. Wasting memory because there seems to be plenty available can have future consequences. Software engineers now not only need to think about what goes into the product, but also consider how enhancements will be made in the future.

The flow computer database holds information for configuration and real time results as well as intermediate results and raw data. By creating this RAM area, related information is kept together so every module can access it efficiently, and variable locations do not change between software upgrades. The above discipline and experience distinguishes and elevates product acceptance and performance in the marketplace and goes some way towards explaining why there are fewer suitable flow computer products available to the custody market today.

Flow computer capabilities

Some of the important attributes that should be present when selecting a flow computer today are listed below. These are important for ensuring that the flow computer will suit the requirements of current and emerging standards. These attributes have been recognised as essential in the selection of flow computers by users such as Saudi Aramco, Pemex, Petrobras, ExxonMobil, BP, Shell and Chevron:

- Near real time computation: computational cycles of 500 m/s or less, with continuous process sampling.
- Concurrent computations involving multiple meters run measuring different fluid products.
- Resident algorithms and measurement tables able to correct the flow of crude oils, refined products, LPGs, NGLs, olefins, chemicals and aromatics.
- Resident algorithms and tables to measure natural gas, speciality gases, steam and water condensate.
- Automatic control of a meter prover with the ability to provide API proving reports and meters factor curve storage and maintenance.
- New meter factor validation for flow/viscosity performance curve and against historical meter factor data.
- Ability to flow weight average all relevant measurement input data and computational results based on hourly and daily intervals, and batch transactions. FWAs allow reasonable verification of real time computed results.
- Automatic reporting and data storage for multiple batches, hours and days.
- Handle all security issues: configuration access and totaliser tampering.
- Provide diagnostic functions and displays to aid in the certification of the calculated results process, including viewing inputs from field devices.

There are users who still rely heavily on contractors who provide few specifications to guide the user in system and instrumentation selection. Consequently, improper instruments or obsolete system architectures are installed for custody transfer use.

API calculation procedure

So how does a flow computer implement the current API volume correction standards for crudes and refined products? (Figure 1). There are actually six steps:

- Step 1: With observed product density at flowing conditions (RHOobs), density at standard temperature (60 °F or 15 °C), and flowing pressure (elevated pressure is calculated, using API MPMS Chapter 11.1, Table 23 A /B or 53 A/B algorithm).
- Step 2: With calculated reference density from Step 1 and flowing temperature, the initial compressibility factor F is

calculated (using API MPMS Chapter 11.2.1 algorithm).

- Step 3: Using initial F from Step 2, equilibrium and flowing pressures, the initial pressure correction factor Cpl is calculated (using API MPMS Chapter 12.2 rounding and truncating rules).
- Step 4: The product density at standard temperature and equilibrium pressure is calculated by adjusting the density at standard temperature and flowing pressure obtained at Step 1 by the Cpl factor calculated at Step 3.
- Step 5: Repeat steps 2, 3 and 4 until the change in Cpl factor obtained is less than 0.00005.
- Step 6: Using flowing temperature and product density at standard temperature (RHOb) and equilibrium or base pressure (Pba), the volume correction factor, Ctl, is calculated (using Table 24 A/B or 54 A/B, depending on whether US customary or metric measurement units are in use).

A common meter-run setup.

API physical properties changes

The floating point operations capability in currently available PC processors and flow computers has encouraged the API to rethink how both the temperature and pressure correction algorithms are performed. Work is almost complete on the modernisation and integration of these temperature and pressure algorithms into one combined algorithm that will calculate the overall volume correction factor Ctpl. The revised standard, API MPMS Chapter 11.1, is currently being balloted.

The new implementation uses increased decimal precision and floating point math routines in place of the original implementation procedures using integer maths designed for the low processing capabilities existing in the 1970s and 1980s. The new algorithms provide Ctl, Cpl and Ctpl factors to a consistent five decimal places.

Underlying data, equations and associated constants have not been changed but there are increased density and temperature ranges that accommodate lower temperatures and higher densities. None of the above applies to the 1952 tables that were derived from empirical data developed during the 1930s and 40s.

Due to the widespread use of real time density measurement, temperature and pressure corrections must be performed as one procedure. Because of current microprocessor technology, API is adopting a more advanced convergence methodology than was previously possible. The procedures have been written without rounding, because they are part of an iterative loop and rounding of factors could mean slow or non convergent iterative calculations.

Older flow computer technology embodying 16 bit technology may have difficulty reproducing the factors exactly to a five decimal place resolution in a timely manner. The new standard requires that all calculations be executed using double precision calculations.

EFM and ELM standards

The standard dealing with electronic flow measurement for gas (API MPMS Chapter 21.1) was published in 1993. The standard dealing with liquid measurement (API MPMS Chapter 21.2) was published in 1998. The liquid standard builds on the foundation of API MPMS chapter 21.1, but goes into considerably more detail on issues such as calculations, security, calibration and configuration.

Topics covered:

- Guidelines for selection and use of system components:
  - Primary, secondary and tertiary.
  - Installation and wiring.
  - Instrument calibration periods and procedures.
  - Total system uncertainty.
- Algorithms:
  - Frequency of calculation.
  - Averaging methods.
- Verification of calculated results.
- Integration methods.
- References to physical properties standards.
- Auditing and reporting requirements:
  - The configuration log.
  - The QTR (quantity transaction record).
  - Alarm and error logs.
- Calibration versus verification issues.
- Security:
  - Restricting access.
  - Integrity of logged data.
  - Protecting the algorithms.
  - Memory protection.
- Computer maths hardware and software:
  - Limitations.

The ELM measurement standard explains, for example, how performing a single calculation for a custody transfer transaction compared to multiple real time calculations in a flow computer will yield different quantities. Existing rounding and truncating rules were designed for (API MPMS Chapter 21.2) reproducibility using a one time calculation, regardless of equipment used. Unfortunately the ability to compare a one time result with 'real time' results is impaired when several thousand calculations are performed each hour using the existing rounding rules.

Users can refer to API MPMS Chapter 21.2, section 9.2.12 and Figure 1 for a fuller appreciation of the verification of quantities calculated by real time flow computation devices.

Any 32 bit flow computer should be capable today of providing the necessary security access and algorithm protection that prevent alteration of the measurement or calculation parameters. Although not specified in API MPMS chapter 21.2, the Institute of Petroleum's petroleum measurement manual part XII, section 3 also recognises the need for special diagnostic and self test routines. Custody transfer totals can be stored in redundant RAM areas as registers containing a checksum. This allows for alarm detection of suspect data and permits automatic correction of custody totals when RAM bits are found to be faulty (e.g. corruption due to severe power fluctuations which interrupt processing activity).

Developments and trends

Multiple functions

Consolidation of functions into the tertiary device is increasing.

PID control of flow, back pressure and delivery pressure is becoming more common. Single stream gas flow totalisers are also being replaced by multistream flow computers that interface directly to gas chromatographs, providing direct serial interface to multiple ultrasonic meter types and also providing master meter proving capability using precision gas turbine or master ultrasonic meters.

To cite an example, Transco Gas, UK, upgraded its entire transmission system with over 200 flow computers with the capability to meter any combination of orifice, turbine or ultrasonic meters as well as a direct interface to gas analysers. These multifunction multistream flow computers also operate as their own station controller and database.

Field mounted flow computer with integrated multivariable sensor.

Real time operating software

There is an emerging trend for some process instrumentation manufacturers to make use of PC-based generic real time operating system (RTOS) software as the backbone to their new instrumentation software designs. This trend has occurred due to the need to shorten development cycles and reduce investment costs. These generic operating systems are extremely flexible and have been designed to be useable in just about any type of application.

Advantages of generic RTOS

- Multitasking is the first advantage offered by generic RTOS, enabling the user to operate separate tasks and programs. It is also possible to split up these programs into independantly developed tasks.
- Certain system resources that are otherwise overlooked by programmers are, however, apparent to the system. The system also enables the user to speed up product and software development and improves maintainability.

Disadvantages of generic RTOS:

- Generic third party operating systems are vendor supplied and, therefore, sometimes offer mediocre support.
- Genric design can add overhead when switching task and also when servicing interrupts.
- Troubleshooting RTOS-related problems can sometimes be complicated due to the black box concept.
- In order to optimise performance, the user must have access to and a full understanding of third party source code.

Embedded processor software

It is important to note the differences between the preceding off the shelf RTOS approach and the established use of embedded processor software design. It remains the leading methodology to achieve a secure, efficient processing environment.

There are several reasons for this. Firstly, unlike RTOS, the software is completely interrupt-driven and has no operating system kernel with interrupt latency that is supplied by a third party. Secondly, the code is 100% company generated and field-proven for optimum use. The context switching times in the software code are also optimised for the hardware, with tight integration between hardware and software.

Field mounted flow computers

There is much interest in skid mounted flow computers today. Such computers can provide the dual benefits of reducing system capital costs and more easily guaranteeing system performance by performing FATs (factory acceptance testing) with all instrumentation wired in place.

Systems requiring separate control room facilities to house flow computers usually have to be disconnected from the metering skid after the FAT, ready for shipment to the customer. This introduces an added uncertainty, 'Will the equipment be correctly re-connected at the customer's site?'

Serial data link connectivity between field mounted computers will be needed to transfer data and commands that provide an integrated station function on larger multirun metering systems. A remote display may be needed when a field mounted computer is mounted in an inaccessible location.

With the advent of serial based meters such as ultrasonic and mass meters, skid mounted flow computers adjacent to the meter's secondary electronics on the same spool piece provide for simplified connectivity and minimal wiring between the metering skid and the host supervisory system. Another challenge for field installed flow computers being used in custody measurement is their performance under a wide range of temperature conditions and tolerance to extreme electrical effects. For this reason, OIML (International Organisation for Legal Metrology) and European Norms are currently the best guidelines that users have for ensuring that products are certified to acceptable levels of performance in the absence of extensive tests conducted by knowledgeable, accredited users.

Internet applications

Major pipeline systems in the US are now looking at the Internet for connectivity solutions that can simplify the hierarchy of MIS/SCADA/leak detection/tank farm/metering systems and minimise their exposure to obsolescence. TCP/IP connectivity is fast becoming accepted and products now exist that preserve modbus-based communications wrapped in TCP/IP high-speed connections.

Windows-based interfaces

Configuration programs have proliferated as notebook computers and have emerged as a standard field technician tool.

Programs now exist for the retrieval of archive data and export to a Windows based spreadsheet (an auditing and calculation checking software incorporating the multiple measurement calculation standards, metric or customary US units. The need for extensive training of measurement technicians to ensure proficiency in these new disciplines is self evident.

This is best exemplified by Windows-based control system supervisory software that is OPC compliant and common in process control systems. Although graphically appealing and user friendly, uncertainties exist due to integrators who may lack in-depth knowledge of the custody application and the communications and data handling capabilities required for metering systems.

New metering technologies

The average user can expect to confront new meter devices using serial digital/numeric data streams with relatively little technical guidance. Today, it is an advantage, in the absence of functional electrical/microprocessor standards, to have intimate knowledge of processor architecture and of the technical specifications of individual manufacturers' sources

Digital or periodic numeric communication (from ultrasonic and mass meters), is replacing conventional instantaneous pulse based data acquisition from meters. Issues such as band width, baud rate, cross talk, signal integrity principles including transmission line properties, and connections are frequently not fully understood.

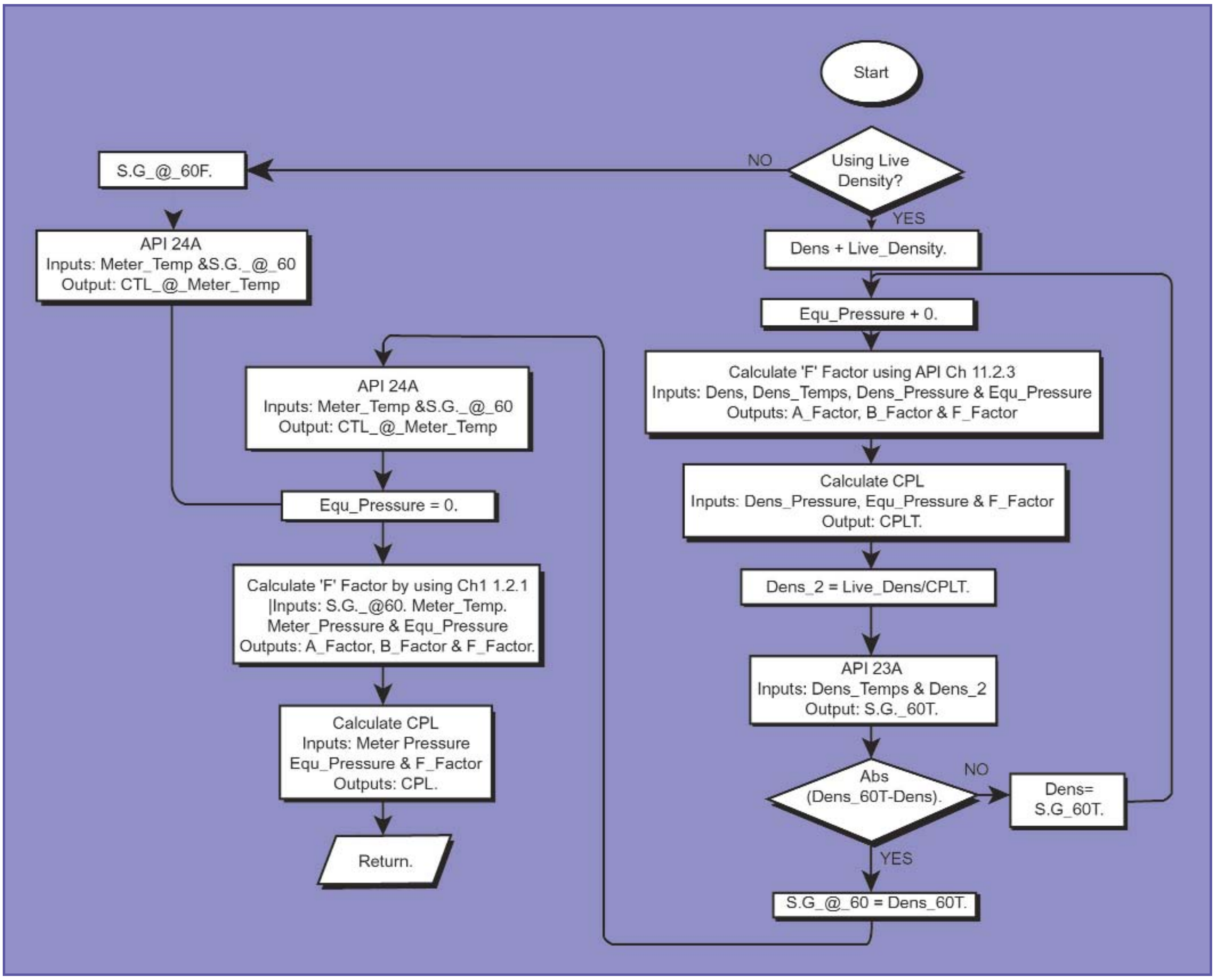

Figure 1. Calculating Ctl and Cpl factors using API 23A/24A and Chapter 11.2.1

Table 1. Tests performed by certification laboratories

Line number	Focus area	Description of test	Reference to standard	GAS-Volume electronics - prEN 12405	OIML measuring systems for liquids - R117	CE EMI/EMC
1	Accuracy	Accuracy tests under reference conditions		A.2		
2	Effect on accuracy	Dry heat, outdoor/indoor (effect of dry heat)	IEC68-2-2	A.3	A.1.4.1	
3	Effect on accuracy	Cold, outdoor/indoor (effect of cold)	IEC68-2-1	A.4	A.1.4.2	
4	Effect on accuracy	Damp heat, outdoor/indoor (effect of damp heat, steady state test)	IEC68-2-3	A.5	A.1.4.3	
5	Effect on accuracy	Damp heat, outdoor/indoor (effect of damp heat, cyclic test)	IEC68-2-30	A.6	A.1.4.3	
6	Electromagnetic compatibility and effect on accuracy	Power voltage variation (electrical power variation -	IEC1000-3-2 AC power)	A.7	A.1.4.5	EN61000-3-2
7	Electromagnetic compatibility	(Electrical power variation - DC powered instrument range test - 16 - 30 VDC	IEC801-4	A.7	A.1.4.10	
8	Electromagnetic compatibility and effect on accuracy	Short time power reduction 0-120 VAC		A.8	A.1.4.6	
9	Electromagnetic compatibility and effect on accuracy	Electrical fast transient burst - DC/AC power ports	IEC801-4	A.9	A.1.4.7	X
10	Electromagnetic compatibility and effect on accuracy	Electromagnetic compatibility/susceptibility/immunity - 26 - 1000 MHs	IEC801-3 IEC801-6		A.10	A.1.4.9 X
11	Electromagnetic compatibility and effect on accuracy	Electrostatic discharge - surface test	IEC801-2	A.11	A.1.4.8	EN50082-3 EN61000-4-2
12	Effect on accuracy	Effect of an overload of pressure		A.12		
13	Effect on accuracy	Mechanical resistance to overload of pressure		A.13		
14	Effect on accuracy	Vibration	IEC-68-2-36	A.14	A.1.4.4	
15	Effect on accuracy	Effects of shocks		A.15		

(continued…)

It is obvious that use of these communications based technologies should be validated under a range of controlled parameters that best represent typical field conditions. The main objective must be to maintain the integrity of the custody measurement data received from the primary measurement device.

This is not to reject the technologies involved. Users should stay abreast of technological developments, experiment where possible, and adopt when the results will drive the value decision. Current technologies still have value.

Measurement fidelity

Error checking, as originally envisioned by API MPMS Chapter 5.5, risks being relegated to a reliance on secondary devices that, in a variety of operating conditions and electrical influences, may not accurately represent the primary signal. At a secondary level, numeric representations of the measurement value could impact the measured results in readouts. However, flow computers implement CRC (cyclic redundancy check) error checking and other checking methods to ensure that data messages to and from other connected devices are not corrupted. Security, configuration settings, alarming, data logging and audit issues are central to weights and measures/excise approvals and sometimes take their cue from API & IP standards.

It remains best practice for the tertiary device to use the instantaneous flow rate value to calculate and totalise the flow. This forms the basis for the totaliser integration within the electronics of these new metering systems. Data transfer is preferably accomplished through serial data transmission. This is particularly relevant in the case of gas ultrasonic meters.

By complementing the serial data with the use of the manufactured pulse output train, which is not identical to a turbine or densitometer-generated pulse train, the user can obtain some pseudo-compliance with the data security issues commonly associated with API manual of petroleum measurement standards (MPMS) chapter 5.5 regarding signal security, and API MPMS chapters 21.1 and 21.2 respectively, regarding gas and liquid electronic metering systems.

Some of the new electronic meters provide totalisers, but these can be difficult to use unless they are provided in a numeric format that increments and rolls over predictably.

The tertiary computing device can compare the totaliser values received between successive serial transmissions, but even this can prove to be difficult because of totaliser rollover and resolution problems in some digital flow meters, and the impracticability of synchronising the reading of successive totaliser readings with the calculation cycle of the tertiary host calculating device.

Metrological testing

The majority of measurement products from the US are not exposed to international metrological and electrical norms, a number of which are European inspired such as OIML R117 for liquids, EN 12405 for gases or EN

(Table 1. continued…)

16	Accuracy	Durability		A.16		
17	Accuracy	Test - accuracy tests, reading, volume deviation, and zero setting			A.3.2.1.1 and 3.2.1.4, A.3.2.4	
18	Accuracy	Test - the behaviour of the flow computer after a power down situation occurred			A.4.2	
19	Accuracy	Test - the behaviour of the flow computer; if differences between the two impulse channel occur			A.4.3.2	
20	Accuracy	Test - the connection between a 4 - 20 mA sensor and the flow computer			A.4.3.6	
21	Accuracy	Test - the connection between a 4-wire temperature sensor Pt100 and the flow computer			A.4.3.6	
22	Accuracy	Test - the connection between a densitometer (Hs) and the flow computer			A.4.3.6	
23	Accuracy	Test - the conversion calculations during batches, with different temperatures and densities			Chapter 3.7	
24	Accuracy	Test - the conversion from actual density to reference density for liquids; API Tables 53 and 54			Chapter 3.7	
25	Accuracy	Test - the indication of a pressure sensor, communicating by means of a 4-20 mA signal			A.2.7.2	
26	Accuracy	Test - the temperature indication, when using a Pt100 temperature sensor within a preset range			A.2.7.2	
27	Electromagnetic compatibility	Conducted emission				EN50081-2 EN55011
28	Electromagnetic compatibility	Radiated emission				EN50081-2 EN5501129
29	Electromagnetic compatibility	Harmonic current emissions	IEC1000-3-2			EN61000-3-2 A.1.4.5
30	Electromagnetic compatibility	Voltage fluctuation/flicker	IEC1000-3-2			EN61000-3-3 A.1.4.5
31	Electromagnetic compatibility	Conducted immunity				EN50082-2 ENV50141
32	Electromagnetic compatibility	Electrical fast transients				EN50082-2 EN61000-4-4 A.1.4.7
33	Safety	Low voltage directive (LVD) - CB scheme report and certificate (US - UL1950; Europe - EN60950; Canada CSA 22.2 #950; International IEC-950)	IEC 950			

50081/2 for EMI/EMC. Those leading manufacturers who seek to obtain a significant installed base overseas or compete with European-based competitors have already recognised their value. Table 1 shows how there is considerable similarity in some areas of testing, many of which are derived from IEC standards.

It has been the experience of the authors that significant benefit is derived from considering such standards in the design and testing of instrumentation. They provide a safeguard for users by establishing minimum requirements of performance and indicate a commitment to quality by the manufacturer. It requires an investment both in quality test equipment and support from certified testing laboratories. Users would need to invest significantly if they intended to prove up electronic performance across the ranges set out by the international standards.

EMI and EMC

Selecting suitable electronic instruments with good EMI/EMC performance can be a challenge. Table 1 can again be referenced for testing procedures for CE approvals. But bringing them all together in a measurement and control 'system' that has good EMI/EMC performance is even more difficult for many engineers. Questions such as 'why does my totaliser increment a couple of barrels when the pump starts up?' or 'why does the displayed flowing temperature change when I talk on my handheld radio?' should cause the system designer to re-evaluate the EMI/EMC performance of the total system, including components, wiring and shielding, and to set proper operating procedures for the metering system.

Manufacturers of electronic equipment can take reasonable steps to minimise, but cannot eliminate, the exposure of the system to disturbances, such as lightning events and switching surges, or to operational practices, such as permitting high wattage radios generating RF interference in close proximity to critical measurement devices. A CE certification is the minimum that manufacturers should provide.

It is assumed that system integration engineers are sufficiently knowledgeable in the system grounding and shielding techniques required to correctly link the components together. Through the appropriate use of grounding and shielding planes, separation of analogue and digital signals, and modular circuitry, an instrument manufacturer can provide a number of extra benefits to the user. Users' instrument engineers are encouraged to review the design and testing associated with EMI/EMC.

In older measurement systems, little attention was paid to EMI/EMC. Consequently, operational difficulties were frequently experienced.

Conclusion

Industry consolidations will continue to impact on the world of measurement. There will be less choice available to users, despite some user preferences. Electronics technology developments in signal processing, microprocessor, memory and communication will continue to challenge and provide opportunities for instrumentation

Installation of flow computers communicating to a PLC sysytem within a control room environment.

manufacturers, and the metrological testing and approvals agencies who regulate them, in areas such as measurement integrity.

Measurement and electronic standards are constantly being revised in continuing efforts to reduce uncertainty and improve system performance. Calculation standards are becoming more exact and require additional processing power. Electronic integrity also becomes even more of an issue, due to flow computers becoming multitasking operational devices with many embedded control, calibration, security and data logging functions. This only elevates their importance.

Users must assure themselves that they have the necessary expertise in an increasingly technological environment. A sound understanding of the software for new products will always be preferred. It should be essential that proper testing, combined with metrological and electrical certification be executed before a product is permitted into field use beyond user trials.

Fieldbus and other technologies that may supersede it appear to offer many benefits for network connectivity in new projects; for example, the flow computer may well emerge as a network node, processing all metering and valve data and diagnostics and then passing on to central host systems. This could encourage more products into a field environment including flow computers.

Measurement data can still only be deduced, defined and proven at a metering system level that incorporates proposed combinations of primary, secondary and tertiary devices. It is probable that complex simulation equipment shall be made available by typical users to emulate real life electrical disturbances when using electronic-based systems. Current testing methodologies employed to validate the metrological results may not always make practical sense to some users but still provide a good guide to nominal environmental and measurement perfomance. All these changing standards are the continuing challenge for designers and users of metering instrumentation.