ABB
Review

The corporate technical journal
of the ABB Group

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Special Report
Instrumentation & Analytics

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To improve productivity – measuring is essential

Only what is measured can be improved. In everyday life, in sports and of course in business, fast and correct measurements form the basis for decision making. Accurate, stable and reliable data provided by instruments are also the foundation for control that results in higher productivity with better quality at lower cost.

The wish to measure and quantify has existed most probably from the beginning of mankind. Hundreds of years ago the first devices to quantify physical variables were developed and used. Simple Venturi flow meters were common even in Roman times, the first thermometer was created by Galileo around 1590, and the Turbine flow meter was invented in 1790.

ABB has a heritage of more than 150 years in the field of instrumentation. Many world-leading companies, eg Hartmann & Braun, Elsag Bailey, Kent, Taylor Instruments, Fisher & Porter, Sensycon and Tieghi, to mention but a few of the most prestigious names, now comprise ABB Instrumentation. Within these 150 years numerous products have been invented and developed.

In 1851, two young Americans started a thermometer manufacturing business in one room over a drug store in Rochester, New York State. One of them – George Taylor – joined his brother and a cousin in 1872 to form Taylor Brothers, one of the enterprises now consolidated in ABB. In 1901, the first standard water meter was patented by George Kent, another predecessor company based in London, UK. In 1909, this company manufactured the first steam meter, and a few years later, in 1914, it introduced the first Venturi gas meter to the market. Over the past decade, the field of Industrial Instrumentation and Analytics has undergone a consolidation process, which will continue for a while. ABB is determined to play a leading role in this process.

Instrumentation market requirements

Industrial instrumentation is not a single unified market nor is it a single application. It is a conglomeration of numerous and fragmented applications in a multitude of market segments. These segments cover areas from measuring and analyzing the composition of pure drinking water to dirty waste water. And ranging from measuring production gas in sub-sea applications to the analysis of various process gases in chemical, pharmaceuticals, food and beverage industries including combustion gas analysis in power stations. ABB offers a wide range of word-class products and measurement solutions for these critical tasks. In this special issue of ABB Review these measurement technologies and their applications will be described in some detail.

Each of these applications raises a variety of challenging problems and requirements. A prerequisite to solving such challenges is a portfolio of standardized products each with a rich set of variations to match the demands of the customers. Material, size, explosion-proof or not, environmental and safety features are but a few parameters that, in combination, create a plethora of product variations. To select the right combination for a particular application requires experience and long-term development. ABB's broad product offering, long time global experience and application know-how provide added value to its customers.

With a global customer base, ABB needs to offer consistent and reliable services of equal standard and quality throughout the world. This means local support provided in local languages to customer sites everywhere. The company's service efforts focus on the avoidance of unplanned stops of plant production. Such shut downs are extremely costly, running into thousands or even millions of dollars in lost revenue. With its presence in more than 100 countries ABB is very well positioned to keep production lines operating.

Today's global market for Instrumentation and Analytics enjoys a healthy and stable growth rate. New plant construction is driven by the emerging markets in China, India, Asia, Middle East, and South and Central America. Additional new technology developments (eg increased implementation of fieldbus technology) and increasing regulations (mainly to improve plant safety and environmental performance, and energy saving measures) are also contributing to growth in the industrial countries of the world. For the next few years, several indicators point to further positive development:

- Emerging markets continue to grow strongly
- Robust energy markets
- High energy prices lead to investments in new energy sources
- Investments to improve productivity of existing plants

Advent of intelligent field devices

After years of slow development, fieldbus technology is finally established, utilizing the data provided by intelligent field devices such as instrumentation, drives, motor control centers, breakers, switchgear, and robots. This way new opportunities to improve plant performance through monitoring, analyzing and optimizing are given to the manufacturer. High on his wish list is predictive and advisory diagnostics to prevent failures or unplanned downtime. Today's intelligent devices deliver a wide range of data and information. These capabilities are significantly improving plant productivity, availability and reliability.

Advancements in health, safety and environmental regulations

Improved health, safety and security standards are emerging in all parts of the world. ABB is committed to developing products and solutions to assist customers to operate within these regulations and to create a safe industrial environment for their employees. Recent accidents, terrorist attacks and the activities of computer hackers have considerably raised the public awareness of security shortcomings.

To achieve a sustainable environment, significant investments to improve energy efficiency and to minimize pollution of air and water resources are necessary and under way.

Technology trends

Last but not least, some words about future developments and technology trends. More effective use and management of assets will be the central topic and high on the agenda of all manufacturers. Increased use of wireless networks will play a key role in the coming years. Remote monitoring and diagnostics will be the first application – removing distance issues and the particular problems of lonely islands. A combination of several emerging technology trends is enabling the development of wireless networks – low-power sensors, radio and battery technologies, new communication protocols and software are the most important. PDA's will take over communication tasks, calibration, diagnostics, preventive maintenance etc. Better utilization of existing data, together with lower installed costs from reduced wiring and installation time, will be the result. This technology will also support more agile production lines that will emerge to match the demand for custom-made products.

Increased safety features will be a second important area for development. Systems instrumented for safety will have an increasing role to play in fulfilling the customers' efforts to prevent hazardous situations from arising and to avoid plant accidents.

A third area of importance is keeping the devices easy to use.

Cost cutting efforts very often result in the downsizing of engineering and technical staff. Increasingly therefore, the latest sophisticated products need to be very simple to install and operate.

Welcome to the world of Instrumentation!

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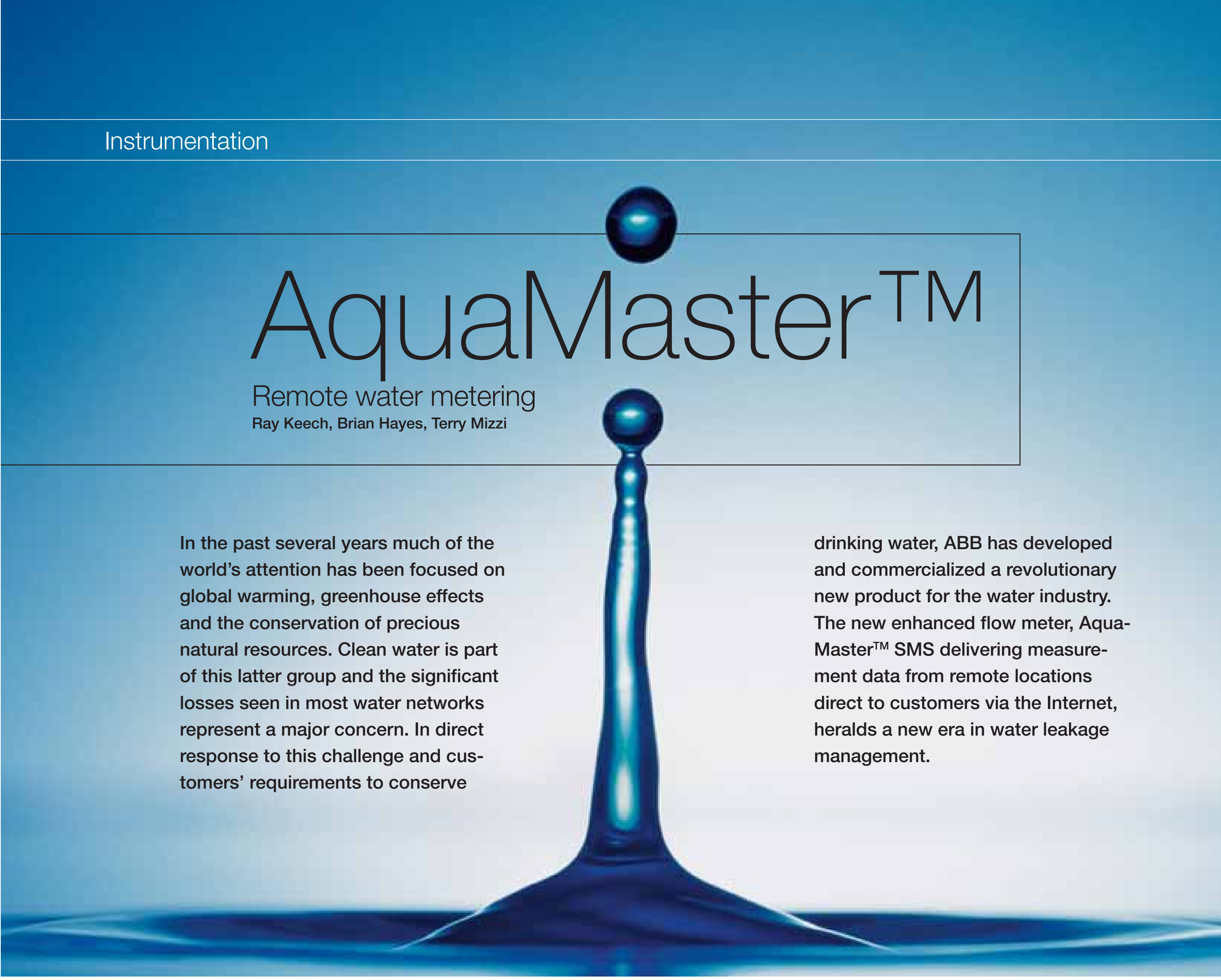


AquaMaster™

Remote water metering

Ray Keech, Brian Hayes, Terry Mizzi

In the past several years much of the world's attention has been focused on global warming, greenhouse effects and the conservation of precious natural resources. Clean water is part of this latter group and the significant losses seen in most water networks represent a major concern. In direct response to this challenge and customers' requirements to conserve drinking water, ABB has developed and commercialized a revolutionary new product for the water industry. The new enhanced flow meter, AquaMaster™ SMS delivering measurement data from remote locations direct to customers via the Internet, heralds a new era in water leakage management.

The AquaMaster™ is a product that is on the cutting edge of technology with features and applications that are unique within the water conservation and distribution market.

This article traces the history of specific applications, their features and successes that have driven the development of the latest generation of metering devices. It describes their place in today's modern water distribution and revenue collection potable water systems.

ABB introduced the AquaMaster™ flowmeter in 1999. It has since come a long way from its basic idea of applying electromagnetic technology to a market dominated by mechanical flow meters. Prior to its introduction, water companies only used electromagnetic devices on large pipe diameter applications such as district mains. The idea of applying the same approach to revenue collecting applications was new. AquaMaster™ sales volume has grown from 0 units back in 1998 to many thousands in 2005. Now, in 2006, customers expect more from a flowmeter than just flowrate measurement. ABB realized that customers were not interested in the instrument itself, but in the flowrate data, delivered to them as part of their management information system. The new AquaMaster™ SMS, a member of the AquaMaster™ family of meters, fulfils these demands.

AquaMaster™ – a growing family

AquaMaster™

The battery-powered electromagnetic meter, the AquaMaster™, established a new level of performance as compared to mechanical meters. Water companies have been making do with an accuracy of ± 2 percent. By using an ABB AquaMaster™ electromagnetic meter with an accuracy of ± 0.5 percent for pipe sizes above DN100, the meter pays for itself in less than a month, simply by measuring and charging the water more accurately. For example, exchanging a mechanical DN150 flowmeter, accurate to within ± 2 percent, for an AquaMaster™ would save the operator around US$ 4,730 of revenue. As a consequence, many customers are switching to AquaMaster™ as the flowmeter of choice, even in sizes as small as DN40.

Further savings and increased revenue come from the maximum and minimum flow rates, or operating range, of an electromagnetic meter compared with that of a mechanical meter. Its unique low flow rate capability enables previously unrecordable minimal night flow rates to be properly metered, which would double the saving potential to US$ 9,000 per annum.

In addition to the headline improvement in accuracy, AquaMaster™ has many other benefits, which are inherent in electromagnetic measurement technologies such as:

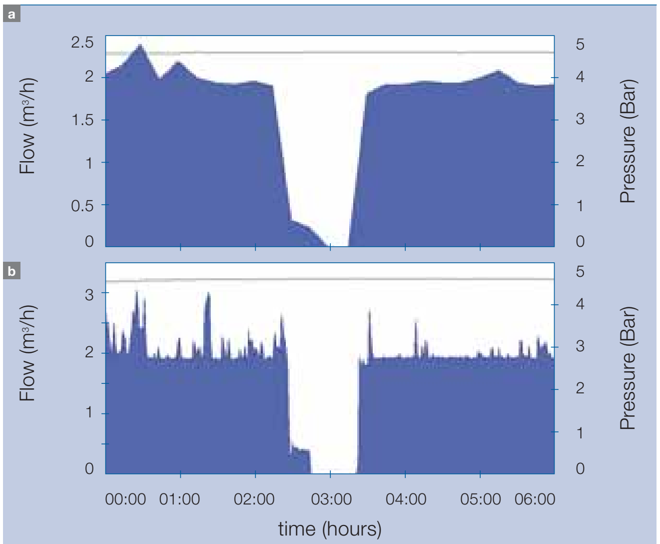
- Absence of moving parts eliminates the need for routine maintenance.
- Lower installation costs because the end user does not need valves to isolate the meter during maintenance and replacement. The possibility of being submerged in water or buried under a busy road without chambers further reduces whole life cost.
- The lack of moving parts also means that the accuracy of electromagnetic flow readings will not deteriorate through wear, whereas a mechanical meter's accuracy will deteriorate with age resulting in under-reading.
- An extremely high turndown ratio is needed to ensure that readings will be accurate at both high and low flows. Today's AquaMaster™ meters boast an ISO-certified and Measuring Instruments Directive compliant turndown ratio of 1000:1!
- A novel hydraulic contour of the meter also makes it far less sensitive to hydraulic disturbances up- or downstream, even if the meter is positioned, for instance, near a bend or a valve.

AquaMaster™ S

A variant of the AquaMaster™ family offers a range of options attractive to the end user depending on his particular needs. Flow measurement is often accompanied by other equipment, such as pressure sensors, and the next obvious step was to integrate pressure sensing as an option.

Data logging is another common requirement, so the AquaMaster™ family offers an option of logging the flow-rate and pressure every 15 minutes. By virtue of the digital connection between the flow measurement and the data logger, high resolution data can be logged at a rate not possible with traditional solutions. This is much more significant than it first appears. With a traditional external data logger solution, pulses are captured over the logging interval, but due to upper frequency limitations by the flowmeter only a limited number of pulses can be counted in the log interval. So for a meter with a large turndown ratio, it is not uncommon to get measurement or "quantization" errors of around 10 percent or more, the data being very stepped or "quantised" as a consequence. AquaMaster™, with its direct digital connection to the data logger, reduces quantisation associated errors to insignificant levels. In addition, AquaMaster™ offers in a second channel high speed, high resolution logging at an interval of up to 15 seconds. This is invaluable for capturing transients during network step testing. Within water networks, step testing is a well established technique for localizing water loss in a zoned distribution system. It requires the establishment of zones where water can be supplied through a single meter after all boundaries and circulation valves have been closed. Closure of a valve isolates a specific section of the zone. A large drop in flow indicates a leak within that section.

1 Leak Detection: Step testing – 15 min a and 1 min b data logging



2 AquaMaster™ SMS Transmitter

The benefit of AquaMaster™ S in such step testing is best illustrated by comparison of 1a, on a traditional 15 minute log interval with 1b, captured in great detail from the second channel one minute log.

In this step test, one zone valve was closed at 02:30, with a further zone valve closed at around 02:40. From the one minute log, the zone with a significant leak was clearly identifiable from the sudden drop in flow, with a second smaller leak within the second zone. The magnitude of the leak in the two zones is significant, at around 2 m^3/hr.

Step testing with AquaMaster™ is far simpler, cheaper and faster than established practises. It no longer requires a skilled technician with an external step-test data logger. All that is necessary is a simple procedure and a person to close a valve at specific pre-agreed times. Also, any disruption to water consumers is minimised by restricting the time a valve needs to be closed to only a few minutes. Within the following week, the high resolution logger can be downloaded and analysed to identify the source of the water leak. This step testing process is significantly enhanced by the use of radio communication to obtain meter data, which leads to ABB's latest enhancement, AquaMaster™ SMS.

AquaMaster™ SMS

Traditionally, data is logged externally from the flow measurement and recovered manually by sending someone on site to download the data, or sometimes by retrieving the entire data logger and exchanging it with a second one. More recently, customers have switched to using radio for meter reading.

ABB's new innovation is to equip AquaMaster™ S meters with the option of GSM SMS radio technology 2 . This product was initially released in late 2003 using GSM dial-up based technology. In 2005 this feature was upgraded to use SMS text messaging to convey flow and pressure data.

SMS text messages are automatically sent, typically once per day to conserve power in the case of a battery powered AquaMaster™. In the event of a fault, an SMS message is sent as an alarm, eg if the meter is being tampered with.

The AquaMaster™ also responds to SMS text messages sent to it, such as configuration changes or requests for specific data. Up to three months of data can be stored internally.

Delivering measurement data to the customer

Measuring and logging the flow and optionally pressure are only part of the equation. Getting the collected data onto the customer's computer, management information or leakage management system is the other part. Discussions with key global customers showed that they could be partitioned into 2 groups with different requirements:

1) Customers with an existing infrastructure and established water management system.
2) Greenfield customers who have measurement requirements but no back office system to handle the measured data.

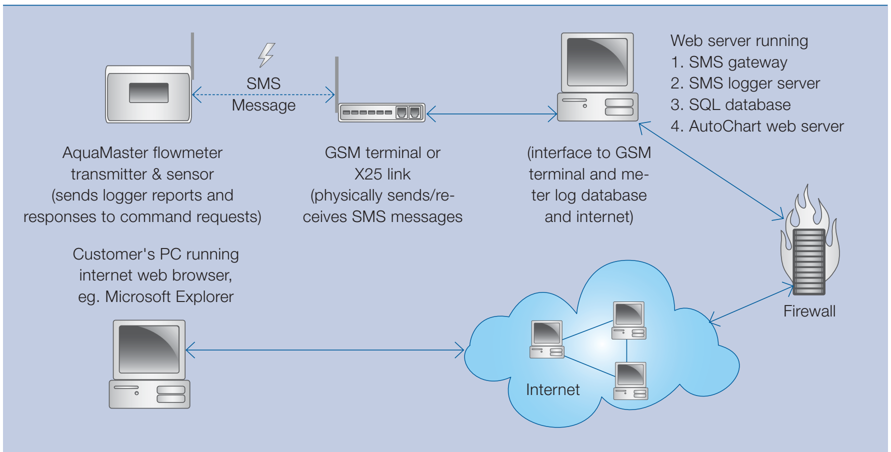
One of the key design objectives was to make the system as easy as possible to configure.

To address both customer needs, ABB devised a solution based on delivering remote meter data via SMS text messages to virtually any database, using industry-standard programming mechanisms. The SMS Logger Server delivers the data seamlessly to databases such as Oracle, SQL Server, MS Access, solving the data delivery issue for group 1. For customers belonging to group 2, two options exist:

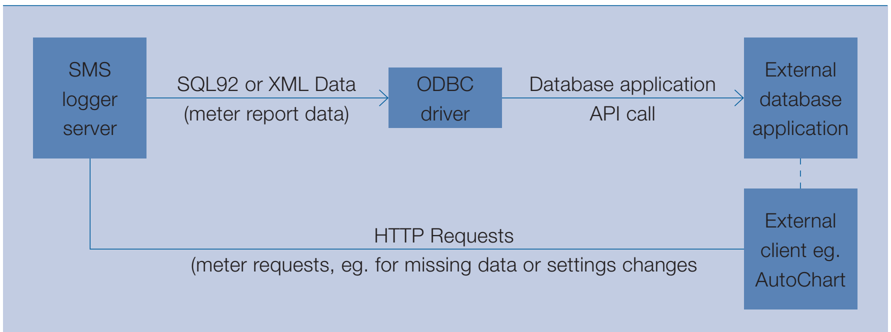
- Install any supported database, and use the SMS Logger Server software from ABB, combined with third party software, to manage and display the flow data.
- Use the same setup as in above, but use a web server to deliver the data via the Internet. An example of such a server application is AutoChart™ from I+P Services, UK.

Processing SMS data sent from an AquaMaster™ with Internet access is best illustrated by reference to 3. SMS data is received, either on an SMS engine connected to a PC via an ABB-provided SMS Gateway, or alternatively, for high numbers of meters, an X25 link direct from the SMS service provider.

3 Internet delivery of AquaMaster™ data



4 AquaMaster™ SMS Data handling



Encryption

In some applications security of information is critical. To protect the data from eavesdroppers, AquaMaster™ SMS encodes the flow data with a two key encryption system. The encryption algorithm, based on a well know public domain technique, is currently believed to be uncrackable. Every AquaMaster™ in the world has a unique, hash encoded, service password, which changes every time it is used, protecting the first security key. Received SMS logger data messages are deciphered by a Windows DLL provided by ABB. The second key for unscrambling the coded message is produced by the secure ABB SMS Logger Server application. With this two-key encryption procedure the customers can have total confidence in the security of the data delivered by their AquaMasterTM SMS flowmeters.

Database population

Processing of the SMS data by ABB Server application is best illustrated by reference to 4. The ABB application handles all incoming and outgoing AquaMaster™ SMS messages and delivers the data to a database. To make the system as universal as possible it uses industry-standard SQL 92 database queries supported by virtually all existing databases. For newer, platform-independent databases, ABB Server supports an XML-based scheme. Connection to the database uses industry-standard Open Database Connectivity (ODBC). Queries from the customer client to the flow meters use HTTP requests. This makes it simple to setup and deliver AquaMaster™ data to virtually any database. All ABB applications are based on .NET technology and will work on Microsoft Windows 2000 onwards.

Auto configuration

One of the key design objectives was to make the system as easy as possible to configure. Taking this to the ultimate, the designers achieved a self-configuring implementation, where any number of AquaMaster™ SMS flowmeters can be connected with zero setup effort of the ABB SMS Logger Server application. All a customer is required to do is to enter the phone number of the server into the AquaMaster™ SMS flowmeter located in the field. A daily data set will then automatically be delivered from it. On larger scale systems with thousands of AquaMasters™ this has immediate time and cost saving benefits.

Measurement data via Internet

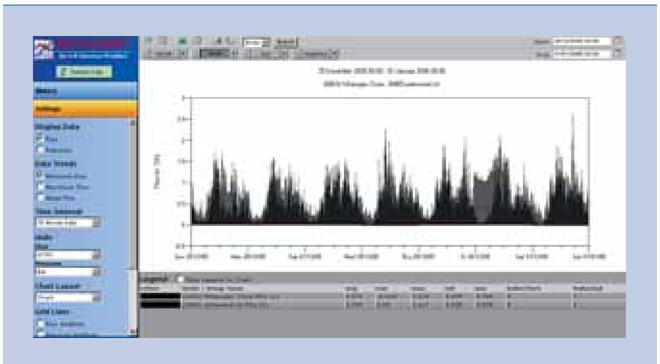
This section illustrates a case study, in which real data was delivered via Internet to a customer A. AutoChart™ with an SQL server database was used in this solution, combined with the ABB SMS Logger Server application. Being Internet-based, the information is made available worldwide to any registered user. No proprietary software is required on the customer's PC, just a web browser and an Internet connection.

AutoChart™ delivers information on the customers' AquaMaster™ flow meters, either singly or as a group, with data available in an easy-to-use graphical or tabular presentation format. An example of a typical diurnal pattern for two meters is shown in 5. The interest of the customer is focused on the sudden increase in consumption on Friday 30th December, compared with other daily profiles.

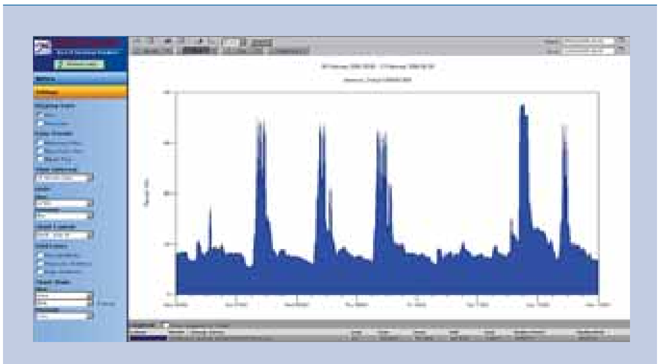
With Internet access it is possible, not only for the water utility to see the consumption profiles and revenue information, but if enabled, the same data may be accessed by the consumer. Such a strategy opens up major possibilities for management of water usage and detection of leaks. For instance, one user recently identified an abnormal usage of water that was caused by continuous automatic flushing of urinals. By fitting simple motion detectors for controlling the flushing, the water consumption was reduced by over 30 percent. A similar example metering a hotel water-feed is shown in 6 .

AquaMaster™ SMS is also unique in that the volume totals from the instrument index register are also sent by SMS text message. In AutoChart™, these are displayed with the profile information and can also be displayed as daily consumption, as shown in 7 . In effect, by combining AquaMaster™ SMS with AutoChart™ ABB is now able to offer customers the electronic equivalent of a human meter-reader visiting the flowmeter every day to note the totalizer reading on the display – but automatically and over the Internet.

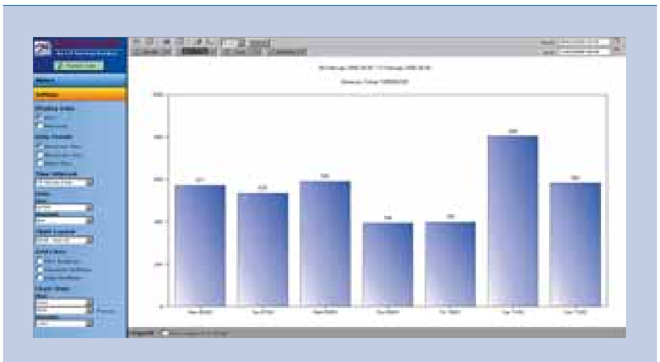
5 Profile from a pair of AquaMaster™ flowmeters



6 Hotel water-feed in Qatar – flow consumption profile



7 Hotel water-feed – daily totals



The challenge

When the first AquaMaster™ meters hit the market in 1999, they were totally unique. Now, some seven years later, ABB has raised the barrier in providing a total measurement data delivery solution for remote metering for both existing customer information systems and for new Internet-based delivery for greenfield installations.

But staying ahead of the competition for the next few years will mean listening to customer requirements and continuing the vigorous process of innovation that has already brought the AquaMaster™ family this far.

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Charting trends

Videographic recorder sets new trends in charting

Geoff Selley

The chart recorder industry is at a critical turning point in its history. Paperless technologies such as data acquisition systems and videographic recorders are challenging the existing paradigm of data collection. The mission-capable videographic recorder can capture and display process data, then save it in an electronic record that can be ported to a PC environment. Pertinent batch information can be saved in a single, secure data file that can be archived and recalled on demand. Paper chart recorders simply can't compete, in terms of accuracy, efficiency and security.

Videographic recorders offer markedly reduced cost of ownership. The solid-state construction of these devices means there are no mechanical components that need monitoring or maintenance. There is also no need for additional costs, such as replenishing charts and pens, which can add significantly to the cost of a paper chart recorder through its operational lifetime.

Apart from its traditional customer base within the Process industry sector, videographic technology is likely to be increasingly used in the Original Equipment Manufacturer (OEM) sector and in the natural gas and petrochemical industries as well as in the laboratory market segment.

The SM500F – standing out from the crowd

In January 2005, a project aiming to raise videographic technology to a new level was initiated at ABB. The experience gained with the existing Screenmaster range of videographic recorders provided the foundation for the SM500F project.

While instrument manufacturers in recent years have largely focused on adding more "bells and whistles", most recording applications still require only basic monitoring of up to four process inputs.

Manufacturers of videographic recorders are largely addressing a range of basic temperature, pressure and humidity monitoring requirements for example in cold storages or warehouses, effluent monitoring and heat treatment applications – by heavily discounting their mid-range products. The goal of this project was not to offer another cut-price device, but to create a dedicated, competitive product that aggressively addresses this key market segment by exceeding the functionalities of traditional paper recorders, as well as other electronic data logging systems.

Videographic recorders and indicators are traditionally panel mounted. Sometimes, however, a panel is not available close to the process being monitored – the place where an operator most needs the information. The first objective was to produce a rugged and slim-line field mountable recorder, thereby eliminating the considerable cost of field mounting a traditional recorder, while still offering the option of panel mounting.

The second objective was to develop an advanced common Human Machine Interface (HMI) component for reuse across ABB Instrumentation's range of products. This is compatible with customer expectations of increasingly sophisticated HMIs, providing clearer and greater information and control. A versatile HMI provides a potential edge in the market. As the sophistication level of the HMI rises, so does the development effort required to produce and maintain such functionality. A common advanced HMI provides a cost effective solution, if designed to be customized for use as a dedicated user interface for many different instruments. It brings all the advantages of commonality, not just to design, but also to customers, sales, support and service personnel, who have a common interface to learn and work with.

While instrument manufacturers in recent years have largely focused on adding more "bells and whistles", most recording applications still require only basic monitoring of up to four process inputs.

Creative problem solving

To meet project objectives it was necessary to achieve a significant cost reduction from established videographic products.

The first step entailed a rigorous appraisal of the product specification and functionality. This meant determining what was really important to the end customer; re-evaluating each existing and new feature for customer value versus cost; and ensuring that design attention and component costs were focused on providing high quality core functionality and not secondary "nice to have" functionality. To achieve cost targets, new suppliers of major components and assemblies were identified in China and South East Asia. The considerable saving in tooling costs and the purchase of component parts could be passed on to the customer through a markedly lower purchase price.

To meet the project objective of creating a device that can easily be wall 1a, pipe 1b or panel mounted, a unique, compact housing was required. The overall depth of the product had to be reduced from the industry norm of over 200 mm, to less than 85 mm 2. The housing for the main processing and data storage electronics had to be completely enclosed and protected to meet the demanding NEMA 4X/IP66[1] standard 3. To achieve this, the traditional inner chassis was replaced by a

Footnote

[1] The NEMA (National Electrical Manufacturers Association) 4X standard specifies that an enclosure must provide a degree of protection against corrosion, windborne dust, rain, splashing water, hose-directed water and formation of ice, but not necessarily against internal condensation and ice formation. The IP66 (ingress protection) standard uses two digits to describe the protection level. The first digit relates to solid objects (6: must resist ingress of dust) and the second to liquids (6: water from jets may not enter the enclosure in harmful quantities).

1 Whereas most traditional devices are only designed for panel mounts, the SM500F mounting variants include wall a and pipe b

robust hinged door, capable of withstanding heavy industrial use. Additional design elements include rotatable flanges that allow different mounting mechanisms for the standard product 1, and panel clamps with a special feature to prevent overcompression of the panel seal.

Traditional knock-outs for cable gland entries that are often difficult and time consuming to use have been replaced with pre-molded holes and water-tight hole-plugs. Specialized mouldings allow the door to be opened more than 180 degrees affording easy access for wiring and field upgrading 4.

Creating an analog input measurement that remains very stable over time potentially reduces the cost of ownership by eliminating the need for annual re-calibration of the device.

A sensitive, yet stable measurement system

One of the most important aspects in the design requirements of a videographic recorder is its ability to measure a range of signal types. Unlike many other instrumentation devices, the inputs are not dedicated to one type of sensor, but need to be able to cope with inputs from a number of transducers, eg sensors/transmitters for pressure, level, temperature, flow or humidity. This means the dynamic range of the recorder's measurement system needs to be able to cope with signals ranging from a few microvolts to 50 volts.

2 The small dimensions mean it can be fitted almost anywhere

Creating an analog input measurement that remains very stable over time (less than 0.01 percent drift per year) potentially reduces the cost of ownership by eliminating the need for annual re-calibration of the device. As the device is designed to be field mounted, it is essential that the effect on the measurement of large changes in ambient temperature be kept as small as possible.

Offset voltages are key contributors to drift in sensitive measurement circuits. It was, therefore, necessary to employ components and techniques that would minimize these effects. To achieve the high stability required, a signal chopping technique was used. This technique alternately inverts the signal polarity prior to measurement. By averaging the inverted and un-inverted measurements, the effect of offset voltages is eliminated.

In an industrial environment, a number of different interfering phenomena must be guarded against such as ground loops, common mode noise, electrostatic discharge and high frequency electromagnetic interference (EMI). A sigma-delta[2)] analog to digital conversion technique was used to help resolve these issues. This oversampling method provides very low quantization noise and excellent rejection of 50/60Hz power frequency noise, without the need for large, passive filtering components on the front end. Full galvanic isolation of each measurement channel provides excellent immunity against ground loops and electromagnetic interference. Again, this reduces the cost of ownership for many customers, by providing an instrument that is more tolerant of wiring problems, particularly when used with low cost system components with no Input-Output (I/O) isolation of their own.

Secure data storage

The integrity of the data produced by a videographic recorder is crucial, especially in applications where the data provides evidence of compliance with public safeguards. Corruption of data can occur through component failure and deliberate tampering of data. Both scenarios needed to be addressed in such a manner as to provide foolproof security.

Although flash memory is a preferred storage means for long life spans and products with high Mean Time Between Failure (MTBF) rates, it can suffer from a phenomenon known as "bit flipping". This very rare occurrence may be of little consequence in a stored picture or music file, but for critical process data it can have severe repercussions. To overcome this, flash memory that has built in Error Detection Code/Error Correction Code (EDC/ECC) mechanisms and bad block management was employed in the SM500F.

A Secure Digital (SD) media card interface was also provided for automatic data back up 5. These postage stamp-sized flash memory cards provide robust solid state storage, with no moving parts or battery back up, and are capable of operating at temperatures well beyond the scope of floppy disk storage media.

The integrity of the data produced by a videographic recorder is crucial, especially in applications where the data provides evidence of compliance with public safeguards.

To prevent illegal modification of stored data, a binary format with built-in error checking was employed for data storage. Archive files stored on the SD Card are protected by encrypted digital signatures. These sophisticated protection methods

Footnote

2) Sigma-delta is a sampling technique that reduces the effects of noise through oversampling and integration.

3 Tested for tough environments

4 The door opens more than 180°, allowing for easy wiring and upgrading

5 Inserting the memory storage card – as easy as on a digital camera!

ensure that any attempts to tamper with data files can be identified and isolated.

Further security is offered by a physical lock mechanism on the door latch and provision for a tamper-proof seal.

These comprehensive security features enable compliance with FDA CFR21 Part 11 requirements for electronic record storage.

Email capability was added to deliver routine status reports and warning alerts directly to an engineer's mobile phone or PC.

Creating an advanced common HMI component

In many technical products the effectiveness of the HMI can determine the acceptance of the entire solution by the intended users. The ease of use of the user interface is perceived to be far more important than the internal mechanism. The challenge was to provide a reusable HMI component with additional functionality, while maintaining ease of use.

An operating system and hardware platform capable of delivering a responsive, sophisticated and above all, intuitive user interface, were essential. The SM500F uses Microsoft Windows CE with an ARM based 32-bit processor. Designed from the ground up for the embedded market place, Windows CE combines an advanced, real-time embedded operating system with powerful tools for rapidly creating customized devices. The universally familiar Windows style of interaction automatically reduces the learning curve for new users of the device and allows easy construction of intuitive interfaces. Windows CE is also highly componentized and scalable allowing alternative displays (eg, color, monochrome), input devices (eg, keypad, touchscreen, barcode reader) and communications networks (eg, for remote monitoring) to be implemented to meet the cost performance criteria for a particular product.

Remote monitoring is an area of increasing importance for instrumentation products and the HMI design includes a built in web server allowing the device's current operator displays and status to be accessed from a standard web browser. Email capability was added to deliver routine status reports and warning alerts directly to an engineer's mobile phone or PC.

A context-sensitive online help system provides instant answers on the information currently displayed, or to be entered, dispensing with the need for poring over lengthy documents or manuals. The HTML based system designed for the HMI also allows much greater detail to be provided in response to system or alarm conditions. For example, if an internal diagnostics system identifies that a pump motor requires changing, a full description and diagrams of the parts and procedures can be displayed.

The universally familiar style reduces the learning curve for new users.

The right decision

The SM500F low cost videographic recorder was successfully launched in early 2006, and has created a sea of change in videographic recording. In addition, the first product to use the advanced HMI component, the AW600 water analyzer, is already in an advanced stage of development.

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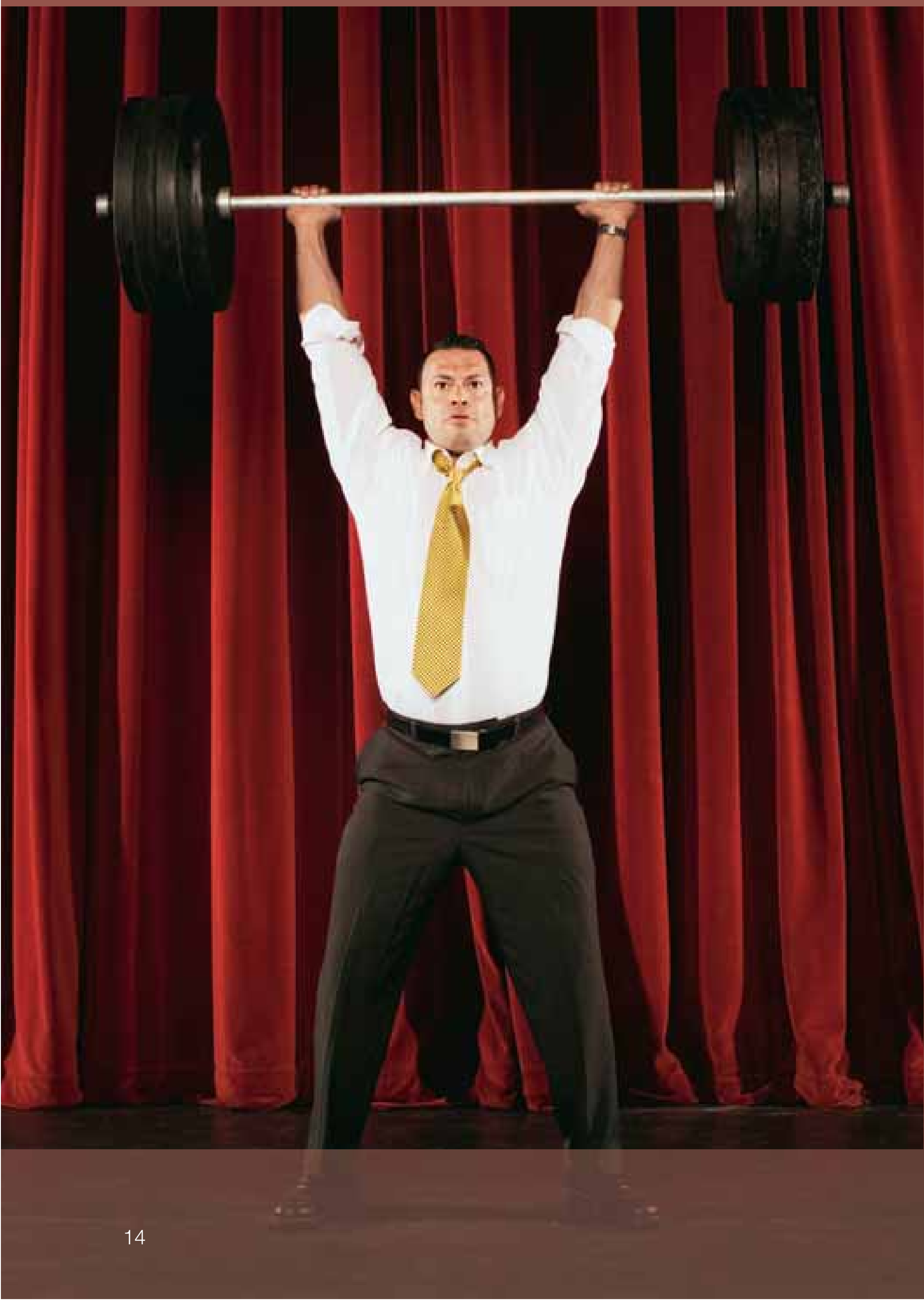
Performance under pressure

Cost-effective pressure monitoring using the 261 series of pressure transmitters

Wolfgang Scholz



The challenges of pressure measurement in process industries are many. The measuring devices must withstand the heat of deserts and the cold of Siberian winters, while remaining sensitive to minute changes in process conditions. The 261 series of pressure transmitters from ABB Instrumentation features a robust stainless steel housing, suitable for use in diverse environments, and a choice of sensors for measuring a range of pressures. With conventional applications in the chemical, oil and gas industries, the 261 transmitters also meet the stringent requirements of the food and beverage and pharmaceutical industries. All the transmitters are equipped with ABB platform electronics, which provide a standard 4–20 mA DC output with HART communication, enhanced flexibility and easy operation.

ABB's type 261 pressure transmitters ■1 are each contained within a compact stainless steel housing that is waterproof, dust- and sand-tight, and highly resistant to corrosion. This allows them to be used in the harshest of environments. They can tolerate extreme humidity, and temperatures from – 40 °C to + 85 °C. The smooth outer surface of these versatile transmitters is favoured by the food and beverage, and pharmaceutical industries for use in hygienic processes.

Sensors

Members of the 261 series are equipped with a choice of pressure sensors that measure either absolute or relative pressure over various measuring ranges (up to 600 bar). The relative pressure sensors measure against atmospheric pressure, via a special ventilation cell (or breather), while the absolute pressure sensors use an internal vacuum as a reference. The lower sensor ranges (0 to 60 mbar and 0 to 400 mbar) are covered by ceramic sensors with a capacitive pick-up system[1)]. The higher sensor ranges (≥ 2.5 bar) are covered by silicon sensors using a piezo-resistive pick-up system[2)].

The advantage of using ceramic sensors lies in their sensitivity and their high overload capacity, a feature increasingly demanded by users. Ceramic sensors are sealed against the transmitter housing by means of O-rings and the measuring diaphragm is in direct contact with the process medium ■2. This ensures accurate readings, even at very low pressures (down to 0 mbar absolute). Ceramic sensors are highly resistant to corrosion and are unaffected by adverse process conditions, such as high temperature in combination with vibration.

The silicon sensors, used for the higher measuring ranges (above 2.5 bar), are much smaller than their ceramic counterparts. In these sensors, pressure is transferred from a separating diaphragm, which is in contact with the process medium, through the filling fluid, to the measuring diaphragm ■3. This arrangement protects the measuring diaphragm from the process medium and ensures maximum life expectancy of the transmitter.

Electronics

The 261 series uses standard ABB microprocessor-controlled electronics. Sensor signals are converted into analog electrical signals, producing an output signal of between 4 and 20 mA. The electronics automatically compensate for temperature effects of the sensor and the output signal is shown either on an optional built-in digital display, the HMI (Human Machine Interface) unit, or a DTP (Device Type Manager). The output can be superimposed on an FSK (frequency shift keying) signal that conforms to HART (Highway Addressable Remote Transducer) specification for communications purposes. It can be transmitted to a centralized process controller, allowing remote monitoring of a single transmitter, or of a whole suite of transmitters, collecting data from multiple process stages and locations. The 261 transmitters are compatible with standard process management and diagnostics software systems, and can interface with ABB's device management software.

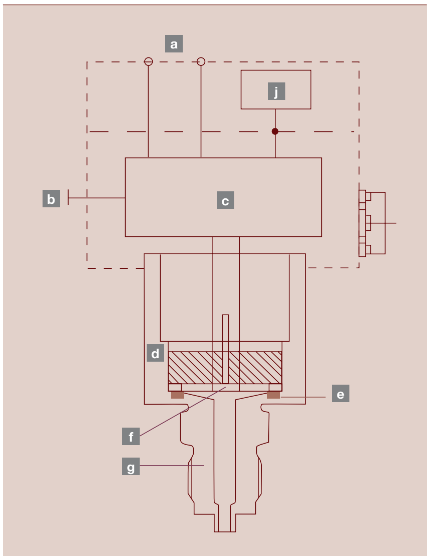
HMI

While all the 261 transmitters can be equipped with an optional HMI unit ■4, the basic parameters can be easily set without a display unit. The zero point and measurement span is set via a button on the electronic system; pressing the button for up to two seconds sets the zero point and pressing it for more than five seconds sets the maximum span point.

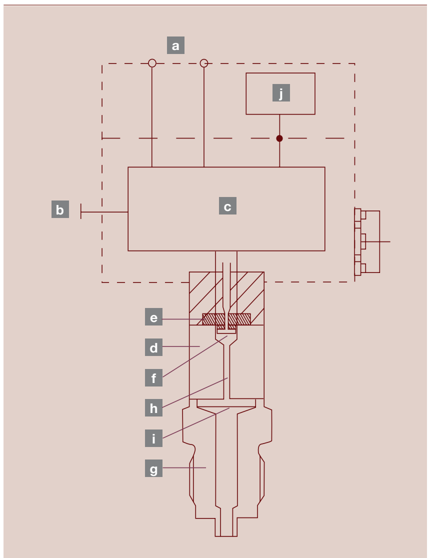
Basic settings can also be entered via the HMI unit. Like the transmitters'

■1 Pressure transmitter 261 from the 2600T series

■2 Pressure transmitter for absolute pressure



■3 Pressure transmitter for relative pressure



a Output and auxilary power supply
b Zero/span adjustment
c Microprocessor-supported electronics
d Measuring mechanism
e O-ring
f Measuring diaphragm
g Process connection
h Filling fluid
i Separating diaphragm
j Human machine interface

4 Optional Human Machine interface of the model 261 pressure transmitters. Operation is intuitive

5 Diagnostic messages can be simulated and displayed by means of the Device Type Manager

electronics, the HMI has been made to ABB standard specifications and can be used with a number of ABB instruments. This affordable unit is operated through a logical menu-driven system, offering simple and intuitive commands that will be familiar to users of other ABB instrumentation. Set up is quick and simple, and text entries can be assigned to named measuring points. Once the transmitter has been set up, parameters can be write-protected, allowing changes by authorized personnel only. All parameter and diagnostic data is presented on the graphic display of the HMI unit, with no need for additional resources, such as laptop or hand-held terminals.

Diagnostics

The 261 transmitters supply three categories of diagnostic information. They report on systems failures, conditions exceeding scheduled operating limits, and checks on electronic components. Defects in the pressure sensor, sensor electronics, sensor temperature and A/D converter function can all be reported. Pressure values outside the sensor limits are also detected and signaled. A check is made on whether the sensor temperature is within the specified limits of the instrument and, finally, electronic components are monitored, eg, the EEPROM (electronically erasable programmable read only memory) is checked and a warning is generated if the maximum number of write cycles has been reached.

> If operated under recommended conditions, the model 261 pressure transmitters require no maintenance.

Modern control systems enable remote diagnosis to be carried out at specific workstations. Information is supplied as a plant-specific message or an alarm. Unfortunately, these functions cannot be tested. An electronics failure, for example, cannot be raised by the user. However, any diagnostic information that might emerge during operation can be simulated by means of the DTM (Device Type Manager) 5, for example during commissioning. The diagnostic information can be evaluated and action initiated by the control system. Such action can range from the activation of a maintenance job request to intervention in the process itself. Threshold monitors or limit switches can also be tested using the simulation function, without any additional resources in the installed plant.

Thanks to ABB's reliable sensor technology, none of the instrument's components are subject to wear. Therefore, if operated under recommended conditions, the model 261 pressure transmitters require no maintenance.

Approvals

The electronics of the 261 pressure transmitters are designed for use in intrinsically safe electrical circuits. They comply fully with the European (ATEX), North American (FM and CSA) and Chinese (Nepsi) directives on use of electronic devices in hazardous environments. They are also suitable for use in hazardous applications requiring safety integration level (SIL) 2 integrity, as defined in IEC 61508. The transmitters were developed in accordance with standard ABB development and testing procedures, and achieved a SFF (safe failure fraction) of greater than 90 percent. The HFT (Hardware Fault Tolerance) is 0. The transmitters' housing meets with NEMA 4x/IP67 specifications. A higher degree of protection, corresponding to IP68 or IP 69k, is available as an option.

A variety of process connectors exist for the 261 transmitters, making them suitable for a wide range of industrial applications. Specialized flange connectors for chemical applications and hygienic connections for use in the food and beverage industry are available, as are remote seals for a variety of applications in the oil, gas and power industries. All of these features are supported by international industry approvals, including 3A, EHEDG (European Hygienic Equipment Design Group), and MVO.

Flexibily and Cost-effective performance

The 261 pressure transmitters are affordable, high-quality instruments for use in a range of process industries. Their versatility makes them suitable for use in many applications, from simple measuring tasks to components of highly developed automated systems.

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Footnotes

1) Piezo-resistive pickups rely on changes in the resistance of a semiconductor that occur when stress is applied to the measuring diaphragm.

2) Capacitive pickups respond to changes in capacitance caused by pressure exerted on the measuring diaphragm.

Feeling the heat

Tough and trustworthy temperature sensing devices

Ralf Huck

Monitoring and controlling critical process parameters such as pressure, temperature, level, and flow enables the optimization of plant performance. As the level of automation increases, customers look for greater functionality, higher reliability and accuracy in measurement instruments. Precise information about critical parameters is a vital tool in the hands of process engineers, helping them to make informed decisions and to provide a safe working environment. These requirements apply equally to the most classic of all measurements – the temperature.

Accurate temperature measurement in changing ambient conditions is the toughest challenge for industrial measurement experts. Classic, near-impossible measurement situations can be found for example in steel mills. The background in the reheat furnace of a hot strip and bar mill can be considerably hotter than the object of measurement. Yet lack of precision in temperature measurements in steel processes, for instance in the process of galvannealing, where a rust-resistant coating on sheet steel is formed, can cost the steel industry millions of dollars annually.

One of the most important trends today, is the migration from mechanical, stand-alone temperature monitors to digital, networked and integrated systems. Mechanical systems will continue to be employed for niche applications, where electronic systems fail to perform, for example in extremely high temperature conditions. However, recent advances in fiber optic, acoustic and oscillating crystal technologies are expected to help develop devices capable of withstanding the harshest environments, while providing the highest accuracy in measurement.

Old and new techniques for measuring temperature

Temperature is the most frequently measured environmental quantity. This is to be expected because it affects most physical, chemical, electronic, mechanical and biological systems. Some processes work well only within a narrow range of temperature. When these processes need to be optimized, control systems maintain the temperature within specified limits by using feedback from temperature sensors.

The use of several temperature sensing devices, such as, Resistance Temperature Detectors (RTD), thermocouples, thermistors and sensor integrated circuits (ICs) has been widespread. However, precise thermometry can be compromised by undesirable characteristics such as non-linearity, insensitivity, self-heating, insufficient long-term stability, low signal level and dependence on magnetic fields. Conventional measuring techniques pose at least one of these disadvantages.

Higher product quality, tighter environmental regulations and relentless demand to optimize productivity are all stretching the plant to operate at its boundaries. This in turn puts pressure on all sensors accuracy and robustness including temperature.

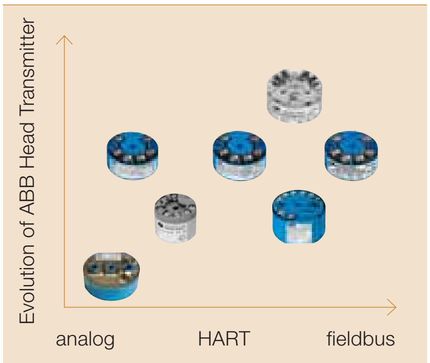
In addition compulsory documentation and traceability, as required by ISO 9000, have spurred the development of new materials and further improvements in micro system techniques.

The use of new sensors – fiber sensors, oscillating crystal temperature sensors and acoustic sensors – is presently limited to niche applications and laboratory use. For industrial purposes contact thermometers based on platinum resistance thermometers or thermocouples still offer the best combination of robustness, accuracy and economy.

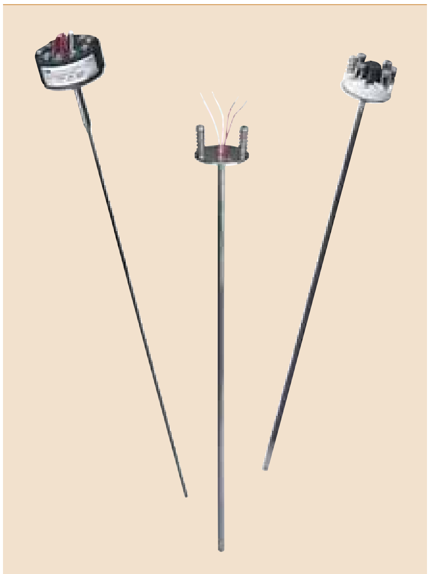
A contact thermometer comprises a temperature-sensitive element integrated in a so called protection tube. It protects the sensor against harsh operational conditions and also permits it to be exchanged without disrupting the process. Standardized protection tube designs, different for measuring gases, steams and fluids, are available. Although temperature-sensitive sensors for rough industrial applications might look the same, they are actually significantly different concerning long-term stability and service life. The right combination of assembly, connection technique and quality of material is the key to accuracy and stability of temperature measurements.

Transmitter design is the most significant innovation in temperature measurement techniques. Digital signal processing enables failure compensation and self-control in addition to flexible alignment of the transmitter to its real measuring task. The loop powered head transmitter – located in the connection head of the thermometer – achieved worldwide acceptance, because it reduced the need for cabling and offered higher insensitivity to interference. Today, the demand for analog instruments in process engineering is being reduced by the availability of low-cost, more powerful and intelligent HART converters. Transmitters can be seamlessly interfaced with most popular network architectures like Foundation Fieldbus, PROFIBUS and HART. This presents a large range of diagnostic possibilities in temperature measurement in the future 1.

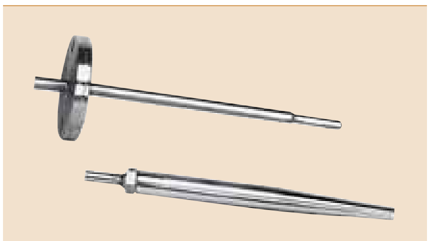
1 Evolution of temperature transmitters



2 Temperature probes



3 Protection tube designs for different test conditions



Despite all the innovation in the area of transmitters there still exists a lack of knowledge on the temperature measurement itself. Errors either occur because a measuring element has significantly high production tolerances or the thermic coupling between measuring subject, protection tube and temperature-sensitive sensor is insufficient. Errors often exceed the accuracy specification of the transmitter. For example, measuring deviations of up to 10 °C may occur if emersion depth is misinterpreted or mounting is unfavorable.

Thermometer series SensyTemp TSP100 and TSP300

In process industries even an easy-to-handle thermometer may cause problems that could result in high service expenditures and sometimes lead to facility shutdown. A detailed design concept that takes into account all influences, from construction to installation and operation, is the only protection possible.

The temperature-sensitive sensor is the heart of the thermometer series SensyTemp TSP 2. In suitable RTDs, such as the commonly known PT 100, the long-term stability of the element in the specified temperature range is proven. To assure long-term stability of thermo-elements, compliance to defined procedures during production is mandatory.

Approved laser welding – with the special benefit of reproducibility of parameters – ensures high quality mechanical and electrical connections and robustness under extreme operating conditions. The sturdy construction undergoes endurance testing, which is 30 times the value of vibration resistance required by the German institute for standardization, DIN[1)].

The environment, in which the thermometers are mounted, might exhibit anything from ambient conditions to potentially explosive atmospheres. The thermometer series SensyTemp TSP100 and TSP300 cover all of the requirements associated with such areas. For measuring gases, steam and liquids at different pressures and at different flow rates the protection tube best suited to the task can be selected from a range of designs 3. Thermometers with welded protection tubes are mainly used in tank and pipe construction under relatively low chemical and mechanical pressure. Under high pressure, temperature sensors with drilled material are appropriate. The series TSP121 can be used for all standard applications within the process industries. The series TSP331 is used when special sturdy housing or pressure-resistant casing is required. ABB also offers a wide range of special solutions for specific customer requirements. These are accepted as approved customer-specific standards worldwide.

Head mounted temperature transmitter TTH300

The new temperature transmitter TTH300 offers functions once unthinkable for compact head designed transmitters: two real inputs, signal transmission in 4–20 mA, HART communication and a serial interface to connect a local operating and display unit 4. The transmitter clamps allow for alternative contacting, either from the center or from outside. They are suitable for direct brazing signal lines or in parallel contacting a handheld terminal. The local handling and display unit just has to be snapped onto the top of TTH300 and is automatically connected. Thus, the TTH300 offers improved accessibility and easy handling.

In the past, a permissible error of measurement, or temperature difference was acceptable, because the alternatives – eg best in tolerance or factory-side calibrated sensors – were prohibitively expensive. Consequently, the customer accepted a deviation in reproducibility when the sensor was exchanged. For instance, a PT 100 sensor, class B, at 100 °C measurement temperature, would have a deviation of up to 1.6 °C.

This deviation can easily be compensated for with the TTH 300. The transmitter has to be coupled with the measuring element and then submerged in a temperature bath of exactly known temperature. As soon as the temperature balance is reached, the measuring deviation of the temperature-sensitive element will automatically be compensated when the calibration routine of the transmitter starts. The error adjustment is completed when the measured temperature matches the temperature of the bath. In case of error adjustment over the full permissible measurement range the TTH300 offers the possibility to parameterize sensor specific curves.

4 The new breed of temperature transmitters, the TTH300, with HART communication

5 The high-performance TTF300 temperature transmitter

Measuring accuracy in wide temperature ranges of under 0.1 °C is reached.

The TTH300 sets the future standard for service. Previously – in case of an element breakdown – it was necessary to start up by manually reconnecting with a one-channel transmitter. The TTH300 allows the direct connection of two independent PT 100 test points in a three-wire-technique. When one measuring element fails, this failure is recognized and immediately reported and the transmitter is switched to its redundant element. This is possible because of the integrated "hot swap" function, where the availability of the test point is assured. Repairs are therefore only required at the next planned service. If a long period between services is required, the automatic drift detection of TTH300 can be employed. Temperature-sensitive elements are implemented using a PT 100 sensor and a thermo element. When using identical sensors, a parallel drift may occur and go unnoticed. Aside from the actual measuring task, the transmitter continuously compares the difference of both test points. In case of a deviation higher then a given value, the transmitter automatically sets off an alarm. Manual tests are reduced because calibration is only carried out when actually required. TTH300 reduces service and maintenance, thus reducing cost of ownership.

Another outstanding feature of TTH300 is the possibility of local start-up via its pluggable handling and display unit when used in the connection head of the new thermometer series SensyTemp TSP100 and TSP300. All measuring values and diagnostic data are available, configuration and parameters can be adjusted locally. There is no need for a separate handheld terminal. An identical handling and display philosophy ensures easy handling of all new ABB transmitters.

Field mounted temperature transmitter TTF300

The TTF300 (for remote mounting in field housing protection class IP66) is deployed in places where good local operability and easy accessibility to the measuring device is required 5. The TTF300 combines all the performance features of the TTH300 with robust housing and big terminals suitable for remote field mounting. Both sensor cables and the 4–20 mA loop are inserted from below and are, therefore, protected against humidity. The sturdy 2.5^2-terminals are easily reached from all sides. The large handling and display unit is easily connected to the terminal level. Because terminals and display are facing the same side, it is not any longer required to turn the housing to reach its front- and backside. The transmitter electronics are electromagnetically encapsulated and, therefore, protected even when the housing is open.

The need for industry standards

The shifting requirements that industrial temperature metrology must meet and the pressing need for standardization pose a unique conundrum. In fact, the incompatibility of measuring system interfaces is the main reason for the cautious introduction of fieldbuses. Though implementation of standardization may take a long time, it is inevitable in the end. Process industries cannot provide separate training for each measuring sensor; therefore, the onus is on the manufacturers to provide uniform, standardized, manufacturer-independent mechanical and electronic interfaces and user environments. Across ABB there is a strong awareness of the need for conforming to one standard, within the company for a start. All development efforts use company-wide standardized components, such as housings, operation and display units, and HART or fieldbus communication platforms. The new families of temperature measuring devices ABB recently introduced combine robustness with high accuracy and low maintenance cost. A win-win situation for all!

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Footnote

1) Deutsches Institut für Normung (DIN) is the German institute for standardization, headquartered in Berlin. Since 1975 DIN has been recognized by the German government as a national standards body representing German interests at the European and international level.

Common sensing

Multivariable flow transmitter connected to Foundation Fieldbus – a global first for the pulp and paper industry

Dimitrios Charisiadis

The Pulp and Paper (P&P) industry is a large consumer of power and steam for driving, drying and heating purposes. Both are generated in a power plant, which is normally internally owned. High efficiency and productivity require accurate measurement of air flows to burners and steam flow to turbines. In both cases measurements challenges arise, which ABB's multivariable transmitter has conquered in a power plant owned by Borregaard.

ABB supplies an unparalleled range of instrumentation equipment and automation systems for use throughout all stages of the pulp and paper manufacturing processes.

This portfolio includes flow, temperature, pressure and differential pressure transmitters as well as several analytical measurement devices and control solutions. Electro-pneumatic valve positioners and electrical actuators rounds off this comprehensive product portfolio for the P&P industry.

In order to control the combustion efficiency in the power plant, airflow to the burners needs to be measured accurately. The air flows through large ducts, which reduce its velocity resulting in differential pressures (dp) as low as 2 to 3 mbar. ABB provided Borregaard with the only real draft-range multivariable transmitter (with a 10 mbar dp range) for this application in the market. This ensures superior performance and efficient control, which ultimately translates into cost savings.

The steam used in Borregaard exceeds 400°C, which excludes the use of even the high temperature version of the Vortex transmitter. If the temperature exceeds 400 °C and/or the static pressure exceeds 250 bar, the only possible way to achieve an accurate steam measurement is to use a primary element, such as orifice, nozzle, Venturi tube, or pilot tube, in combination with the dp, pressure and temperature measurements. These measurements are necessary to calculate the compensated flow or mass flow.

1 Installed multivariable transmitter

Mass flow measurement

Due to its multisensor technology, ABB's multivariable transmitter, the 267/269C, allows the measurement of three separate process variables simultaneously. This provides the ability to dynamically calculate fully compensated mass or volume flow rate for gases, steam and liquids. An installed multivariable transmitter is shown in 1. It measures differential pressure and absolute pressure from a single sensor and process temperature from a standard 100 Ω RTD (Resistance Temperature Detector).

The flow calculation includes compensation for pressure and/or temperature as well as for more complex variables such as discharge coefficient, thermal expansion, Reynolds number and compressibility factor.

The transmitters 267/269C include flow equations for super heated steam, saturated steam, gases and liquids. The enhanced compensation approach provides much better accuracy than the "old approach", where three different transmitters – differential pressure, absolute pressure and temperature – report their values to a control system or flow computer, where the calculation typically considers changes in temperature and pressure according to:

$$Q_m \approx \sqrt{dp \cdot \frac{p}{T}}$$

The dynamic mass flow compensation of models 267/269C is based on AGA 3 and EN ISO 5167, two more advanced standards for massflow calculation:

$$Q_m \approx C \cdot E_v \cdot Y_1 \cdot d^2 \cdot \sqrt{dp \cdot \rho}$$

Q_m = mass flow rate
C = discharge coefficient
E_v = velocity of approach factor
Y_1 = gas expansion factor
d = bore diameter
dp = differential pressure
ρ = fluid density

Discharge coefficient

The discharge coefficient is defined as the true flow rate, divided by the theoretical flow rate. It corrects the theoretical equation for the influence of velocity profile (Reynolds number), the assumption of no energy loss between taps, and pressure tap location. It is dependent on the primary flow element, the beta ratio and the Reynolds number. The Reynolds number is in turn dependent on the viscosity, density and velocity of the fluid, as well as the pipe diameter, according to the following equation:

$$Re = \frac{v \cdot D \cdot \rho}{\upsilon}$$

v = velocity
D = inside pipe diameter
ρ = fluid density
υ = fluid viscosity

Dynamic compensation of the discharge coefficient provides high accuracy for orifices, Venturi and nozzles.

Gas expansion factor

The gas expansion factor corrects for density differences between pressure taps caused by expansion of compressible fluids. It does not apply for liquids, which are essentially non-compressible.

The gas expansion factor is dependent on the beta ratio, the isentropic exponent, the differential pressure and the static pressure of the fluid according to the following equation.

For orifices:

$$Y_1 = 1 - (0.41 + 0.35 \cdot \beta^4) \cdot \frac{dp}{p \cdot \kappa}$$

For nozzles:

$$Y_1 = \left[\left(\frac{\kappa \cdot \left(\frac{dp}{p}\right)^{\frac{2}{\kappa}}}{\kappa - 1} \right) \cdot \left(\frac{1 - \beta^4}{1 - \beta^4 \cdot \left(\frac{dp}{p}\right)^{\frac{2}{\kappa}}} \right) \cdot \left(\frac{1 - \left(\frac{dp}{p}\right)^{\frac{\kappa - 1}{\kappa}}}{1 - \left(\frac{dp}{p}\right)} \right) \right]^{\frac{1}{2}}$$

β = beta ratio
dp = differential pressure
p = static pressure
κ = isentropic exponent

Velocity of approach factor

This factor is dependent on the beta ratio as defined by the following equation:

$$E_v = \frac{1}{1-\beta^4}$$

In turn, the beta ratio is dependent on the bore and pipe diameters, which are functions of temperature. The material of process pipe and primary flow element expands or contracts with measured temperature changes in the fluid. The thermal expansion coefficients are dependent on the material of pipe and flow element and are used for calculating the change in diameters.
This ensures high flow rate accuracy at both low and high temperature applications.

Density of fluids

Density directly affects the flow rate calculation. The transmitters 267/269C compensate for density of fluids for changes in temperature and/or pressure as follows:

- Gases, as a function of *p* and *T*, per the gas law equations
- Heated steam, as a function of *p* and *T*, based on steam tables
- Saturated steam, as function of *p*, based on steam tables
- Liquids as a function of *T*

In order to calculate the compensated flow or mass flow, three process values need to be measured:

- the differential pressure across the primary element
- the static pressure in the (pipe) line
- the process temperature of the measured media

Traditionally this has been realized using three different transmitters:

- one *dp* transmitter
- one pressure transmitter, and
- one temperature sensor plus temperature transmitter

The three measurements have been connected either to a flow computer which executed the flow computation or directly to a system, which would perform the compensated flow calculation.

Direct mass flow measurement

The innovative and smart way to measure mass flow more directly is to use a multivariable transmitter: It combines the *dp* and the static measurement *p*, and provides a temperature transmitter, in a single device. Furthermore, the compensated flow or mass flow computation is included in the firmware of the device itself 2, 3.

Using fieldbus communication the multivariable transmitter offers, not only the mass flow measurement, but also all three process data (*dp*, *p*, *T*) individually. All alarms and diagnostic parameters are communicated to the system where applicable. ABB is the only worldwide supplier of a multivariable transmitter with HART, PROFIBUS, Foundation Fieldbus, and Modbus communication protocols. After having installed the first PROFIBUS multivariable application worldwide in the year 2000, ABB now is proud of having realized the first Foundation Fieldbus application together with Borregaard in 2004.

3 Smart massflow meter

The benefit of using a multivariable transmitter is in reduced procurement, because of fewer instruments and manifolds in the field, but also a reduction in the number of I/O cards needed. Even more significant savings can be made through simplified installation, less engineering (on the system side), commissioning and maintenance work.

Borregaard discovered these benefits and used them throughout its new P&P plant. Borregaard and ABB made the world's first Foundation Fieldbus multivariable transmitter installation together. It will not be the last, that's for sure . . .

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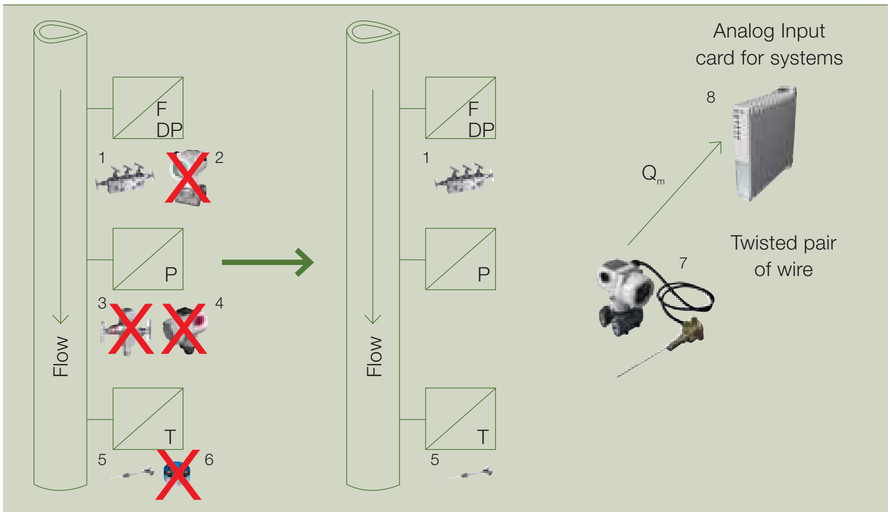
2 Overview of smart measuring principles – simplification thru integration



Borregaard

Borregaard is the world's leading supplier of wood-based chemicals, and holds also strong positions within ingredients, fine chemicals and energy. Strong innovation efforts and global presence increase the added value to their customers.

The multivariable transmitters from ABB are used at Borregaard Alva for air and steam measurement. The main task for "Alva" is to produce steam by burning aqueous organic residues from the production of cellulose and vanillin with backup of oil fuel.

The 364DS

The "common sense" approach to pressure instrumentation design

Andrea Moroni, Aurelio Fanoni

Today's sensor devices are certainly high-tech, but the rate of innovation in sensor technology over recent years has been disappointingly slow. This is because most users would rather stick with tried and tested technologies than expose their processes to the potential vagaries of new instrumentation. If problems with an instrument arise, the loss of a day's production, in even a medium sized plant, can easily exceed the cost of the entire instrumentation package. Hence reliability has highest priority in the eyes of an instrumentation user, then comes accuracy and cost. When defining the specification of the new ABB pressure transmitter series, ABB decided to respond to these priorities and provide reliable technology and common sense solutions. The result is the 364DS pressure transmitter.

Over the past few years, an increased emphasis on "base" accuracy, as defined in product specifications, has taken place. Significant improvements in accuracy have been made (from 0.1 percent in the late 90ies to current values of 0.025 percent), but what does this actually mean in terms of customer value? The drive for lower costs has caused some leading manufacturers to advise against redundancy, on the grounds that it is as a source of problems rather then a safety feature. This is like recommending a single-engine plane over a two-engine plane: Both will fly perfectly well, but the second plane is less attractive because it has two engines that could fail instead of just one.

Despite the huge variety of different customer interests, there are certain features that benefit everyone. ABB has concentrated on these, making their new range of pressure transmitters, the 364DS series, reliable, robust, compact and simple (see picture above).

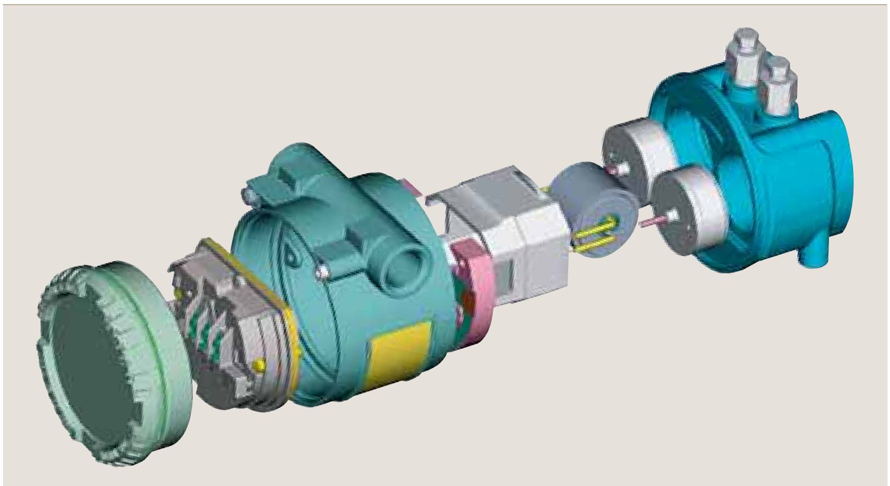
Reliable – fewer parts mean fewer break downs

A detailed analysis of parts function carried out by ABB Corporate Research on existing ABB and competitor devices showed that each device comprised more then 120 parts, 15 sub-assemblies and 50 operations. The minimum number of parts defined by the analysis was 24, demonstrating a significant potential for simplification and reliability improvement. The design concept for the new sensors was centered on features of the most popular devices delivered to customers by ABB and its competitors over the previous three-year period. The devices were reduced to a minimal number of parts and material variants. Housings and flanges were simplified and reduced in size. Materials specifications were raised (eg, stainless steel was chosen as the standard instrument housing and Hastelloy C was used for the seal diaphragm). Most importantly, all potential sources of leakage were eliminated by removing gaskets and introducing an innovative "all welded" body, a technology that has since been patented by ABB. The manufacturing process of the new pressure transmitters uses the most advanced techniques, such as laser welding, a high-power CO_2 source, high-vacuum techniques, and high quality material treatments.

Robust – all stainless steel housing

Encasing a pressure transmitter in an all stainless steel housing is an attractive, but generally expensive, option. Aluminum housings are often used in an effort to cut costs, but there are few, if any, who would actually prefer to use this material if other solutions were available at similar cost levels. Thanks to ABB's new design, the cost of an all stainless steel housing has

1 The 364DS pressure transmitter, exploded view



been reduced, making it affordable by all. The new housing has been designed and assembled to operate at more then four times the required explosion stress. Tests have shown that it can tolerate an internal pressure of approximately 100 bar (100 kg/cm^2) with no significant deformation of the mechanical structure. The housing also protects the sensor from vibration and physical shock. The higher safety specification of the housing reduces costs by limiting the number of production tests required.

Compact – large inside, space-saving outside

It is easy to make sensors smaller, but a reduction in size is often accompanied by a reduction in accessibility. Some of ABB's competitors are producing very small units indeed – some instruments have even been halved, but none are as accessible as the 364DS series. The latter are smaller than their competitors, and yet more accessible. This is because the "all welded" body incorporates the housing for the electronics as well as a large, fully accessible terminal block 1.

Simple – the 364DS series has a simple four-button menu system

One major source of problems with any new electronic device is the set-up, which usually involves complicated procedures and obscure manuals. The HMI (human machine interface) of the 364DS is centered on four buttons that allow the user to navigate easily through a self-explanatory menu, similar to those used in current cell phones. The "easy set-up" feature permits user operation during commissioning of the transmitter. The HMI also offers a choice of operating languages (Chinese will be available in September 2006).

Over-designed for maximum human safety

Safety was of paramount importance throughout the design and development of the 364DS transmitters. The lower range instruments are resistant to pressure in excess of 1500 bar (150 MPa or 21,750 psi) after 1,000,000 over-range pressure cycles. The seal diaphragms have been approved by tests on the effects of crevice- and stress-corrosion carried out at the Politecnico di Milano. Materials approved by the National Association of Corrosion Engineers (NACE) are used in the devices to ensure maximum corrosion resistance. The devices comply with a number of Hazardous Area certifications, selectable by the end user (eg, FM, CSA and ATEX), and with IEC61508 Safety Integration Level 2. A 4 kV 1.2/20 µsec surge protector is included as standard on the instruments, as is a high performance filter that provides 30 V/m of electromagnetic field immunity.

Other significant features

The instrument housing has an ingress protection rating of IP67 (NEMA 4X), but the instrument itself can actually work with covers removed in environments of 100 percent humidity. The very large HMI (2-inch screen), which is standard for all new ABB Instrumentation products, is easily readable, even at extremes of temperature (from – 20 °C to 60 °C). The 364DS is a typical "off the shelf" product. It can be shipped within moments of an order being placed and, in spite of its stainless steel construction, it weighs much less than its aluminum-housed competitors. The units are also equipped with replaceable, upgradeable electronics, an auto-repairing database, remote indicator options, a flow totalizer, programmable alarm saturation limits, advanced internal diagnostics, and a square root cut off.

Enhanced performance

The actual performance of measurement devices in situ is generally worse than that specified by manufacturers (the "base" accuracy), by a factor of 3–5. This is because of the effects of turn down, mounting, static pressure, temperature, vibration, electromagnetic compatibility, etc. This short fall in performance was a significant motivating factor in the design of the 364 series. Through the implementation of the four key requirements for the instruments (ie, that they be reliable, robust, compact and simple) the base accuracy of the new instruments has been improved to 0.06 percent of the upper range limit (URL). More importantly, the influence of temperature has been limited to a maximum of 0.15 percent in the – 40 °C to + 85 °C range, and the stability has been improved to keep errors below 0.15 percent of URL over the transmitter's 10-year working life.

In essence

ABB's common sense approach to design and development, combined with its experience in the field, have produced a series of transmitters that will provide customers with the maximum return on their capital with the highest degree of safety.

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Water quality control in power generation

Groundbreaking technology for monitoring contaminants in water-intensive industrial processes

Eric D'Costa

World population crossed the six billion mark in June 1999, according to the US Census Bureau. This means that the earth's population is over 3.5 times the size it was at the beginning of the 20th century, and roughly twice its size in 1960. This explosive growth has created an unprecedented demand for energy, leading to further exploitation of the planet's already limited natural resources. The surge in energy demand can only be met through the adoption of sustainable production practices and a drive to achieve higher levels of efficiency [1, 2].

To achieve greater efficiencies in power generation processes, ABB's AW600 is providing advanced monitoring of the chemical composition of the steam-water cycle.

Recognizing the need to conserve resources, ABB is committed to the development of energy efficient products and processes that yield a reduced environmental impact over their complete life cycles. The next generation of instrumentation products form ABB is embracing global environmental challenges, while capitalizing on the significant business efficiencies brought about through the company-wide Common Components Development process.

The critical role of water quality measurement in power generation

In the power generation process, water is heated in boilers and converted to steam, which is used to drive turbines and generator sets to produce electricity. Many different fuel types may be used to generate electricity, but the production of huge quantities of steam in the energy conversion process is universal. For example, a typical fossil-fuel power station converts around 650 tons of water into steam per hour, in each of four 160 MW boilers. This represents around two million tons of water usage per month.

With such a large throughput of water in the steam-raising process, the chemical quality of the water used is critical [3]. Even the smallest concentration of contaminant or minor excursion in water chemistry can have serious and expensive consequences in relation to performance, reliability, efficiency and safety. Analytical measurements are essential therefore, to monitor contaminants and to minimize corrosion in the steam generating plant.

Water quality monitoring in power generation represents a core market for ABB and is addressed through a comprehensive range of chemical measurements. Silica, second only to carbon as the most prevalent element in the lithosphere, and phosphate, used as a pH reagent to limit corrosion, are two of the many such substances that must be monitored closely in boiler feedwater and condensate.

Silica is a naturally occurring substance that is difficult to remove from water. At high temperatures and pressures it is volatile, and is carried over with the steam and deposited unevenly on the superheater tubes and turbine blades. Silica forms tenacious deposits that are very hard and resemble porcelain. Even small amounts of silica can cause significant loss of power generation efficiency and result in serious mechanical damage 1. Minor leaks in the condenser can also contribute to silica contamination in the steam-water cycle. Constant monitoring of silica at a number of points in the steam-water cycle is critical to prevent boiler and turbine damage. Phosphate, on the other hand, is added to the water in some power stations to control the pH tightly throughout the steam-water cycle, thus minimizing corrosion through acid or caustic attack. It too must be monitored constantly to avoid expensive corrosion in the steam-raising tubes 2.

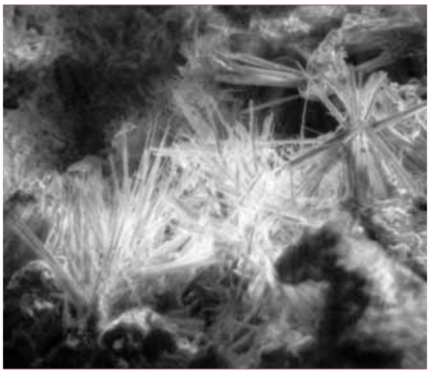
Even the smallest concentration of contaminant or minor excursion in water chemistry can have serious and expensive consequences in relation to performance, reliability, efficiency and safety.

The cost of poor water quality

Water chemistry problems lead to corrosion failure, super heater fouling and/or chemical deposition on turbine blades. This results in efficiency losses and ultimately, plant downtime, which in turn contributes to increased electricity generating costs.

A one-week boiler shutdown in a typical power station, caused by an acute water chemistry excursion leading to corrosion and chemical deposition, is estimated to cost around $4 million ($0.2 million for repairs and chemical cleaning, and $3.8 million for lost production capacity). A catastrophic failure resulting from poor water quality would take even more time and money to repair. It is not easy to estimate the value of good water-quality control through chemical measurements, but the following data, from US fossil fuel power utilities, reported in the mid-1980s, are still relevant today [4]:

1 Silica deposition on turbine blade



2 Tube weld corrosion due to poor control of chemical conditions in steam-water cycle

3 AW600 Silica Analyzer

- Around half of forced power generation outages are corrosion related
- More than $3 billion per year in operation and maintenance costs is due to corrosion and chemical deposition
- More than 10 percent of the cost of electricity is due to corrosion related costs
- For a 100 MW unit, a one percent loss in efficiency represents around $150,000 annually in increased operating costs

The AW600 analyzer is leading from the front

The new AW600 analyzers for silica and phosphate are the most advanced water quality analyzers in the market today 3. Taking into account the current issues and future challenges facing power plant operators, the AW600 has a low environmental impact throughout its life cycle. It also delivers the lowest cost of ownership of any comparable water quality analyzer. Asset management features and communication capabilities designed into the product help deliver greater efficiencies in the power generation cycle.

What customers get is a high quality water analyzer that allows them to control the process, achieve cost and reliability targets, manage assets (plant and instrumentation) and ensure compliance with local and international regulatory controls.

Customers also realize significant cost savings through lower reagent and consumables costs, and lower service costs. Owing to the simplicity of design and low maintenance requirement of this analyzer, the skill level of operators can be downgraded. With state-of-the-art communication capabilities, internal diagnostics, preventative maintenance functions and data trending routines, all incorporated in the AW600, customers can streamline business processes by only committing resources when required, or at pre-scheduled times 4.

Data handling, storage and security allow the user to perform entirely new tasks and functions, to extract greater value from process data and even to automate certain reporting tasks. The new, modular design of the AW600 eliminates some of the frustration previously experienced by users and service personnel when undertaking routine maintenance tasks, troubleshooting or repairs.

AW600 and the environment

The positive environmental aspects and product life cycle cost benefits of the AW600 are significant, especially when compared to contemporary analyzers. The AW600 consumes around one-fifteenth of the volume of reagents used in conventional analyzers. This results in lower reagent costs and less waste. The weight and volume of materials used in the construction of the AW600 analyzer has been reduced by about 60 percent. The new design complies with the latest WEEE and RoHS1) directives, using environmentally friendly materials, designed for easy dismantling and cost-effective recycling.

Service intervals have been extended to 90 days – about three times longer than currently needed for the maintenance of competitor's measurement instruments. Alongside this, service times have been reduced by two-thirds, yielding significant savings in service costs.

Considerable thought has gone into adding user-friendly features. For instance, viewing instrument status remotely via the Internet and using SMS instant messaging whilst on the move precludes the need for frequent service visits. Even inadvertent spillage of potentially harmful chemical reagents is guarded against by incorporation of secondary containment measures in the analyzer design.

Design considerations

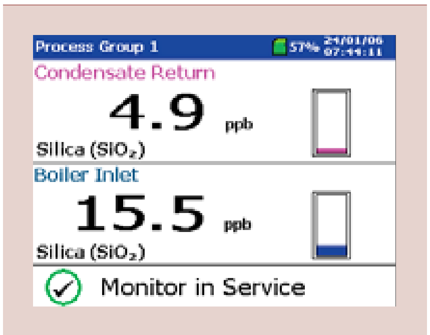
Of all requirements, reliability and accuracy of measurement were paramount. Over and above that, the design team has taken an exacting and complex analytical chemistry and packaged it into a simple-to-operate modular product. Where reliability and accuracy risks were considered high, such as in the reagent transport system, well-established technologies were employed. In those areas where the technical risks were lower, bespoke solutions were developed on the basis of significant breakthroughs. For example, the videographic user-interface, optical sensing module and internal diagnostic sensors were three areas where technical innovation was needed to deliver value-generating functionality.

The design team met the challenge of significantly reducing manufacturing costs and lead time by creating a modular design, in which the primary parts and sub-assemblies were constructed so as to streamline the manufacturing process. The emphasis was on elimination of labor-intensive steps, purchasing of pre-tested parts, and sourcing of materials from low-cost countries. To achieve this aim, more than 80 percent of the material content has been sourced from China and the Far East.

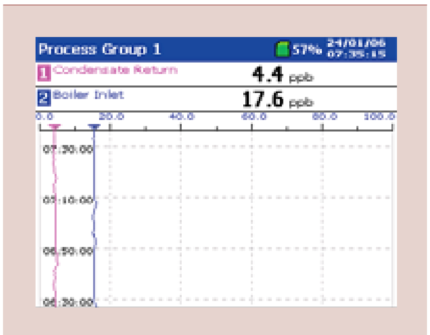
4 Advanced communications and diagnostic features in the AW600 Analyzer allow the plant operator a high degree of instrument control and asset management capability

Instrumentation

5 The AW600 incorporates ABB Instrumentation's clear and distinctive advanced HMI



6 The graphical display capability allows the simultaneous monitoring of multiple process streams and the review of historical data



A significant design goal was to utilize a high percentage of components from ABB's Common Components Program. The advanced HMI, common software framework and common fieldbus device were all created within the Common Components Program. The AW600 electronics enclosure was also developed as a Common Component that will be used for future ABB Instrumentation products. All of the major AW600 modules (electronics unit, wet section components and wet section enclosure components) will also be used in future analytical products, thus saving significant development investment.

Major features

It was considered of prime importance that the AW600 deliver additional value to the customer, beyond that of basic analytical measurement. This value-addition was accomplished by the creation of a hugely powerful graphical user interface (GUI) 5 – ABB's advanced HMI common component.

The GUI is based on the newly released SM500F Graphical Recorder hardware. The application firmware is specifically written to give the user a more comprehensive visualization of the measurement of interest, the status of the instrument and in-context information about the process or application. For example, the user can monitor up to six process streams and review historical data and instrument events as graphical trends or tabular data 6. The AW600 also allows the user to save data via a number of optional levels of security to a Secure Digital (SD) card for later review and reporting. A further benefit of the SM500F module is its ability to update instrument firmware as product improvements, newer features and additional measurands[2] are added to the platform.

A battery of internal diagnostic sensors within the AW600 is used to monitor the real time status of the instrument. Information, such as measurement time remaining, based upon reagents and standard solution liquid levels can be assessed and alarms preset to alert the user, when replenishment of consumables is needed. Internal flow and liquid level sensors monitor pump efficiencies and notify the user, when preventative maintenance is deemed necessary, so that future failure can be averted. Regular automatic calibrations and compensation corrections can be set up to reassure the user that the measurement is valid at all times.

Communications

The very latest communication capabilities are included in the AW600 analyzer. PROFIBUS DP-V1[3] provides cyclic bus connectivity to ABB's latest Distributed Control System, the System 800xA. Further advanced communications are provided with e-mail messaging and Internet connectivity via an Ethernet module. An associated PC software application allows the user to interrogate the AW600 in real time from a desktop PC or from a laptop using mobile technology. Users can receive updates and status information on their mobile telephones using the SMS text messaging service provided via a GSM module. Future adaptations will allow the user to operate and configure the AW600 using the wireless capabilities of a mobile computing device, such as a PDA or Pocket PC.

The AW600 instrument platform

The silica and phosphate analyzers represent just the first two products to be released from the new AW600 platform. Future water quality analyzers based on the AW600 will include numerous applications for potable water and wastewater. They will be targeted at core markets, such as power generation, municipal water and chemical processes.

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[2] A. Bursik: Power Plant Chemistry 4 (2002) 1, 18–21.

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Footnotes

1) Waste Electrical and Electronic Equipment (WEEE) regulation encourages reuse, recycling and recovery to improve the environmental performance of all operators involved in the lifecycle of electrical and electronic equipment. Restriction of Hazardous Substances (RoHS) requires substitution of heavy metals (lead, mercury, cadmium and hexavalent chromium) and brominated flame retardants in new electrical and electronic equipment put on the market, effective from July 2006.

2) Measurand is the physical or electrical quantity, property or condition, which is measured. The term "measurand" is preferred over "prime parameter to be measured".

3) Ninety percent of PROFIBUS slave applications are PROFIBUS Decentralized Peripherals (DP) protocol, available in three functionally graded versions: DP-V0, DP-V1 and DP-V2. PROFIBUS DP-V1 contains enhancements geared towards process automation, in particular acyclic data communication for parameter assignment, operation, visualization and interrupt control of intelligent field devices, in conjunction with cyclic user data communication.

Sub-sea challenge

Oil and gas flow measurement on the sea bed

Harry Lawrence

The deeper the sea, the more unsuitable traditional techniques for the extraction of oil and gas become. To be able to economically exploit such sources, a different approach is adopted. Instead of a fixed platform on which all vital equipment is positioned, much of this equipment is moved to the sea bed and the oil is raised to the surface by flexible pipes leading to a ship-like surface station, the FPSO (Floating Production, Storage and Offloading).

But the approach is not as simple as it may sound. For equipment to function on the sea bed it must be designed for a minimum of human intervention. It must be sufficiently rugged to withstand the hostile environments of both deep-sea and oil and gas extraction. And when someone does intervene, it will be a diver wearing a heavy protective suit and gloves, or a remotely operated vehicle – so little chance of gentle handling. ABB develops and manufactures flow meters for exactly such environments.

Instrumentation

ABB's Workington plant in the North of England is a center for the manufacture of a comprehensive range of flowmeters, including differential pressure (DP) flow meters which find widespread application within the oil, gas and power generation sectors, as well as across many other industries. The basic principle of operation is based upon the fact that, when a fluid is passed through a restriction, the pressure is reduced as the velocity increases.

The law of conservation of energy tells us that energy cannot be created or destroyed and that a gain in one form of energy in a system must be at the expense of another. Here, a reduction in the pressure energy balances the gain in kinetic energy that results from the increased velocity through the restriction. This is the same phenomenon as that which applies to an airplane wing (or aerofoil), where the air flowing over the top of the wing is forced to travel further than that below the wing, but in the same time. This creates a faster moving air stream over the top of the wing, resulting in a lower pressure, which in turn provides aerodynamic lift. This lift increases as the velocity of the air increases.

A DP primary element uses this effect to measure the rate of flow of a liquid or gas. The fluid is passed through a restriction – for example the hole in an orifice plate or the throat of a Venturi tube. By measuring the pressure difference across the restriction, the flowrate can be determined.

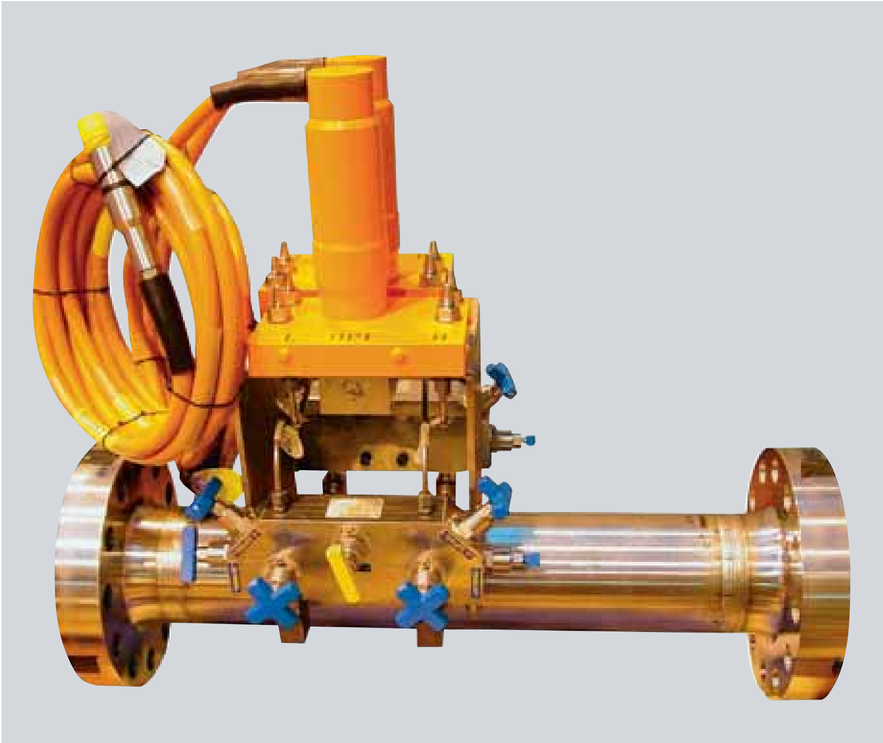
The flowrate Q and the pressure difference h are related by the much – simplified equation:

$$Q \propto \sqrt{h}$$

Why measure in a sub-sea environment?

The offshore oil and gas production sector has traditionally used technology that was originally developed for exploration and production on the mainland. This equipment was modified for use on an offshore platform. In recent years, however, the industry has had to seek ways of tapping oil and gas more cost-effectively. Factors leading to this include:

- the historically low price of oil (which is frequently low, even if this has not been the case recently!)
- the increasing depth of offshore oil and gas discoveries, as most of the shallow fields have been exploited



Every DeepSeaMaster is different – it is custom designed to the customer's project specification.

The latter factor in particular leads to one of the economic solutions being implemented – the installation of some of the equipment (and also performing some of the processes) on the seabed itself, rather than on a platform at the surface. This is where ABB DP flow meters can be applied to great effect.

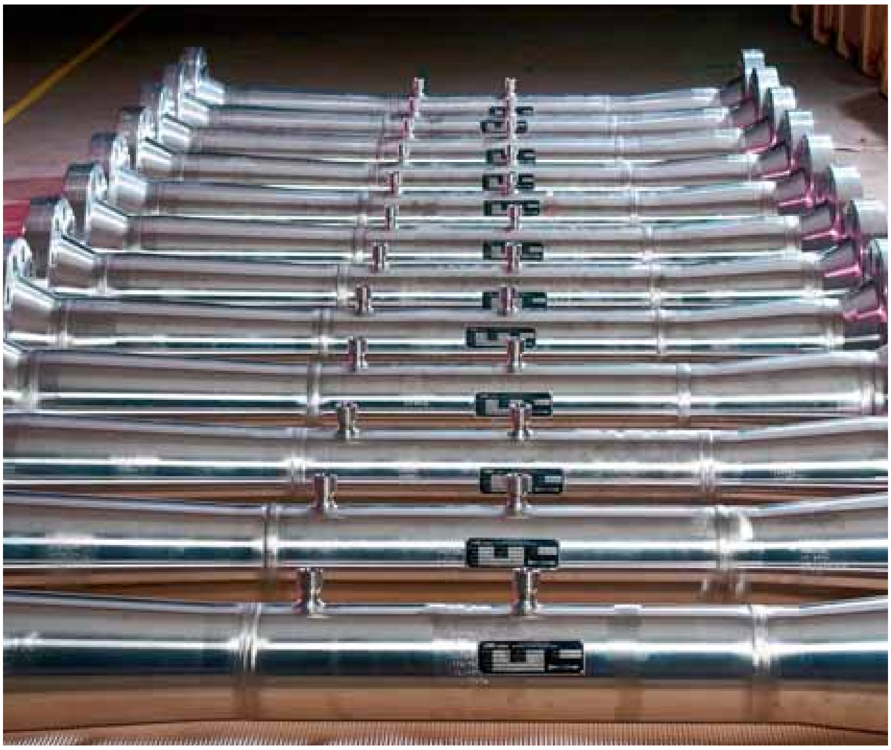
The increasing need to tap these deepwater fields has led to the use of a vessel referred to as an FPSO (Floating Production, Storage and Offloading vessel). FPSOs are ship-like in appearance and, in fact, are sometimes created by converting existing tankers. They are effectively floating oil/gas tanks and designed to store the oil or gas produced by the field/wells.

Oil from offshore installations can be transported to the mainland either via a fixed pipeline or by tanker. When a tanker is used, the oil or gas is stored in the FPSO as it is produced until there is sufficient stock to fill a transport tanker. Some FPSOs have the capability for oil separation in locations where seabed pipelines are not cost effective.

The FPSOs are anchored to the seabed in a fixed location – sometimes even pivoting on a pylon rising up from the seabed. This system allows the vessel to do what a normal tanker would do in bad weather – that is to point its bow into the prevailing sea. The deepwater fields are often subject to weather and currents every bit as bad – and sometimes much worse – than those experienced by fixed production facilities. They are fed via flexible pipes from the oil wells on the seabed, via a network of sub-sea valve manifolds that are commonly referred to as "Christmas trees".

What is special about sub-sea application requirements?

Sub-sea equipment needs to meet the normal oil field operating conditions



and design codes, including the containment of corrosive liquids or gases at high pressure and temperature.

Consequently, special construction materials, such as super duplex steel alloys are commonly used. In some cases, an even-more exotic alloy (eg, Inconel 625[1)]) is laid over the base alloy to provide additional corrosion resistance.

In addition, external pressure increases with the depths of water above the equipment. In approximate terms, for every 10 metres of water depth, the pressure rises by 1 bar. So when the equipment is, say, 300 metres under the water surface, the pressure on it is approximately 30 times the pressure at the surface. This high pressure, coupled with the need to be able to disconnect/reconnect electrical components underwater, requires that the differential pressure transmitters used with the meters are fitted with "umbilicals" (cables) and electrical connectors designed for use under sea water and at high pressure. This equipment needs to be serviced by a diver in a heavy suit with gloved hands. If the seabed is at an extreme depth, such servicing would be performed using a remotely operated vehicle (ROV).

Footnote

1) An alloy of nickel, chromium and iron

The ABB solution to sub-sea metering

ABB's DeepSeaMaster is a differential-pressure flowmeter, usually based upon the Venturi tube element. It is designed to operate at the bottom of the sea under high external and internal pressure. The meter is usually supplied with one (or more, for redundancy or large flow ranges) special integral DP transmitters designed for sub-sea operation, and special manifolds designed to be manipulated by a heavily-suited and gloved diver in mind.

Every DeepSeaMaster is designed to the customer's project specification. Typically, this specification (albeit expressed in very basic terms) conforms to the following:

- A Venturi tube measuring element (or a metering-pipe run fitted with a conical entrance orifice plate when the application involves flowing conditions that are too low for a Venturi tube)
- Pipe sizes typically in the range 2" to 6" (DN 50 to DN150)
- Constructed from Super Duplex (eg, UNS32760)
- Pressure rating of 10,000 lbf/in^2 (690 bar)
- Designed to American Petroleum Institute standards for wellhead/sub-sea equipment (API 6A; API 17D)
- Fitted with a single DP transmitter (or duplicate transmitters for operational redundancy)
- Manifold or double block & bleed valves (optionally removable)

Sub-sea applications for ABB DeepSeaMaster

Examples of applications for which DeepSeaMaster has been used to date include:

- Measurement of dry or wet production gas
- Measurement of light or heavy oil at low Reynolds Numbers and/or low flow rates
- Water injection Textbox 1
- Injection of MEG (Mono ethylene glycol) to combat well blocking caused by hydrate formation Textbox 2

Customer peace of mind based on technical excellence and verification

In common with all DP flowmeters manufactured at Workington, DeepSeaMaster is supplied with comprehensive certification and documentation and is subject to stringent testing. ABB supply the material traceability certificates that the oil and gas industry needs. These ensure the quality and suitability of the material used in the manufacture of all of these DP flow elements.

ABB's Workington facility offers a wide range of certification and testing, including:

- Chemical and physical property certificates
- Hydrostatic pressure test

Textbox 1 Water injection

When it is necessary to force oil and gas out of older wells, water can be injected. This works in two ways: increasing the well pressure to force the product out and also by helping to "lift" out the oil, as it has a lower density and therefore floats on water. Sometimes some of the gas produced is compressed and re-injected to keep the oil flowing.

Instrumentation

Textbox 2 Mono ethylene glycol

Gas hydrates are crystalline molecular complexes formed from mixtures of water and suitably sized gas molecules. The water molecules associate in a lattice-like pattern. Such formations are unstable and have many cavities within them. The gas molecules can occupy these cavities and once a certain number (or percentage) of these cavities have been filled, the lattice crystal becomes stable and forms a solid (gas hydrate). This happens at low temperatures, but above 0 °C (the temperature normally needed to form solids from water – ie, ice!).

These hydrates can appear only if gas molecules (of the appropriate size) and water are both present. Gases such as methane and carbon dioxide are known to behave in this way. In oil exploration and production, they are a serious problem on both cost and safety grounds. Hydrates are formed under a suitable combination of high pressure and low temperature – exactly what is found in many sub-sea applications. They can block pipelines or sub-sea transfer lines and can actually form in the well itself and associated pipe work. They can lead to huge losses in revenue through lost production.

One solution to the problem is to inject a chemical that prevents the formation of hydrates. MEG (mono ethylene glycol – better known as the basis of antifreeze) is such an inhibitor. The more water there is in the oil stream, the more inhibitor is needed to treat it. However, simply saturating the oil with inhibitor is not the answer, as the water and inhibitor both need to be separated from the product later in the process. Adding more than is really needed is doubly costly – addition and removal! The solution is to add just the right amount. This is complicated by the fact that the oil/water ratio changes as the well "matures", so a fixed ratio cannot be used.

In this application, DeepSeaMaster is used to measure the flow rate in the MEG injection line to ensure that the injection rate is in the correct ratio to the flow rate of water in the oil.

- Radiographic inspection
- Magnetic particle inspection
- Dye-penetrant inspection
- Ultrasonic examination
- Positive Material Identification
- Flow calibration
- Independent authority inspection

These are supplemented by the availability of comprehensive customer documentation packages, including:
- Throat bore calculations
- Welding and weld procedure qualifications
- NDE certificates and procedures
- Quality plans

ABB has supplied DP flow meters to many of the leading global oil and gas exploration companies – including BP, Chevron Texaco, Shell and Statoil – for use in the North Sea and other global fields.

One of the economic solutions being implemented is the installation of equipment on the seabed itself.

ABB, via its Workington facility, has the products that the oil and gas industry demands for harsh sub-sea applications. This factory also has an enviable capability in the key support fields and disciplines (engineering, manufacture, documentation and testing) that are as important to the Oil and Gas industry as the products themselves.

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Mastering the assets

Asset Master software improves productivity

Eric Olson

Every year, heavy industries spend billions of dollars on maintenance; yet, equipment failure is the principal cause of production losses. There is now a wide appreciation that the development of new monitoring technologies is critical to reducing downtime and containing cost. Most importantly for industrial work practice, employing asset management will impel a shift in work culture, from routine and reactive to proactive maintenance.

As ships were to seafarers in the 15th century, the computer was to information processing in the 20th century. From number crunching to problem solving, it has become an indispensable tool in the ever-increasing complexity of today's work environments.

The history of computing is peopled with the most picturesque characters: Charles Babbage and his "Analytical Engine"; Ada Byron, who anticipated computer programming by more than a century; John von Neumann, who proposed storing a program as electronic data; and Alan Turing, who believed that an algorithm could be developed for almost any problem.

Today, large organizations expect to examine and monitor the status of even the most remote outpost at the push of a button. Networks make this possible. It was in the 1970s that ARPANET was set up to connect research organizations throughout the US. In time, this evolved into a worldwide network – the Internet. Taking advantage of networking technologies, it is now possible to create richer and more powerful applications that enable organizations to achieve higher operational efficiency.

Each progression in the evolution of information technology has been the result of a timely idea. The focus today is on integrating disparate technologies and systems to achieve the next level in industrial automation.

Creating Asset Master – a complete asset management tool

Every year, heavy industries spend billions of dollars on maintenance; yet, equipment failure is the principal cause of production losses. There is now a wide appreciation that the development of new monitoring technologies is critical to reducing downtime and containing cost. Most importantly

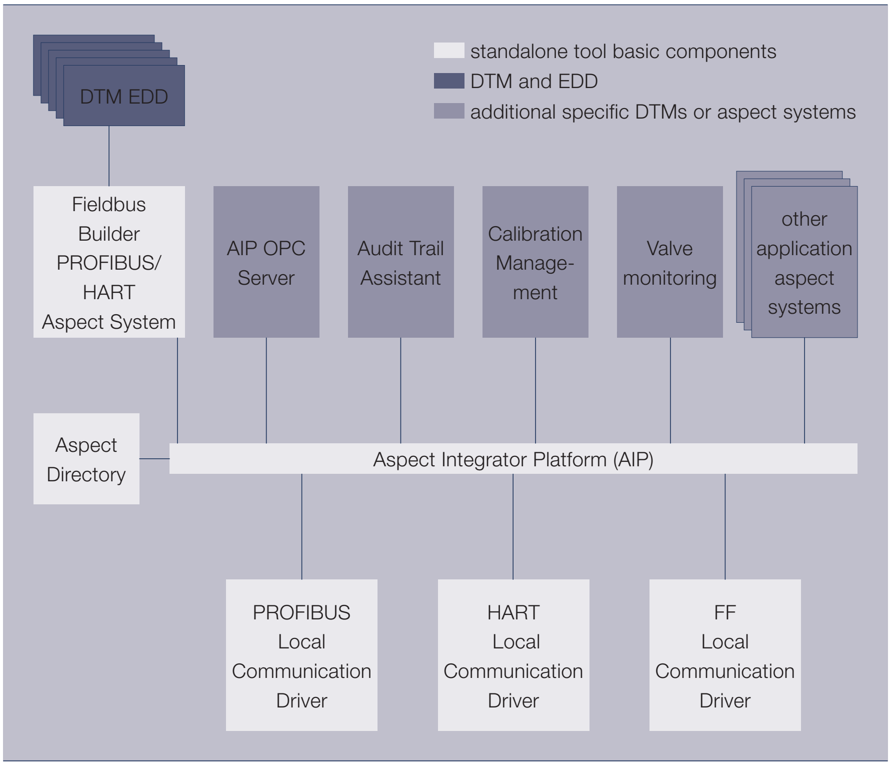
Instrumentation

for industrial work practice, employing asset management will impel a shift in work culture, from routine and reactive maintenance to proactive maintenance. Complete asset management in industrial plants is an emerging opportunity and a present challenge, as changing customer needs tend to raise the bar in innovation.

The first step in defining Asset Master or "must have" features was to identify specific industry needs: The application needed to be capable of managing all areas of field instrument engineering, commissioning, and maintenance. It had to support ABB and third party devices. It needed to provide easy access for online and offline device configuration, parameter setting, online monitoring and tuning, diagnostic alerts, asset monitoring, calibration management and integral work order processing.

Most of these features are already present in ABB's 800xA System and thus, it provided the perfect platform for creating Asset Master.

1 800xA software architecture concept



In concert with the connectivity and integration needs of the company's global instrumentation portfolio, its instrumentation and automation businesses could benefit from a common set of engineering resources and components. Towards this end, a cooperative effort between the two businesses was initiated and, by late 2004, a six-tiered strategy was agreed upon for supporting a number of use-cases Textbox.

The tiers provide extensive scope, from an "electronic screwdriver" at one extreme to a full device management tool installed on the common network using a central database at the other. Customers can start with a small maintenance based application and develop it into a larger control system using the same configuration data and navigation methods for both.

Named Asset Master, the software application for Tiers 3 through 5 is a single tool for all instruments, independent of the manufacturer of the device or the communication protocol (eg, HART, PROFIBUS, or Foundation Fieldbus).

Asset Master Architecture

Asset Master is based on the 800xA System and makes use of common features and components. It can be upgraded by using existing 800xA components, such as audit trail, calibration management, maintenance trigger, etc. 1 shows the 800xA System architectural concept. The goal is to reuse as many components as possible.

The functionality of Asset Master will be synchronized and expanded with each release of 800xA. The public release of Asset Master, scheduled for September 2006 will run on a standalone PC. It will employ a new Asset Master maintenance workplace 2 derived from the existing maintenance workplace.

Instrument connections with Asset Master will be made in support of two primary use applications:
- point-to-point access for bench work configuration (HART via modems, PROFIBUS via adapters, and Foundation Fieldbus via ABB's LD800HSE)
- multiplexer access for online network configuration.

The Mobility hand-held calibrator for integrated calibration is an optional extra. In support of asset optimiza-

Six-tiered approach to asset management

- **Tier 1:** Device configuration – PC-based setup tool, factory configured devices, and local device Human-Machine Interface (HMIs)
- **Tier 2:** Device configuration – Hand-held configuration of ABB and third-party devices and hand-held calibrator
- **Tier 3:** Configuration and visualization – 800xA based standalone PC configuration and visualization tool (base offering)
- **Tier 4:** Calibration – Device management calibration software (option to base offering)
- **Tier 5:** Asset optimization – Asset monitoring and reporting (option to base offering)
- **Tier 6:** 800xA-automation system (upgrade from base offering + options in tiers 4 & 5)

tion, interfaces to asset condition monitoring and Computerized Maintenance Management System (CMMS) are also available as optional offerings.

Considering the rise in transfer of digital information over cellular networks, an option for SMS messaging to cell phones and pagers will also be supported. The 800xA includes all of these optional features and provides them unaltered for use by Asset Master.

The main challenge faced by the product development team was to re-package the 800xA installation software, stripping it of unnecessary functions – functions used in a control system, but not needed for device management. These functions comprise batch management, information (historian) management, AC800M controller and engineering tools, process operator graphics and runtime video. Streamlining the installation software had to coincide with the removal of these applications.

Streamlining Asset Master

Product Management from ABB's instrument business furnished product specification and use-case Scenarios to developers. The specification calls for three new features to be added to the 800xA, each presenting a distinct challenge to the developers.

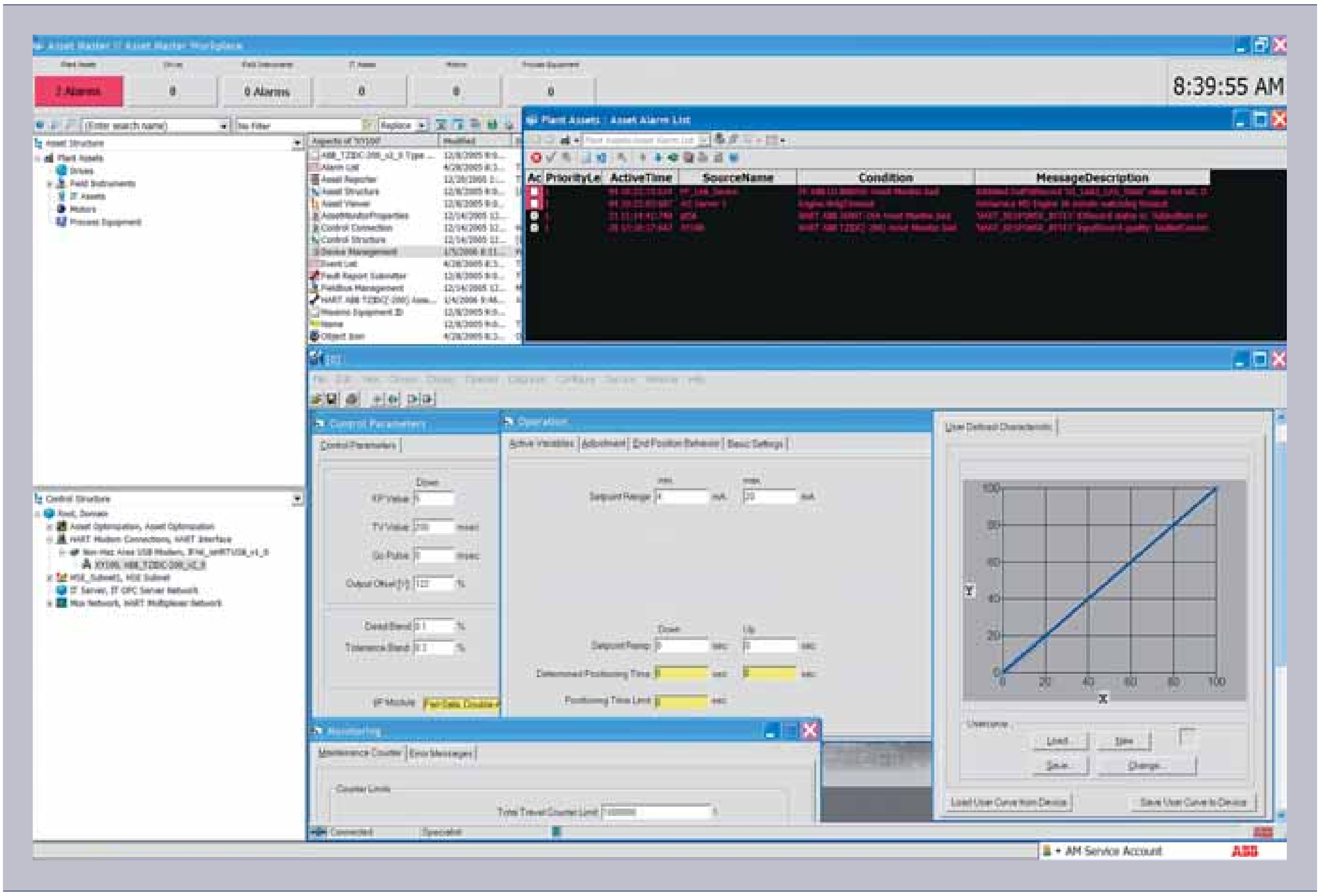
Today, large organizations expect to examine and monitor the status of even the most remote outpost at the push of a button.

Streamlined product installation is the primary requirement. Removing the numerous process and control needs that are integral to the existing 800xA System, but not needed in Asset Master, proved more complex than originally assessed. Consequently, for early adopters, the pilot release of Asset Master, will be pre-installed on PCs. At a later date this streamlined installation software will be provided on a CD/DVD.

The second task of the developers is to support HART modem and PROFIBUS adapter point-to-point communications for offline bench configuration of devices. Despite being equipped with a vendor-supplied Device Type Manager (DTM), HART modems and PROFIBUS adapters need to be packaged to be readily added to the object structure of Asset Master. Another of the challenges lay in removing software dependencies on the AC800M controller from the original system, before the PROFIBUS adapter object could work properly with Asset Master.

The third feature is the creation of an Asset Master workplace to support a portfolio of offline devices that can be inserted onto a HART modem or PROFIBUS adapter for online communication. The 800xA System enables users to view and access their devices in different structures. For instance, de-

2 Asset Master maintenance workplace



vices can be shown by their position in the Location Structure and they can be shown by use in the Functional Structure. However, no matter how devices are displayed, only the Control Structure is used for making actual connection and communication with them.

A plant may have hundreds of devices, but in most cases, only one of them will be connected to a modem or adapter at a time. If all of these devices were to be placed in the Control Structure simultaneously, communication would be attempted with them all. Since typically only one would be connected, the rest would experience communication timeouts leading to excessive delays and degradation of PC performance.

To overcome this problem, Asset Master must support a repository of unconnected offline devices. This is achieved by using the Asset Structure to define all of the instruments and then inserting the device onto the modem or adapter object that exists in the Control Structure. This way, the connected device is replaced. To support this functionality, two structures must be open at the same time. None of the existing workplaces supplied by 800xA supported this functionality. To accomplish this, the existing Maintenance Workplace was used as a starting point for creating an Asset Master Workplace to show two structures **2** maintenance.

Key Benefits

In the area of Fieldbus Device Management, Asset Master provides significant benefits. Primarily, it offers a single tool to configure and diagnose multi-vendor devices, thus reducing capital expenditure on tools and training and removing the user's burden of selection.

The full value of intelligent field devices, that provide critical information on their own health and the health of processes and equipment around them, can be realized only when used in combination with asset optimization software. Asset Master offers improved productivity through choice of devices that best fit the application, independent of fieldbus-type.

Asset Master reduces configuration time by using pre-configured field device objects with extended functionality to access device data, asset information and documentation. It also enables faster commissioning through certified devices and approved field device libraries.

Customers can start with a small maintenance based application and develop it into a larger control system using the same configuration data and navigation methods for both.

It is in the area of Asset Optimization that Asset Master provides tangible economic benefits by reducing maintenance costs over a plant's life cycle and thus boosting the bottom line.

Independent of asset type, Asset Master provides a single interface for engineering, notification of plant maintenance and asset optimization information. Real-time monitoring and alarming of asset Key Performance Indicators (KPI) facilitate fast, reliable implementation of corrective actions. Asset Master collects, aggregates and analyzes real-time plant asset information to provide advanced warning of degrading performance and/or impending failure. Asset Master's reporting features provide visualization of current health conditions, while its analysis features provide the ability to drill down to the root cause of failure. Integration of disparate CMMS, DMS and Fieldbus engineering tools provides users with a single view, leading to quick and efficient assessment of maintenance needs.

In his book on predictive maintenance, Keith Mobley [1] points out that in the US alone, every year, upwards of $200 billion is spent on plant equipment and facilities maintenance. Every year, ineffective maintenance management results in a loss of more than $ 60 billion. Thus, maintenance can represent 15 to 60 percent of the cost of goods produced, depending on the specific industry. In an oil refinery, for example, the failure of a single valve during peak hours could result in a loss of hundreds of thousands of dollars.
A one per cent decrease in productivity could reduce output by hundreds of barrels of oil a day. Therefore, implementing Asset Master creates a substantial savings potential.

Asset Master can provide another significant benefit by ensuring industry compliance. For instance, pharmaceutical units, subject to rigorous Food and Drug Administration (FDA) regulations, rely on the trustworthiness of electronic records generated/managed by critical systems. A recent FDA regulation, 21 CFR Part 11, covers electronic records and signatures that affect production, quality and distribution of drugs in pharmaceutical units. With integration of Mobility Device Management System (DMS), Asset Master can provide users with FDA regulation 21 CFR Part 11 – enabled calibration solutions. In an industry where data integrity is critical to product quality and/or public safety, systems must be overall compliant with FDA regulations. Integrating DMS in the control system offers versatile plant life cycle management and organization allowing the user to derive maximum value from plant assets.

Reusing several 800xA award-winning features resulted in reduced development time for Asset Master and an end-to-end Asset Management Tool that assures compliance with industry regulations. Even now, the combination of intelligent field devices and asset management software is setting new standards for what can be expected and accomplished from the control room. This growing trend in using Asset Optimization will most likely accelerate in the future, fueled by the need for output improvement and cost reduction.

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Uptime all the time

Predictive maintenance in instrumentation

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In industries that operate 24 hours a day, unplanned stops can no longer be tolerated. New strategies are being implemented to avoid production losses and wasted material because of failing equipment. The strategy of choice is predictive maintenance, which can be employed using health monitors of critical assets such as instrumentation, drives, robots ABB, as a leading service provider, is at the forefront of lifecycle support.

ABB offers its customers a full range of instrumentation lifecycle services, of which there are many Textbox. By combining these services with the application and process knowledge existing within the company, its customers benefit and measurable and sustainable performance improvements are achieved.

Lifecycle services related to instrumentation

- Installation and commissioning
- Support and maintenance services
- Migration planning and upgrade projects
- Instrumentation consulting and process analysis
- Training services
- Calibration services
- Parts and repair services

Avoiding unplanned stoppage

One important aspect of these services is assisting customers to avoid unplanned shutdowns due to questionable signal integrity or complete failure of an instrument or actuator. An unplanned shutdown can be extremely expensive, costing thousands or even millions of dollars in lost production and wasted resources. Of course, one service provided by ABB is emergency repair assistance to minimize the length of an unplanned shutdown, if it does occur. However, the object is to avoid these situations altogether. To do so, maintenance services have traditionally been utilized as part of a preventative maintenance program. In this case, a customer requests a visit or contracts with an instrumentation supplier to carry out periodic maintenance during scheduled shutdown periods. The downside is that until recently, it was impossible to know how long one could stretch the period between these planned shutdowns without increasing the risk of an expensive unplanned one occurring. A further complication is that compromised signal integrity can be the result of defects in any portion of a control or sensing loop. The most common causes are, however, mostly related to such instruments that are in contact with the process. Methods to validate and service these devices only when needed, would reduce direct, as well as indirect, troubleshooting costs.

Predictive maintenance programs

To assure maximum performance from the instrumentation in a plant, while minimizing downtime, many companies are now employing predictive maintenance (PDM) programs, either as a standalone service, or as a part of a full asset management or optimization program. When managed by a professional service organization such as ABB's, these programs can prove dramatically less expensive than traditional preventative maintenance services.

The objective of PDM is to predict when an instrumentation device will fail to provide a signal with integrity (hard failure or calibration drift). Having access to such information will reduce unplanned downtime, thereby increasing productivity without jeopardizing quality. This objective is achieved by employing intelligent devices with on-board monitoring, advanced algorithms and notification technology. By adding microprocessor driven diagnostics and application software inside the instruments, these new "smart" devices are capable of monitoring themselves. With the use of fieldbus communications – HART, PROFIBUS, or Foundation Fieldbus – these devices will provide a "health status". This status information can then be leveraged by asset monitor applications that are part of modern automation systems such as ABB's 800xA Extended Automation System. These asset monitors detect performance degradation and notify the appropriate individual that further investigation is required, if appropriate with suggestions of remedial action. Notification can take several forms including pagers and e-mail. Whether implemented as a simple display or alarm message, or as part of a complete control system, these features allow ABB's customers to proactively optimize the usage of their assets, rather than react to surprises.

The implementation of Total Quality Management (TQM) and ISO 9000 programs also drives the need for PDM programs. TQM and ISO 9000 include a requirement for maintenance program procedures to assure that a process and all its components continually perform at a high level. The rationale is that if the process works correctly, then the product will be of the desired quality. ABB's instrumentation equipment and associated services are designed around this philosophy. On page 25 in this edition of ABB Review, the new ABB AW600 Analyzers for Silica and Phosphates, the most advanced water quality analyzers in the market today, are described in some detail. Many of the functions that set this analyzer apart from its competition are related to its advanced maintenance features. Two more examples of "smart" devices, which facilitate the adoption of Predictive Maintenance practices, are presented below.

The knowledge of an instrument's need for maintenance can translate into significant user savings at both ends of the "traditional" maintenance spectrum. At one extreme are under-maintained instruments. The CalMaster case, described below, shows that devices that are inaccessible or costly to maintain are often left un-maintained. This practice typically results in accounting for the "assumed" or inferred inaccuracy through business practice allowances, resulting in lost billings and/or wasted assets. PDM removes the guesswork, and allows owner/operators to make sound business judgments based on verifiable data. Over-maintained devices are at the other extreme; this is the case where failure of a device could cause the kind of shutdown the owner/operator desperately wants to avoid. To minimize this possibility, these devices receive "scheduled" service at regular intervals, regardless of whether they need it or not. While this practice does indeed mitigate the occurrence of unplanned shutdowns, it is extremely costly and could be avoided or substantially reduced if the sensing device was "smart" enough to allow PDM practices to be employed. The ABB 2600T Pressure Transmitter case, discussed at the end of this article, shows how this can be achieved.

CalMaster – enabling predictive maintenance

One excellent example of "smart" instrumentation and a predictive maintenance service providing real value to a customer, is ABB's CalMaster flowmeter verification system. CalMaster was developed to enable customers to check the accuracy and condition of an installed electromagnetic flowmeters. These flowmeters are broadly used in many industries because of their high volume capacity and accuracy. In the water utility market, large volume magmeters, capable of measuring millions of gallons per day, are commonly used between municipalities to provide accurate data for custody transfer and billing. Accurate measurement also ensures that only the necessary amounts of chemicals and energy to treat the water are used, conserving them and protecting the environment. If this accuracy is ever called into question, "demonstrating

1 A typical plant can have hundreds of pressure transmitters installed

2 Harsh environment with high risk for plugging

3 Pressure transmitter 2600T with plugg compensation

the measurement validity" can be a very expensive proposition.

In such a case, the instrument is being used for a function that has a direct monetary impact; custody or "ownership" transfer of product. Perceived problems call into question the validity of the billing. A buying municipality questioning why their supplier's meter is showing a different measurement than their own meter gives rise to dispute. Historically, the billing company had no easy way of proving that their meter was still accurate. Most solutions are so expensive and disruptive that they are seldom employed. The supplying municipality would typically err on the side of caution, adjusting the measurement and lowering bills.

In a similar scenario, a case is considered where the accuracy of a magmeter used to determine quantity of water needing treatment is called into question. Inaccuracy could cause increased treatment cost (in the form of unnecessary chemicals and energy) and negative environmental impact. As in the above example, a municipality or industrial user/owner needing to treat water would only be able to detect measurement inaccuracy by shutting down the process, digging up the meter and shipping it back to the factory. This extremely costly form of accuracy verification is seldom (if ever) conducted over the lifetime of the meter.

However, ABB's CalMaster, with its predictive maintenance service, has changed all of that. Used in conjunction with the MagMaster magnetic flowmeter, the CalMaster technology enables service engineers to check 50 unique performance and device-health parameters of the MagMaster in minutes, without disrupting the flow measurements. CalMaster certifies that the meter is operating to the same specification as when it left the factory – or it will identify any problems that may have occurred such as liner wear, water infiltration into electronics or sensor, corrosion etc. In addition, it will provide information related to whether these problems are affecting the current performance or how long until they may do so in the future, thereby predicting when service of the meter may be needed.

2600T Pressure Transmitter – Plugged impulse line detection savings

Differential pressure transmitters are found in many industrial and utility applications where they are used for sensing the pressure between two points in a process stream. Their main application is computing the flow rate inside a pipeline. A typical plant may have hundreds of these pressure transmitters installed, many located in areas that are very difficult to access for maintenance 1. Consequently, checking these devices for potential problems is a time-consuming and expensive task that companies would like to minimize – but not at the expense of safety.

Differential pressure transmitters determine flow rate by measuring the pressure drop caused by a primary element, typically a Venturi tube, Wedge meter, or an orifice plate. Based on this measurement, and combined with the knowledge of the geometry of the primary element, the flow rate can be computed. The primary elements are typically connected to the process through two pipes called impulse lines. These normally have a small diameter, less then 1 cm (0.39 inches), and can be very long. During the life of the device, its impulse lines can become partially or completely plugged 2. The most frequent reasons for this problem are the following:

- Solid material present in the process blocks the connections.
- Sedimentation occurs and progressively plugs the impulse lines (eg, limestone scaling).
- The fluid inside the impulse lines freezes.

A plugged impulse line can be a potentially dangerous and expensive issue. It has no visible impact on the device hardware and the process value being transmitted to the control room may appear to be valid. This is because the plugging of the impulse line traps the current pressure state and decouples it from the true process state. The control system continues to use the pressure value in control loops not knowing that it is "frozen". The only indication the process operator has that such an event has taken place is the misbehaviour of the affected control loops. Incorrect pressure and flow measurements can lead to expensive and even catastrophic failures if unchecked.

The maintenance effort of identifying a plugged impulse line and removing the plugging is therefore essential but expensive. In order to avoid production interruptions, it is common practice to include DPs (differential pressure transmitters) on time-scheduled preventive maintenance programs, which is quite costly. In addition, certain process fluids are known to cause plugging more often, and are therefore scheduled even more frequently at even greater expense. ABB's 2600T has built-in diagnostics called "Plugged Impulse Line Detection", PILD 3. It identifies plugged impulse lines quickly and relays this information to the control room, eliminating the need for an expensive preventative maintenance program.

The PILD function measures the noise level of the differential pressure signal in an unplugged impulse lines (reference phase). During normal device operation it compares statistically the noise level to the values stored from the reference phase. If the statistical analysis shows a significant difference between the present values and the reference ones, an alarm occurs showing that one or both impulse lines are plugged.The function has been recently integrated into the new release of the ABB 2600T Differential Pressure Transmitters with Foundation Fieldbus interface.

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The future of instrumentation

Future trends in instrumentation technology

Sean Keeping

The comprehensive portfolio of instrumentation products marketed by ABB is founded upon the inherited knowledge of some of the industry's most well known and respected names. Through acquisitions in the 90ies, combined with organic growth, ABB's portfolio has expanded steadily from $50 million to $500 million. New advanced products are now being launched with a unified look and feel, incorporating new innovative technologies and based on common design criteria.

In 1990 ABB's instrumentation business was largely based around the UK- and Italian-based Kent group. However, in the early 1990s, ABB acquired Combustion Engineering, which added products of the US based Taylor Instruments to the mix. With the acquisition of Elsag Bailey in the late 1990s, many more US and European based Instrumentation companies were added to the portfolio, including Hartmann & Braun, Fischer & Porter, Sensycon and TBI.

By 2003, it was clear that the combination of growth and acquisition had helped to create the global instrumentation business that ABB is known for today. Furthermore, a broad product portfolio of core measurement technologies was now supported including pressure, flow, temperature, positioners, water and gas analysis and recording and control.

Significant investment has recently been made to develop an innovative approach to incorporate new technologies into ABB's product families to secure their future competitiveness. This article will focus on three such main areas:

- One ABB instrument portfolio – building a portfolio around shared platforms, components and technologies
- Maximum availability of accessible data – enhancing the value of sensing data and diagnostics in addition to developing deep and robust system integration
- Future technologies – developing wireless capability to support the full intelligence of ABB instrumentation

One ABB instrumentation

Posing the problem

A product offering consisting of the combined portfolios of many acquired companies lacked commonality and economy of scale. This was most keenly demonstrated by the fact that there were more than 40 different transmitter (packaged electronics) platforms. As most instrumentation products consist of a transmitter, connected to a sensor, this proliferation in variety did not add value. A unified HMI (Human Machine Interface) and mode of operation was desirable but non-existent, especially in product

1 Portfolio of old and new generation

families inherited from different companies. A single identifiable instrumentation portfolio would also reduce the substantial cost of supporting and maintaining the plethora of variants, which consumed approximately 40 percent of the available R&D budget preventing the development of new value added features.

ABB's customers list ease of use as a top criterion for instruments. This is reflected in the HMI design for the new product generation Textbox .

To tackle these concerns, ABB recognized it was necessary to embark on the ambitious process of re-developing its instrumentation portfolio. The aim was to create one global product range, based on common, reusable technologies and components, developed by a single global R&D team 1.

Solving the issues

In early 2004 the global ABB Instrumentation R&D team met to discuss how the next generation of products would be developed, but more importantly, what features, method of operation, functionality, look and feel and cost base they would share.

Common components

1. HMI: The display, its menus, architecture and switches share a common method of operation and look and feel. The variety of hardware platforms is minimised to three 2 .
2. Software framework: The software for all new products is based on a common software framework, into which common sub-modules can be inserted. Customer benefits associated with this are usability, consistency and reliability due to the reuse of proven solutions.
3. Housings: A number of different transmitter housing styles are needed, but this is restricted to six basic families, with defined global approvals and a common look and feel. Customer benefits are greater commonality of housing features and re-use of approvals cut the product development cycles.
4. Connectivity: Where fieldbus connectivity is required, all instruments have HART, PROFIBUS and Foundation Fieldbus available based on the same hardware/software platform. Customer benefits are confidence in the behaviour and consistency of all ABB fieldbus enabled devices.
5. Device drivers: All fieldbus enabled instruments require a device driver. ABB offers FDT (Field Device Tool) or EDD (Enhanced Device Description), based on a common toolkit approach. Customer benefits are related to freedom of choice to integrate an ABB instrument reliably into any systems, with consistency of operation and look and feel
6. Look and feel: All ABB instruments share a common look and feel (philosophy) to ensure consistency and quality of the ABB brand. Benefits are provided by reinforcing the identity of the ABB instrumentation portfolio and strengthening its quality image.

2 Human Machine Interface

This process started by identifying at least ten major new product developments that could be released before the end of 2006. The next step was to define common technologies and components that the transmitter design should possess. The Textbox shows the conclusions from this investigation.

As a result of this work, the global R&D team is now not only developing new products but cross functional teams have also been formed with the charter to develop a common library of technologies and components from which the new product generation of transmitters is being built.

Maximising availability of accessible data

By developing the next generation of instrumentation transmitters on a common technology and component platform, ABB is freeing up valuable R&D time to focus on value added features for new products.

The primary measuring feature of any instrumentation device is of course the sensor. ABB is in continuous discussion with customers and end user groups to determine new sensor technology requirements for each product line. Additionally, ABB is ensuring that its customers get the greatest value from the instruments and sensing capabilities to:

- Maximize the value of data from the measured output
- Diagnose or predict, service, maintenance or fault conditions of an instrument
- Diagnose or predict, efficiency or fault conditions of the process or plant itself

Some examples of how ABB transforms the sensor data into value added information are described below.

Pressure: Plugged impulse line detection

A diagnostic function was recently integrated into ABB's pressure transmitter for automatically detecting a very common problem in the field – the blockage or plugging of the instrument connections (impulse lines) to the process. Pressure transmitters equipped with this diagnostic function have the potential to reduce preventive maintenance actions and, therefore, the overall maintenance costs of a plant.

Flow: In-situ validation of electromagnetic flowmeters

ABB has not only advanced the diagnostic capabilities built into its instruments, but the company has also invented (patent protected) the concept of in-situ validation of electromagnetic flowmeters. This requirement was identified by understanding customers' needs and matching these needs with technology. ABB initially released a product called CalMaster and more recently extended its capabilities with the new CalMaster 2 and CheckMaster products. These products are verification devices. By simply connecting them to existing ABB electromagnetic flowmeter installations and running a series of detailed tests, the accuracy and repeatability of in situ flowmeters are verified against their original factory calibrations. Validation is based on advanced fuzzy logic analysis of the measurement data by tracking any changes right back to the original "fingerprint" information measured at the factory during flow calibration. A printed test certificate per flowmeter to be included in the customers' quality records is the final and most important outcome of the verification scheme.

Water analyzer: Reagent level sensing

An important value-creating feature of the AW600 series of water analyzers is its state-of-the-art built-in communications capability when used in conjunction with real-time data from the AW600's array of internal diagnostic sensors. For example, when data from the reagent level sensor is analyzed, the AW600 can signal, via email or SMS text message, the reagent status to a remote operator with up to the minute accuracy. Such a capability will save significant time and cost, by predicting required maintenance activities, eliminating unnecessary site visits and preventing undetected out-of-service incidences.

The diagnostic and predictive maintenance features of an instrument are currently realized in the ABB system through Asset Monitors, which interpret available information from and condition of the device. However, with the continued extension and enhancement of the sensing capability of the devices, ABB will fully exploit this additional value by providing custom-prioritized features tailored to a specific application. Therefore, in the future these features will be either customer commissioned or packaged into special Asset Monitor files, either of which can be integrated into the ABB system tool 800xA or into the standalone tool Asset Master to maximize the value of the total ABB solution.

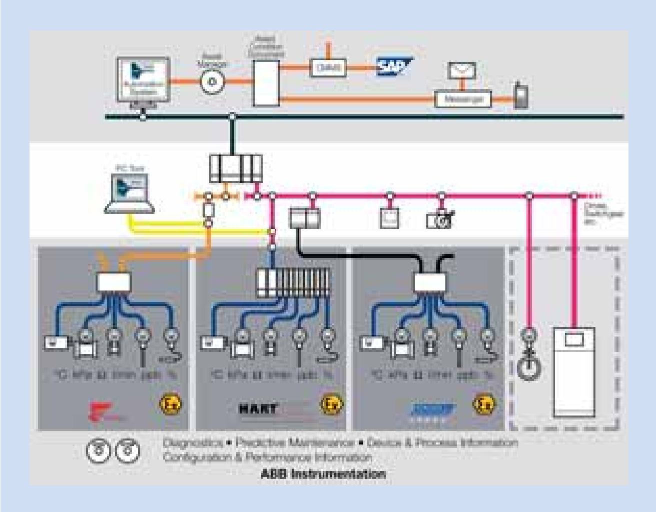
However, ABB is directing more investment towards customers who want to integrate an instrument into a third party system tool, ABB is working with other automation system providers. This ensures the freedom of the customers to fully integrate ABB's new generation of instruments into the systems or standalone tools of their choice 3.

This freedom of choice enables any ABB instrument to be fully connected to any ABB or third party automation system in the following ways:

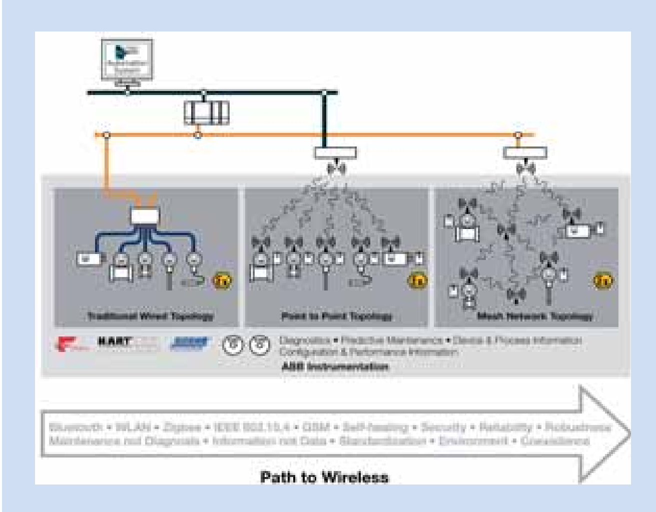
- Uniquely, ABB offers all instruments with HART, PROFIBUS and Foundation Fieldbus connectivity protocols.
- ABB will provide both FDT (Field Device Tool) and EDD (Enhanced Device Description) device driver tool standards.
- ABB is a board member of all major bus and tool bodies/organizations and is influencing the development and harmonization of protocols and tools for the benefit of its customers.
- ABB is currently investigating new connectivity methods including Industrial Ethernet and wireless.

An ABB instrument should be the customers' obvious choice based on functionality, connectivity, freedom of system integration and economic benefits

3 Connectivity and integration topology



4 Wireless network topology



such as reduced Capital Expenditure (CapEx) and reduce Operational expenditure (OpEx).

However, a total ABB solution, consisting of instruments and the 800xA system, ensures ease of use and consistent look and feel, common methods of operation and presentation of information in an innovative format for value based decision support.

Future technologies – wireless

To provide the ultimate support for asset management and fieldbus technologies, ABB Instrumentation is actively engaged in a variety of projects using wireless technology, which will eventually lead to a wireless network connecting an automation system with associated field instrumentation.

ABB has significant experience with wireless technologies. This began with products within factory automation such as the wireless proximity switch, which has been on the market for several years.

Recently, the AquaMaster battery powered flowmeter was launched, offering wireless communication over very long distances for remote applications.

ABB is extending its experience together with key customers in dedicated applications, to provide security, power management, network coexistence and environmental robustness.

To facilitate the establishment of this emerging technology within the process industries, ABB is guiding the standardisation process. This is important to ensure that customers and other users have the confidence to invest in such powerful new technology.

In order to implement wireless solutions ABB is testing applications, such as wireless HMI for remote monitoring and configuration.

Naturally, the next step is to extend wireless capability to a complete network (point to point, meshed etc.) of instruments for the full range of industrial applications. This will mean unlimited access to the full intelligence within the device without wires 4 .

The customer benefits of a wireless network include:

- Reduced installation costs for materials and labour
- Lower operating costs through remote central logging rather than manual methods
- Improved profitability based on more ad-hoc measurements
- Easier implementation of condition monitoring (temperature, vibration etc.)
- Compliance with environmental safety regulations is cost-reduced because of wireless infrastructure

From proximity switches to long distance data reporting for utility meters, ABB has been a significant contributor in offering innovative wireless products. However, several issues are still awaiting solutions:

- Availability of open standards and choice
- Local regulations for radio transmission
- Information and data security
- Robustness of a self healing network

ABB is now extending its range of wireless devices to incorporate development efforts in response to these concerns.

Continuous innovation

The development cycle over the last three years has seen exciting use of new technology and the implementation of many new features in the new product generation. The renewed product portfolio is delivering benefits to ABB in terms of improved cycle time, reduced support costs and improved quality and reliability. These new technologies and improvements are bringing tangible benefits to the customers, enabling ABB Instrumentation to deliver innovative new products, with the right features, at the right price and at the right time.

However, this is not a programme but a process, and ABB plans to continue its innovative approach to new product development to ensure that it can offer the best global instrumentation portfolio available in the market.

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ABB Process Analytical Devices

Cement plants to refineries and hydrocarbon processing plants; waste incinerators to satellites; what single business encompasses such a broad range of industry and process applications? The answer is, ABB's Process Analytical Business. Humans have always used the most fundamental of analyzers (the nose) to sniff air and food for quality; later more advanced devices were developed, such as the canary in the coal mine that tested for air quality. Today we use advanced analytical instrumentation with a wide variety of measurement principles and processing techniques to test and analyze gases, liquids and solids.

ABB's Analytical Business is made up of process analyzer products, lab analyzer products, integrated systems and the corresponding application and field services. The products developed and manufactured at our facilities in USA, Canada and Germany include:

- Continuous Gas Analyzers
- FTIR and FT-NIR Spectrometers
- Gas Chromatographs
- Infrared and Ultraviolet Photometers
- Physical Property Analyzers
- Natural Gas quality and custody transfer
- Analyzer network components

Additionally, our Systems Integration (SI) business supplies complete analytical systems and shelters along with start-up and commissioning services. Project management, sample-systems design, packaging and environmental conditioning and engineering are all core strengths for this business.

Even the best product or system will struggle in a harsh field environment without a capable service and support network. ABB's Process Analytical service team is sharing processes, tools, and infrastructure with ABB's 15,000 strong global service organization for process automation. This includes service manpower planning and dispatching, parts logistics centers, call centers, and repair centers. However, a large global team means nothing without local presence. The ABB Group embraces the phrase "Think Global, Act Local". Local field engineers, close to the customers and sharing their language and culture are the front line. They know they can rely on the back-up of a larger global support network.

Market trends

Most process analytical devices owe their origins to laboratory analysis. Laboratory analyzers were developed to replace what was traditionally measured using titration or other chemical quantitative analysis techniques. The fast, reliable and repeatable measurement offered by the laboratory analyzer was a welcome addition to the research and manufacturing site quality control lab. As advanced chemical and petrochemical manufacturing plants developed, laboratory analytical instrument soon became a limitation. Both the time delay from 'grabbing' a sample to complete analysis and the difficulty in keeping the sample composition in tact drove the need for field hardened at-line and on-line process analytical devices.

To meet this need, many suppliers simply took their laboratory instrument and adapted it to a process environment by adding environmental enclosures and process sampling systems. These analyzers often lacked a fitting design for process use and required highly trained on-site maintenance service personnel to keep them operational. As a result, many earned a poor reputation. ABB has taken a different approach to the analytical instrumentation market: It has built upon its industrial automation heritage to create a line of process analyzers specifically designed for process applications.

The demand for new and better process analytical measurements is expecting to continue to grow driven by several key factors:

1. Product quality and production yields can only be optimized with the availability of real-time process measurements for control. A good example is the use of FT-NIR spectroscopy for finished product gasoline blending. Gasoline blending is a complex process as the refinery must meet the strict fuel quality requirements plus local government standards and do so at the lowest possible cost. Without an on-line process analysis, the blending process must be periodically stopped to extract samples for laboratory analysis. The result is a long response time – lowering the process yield – and a poor analytical repeatability requiring the producer to "give away" unnecessary energy to guarantee that minimum quality specifications are met at all times. On-line analysis allows the producer to blend continuously and at a higher rate and so reduce feed stock blending inventory and demurrage costs. Another example is the current FDA initiative for Process Analytical Technology (PAT) in the pharmaceutical industry. Pharmaceutical manufacturers have lagged behind other process industries in on-line measurement and control of process parameters due to strict validation procedures and still-mandatory laboratory testing. Continuous analysis of active ingredient dosage and content uniformity allow producers to find and correct problems as they occur; this vastly improves process yield by reducing product waste.

2. Energy cost and energy sources will increasingly become an area of focus for energy-intensive process industries. With world production expected to peak around 2037, alternative sources of energy and better utilization of existing energy sources will drive the need for new analytical techniques. Most of our every-day household

products are made of plastics, resins, and fibers all derived from petroleum feed-stock. The production of these products all require significant petrochemical plant processing of oil based derivatives and an increasing demand for accurate process analytical instrumentation. Natural gas was once considered a waste by-product of the oil drilling process, particularly in the Middle-East region where there was no local market for it. Liquefying methane into LNG (Liquefied Natural Gas) generates a compact, higher valued form of energy that can economically be transported around the world by ship. However, the capital requirements to build a LNG plant are very high – typically running into the billions of dollars. As energy prices rise, this process becomes increasingly cost effective as do newer developmental processes such as GLT (Gas-to-Liquid Processing). GLT processing converts methane to liquid petroleum products for which there is a much higher market demand. Because fuels generated from gaseous methane have practically no sulfur and other contaminants, both environmental contamination and engine corrosion are significantly reduced. With the enormous quantities of natural gas available around the world and the advantages of cleaner fuels, GLT processing shows great promise. Both LNG and GLT processing plants place a heavy demand on process analytical technology in their designs. Process analyzer unit counts often run into the hundreds per processing plant. In general, these more advanced process applications demand a higher visibility into each stage of the process which subsequently drives the need for more and better process analytical measurements.

3. Health, safety and environmental regulations evolve continuously – driven by the availability of new technologies, newer fuel and industrial processes, world population growth and industrial globalization. The growing population will put more and more pressure on clean air and water. This demand can only be met by raising process plant efficiency and tightening environmental standards for greenfield and brownfield plant sites. Additionally, as environmental awareness increases in the fast growing Asia Pacific region, corresponding government requirements will become more stringent. All of these developments are drivers for more and better process analytical instrumentation. In fact, ABB is the only process analytical instrument supplier to leverage technologies developed for space satellite applications in the industrial field. We have FTS-based devices currently orbiting the earth measuring atmospheric ozone depletion and other atmospheric chemistry parameters used for weather prediction. Technological progress derived from these projects directly enhances our FTIR/FT-NIR spectrometers used in chemical, pharmaceutical, semiconductor and petrochemical industries.

4. New advancements in core analytical technology will enable development of smaller, higher accuracy process analyzers. Today, most process analyzers are located in environmentally conditioned shelters remotely from the process. One of the biggest challenges is extracting the sample from the process, transporting it to the analyzer in a state to enable accurate analysis. The cost of the sample transport conditioning system, shelter and power/environmental conditioning often exceeds the cost of the analyzer itself by a factor of five. New generations of process analyzers will seek to minimize these costs by moving the analyzer to "by-line" or "in-situ" applications. Both techniques dramatically increase the speed of analysis and decrease its cost. A good example of a by-line instrument is ABB's new NGC 8200 used for natural gas analysis of BTU and flow computing for custody transfer in a single, compact explosion-proof package. Industry demands will continue to drive development towards micro-analytical devices, with the ultimate goal of achieving a "sensor or lab on a chip" (nano-labs).

People and technology

While technological advances in our R&D departments fulfill the product demands of today and the future, we also keep attentive focus on Operational Excellence in our product development and manufacturing operations. Operational Excellence is an all-encompassing program that includes elements of quality systems, lean manufacturing and strategic outsourcing which is ultimately measured by two parameters: cost-of-poor-quality and customer satisfaction. We measure and track dozens of parameters using four-quadrant charts to drive towards continuous improvement in all aspects of our business processes; simply put, the goal is to "do it right the first time".

We strive for continuous improvement in our complete value-chain including the customer-facing organization. Because ABB Process Analytics has such a wide variety of industrial applications, no single sales and service channel can suffice. Our goal is to optimize our industry and market coverage via a combined and complimentary direct ABB and partner sales and service channels. Regardless of the channel, our customers expect only highly skilled personnel. We are defining the competencies required for each role and developing a certification program for both our field sales and service organizations. New web-based training and tracking tools are being used as enablers to drive continuous improvement in our people located all across the globe.

In summary, ABB's Process Analytical Business strives to be the analytical partner of choice in a wide range of process and industry applications. Both our people and our technology are the reason why more manufacturers choose ABB. I trust you will be both enlightened and intrigued as you read the following product technology articles in this special issue of ABB Review.

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Gazing into the universe

FT-spectrometers from ABB in astronomical telescopes

Frédéric J. Grandmont

Often, innovation comes from applying a technology which has proved itself in one discipline, to a completely different field. Sometimes the experience gained in such applications flows back to augment and open new possibilities in the original field. This is the case for Fourier Transform Spectroscopy (FTS) which was developed for astronomical telescopes in the 60ies but found a far broader market in chemical monitoring in industrial processes. The enhanced technology is still equipping high-tech telescopes – where it is revealing the secrets of matter in the furthest reaches of the universe.

In 1998–1999 an international effort worked on defining the best instrumentation for the James Webb Space Telescope (JWST), which is scheduled to be launched in 2012 as successor to the well-known Hubble Space Telescope. ABB Bomem took an active part in this endeavour by presenting an astronomic imaging adaptation of their FTS (Fourier Transform Spectroscope) to the NASA/ESA/CSA consortium. This allowed astronomers to recognise the great potential of IFTS (Imaging FTS) and the experience of ABB Bomem in the control of such a precise clocking device. In late 2000, following on from this proposal, Laval University and ABB launched a joint effort to design an operational ground instrument for the 1.6 meter telescope of the Mégantic observatory in Canada. The instrument was first tested on the telescope in February 2004. In terms of the number of pixels (1.7 M) and the field of view (12 arc minutes), this IFTS is by far the largest ever used on a ground telescope and the only one to operate in the visible band. ABB is the integrator of the complete instrument, which includes an innovative step-scan FTS module, two CCD (charge-coupled device) cameras, two lens assemblies for the output optics and a collimating lens set. The instrument's overall dimensions are 133 × 80 × 80 cm and its weight is approximately 110 kg.

The design goal of this instrument is to maximize throughput and transmission to help astronomers collect as many photons as possible. The instrument operates in the 350–950 nm band to match the sensitivity of the two 1340 × 1300 pixel CCD cameras at the interferometer[1] output ports. Because the interference occurs at visible wavelengths, a mechanical control is required in the nanometer range. A piezo-based frictionless translation stage has been designed to control the angle and position of the moving three-inch mirror of the interferometer. A sophisticated laser-based metrology system optically reads the position and angle of the mirror, 8000 times per second. A dedicated computer determines corrections to apply to the piezo translators in order to stabilize the fringe images and maximize the contrast recorded on the CCDs.

The dual output port design (2 CCDs) is achieved using flat mirrors and by inserting the science beam off-axis. This is the first implementation of this kind described in literature. The arrangement reduces the number of reflections encountered by the science beam. The beam splitter has a sophisticated multilayer dielectric coating that strongly modulates light in the specified waveband without contributing undesired absorption. The seven lenses used for collimating and re-imaging enable the fulfilment of the light-collimation requirement, and also the sub arc-second panchromatic point spread function at the image plane. About a million independent spectra can be collected from distinct scene elements. This is more, by a factor of about a thousand, than is offered by traditional multi-object/imaging spectrometers. The total system transmittance reaches over 60 percent (30 percent per CCD) at 500 nm, thanks to the use of a detector with 90 percent quantum efficiency. This is a value that is unmatched by any other spectrometer. The cameras are cooled with liquid nitrogen, enabling a very low readout noise (3 electrons) and hence a high sensitivity. This instrument can literally count photons.

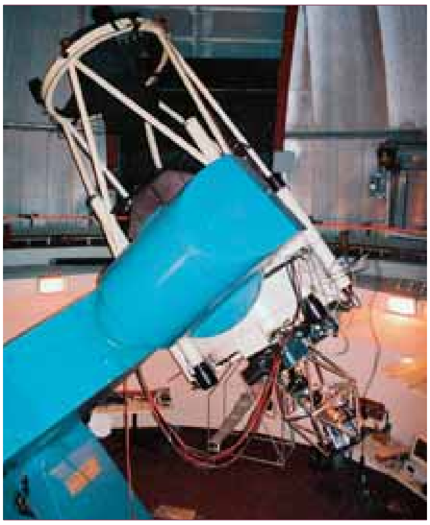
The instrument is controlled remotely using a LabView application. The user has full control over the following parameters of the scan:

- Step-size (related to spectral range)
- Number of steps (related to spectral resolution)
- Integration time per step (adaptability to scene intensity)
- Acquisition order of interferogram points (ability to manage bad sky conditions)
- Camera readout rates (1.8 sec or 18 sec influencing noise level)

The wealth of data from this IFTS comes at the cost of measurement time. A typical cube acquisition[2] runs from minutes to hours, depending on the parameters selected. However, as astronomers are accustomed to sitting and waiting for light to shine into their instruments, this is no impediment. A data reduction software package was developed at Laval University.

The instrument is still under commissioning at the Mégantic telescope 1. It is foreseen that it will be made available to the astronomers in mid 2006 for use on any type of science program. ABB hopes the interest raised in the community from the science papers published using results from this instrument will bring the opportunity to build other units for the current generation of large ground based telescope (>10 m) or future space based facilities.

1 The Mégantic telescope in Canada uses an Imaging Fourier Transform Spectroscope from ABB.



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Footnotes
[1] See textbox "Principle of the interferometer" on page 53
[2] See textbox "Datacubes" on page 49

Nebulae

The Helix Nebula (main picture) is a cloud of gas expelled and illuminated by the dying star at its center. Picture taken by Hubble Telescope (NASA, STSCI).

The inset on the left shows the Dumbell Nebula (M27). This picture was recently made with the described instrument.

Military precision

The Spectral/Spatial Airborne Radiometric Infrared System

Stephane M Lantagne

Infra-red Fourier Transform Spectroscopy permits the determination of the surface temperatures of distant objects. Combined with imaging capability, the technology makes rapid temperature mapping possible. Military applications of this include the automated recognition and tracking of heat-emitting objects such as aircraft, missiles, decoys, and even ground targets. SARIS is an application of this principle small enough to be fitted to a plane.

2 SARIS IFTS in the turret

SARIS (Spectral/Spatial Airborne Radiometric Infrared System) is an Imaging Fourier Transform Spectrometer (IFTS) commissioned by the 46th Test Wing of the US Air Force. SARIS is built in a mobile turret that can be mounted under high-performance jet fighters, such as the F-15 1. ABB Bomem was responsible for designing, manufacturing, integrating and testing the instrument and its companion software packages and support equipment such as ground calibration sources. The system was delivered to the Elgin Air Force Base during the summer of 2003.

SARIS will be used to characterize infrared targets (such as aircraft, missiles, flares, etc.) from the air. The instrument can also be attached to ground trackers were it will be able to perform the same function but from the ground.

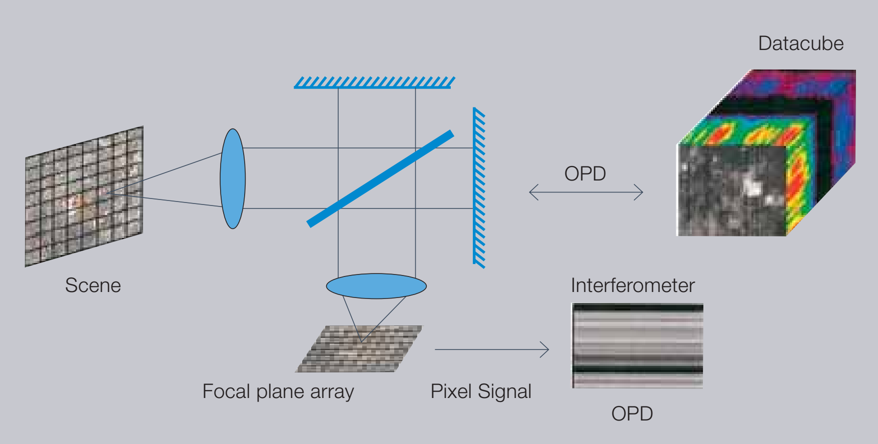
1 The SARIS pod under the right wing of an F-15

The core of SARIS is its imaging spectrometer. An imaging spectrometer is an optical instrument that captures the radiation from the target and constructs images of that target at different wavelengths. The information is gathered in the form of a "cube" of data Textbox. In the case of SARIS, the specific type of imaging spectrometer is a Fourier Transform Spectrometer (FTS). An FTS is an optical interferometer[1)] that modulates the incoming light as a function of time to create an interferogram[1)]. This contains all spectral information of the scene. A spec-

Datacubes

An imaging spectrometer produces cubes of data. This means that not only the two spatial coordinates of a light source are recorded but also the wavelength (or energy) of the photon. In other words, multiple images of the scene are recorded at various wavelengths. This set of images is called a cube of data.

3 Schematic representation of an imaging FTS (IFTS)



trum (radiance vs. wavelength) can easily be reconstructed from it. SARIS is an imaging FTS. Its detector has multiple pixels and a spectrum is acquired for every pixel simultaneously.

The data from the imaging spectrometer allows scientists to determine information, such as the distribution of various chemicals over the target or the spatial distribution of temperature 3. The spectral range of the IFTS in SARIS is 2–5 µm (infrared). Its spectral resolution is selectable, from 1 to 8 cm^{-1} (it has between 3000 and 200 spectral bands). The focal plane array detector has a 16 × 16 resolution, covering the entire field of view (selectable on the ground between 17.7 and 70 mrad). It is also equipped with a co-registered, high-definition infrared camera and two internal blackbody sources for performing in-flight radiometric calibration. The dynamic range of the system permits it to observe targets at between 20 °C and 1500 °C. It generates data cubes at a rate of 5 to 150 Hz, depending on the selected spectral resolution and spectral band.

The data from the imaging spectrometer allows scientists to determine the distribution of various chemicals over the target.

SARIS is mounted in a pod 2 4, the front-end of which contains a turret holding the optical instrument. The turret can be rotated to track a target in flight and can also be turned to look at an internal calibration source. This reference source permits the spectrometer to be calibrated during the flight. The instrument is designed to resist the harsh thermal and mechanical environment associated with operation under a high-performance jet fighter.

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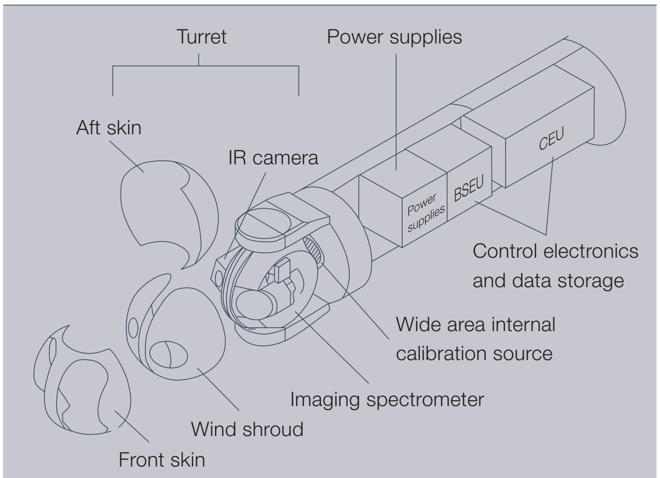
Footnote
[1] See textbox "Principle of the interferometer" on page 53

4 Schematic view of the SARIS pod



Characteristics of SARIS

Parameter	Specification
Nominal Spectral Band (extended)	3.5 – 5.0 µm (2.0 – 5.0 µm)
Spectral Resolution, unapodized	1, 2, 4, or 8 cm^{-1}
Datacube Rate (extended)	19 (5), 37 (10), 75 (20), or 150 (40) Hz
Number of Spatial Pixels	16 × 16
Total Field-of-View, Nominal	17.68 × 17.68 ± 0.08 mrad
Total Field-of-View, Wide	70.4 × 70.4 ± 0.1 mrad
Radiometric Accuracy, at 4 cm^{-1}	± 25 %, for 20 °C < T_{Scene} < 100 °C ± 10 %, for 100 °C < T_{Scene} < 1000 °C
Dynamic Range	20 °C < T_{Scene} < 1500 °C

Looking at the air from space

FTIR atmospheric sounding applications for remote sensing satellites

Marc-André Soucy, François Châteauneuf, Jacques Giroux, Claude Roy

The chemical composition of the atmosphere is rapidly being modified by emissions. The consequences are far reaching – a significant increase in the Earth's temperature and severe climatic change are real possibilities.

To better understand and deal with these effects, better monitoring is required of the air's chemical composition and temperature. How can this be done? Each molecule possesses a fingerprint signature in the infrared spectrum. These fingerprints can be visualized with Fourier Transform Infrared Spectroscopy (FTIR). Satellites equipped with ABB analyzers are providing data for a deeper understanding and an early warning of risks.

Human activity continues to increase emission of gases into the atmosphere. These are transforming its composition and properties. The resulting effects, such as global warming Textbox 1, ozone layer depletion and air quality problems, have drastic consequences. Global warming accelerates water evaporation, which in turn increases average global precipitations. Soil moisture is likely to decline in many regions, and intense rainstorms could become more frequent. Air quality and climatic change also have significant economical and social impacts: Extreme weather conditions pose risks to human populations, either directly or more frequently to their means of production. Rises in infrastructure costs, concentration and age of population, and the resulting greater dependency on these infrastructures further aggravate the risk. To improve the prediction mechanism for these phenomena, more powerful data capturing tools are required.

The FTS instrument is a powerful sounder, dedicated to the measurement of valuable atmospheric parameters.

Atmospheric monitoring by satellite is an important factor in forecasting and developing improved atmospheric models. ABB Analytical Business in Quebec City makes Fourier Transform Spectrometers (FTS) that are carried on such satellites.

The thermal infrared radiance emitted by the Earth's atmosphere contains all the relevant information about the column of air being observed. Every molecule has its own fingerprint in the infrared spectrum. When dealing with pollution measurement, atmospheric chemistry, or the monitoring of ozone, the concentration of molecules is determined by measuring the absorptivity or emissivity of the molecules in the infrared band. For weather applications, the absorption and emission behavior of carbon dioxide at wavelengths around 15 µm allows an indirect measurement of the atmosphere's temperature. Atmospheric windows, ie, parts of the spectrum where the atmosphere is transparent to infrared light, permit the temperature of the Earth's surface to be determined. The portion of the spectrum between 5 and 8 µm permits an indirect determination of the moisture in the air. Not only do these measurements provide a total apparent temperature or humidity at the top of the atmosphere, but they can also be used to retrieve precise profiles of temperatures and water vapor concentrations. This retrieval process transforms the FTS instrument into a powerful sounder, dedicated to the measurement of valuable atmospheric parameters which are used to feed weather forecasting models.

Atmospheric infrared sounder

These atmospheric infrared sounders can be carried on two types of satellites. The first type are the Low Earth Orbiting (LEO) satellites whose orbits are at altitudes between 700 and 850 km. The second type are at an altitude of 36,000 km in an orbit that is said to be "geosynchronous"[1)]. These two types of orbits address different needs but also come with different technical challenges and constraints. On a low Earth orbit, the spacecraft takes 100 minutes to circle the planet. To avoid smearing effects (because of the great speed of the satellite relative to the Earth's surface), the measurement time must be very short. This sets high demands on sensitivity. Geosynchronous instruments, on the other hand, always align with the same location on the surface permitting the measurement to take far longer. However, the greater distance between the spacecraft and the Earth's surface means that the amount of light reaching the sensor is small, again affecting sensitivity requirements. Also, geosynchronous sounders cannot provide global measurements of the earth because they are "locked" at a given latitude.

Textbox 1 Fourier analysis and the Greenhouse Effect

The Earth is exposed to large amounts of solar radiation (about 1.7×10^{17} W outside the atmosphere, or 1366 W per square meter, with a peak wavelength at 500 nanometers). If all of this energy were trapped on the Earth, the planet's surface would heat up very quickly. Fortunately, the Earth loses about 30 percent of this radiation by reflection. The remainder is absorbed by the Earth (16 percent by the atmosphere, 3 percent by clouds and 51 percent by land and water). It is this radiation that makes life on Earth possible. It drives photosynthesis in plants and powers the water cycle and drives natural phenomena. This energy is eventually re-emitted as radiation over a broad frequency range (peaking at about 15 micrometres in the infrared). About 71 percent of the surface radiation is, however, re-absorbed by the atmosphere, slowing down the Earth's natural cooling rate. Without this absorption, the average surface temperature on the Earth would be – 17 °C (instead of + 15 °C). The observed increase in concentration of greenhouse gases is boosting the ability of the atmosphere to absorb radiation, so further increasing the surface temperature (CO_2 concentration has risen from 313 ppm in 1960 to 375 ppm in 2005 according to Mauna Loa observatory in Hawaii).

To obtain further data, the Japanese Space Agency is developing a satellite mission. Its Greenhouse gases Observing SATellite (GOSAT) uses an interferometer designed and built by ABB. It will certainly provide much more information on the concentrations of the molecules that contribute to the warming effect of the Earth's atmosphere.

The mechanism now known as the Greenhouse Effect, is no new discovery. It was first postulated by Joseph Fourier in 1824 and quantified by by Svante August Arrhenius in 1896. It is interesting to note, that Fourier did much work on the mathematical description of heat conduction and infrared radiation – making it all the more fitting that Fourier's other great discovery, Fourier Analysis, remains an indispensable part of the instrument.

The sensors currently used for the atmospheric sounding in the thermal infrared area use an array of narrow band filters to provide spectral information. The number of filters that can be carried is limited (often not more than 20). Moreover, due to the nature of the filters and the width of the required spectral coverage, the spectral bands are not contiguous, meaning there are many gaps in the spectrum and hence missing information. An infrared sounder based on a dispersive spectrometer or on a Fourier Transform Spectrometer (FTS) offers a much more contiguous spectral view. For instance, the CrIS[2)] (Cross-Track Infrared Sounder) will provide over one thousand three hundred spectral channels of information and will be able to measure temperature profiles with a vertical resolution of 1 km to an accuracy approaching one degree Celsius.

1 ACE (Atmospheric Chemistry Experiment) satellite incorporating ABB FTS technology

2 CRiS (Cross-Track Infrared Sounder)

FTS technology has been chosen to replace the filter-based sounders used on LEO spacecrafts because it offers many advantages. For instance, the instrument spectral response function can be easily modeled and included in the retrieval models. Due to its on-board spectral reference – a monochromatic laser diode – the instrument spectral response is also very stable over the life of the mission. Furthermore, the FTS technology is robust and highly reliable – making it ideal for long-term operational missions. ABB is currently under contract from ITT Industries to build the CrIS sounders for the NPOESS (National Polar-orbiting Operational Environmental Satellite System) satellites. ABB is designing and building the interferometer and its metrology system and the blackbody that will be used for the in-flight radiometric calibration of the instrument. ABB is also involved in the definition of the level-one data processing algorithms.

Reliability enhancement activities took center stage early on in the development program. These included life tests on flexure blades and the development of screening criteria for the selection of the laser diodes to be used in the FTS. To further increase reliability, complete redundancy is implemented for the metrology sub-module and for the electronics.

The scanning mechanisms are of a frictionless, flexure-mounted design. These avoid the wearing down of the moving assembly that is so often a problem in space instrumentation.

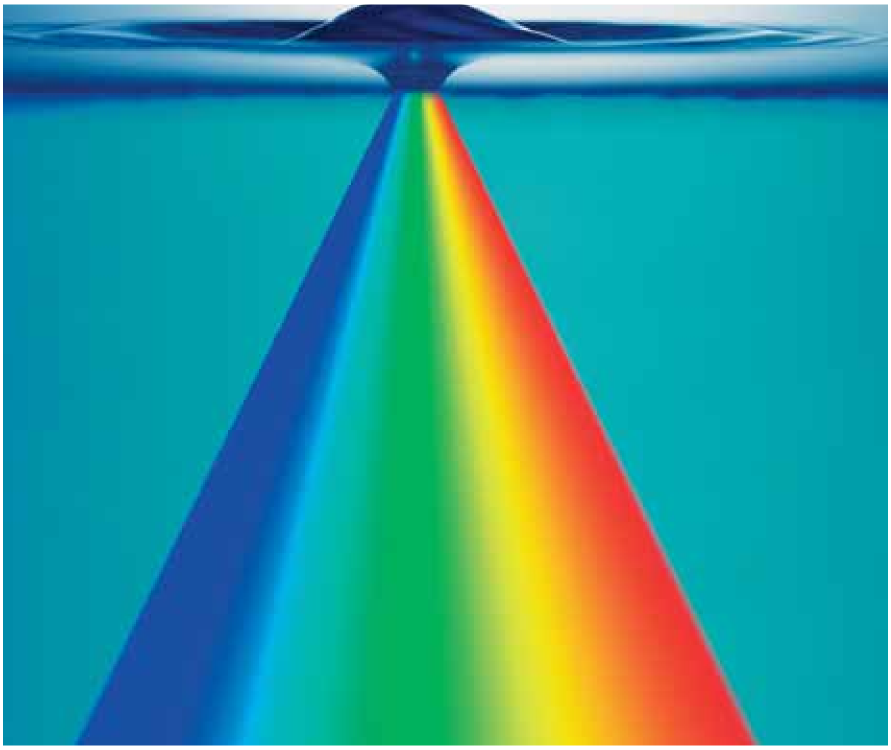
Delivery of the first flight unit took place in November 2005 and flight models two and three were added in the following months.

FTS technology has been chosen to replace the filter-based sounders used on LEO spacecrafts.

Decades of experience

ABB's involvement in the remote sensing of gases in the upper atmosphere goes back to the early 1970s, when the company (then Bomem Inc.) designed and assisted in the operation of a balloon-borne FTS instrument for the Atmospheric Environment Services in Canada. Fourier Transform Spectrometers (FTS) modulate the IR beam in a wavelength selective way by means of optical interference Textbox 2. This method of obtaining a spectrum is elegant, powerful and flexible. ABB now provides full FTS solutions for the analytical market. Building on the experience from such programs as ACE/SciSat-1[3)] 1, CrIS/NPOESS 2, and drawing on its process analyzer know-how, ABB has created a high-reliability Fourier Transform Spectrometer platform.

As mentioned in the introduction to "Gazing into the Universe" (page 46), FTIR technology was originally designed to look into Space. After finding its way into a whole range of other applications, the technology has been launched into orbit and is looking back at the Earth from Space. ABB's expertise in the design and manufacturing of Fourier Transform Spectrometers will continue to serve atmospheric observation needs for many decades.



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Textbox 2

Principle of the interferometer

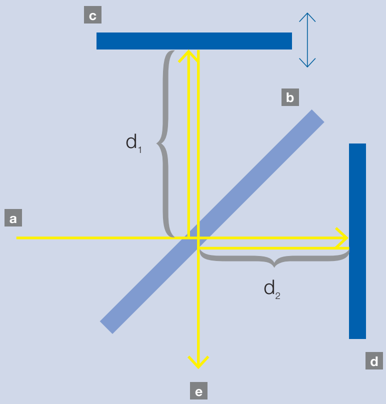
Fourier Transform Spectrometers (FTS) selectively modulate an incoming infrared beam by means of optical interference. The intensity of the incoming light **a** is split in two parts by a half-mirror beamsplitter **b**. The reflected part twice travels the distance d_1 (separating the moving mirror **c** from the beamsplitter). Similarly, the transmitted part travels the distance d_2 (separating the fixed mirror **d** from the beamsplitter) twice. The two parts interfere with each other **e**, in either a constructive or destructive way depending on the wavelength and the distances d_1 and d_2 (see "From wawes to data: a quick guide to Fourier Transform Spectroscopy" on page 60). The intensity at the interferometer output is a function of the position of the moving mirror **c**, because the interference patterns vary from completely constructive to complete destructive. In fact, the intensity of the modulated output, also called the interferogram, for a monochromatic light at wavelength λ (or frequency $\nu = c/\lambda$) entering the interferometer is given by

$$I(x;\nu) = \frac{I_0}{2}\left\{1+\cos\left\{2\pi\nu\frac{x}{c}\right\}\right\}$$

where $x = 2(d_1 - d_2)$ is the optical path difference between the two arms of the interferometer and I_0 is the intensity of the incoming monochromatic light. For a polychromatic input, the total interferogram is simply the sum of the monochromatic interferograms, ie.

$$I(x) = \int I_0(\nu)\,\frac{1}{2}\left\{1+\cos\left\{2\pi\nu\,\frac{x}{c}\right\}\right\}d\nu$$

where $I_0(\nu)$ is the spectrum of the polychromatic incoming light. The interferogram is thus simply the Fourier transform of the spectrum of the incoming light. Therefore, by evaluating the inverse Fourier transform of the interferogram, one retrieves the spectrum of the radiance entering the instrument.



Footnotes

[1] A satellite in geosynchronous orbit appears stationary to an observer on the Earth's surface.

[2] The Cross-track Infrared Sounder (CrIS) will replace the High-resolution Infrared Radiation Sounder on the next generation of National Polar-orbiting Operational Environmental Satellite System (NPOESS) in the USA. The CrIS will provide improved measurements of temperature and moisture profiles in the atmosphere from an altitude of about 850 km. See http://www.ipo.noaa.gov/ for more details.

[3] The Canadian SCISAT satellite helps a team of Canadian and international scientists to improve their understanding of the depletion of the ozone layer, with a special emphasis on the changes occurring over Canada and in the Arctic. The ACE-FTS instrument on-board SCISAT measures simultaneously the temperature, trace gases, thin clouds, and aerosols found in the atmosphere from an altitude of 650 km. The satellite was launched by NASA on August 2003 and is operating succesfully.

A spectrum of applications

Process Analysis using FT-NIR Spectroscopy

Paul Chabot, Mike Simpson, Fabiano De Melas

Keeping processes under tight control is paramount to achieving quality and throughput improvement and cost reduction. A plant's ability to increase efficiency can easily determine whether it operates at a profit or at a loss. In the past, optimization decisions required laboratory analysis of samples removed at different process stages. To achieve a more responsive control, analysis has shifted to on-line measurement. Analyzers are connected directly to the process through sampling systems, probes or non-invasive sampling interfaces. The prerequisite for such analyzers is high reliability, robustness, simplicity of use and ease of maintenance.

Fourier Transform Infrared Spectroscopy (FTIR) is a widely used analytical technique for the on-line monitoring of processes[1]. It offers a fast, accurate and highly repeatable approach to the monitoring of both chemical and physical properties of a process stream. ABB is a global leader in FTIR technology and has dedicated more than 30 years to the development of FTIR analyzers. ABB's FTIR solutions are engineered to meet the tough requirements of process applications for a broad variety of manufacturing industries. They form a unique family of analytical instruments perfectly designed for on-line, real-time monitoring.

FT-NIR (near-infrared FTIR) focuses on the band between approximately 750 and 1400 nm.

The following articles present applications of process FTIR spectroscopy for the monitoring and control of two different types of processes. The first example focuses on an application for the analysis of a gasoline blending process for the Hydrocarbon Processing Industry (HPI), while the second application describes the use of FTIR spectroscopy for the non-invasive analysis of a semiconductor manufacturing process.

Footnote

[1] See also "Principle of the interferometer" on page 53.

On-line analysis of a gasoline blending process

Product blending is an important technique in the refining industry. It is the final stage in the conversion of crude oil into useful fuels. The blender mixes several streams from various process units to provide fuel that meets government, international or customer specifications. As it represents the final stage in a refinery process, its optimization is vital – the benefits of upstream process optimization are easily negated when poor blending produces either a substandard fuel or – more frequently – sacrifices refining margin through suboptimal use of expensive blend feedstocks. This is the step whose optimization frequently offers the greatest benefits in terms of payback.

A sustained global increase in demand for light fuel, driven by the emerging economies – especially China and India – has led to the strengthening of refining margins. This development is continuing despite the rising crude oil prices of recent months. The availability of high production margins for final products has

re-emphasized the role of process FT-NIR in high-value final product optimization applications, including gasoline product blending. The advantages offered by process FT-NIR include multi-property, multi-stream analyses, high analysis repeatability (normally significantly better than conventional on-line analyzers), and accuracy meeting ASTM (American Society for Testing and Materials) norms. In addition, process FT-NIR analyzers are able to model not only direct chemical compositional information, but also bulk process stream properties such as octane, aromatics, distillation curves, cetane, cloud point – which are often the properties most required by unit optimizers, or the most constraining in terms of product release. All of these properties can be extracted from a single FT-NIR spectrum. Typical FT-NIR calibration model performance on gasoline data for a refinery with a good reference laboratory are shown in Table 1.

Provided good statistical practices are followed, process FT-NIR will yield an analytical accuracy exactly as good as the ASTM laboratory reference data used to develop the calibration models. It is perhaps not always fully appreciated how much analytical repeatability and analyzer availability can be improved by the use of process FT-NIR as compared to conventional multi-analyzer blend optimization schemes. For light hydrocarbon streams, which can easily and successfully be prepared for analysis by simple sample-conditioning filtered fast-

Table 1 Typical Process FT-NIR Performance Data

Typical FT-NIR analyzer calibration performance for final product gasoline for a refinery with a good reference laboratory:

	Accuracy (SECV) at 1σ	Precision (r) at 1σ
RON	0.28	0.01
MON	0.32	0.01
% Aromatics	0.8	0.02
% Olefins	1.2	0.03
% Benzene	0.1	0.005
% Oxygenates	0.2	0.01
RVP (kPA)	0.82	0.16
D10 (°C)	1.8	0.1
D50 (°C)	2.1	0.1
D90 (°C)	3.2	0.1
E170	1.6	0.08
E365	0.8	0.011

Table 2 Typical value of octane giveaway

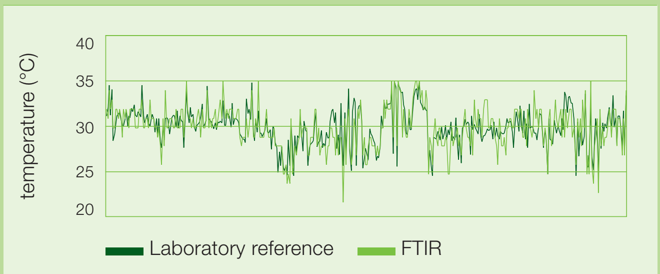
Cost of octane giveaway, $M per year 0.1 PON (Pump Octane) per 200,000 bbl/day CDU capacity

Item	Factor	Value
A	Octane giveaway	0.1 PON
B	Multiplier for APC 99 % confidence level	2.58
C	Refinery margin, $/octane-gallon	0.015
D	CDU to FPB conversion ratio	0.562
E	Average throughput (CDU) bbl/day	200,000
F	Average throughput (CDU) gals/day	8,400,000
	Lost profit, octane giveaway/day	$18,270
	Lost profit, octane giveaway/year	$6,668,550

CDU = Crude Destillation Unit

1 Process FTIR 8 hour repeatability (RON; research octane number)

3 Laboratory versus Process-FTIR trendline



loops, the inherently ultra-low-noise optical technology of FT-NIR can yield exceptional analytical repeatability when compared with conventional physical analyzers.

The outstanding repeatability 1 of ABB's FT-NIR gasoline property measurement is of significant benefit to the blend operator. Changes in blend properties can be tracked precisely during blending. Such changes would otherwise be "lost" in the noisy or infrequent results that classical analyses return. The operator or multi-variable control scheme can make process decisions with the confidence that the observed deviation is real. In addition, the increased repeatability as compared to the traditional laboratory method 2, means that a reduction in property giveaway can be achieved.

Since the process FTIR analyzers used in refinery process stream analysis and unit optimization are secondary analyzers (depending for their operation on correlation models using laboratory reference data) it is important for validation purposes that an ongoing SQC (Statistical Quality Control) track-record of performance relative to laboratory standards is maintained. Useful ASTM guidelines for this practice are covered in ASTM D6122 and ASTM E1655. 3 shows such an example of a laboratory vs. process FTIR comparison for a gasoil blending application.

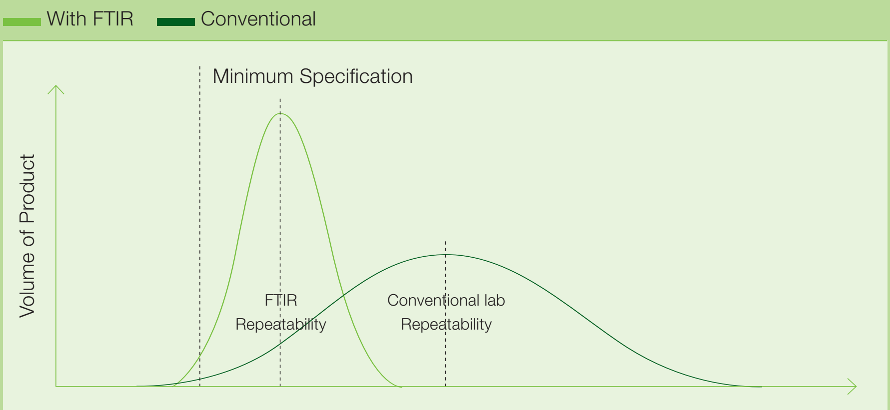
This giveaway can never be reduced to zero, but minimizing it as far as possible makes a decisive contribution to the refinery's overall margin.

Better earnings through better analytical accuracy

The calculation in Table 2 represents the "baseline" giveaway associated with an analytical uncertainty of 0.1 Pump Octane Number (PON).

This giveaway can never be reduced to zero, but minimizing it as far as possible makes a decisive contribution to the refinery's overall margin. The numbers of Table 2 show that a very conservative improvement (an analytical precision of 0.02 to 0.05 PON) in a real-time and on-line process FTIR analysis of the final product leads to a saving in the range of $1.5 M to $3.0 M per year.

2 Reducing giveaway with precise blending control



Clear arguments for FTIR

FTIR is the technology that currently offers the best trade-off in terms of price, performance, value and risk. As an optically-based technology, it allows for the highest flexibility in terms of multi-stream, multi-property applications as it is compatible with both local, fully extractive sampling and remote, multi-cell extractive fiber-optic based analyzer systems. It offers a multi-property analysis with rapid analysis cycle times well tuned to the requirements of an APC (Advanced Process Control) optimizer. It is also well established with hundreds of installations globally providing examples of successful implementation. Historically, the limitation to any spectroscopic measurement for on-line final blended product control has been the difficulty in developing, and more particularly maintaining, robust stable calibration models. This has been to a large extent mitigated by recent developments including very well-controlled analyzer-to-analyzer variability which permits easy maintenance and transportability of developed calibrations. It has been further mitigated through the global development of product databases speeding up calibration development – and the exploitation of novel chemometric modeling procedures has helped to minimize the sensitivity of developed calibrations to changes in blending recipes.

Optimization of a Semiconductor Manufacturing Process

Continuous monitoring and control of the wet chemistry used in the semiconductor manufacturing process enhances production yields, decreases risk of failure, and maximizes profitability. Achieving high throughput, competitive quality standards and low production costs in semiconductor manufacturing requires a very precise control strategy. Among the wet processes used, the wafer cleaning procedure is one of the most important. A well-controlled cleaning procedure is essential in removing impurities and ensuring product quality.

ABB's Wet Process Analyzer (WPA) is designed for the continuous on-line monitoring of the concentrations of the chemicals used in a wide range of etching, cleaning and stripping fluids and provides the communications protocols that permit real-time process control.

System configuration

The ABB WPA couples an FT-NIR spectrometer with a PTFE sampling sensor for non-invasive monitoring. The spectrometer includes an optical multiplexer and a multi-detector module, allowing sequential monitoring and control of up to eight different sampling points. Through the use of fiber optic cables, each measurement point can be up to 100 meters away from the analyzer. 4 shows the system configuration with eight occupied detectors.

Sampling approach

The patented ClippIR$^+$ module enables in-line real-time monitoring. Its installation is fast and simple and does not require an impractical bypass or a cooling unit. Each ClippIR$^+$ is clamped onto the external surface of an existing PTFE tube and directs NIR light through the PTFE conduit and then back to the spectrometer. The ClippIR$^+$ measurement time is 57 seconds for one sample, regardless of the number of components measured in each stream.

Table 3 Wet bench module configuration:

1. SPM/QDR
2. BOE/OFR (not used in this RCA process)
3. DHF/OFR
4. SC1/QDR
5. SC2/QDR
6. IPA (not considered)

Where:
SPM is $H_2SO_4/H_2O_2/O_3$ at 120 °C
QDR is Quick Dump Rinse
BOE is NH_4F/HF (not used)
OFR is Overflow Rinse
DHF is diluted hydrofluoric acid, in this case 100:1 for HF: H_2O at 22 °C
SC1[3] at 5:1:1 for H_2O: NH_4OH: H_2O_2 at 50 °C
SC2[4] at 5:1:1 for H_2O: HCl: H_2O_2 at 50 °C
IPA is Isopropyl Alcohol.

Table 4 Chemical usage calculations (100% production, no idle time, 96 runs/day)

	H_2SO_4	H_2O_2	HF	NH_4OH	HCl	IPA
Consumption gal/run	0.11	0.34	0.0010	0.030	0.020	0.050
Consumption gal/day	11	33	0.096	2.9	1.9	4.8
Consumption gal/week	74	228	0.67	20	13	34
Consumption gal/year	3800	12000	35	1000	700	1700
Yearly Chemical costs	$45,068	$193,560	$611	$7,870	$6,937	$13,580

Because of its compact size, it can fit into small chemical cabinets or inside any other part of the wet station. It is also chemically resistant to corrosion and is suitable for highly aggressive environments.

Successful operation

ClippIR+ was demonstrated on a wet bench that was equipped with a multiple robot handling system to load cassettes of wafers side-by-side into reduced cassettes, and then move them through a series of chemical baths. The wet bench was a 50-wafer tool. Its module configuration (order of chemical steps, concentrations, temperatures) is summarized in Table 3.

All rinses were based on predetermined times or dump/fill cycle counts. In such a process, all chemical tanks must be changed periodically. The bath dump rates for the wet bench are 24 hours for SPM (sulfuric acid, peroxide and de-ionized water mix[1]), BOE (buffered oxide etch) and DHF (diluted hydrofluoric acid[2]) and 12 hours for SC1 (standard clean 1[3]) and SC2 (standard clean 2[4]).

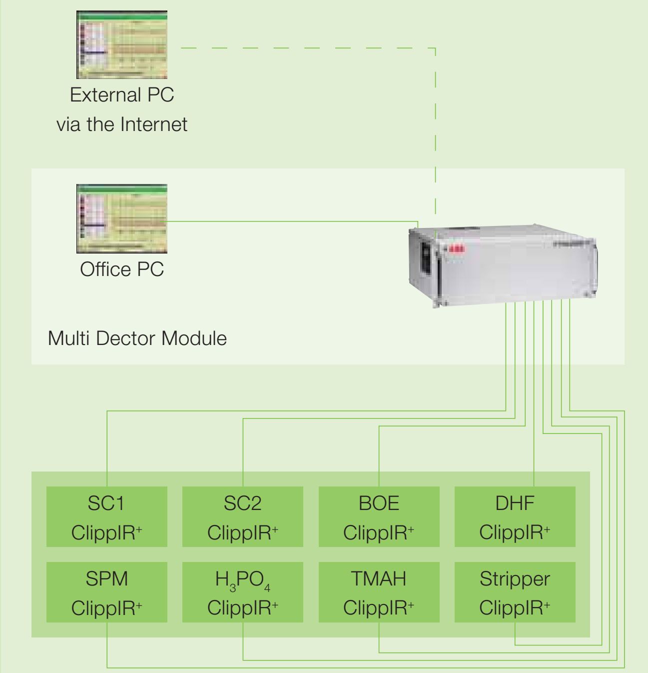
Chemical consumption costs are reduced by at least 20 to 30 percent.

The chemical usage measurements and calculations obtained were performed on the basis of 100 percent production with no idle time. This equates to approximately 96 runs per day. A summary of chemical usage and total annual costs related to the wet bench is presented in Table 4.

The on-line chemical monitoring of each component in a wet station tank improves process control and also extends bath lifetime by buffering the single tanks with replenishment solutions. These are injected at regular time intervals or when predefined threshold concentration values are exceeded.

This demonstration shows how using a chemical monitoring approach with a good control strategy can extend the lifetime of chemicals from a few hours up to several days. Chemical consumption costs are reduced by at least 20 to 30 percent (depending on the process recipes).

4 Configuration of the ABB Wet Process Analyzer



For example, a tight monitoring of HF and NH_4F concentrations in a BOE bath helps production engineers maintain the chemical concentrations within predefined ranges. When predetermined concentration thresholds are reached, the WPA transmits alarm or warning signals to the wet station console. For this to make an effective contribution to process stability and reliability, monitoring repeatability is crucial.

One of the main parameters influencing the WPA performance is the stability of the process temperature.

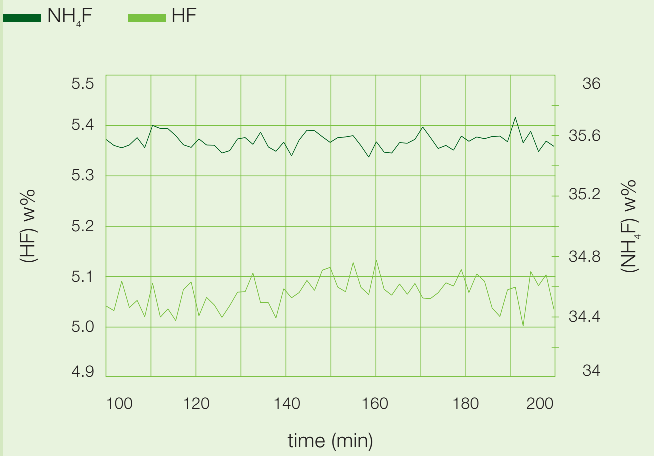
The repeatability of WPA is excellent: typical analytical performances are shown in 5 – repeatability on NH_4F and HF in a BOE bath can exceed 0.1 percent. On the HF monitoring, the target concentration is considered at 5 percent (by weight) and the WPA can follow the concentration with an absolute repeatability of +/–0.03 percent (by weight). For ammonium fluoride, the target concentration is approximately 35.5percent (by weight) and the achieved repeatability is 0.07 percent.

One of the main parameters influencing the WPA performance is the stability of the process temperature. For instance a DHF process controlled with a temperature tolerance of 5 °C (+/– 5 °C) can be typically monitored with repeatability on HF observation of 0.08 percent. With highly performing in-line heaters (tolerance of around 0.5 °C or less), the repeatability at 1 sigma on HF can reach up to 80 ppm.

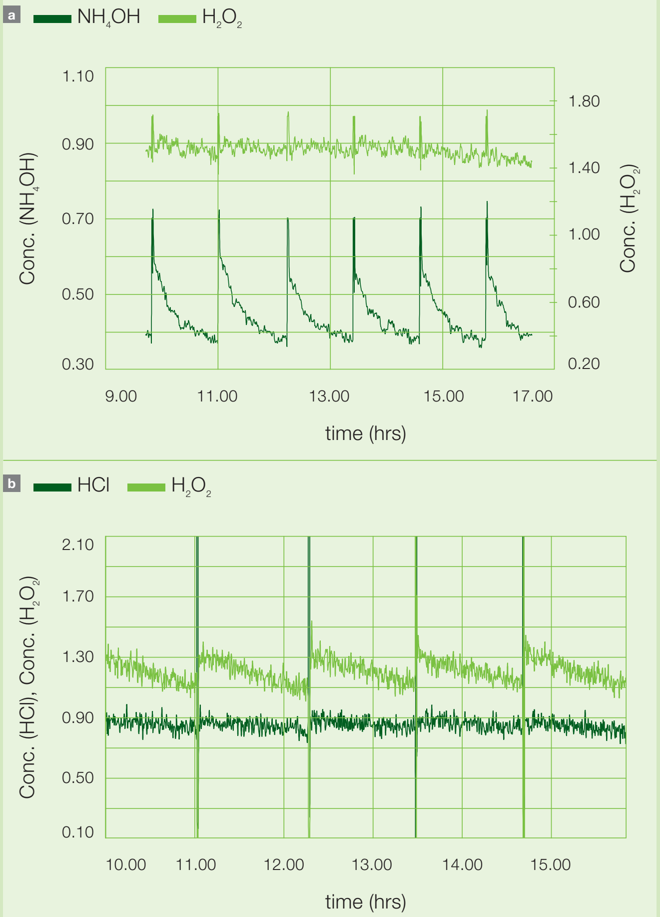
6 shows continuous production monitoring of SC1 and SC2 processes: production cycles and chemical bath changes are monitored with the WPA. In the SC1 process 6a trends of H_2O_2 and NH_4OH are shown. The SC2 process 6b monitoring reports trends of HCl and H_2O_2.

The WPA is of a great value for the optimization of process quality. It helps keep chemical concentrations within predefined limits.

5 Trend line of HF and NH_4F in a BOE (buffered oxide etch)



6 Trend line of a NH_4OH and H_2O_2 in a SC1 bath and b HCl and H_2O_2 in a SC2 bath.



In this SC1 process, the concentration of ammonium hydroxide decreases over constant time periods, while hydrogen peroxide remains constant over time. The WPA helps identify the component in the SC1 solution that is the limiting factor in terms of concentration, defining the threshold concentration values (ie, lower limit on NH_4OH concentration) and finally triggering a complete bath change based on predefined concentration limits. In the example discussed here, SC1 baths are changed when the concentration of NH_4OH drops below 0.37 percent. As an additional precaution, a time limit can be also defined for bath changes.

WPA delivering added value

The WPA is a reliable and reproducible analytical instrument. The WPA can be equipped with between one and eight ClippIR+s – non-invasive on-line sampling sensors that can easily be integrated onto existing process lines without introducing contamination risks. The WPA is of a great value for the optimization of process quality. First, it helps keep chemical concentrations within predefined limits, preventing wafers from being processed with out-of-specification solutions while also providing the required confidence on the concentration measurements: both during the mixing or pre-mixing steps or on the recirculation line of process tanks. Moreover, the return of investment of one single WPA equipped with several ClippIR+s is enormous because it allows end users to save on the cost of chemicals and reduce chemical waste on multiple chemical baths. Hence the WPA has been shown to deliver added value to wet equipment in terms of increased throughput, reduced costs of ownership and much safer and better controlled wet processes.

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Footnotes

1) Also known as "piranha etch", this bath removes organic contaminations.
2) BOE and DHF are used to remove oxides and reduce metal contamination.
3) Uses APM. (ammonium hydroxide, hydrogen peroxide and de-ionized water mixture) to remove particles.
4) Uses HPM (hydrochloric acid, hydrogen peroxide and de-ionized water mixture) to remove metal contamination.

The interferometer

In an interferometer[1], the incident light ray is split into two branches that traverse different paths before being recombined into a single ray. Due to the difference in path length, the phenomenon of interference occurs.

Interference

1a shows waves spreading from a point source. In 1b and 1c a second identical source is added and the wave patterns are superimposed. In places, the patterns combine to form waves of up to twice the amplitude (constructive interference). Elsewhere, they cancel out leaving areas of calm (destructive interference). In contrast to these examples in which interference occurs in two dimensions, the interference in an interferometer occurs principally along a single axis (shown in red in 1). In 1b, the distance between the sources is a multiple of the wavelength and maximum constructive interference occurs along the axis. In 1c, the distance is shortened by half a wavelength leading to destructive interference. More generally, the strength of the signal at any point on the axis varies sinusoidally as a function of the distance between the sources, and at a wavelength that is identical to the signal wavelength. The signal wavelenght can thus be determined by varying this distance while observing the signal strength.

A real measured signal rarely takes the form of a pure sine wave. The signal strength plotted as function of the path difference (interferogram) consists of many superimposed waves of different frequencies. Further processing is required to separate these.

From Fourier to Fast Fourier

In the early years of the 19th Century, Fourier developed a mathematical transformation that maps a function to its frequency spectrum:

$$F(k) = \int_{-\infty}^{\infty} f(x)\, e^{-2\pi ikx} dx$$

where $f(x)$ is the function to be analyzed and $F(k)$ its frequency spectrum.

Digitally recorded signals usually consist of a finite series of numbers acquired at a regular interval. The corresponding Discrete Fourier Transformation (DFT), derived from the general formula is:

$$F_n = \sum_{k=0}^{N-1} f_k\, e^{-2\pi ink/N}$$

where f_k is the k-th element of the recorded series, F_n is the n-th element of the corresponding frequency series and N is the number of samples. This algorithm has one major shortcoming: Its complexity rises quadratically with N. Historically, its use was often beyond available computational means. Various, often inadequate, approximations were adopted.

All this changed in 1965 when Cooley and Tukey published their Fast Fourier Transformation (FFT) algorithm.

How does it work?

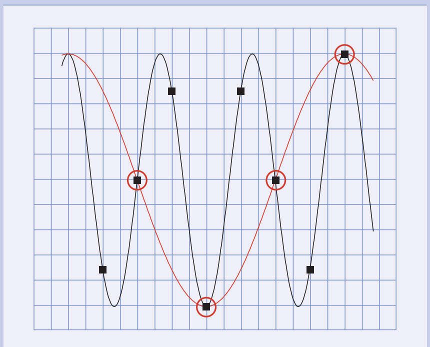
One effect of reducing the sampling rate is that information is lost. 2 shows a sinusoidal curve (black) sampled at a rate of eight (black points) and again at four (red circles). At the latter rate, the sampled signal cannot be distinguished from the red curve and consequently its DFT is identical (the red curve is called the alias of the black – such aliasing occurs for all frequencies above half the new sampling rate). A separate DFT performed on the omitted points returns an equally ambiguous result, but comparison of the two DFTs restores the lost information. Instead of calculating one eight-point DFT, two four-point DFTs are performed, each of which requires a quarter the computing power of the original. This reduction can be repeated recursively. The FFT algorithm is thus most efficient when the number of samples is a power of two.

Footnote

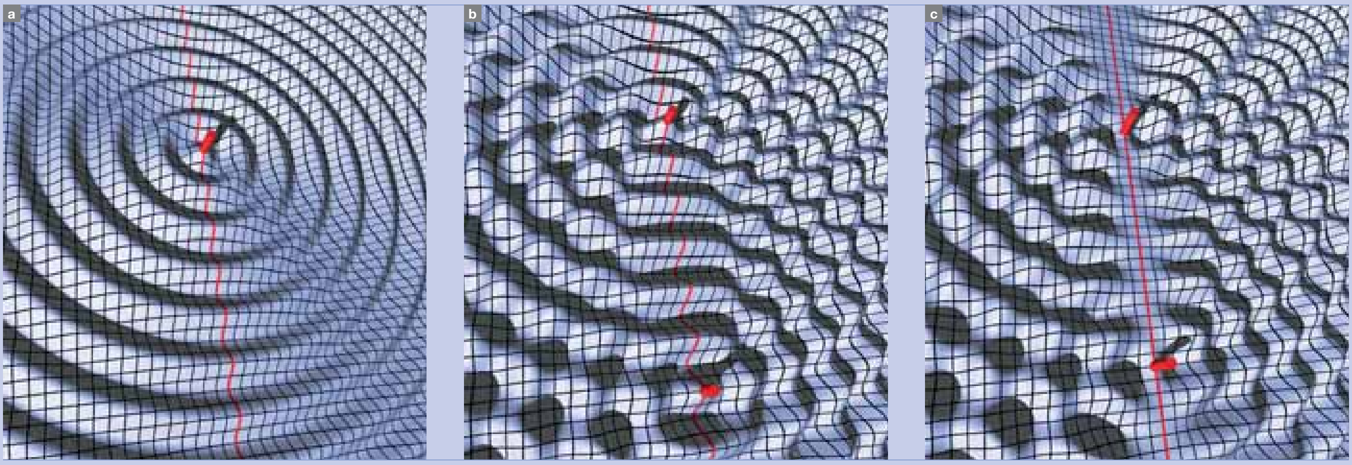
[1] See also the textbox "Principle of the interferometer" on page 53 and "Seeing inside air with FTIR" on page 77.

2 Low sampling rates mean frequencies cannot always be identified unambiguously

— original signal
■ sampling rate = 8
○ sampling rate = 4
— aliased signal for sampling rate 4



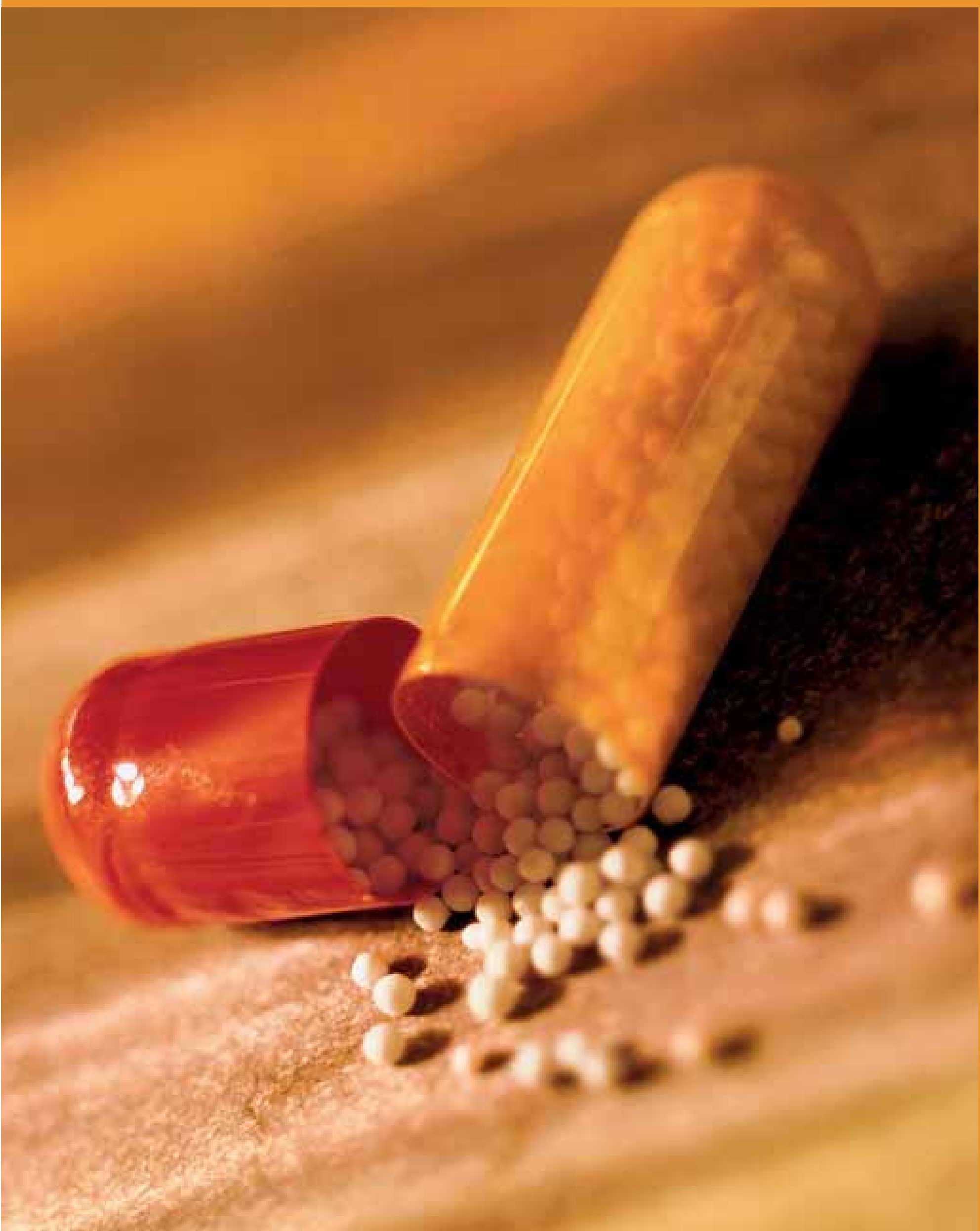
1 Interference of two identical wave patterns: The distance between the sources determines whether constructive b or destructive c interference occurs along the red axis



Process Analytical Technology

Integrated PAT solutions for the Life Sciences industry

Jean-Rene Roy



Pharmaceutical manufacturers have been providing medicines for more than 60 years using tried and tested formulations and manufacturing and quality management processes. In recent years new innovations in measurement, control and IT technologies have helped them to manage their processes more efficiently, with higher productivity as a result.

In addition to these innovations, a specific initiative has also been making its presence felt. Known as the Process Analytical Technology (PAT) Initiative, its goal is to understand and better control the entire manufacturing process within the pharmaceutical industry. Processes are actively managed to achieve a high degree of repeatability and efficiency, and quality assurance becomes continuous and real-time activity.

ABB is working in partnership with its customers to deliver a systems approach to PAT. From measurements to process improvement, ABB supports PAT implementation and the delivery of real business benefits.

Process Analytical Technology (PAT) is a system for designing, analyzing, and controlling manufacturing processes based on an understanding of the scientific and engineering principals involved, and identification of the variables which affect product quality. The PAT initiative is based on the FDA (The US Food and Drug Administration) belief that: “quality cannot be tested into products; it should be built-in or should be by design.”

The primary goal of PAT is to provide processes which consistently generate products of a predetermined quality. Effective PAT implementation is founded on detailed, science-based understanding of the chemical and mechanical properties of all elements of the proposed drug product. In order to design a process that provides a consistent product, the chemical, physical, and biopharmaceutical characteristics of the drug and other components of the drug product must be determined.

The role of on-line advanced measurement systems is pivotal to realizing the benefits of PAT. However, the transformation of process performance to provide greater efficiency and cost effectiveness, in addition to assured quality, requires much more than the application of measurement technologies.

Realizing such gains also requires an integrated measurement, control, workflow management and information environment which meets the needs of research and development, manufacturing and quality processes within the business.

Using PAT, ABB offers a unique industrial solution so that its customers in the Life Sciences industry can enhance their processes to deliver the benefits of PAT, from process investigation right through to achieving operational excellence.

The benefits of PAT

In a nutshell, the benefits of PAT can be summed up in the following sentences: PAT improves asset uptime and availability for pharmaceutical unit operations by up to 40 percent. Costs are reduced by up to 30 percent while fundamental product quality is maintained. How this is achieved is outlined in the following paragraphs.

Better process understanding

The physical and chemical processes involved in the manufacture of pharmaceuticals are complex and not well understood. However, during both the development and manufacturing stages, PAT-enabled processes provide access to information rich data – in real-time – which can be “mined” to find the critical quality parameters through multivariate analysis. Once these are determined, it is then easier to establish accurate control schemes for the relevant process parameters so that a more robust process can be established in a shorter timeframe and right-first time production is ensured.

> ABB has top class analytical technologies, from FT-IR/NIR spectroscopy right through to mass spectrometry and Gas chromatographs.

Repeatable batch trajectory

Quality control requires a highly detailed level of process understanding. ABB offers a combination of advanced and regulatory control based on robust process models that deliver verifiable results. The PAT solutions detect and manage critical control points in the process so that deviations from a required profile are correctly managed and fed back into the high performance control zone.

Reduction in overall cycle time

Processing to a quality-based endpoint is a key part of the PAT quality assurance regime. This eliminates wasted cycle time associated with processing using a fixed time-based endpoint including subsequent reprocessing time – and provides a streamlined workflow through the facility.

Reduction in Quality Assurance (QA) costs

Reduction in Out of Specification (OOS) events and consequent investigation leads to significant cost savings. PAT enabled unit operations reduce the reliance on laboratory testing and associated lead times, thus reducing the overhead costs associated with product quality.

Improvement in Overall Equipment Effectiveness (OEE)

OEE is the industry accepted tool to measure and monitor production performance. It can be applied at the machine, manufacturing cell or plant process level. Making cycle times repeatable and reducing in-batch down-time through improved control and early fault detection delivers a more flexible agile asset with much improved OEE.

ABB’s PAT Center of Excellence (CoE)

Following the need to offer an integrated approach to PAT, ABB created a CoE in 2004. Its mandate is to develop ABB products and services which will enable customers to reap the benefits of PAT. The PAT CoE builds on ABB Analytical’s experience of providing Pharmaceutical PAT Fourier Transform Infrared[1)] (FTIR) and Fourier Transform Near Infrared (FT-NIR) analyzers to the market for the past 10 years, as well as ABB’s position as a leader in Automation and Control, in particular with its 800xA platform.

The PAT CoE leverages ABB’s global resources, which include experienced research and development personnel, application specialists, chemometricians, process engineers, IT engineers, senior validation consultants and advanced process control specialists. Its mandate covers the entire range of PAT applications:

- Initial integration with Manufacturing Excellence programs
- Multivariate analysis
- Basic and advanced analyzers
- Data gathering
- Data storage
- Data mining
- System integration
- Connectivity with manufacturing and business systems
- Advanced Process Control (APC)

Analytical and measurement technologies – the platform for PAT

At the heart of any PAT system is a series of measurements made on real processes under realistic manufacturing conditions. Data from conventional process measurement systems (eg, temperature, pressure and flow) give

Footnote

1) See also “Principle of the interferometer” on page 53.

some insight into manufacturing processes so as to achieve a basic level of process understanding. However, manufacturing processes are usually too complex for simple approaches to be effective in achieving process understanding and control. An in depth degree of understanding and tight control can only be achieved by employing the correct technologies to measure relevant process parameters. These technologies are often based on chemical composition and/or physical form measurements, ie analytical techniques.

ABB has top class analytical technologies, from FT-IR/NIR spectroscopy right through to mass spectrometry and Gas chromatographs. Fully integrated into ABB's Industrial IT (IIT) concepts, the systems have unparalleled connectivity capability and provide a robust measurement platform for all PAT applications. Connected to the IIT information backbone, the process data developed can be used in everything from advanced control to process troubleshooting.

FT-IR/NIR analytical solutions

FT-NIR is, by far, the most widely used and proven analytical technology for PAT applications. ABB has 10 years of experience in supplying off-line, at-line and on-line FT-IR/NIR PAT solutions to the pharmaceutical industry and is a preferred supplier of most of the leading companies. Turnkey analytical solutions are provided for research and development for scale-up, drug substance, and drug product manufacturing.

Typical Drug Substance solutions include:

- Reaction monitoring
- Fermentation monitoring
- Crystallization monitoring
- Dryer monitoring
- Solvent Recovery monitoring

Typical Drug Product applications are:

- Raw Material Identification
- Blend monitoring
- Spray coating monitoring
- Fluid bad dryer monitoring
- Solid dosage form content uniformity
- Moisture in lyophilized solids

Even though the available analytical technology fulfills a wide variety of measurement needs, there is still a very wide Information Technology gap which is preventing the industry from efficiently gathering and using this data in real-time for process understanding and control. To be more specific, most of the advanced PAT analyzers currently available do not share a common user interface and data format, and do not offer the connectivity required to efficiently exchange this data with plant and business systems. Furthermore, the data is highly scattered and is not available in real-time in a central location.

The PAT IT suite

To address these drawbacks, ABB is currently developing a PAT IT suite that features an integrated IT platform using proven analytical and automation core components. This platform is based on the award winning 800xA Industrial IT Automation technology[2]. The concept 1 is based around a flexible, modular, scaleable and open architecture 2 which uses OPC – a standard communication protocol – to exchange data between modules.

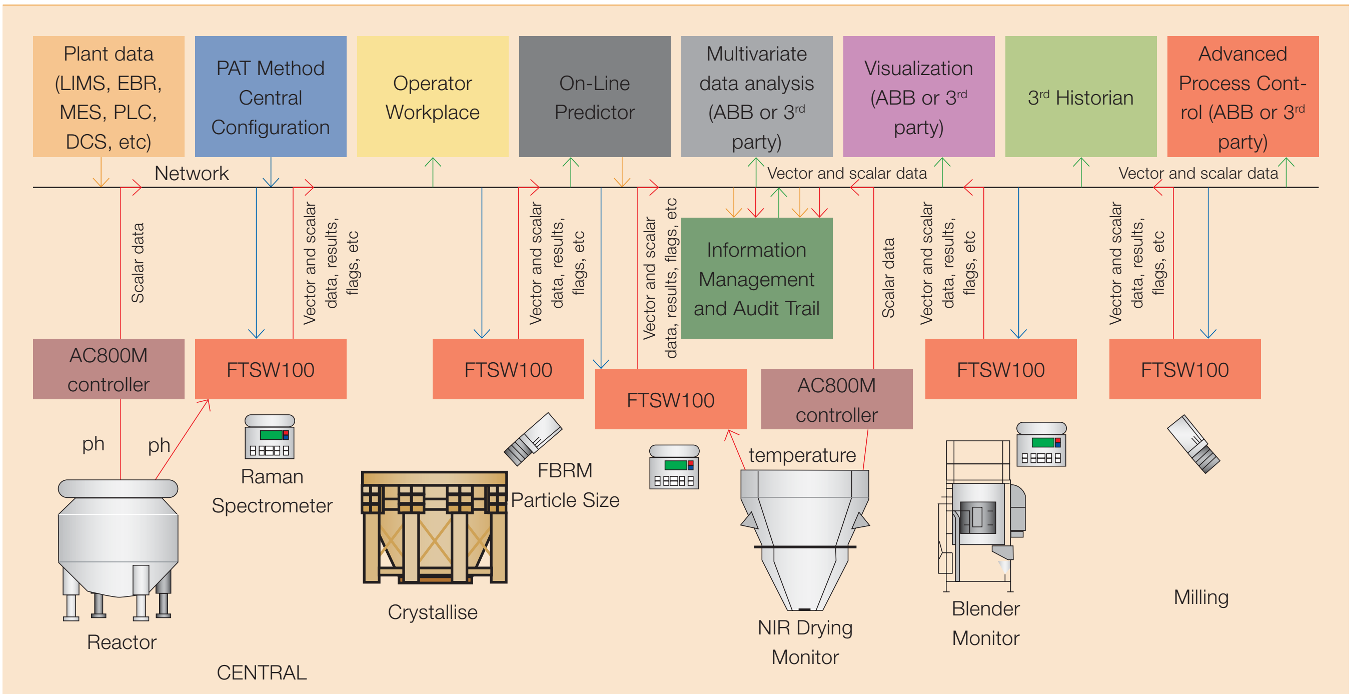
FTSW100 – Spectroscopy Process Software for data generation

This flexible, open architecture process analyzer software 3 is designed for implementing analytical methods and control sequences. It offers a single platform for the local control of

Footnote

2) http://www.abb.com/productguide
Information on ABB's 800xA Industrial IT Automation technology is found under the "Control Systems" section.

1 PAT IT concept



multiple analyzers from spectroscopy (IR, UV-VIS, Raman etc) to other analyzer types (particle size, acoustics, HPLG etc). In addition, it has a single operator interface and tools for multivariate analysis and predictions.

Data Storage: PAT Information Manager

The management of PAT data is highly complex not only because the flow of information is enormous, but because it also includes a mix of data formats (spectral, vector and scalar data) that makes it difficult for standard historians to handle. Furthermore, the centralization of PAT data is not sufficient as it needs to be combined with the batch information coming from the process control system (PCS) and the business systems.

ABB's PAT Information Manager is unique in that it stores all the data in a single database and can handle huge flows of both scalar and vector data coming from the analyzers and the SCADA system: It handles the batch structure data, the vector and scalar data, and alarms and events along with the audit trail. It can also exchange data with other third party historians

Data mining, visualization, multivariate analysis, and batch Management

The PAT IT suite offers a wide range of modules such as the operator workplace, central method configuration, and batch manager all with the ability to connect to third party commercial multivariate analysis tools for off-line and real-time predictions.

Control

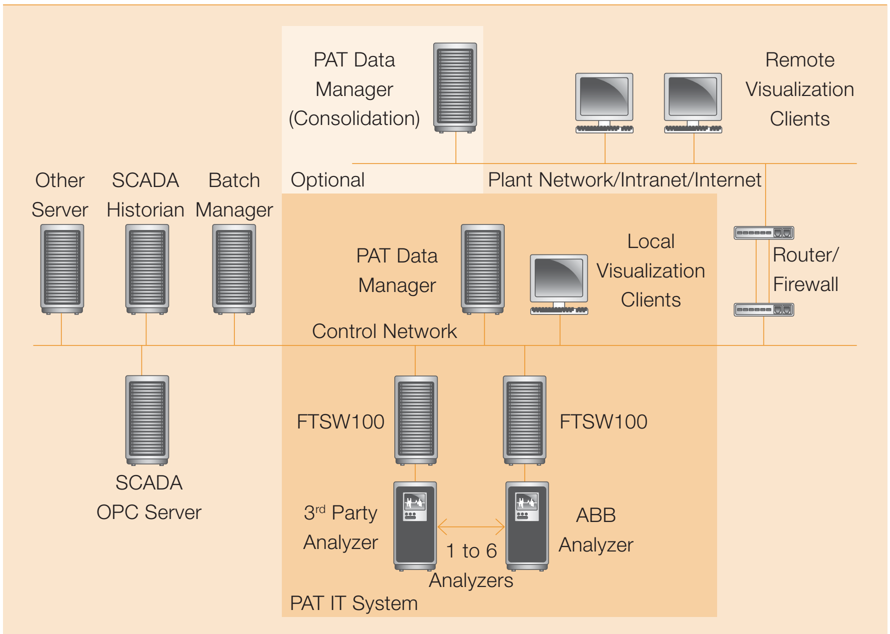
Controlling processes in a flexible and repeatable manner requires process understanding to be realized within regulatory and advanced control environments, while at the same time taking advantage of a range of process models. This is facilitated by dynamic solutions – Predict, Control and Inferential measurement platforms which integrate with operator interface, and regulatory control and process data management components.

The way forward

PAT provides an opportunity to move from the current "testing to document quality" paradigm to a "Continuous Quality Assurance" paradigm that can improve a company's ability to ensure that quality has been "built-in" or is "by design". Not only that, but it gives companies a greater insight and understanding of their processes; it provides the potential for significant reduction in production (and development) cycle times; and it minimizes the risk of poor process quality.

PAT will revolutionize the way pharmaceuticals are made and will forever change the face of the industry. This is why ABB's investment in PAT is the single biggest development initiative in Life Sciences, and it also presents the company with an exceptional opportunity to become the market leader in Life Sciences.

2 PAT IT network architecture



3 Local trending with FTSW100 software

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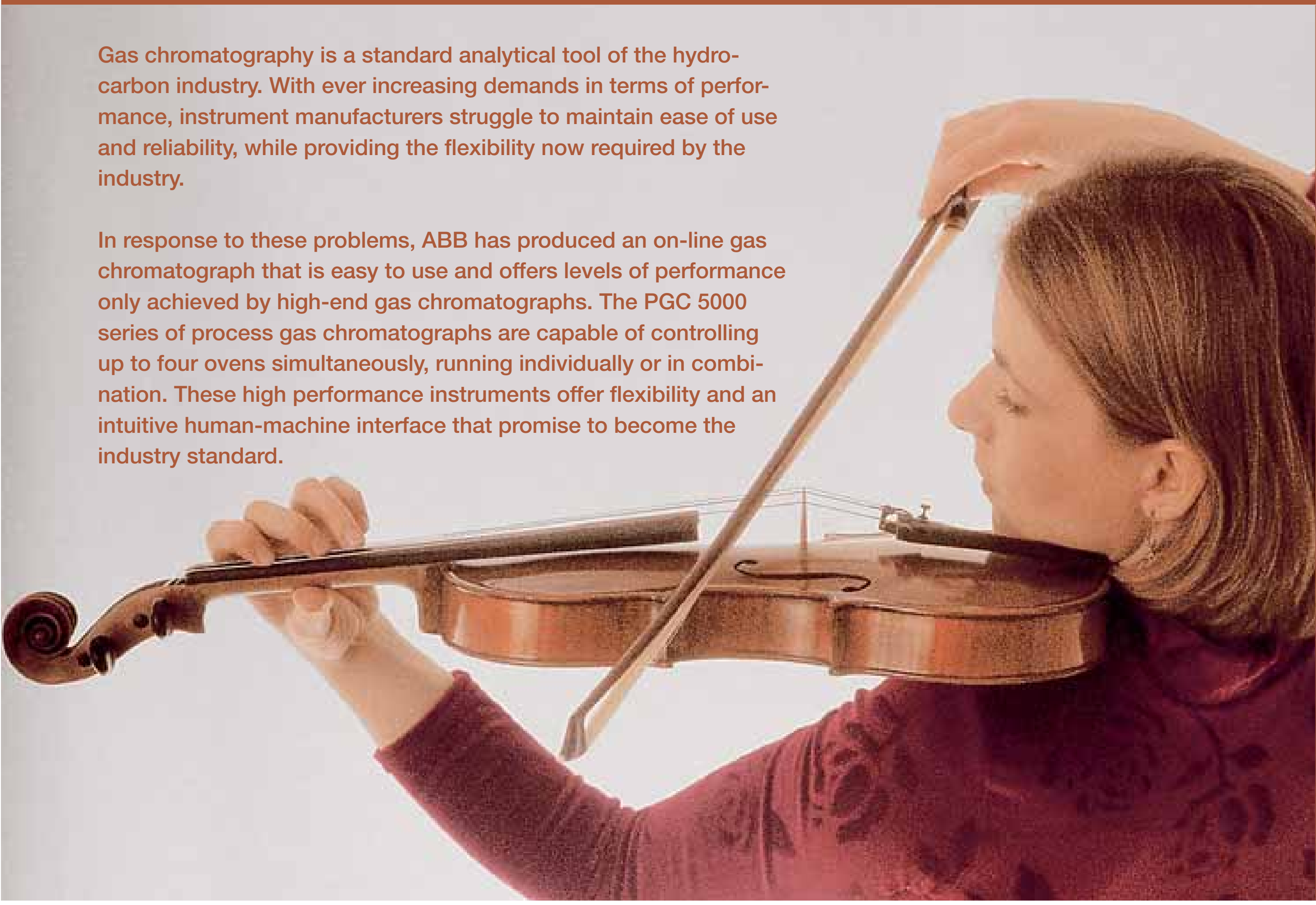
First class performance

A new platform for on-line analysis using process gas chromatography

Damian Huff, Stephen Bostic



Gas chromatography is a standard analytical tool of the hydrocarbon industry. With ever increasing demands in terms of performance, instrument manufacturers struggle to maintain ease of use and reliability, while providing the flexibility now required by the industry.

In response to these problems, ABB has produced an on-line gas chromatograph that is easy to use and offers levels of performance only achieved by high-end gas chromatographs. The PGC 5000 series of process gas chromatographs are capable of controlling up to four ovens simultaneously, running individually or in combination. These high performance instruments offer flexibility and an intuitive human-machine interface that promise to become the industry standard.

Process chromatography [1] is an analytical technique that allows the on-line separation and measurement of the components of a mixture in a chemical process. Chromatographic analyzers utilized for on-line analysis must operate continuously and independently of human interaction, taking a fixed quantity of sample, separating the chemical components using adsorption[1)] or partitioning columns, and measuring the concentration of each with a detector. The chromatograph provides both quantitative results, by measuring the area of the peak generated as the components pass through the detector, and qualitative results based on the retention time, measured from injection to detection.

The process gas chromatograph is the most commonly used process analyzer because of its many applications in the hydrocarbon processing industry. A variety of valve, column, and detector configurations is available for these analyses, which can range from parts per million to percent levels. All

Footnote

1) Adsorption of a substance is its concentration on a particular surface of adsorbent. Adsorption is a process whereby a substance, usually a gas, accumulates as a thin layer on the surface of a solid.

samples must be gas-phase or liquids, that can be vaporized prior to analysis. The analyzers are controlled using a cyclic timing device, which switches valves and columns to provide the necessary separation as the components pass through the system. This time cycle is a limitation of the technique for applications requiring continuous or very fast analysis times. Even with these limitations, the advantages of cost, flexibility, sensitivity, and reliability have made Process Gas Chromatography (PGC) the most widely used analytical technique for on-line process control.

Over the past ten years, increasing demands on PGC have led to the development of highly sophisticated analyzers. Multiple stream switching has become the norm for single-oven analysis, but such sophistication has come at a price. Multitasking analyzers are harder to operate, less reliable, and more difficult to maintain than their less complicated forerunners. A new generation of PGC from ABB instrumentation further promises a future of simplicity and reliability for process chromatography.

Textbox

PGC 5000B and PGC 5000C ovens

The PGC5000B oven, 1, is smaller than the existing PGC 2000 series oven and is designed to keep analyses simple. It can be equipped with a thermal conductivity detector (TCD) or a flame ionization detector (FID), one intercolumn detector (ITC) and no more than three analytical valves, including a single liquid injection valve. This simple set-up ensures greater reliability.

The PGC 5000C oven is approximately the same size as the existing PGC 2000 oven and supports specialty applications, such as total sulfur determination, simulated distillation and temperature-programmed analyses. It can be equipped with two main detectors, including the flame photometric detector (FPD) and/or any third party detectors, two ITC's, and no more than eight analytical valves, which include two liquid injection valves.

The PGC 5000B and PGC 5000C ovens provide an unlimited range of application capability and matchless flexibility. The ability to operate multiple ovens in combination allows complex analyses to be made simple, scaleable and more accessible.

1 A typical process gas chromatography oven – Type PGC 5000B

a Main detector (TCD)
b Analytical valve
c Analytical column

Drawing on 50 years of experience in process chromatography, ABB Analytical in Lewisburg, West Virginia, has developed the simple, reliable and highly flexible PGC 5000 platform. This allows complex analyses to be broken down into their fundamental elements. Each analytical detector has a new digital signal processing (DSP) module, which allows the use of expanded peak integration techniques. The new instruments also incorporate a novel, highly robust, real-time operating system (RTOS), which provides an extremely stable analytical core that is not affected by external conditions, thereby enabling flawless processing of critical analyzer tasks.

Analysis development capability

The ultimate goal of ABB's PGC 5000 platform series is to make complex analysis simple and more reliable. To achieve this, the instruments incorporate a patented analysis development tool that offers two formats in which to construct an analysis: 1) a highly interactive, graphical user interface, and 2) a tabular user interface. Analyses are composed of sequences, containing time-coded analytical functions that are integrated to form a method. Multiple methods are combined to form a complete analysis. On the PGC 5000, each sequence and method is color-coded for easy identification and logical troubleshooting. The system allows complex applications, such as stream analysis, to be broken down into their constituent parts (sequences and methods), which are easier to understand and maintain.

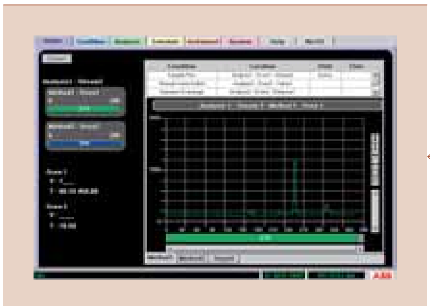
Scalable, modular platform – parallel chromatography

The PGC can be thought of in three sections: an analyzer, a controller and a sophisticated human machine interface (HMI).

The analyzer

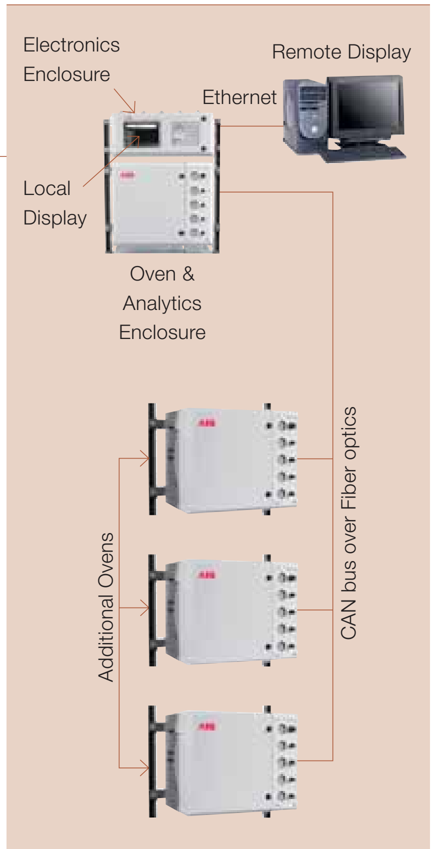
A typical PGC analyzer contains basic hardware components, such as sample valves, columns, column switching valves and detectors, enclosed in an oven Textbox with precise temperature control. The most common analyzer configuration is the isothermal oven. Specialty applications with wide boiling-point range that require temperature programming can also be accommodated. Accurate and precise temperature control is essential for the

2 A typical PGC5000A master controller front panel screenshot display



3 The PGC5000A master controller front panel and keypad

4 The PGC5000 series operating platform



reliability of the analytical hardware and the reproducibility of results.

The controller

The PGC 5000A master controller, 3, can support up to four analytical ovens. Since each has its own controller, a range of activities can be accommodated. For example, a single oven can be dedicated to a specific analysis, or up to four ovens can be used in combination, as shown in 4.

New HMI

The instruments contained within the PGC 5000 platform series carry a new HMI that operates via a simple "point" and "click" method. This new 10.4-inch display has highly visible, color-coded tabs, which allow the user to navigate between operation screens via a fully functional keypad and a mouse touchpad. It is intuitive, and all major functions can be accessed within two steps. The chromatogram is easy to read with simple color graphics 2 and will support nine different languages. Up to four PGC ovens can be accessed and displayed simultaneously, in real time.

Digital Signal Processing (DSP) Module

The PGC5000 platform 4 uses the power of DSP to enhance the performance of automated PGC analyzers. These instruments now operate at levels that were once the exclusive domain of high-end laboratory gas chromatographs with computer-based post-analysis software. The key parameters of the PGC 5000 signal analysis system are:

- Robustness
- Reproducibility
- Automation
- Adaptability

The operating interface can be accessed both locally at the chromatograph and remotely. It is designed to function in two principal modes of operation:

Model Based Analysis

This mode produces a functional representation of each peak, on which subsequent chemical component concentration, confidence estimates and GC performance measures are based. Such functional representations enable maximum compression for chromatogram storage.

Gated Integration Analysis

This mode utilizes user-specified and/or automated time gates, within which the chromatographic peaks are integrated, to obtain area factors to determine the chemical component of the concentration. This is an advanced form of the traditional, gated GC analysis.

In addition to these modes of operation, the raw chromatogram data can be made available to computer resident, third party post processing software, either explicitly or in response to alarms generated by the GC resident analysis software.

The operating system

The PGC 5000 platform uses the INTEGRITY RTOS, from Green Hills Software, to ensure reliable co-processing of critical real-time analyzer tasks with multiple networking/user-requested tasks. The operating system provides the analyzer with a robust analytical core, capable of handling all major instrument functions without interference from other devices. It makes a vital contribution to the reliability of the PGC 5000 platform, ensuring the long-term stability and reliability that are essential in a process analyzer.

With the PGC 5000 platform series, ABB demonstrates its commitment to the development of a simple and reliable process analyzer with a limitless range of application capability and matchless flexibility. This next generation of instruments will become the new standard for PGC.

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Intelligent detection and monitoring

Condition-based maintenance in gas analysis

Bernd Wemhöner, Berthold Andres, Heiko Petersen, Peter Schastok, Lothar Schuh, Gerd Zornig

Sensors are the eyes and ears of process control. A modern manufacturing plant is alive with sensors observing every aspect of its activity. The tightening of standards and the drive for greater asset effectiveness are further increasing the dependency on such devices. To prevent the waste or fines that can result from a faulty sensor, the sensors themselves increasingly need to be observed. But watching alone is not enough – operators and maintenance planners must have advance warning that a sensor may soon cause trouble.

ABB's AO2000 (Advance Optima) gas analyzers record the output of sensors and process it into statistics and trends. The remaining lifetime of devices can be accurately predicted, permitting replacement to be better synchronized with planned plant downtime. Good maintenance planning is no longer a matter of luck.

Modern analyzer systems 1 are used in industrial and municipal facilities for the monitoring and control of diverse processes – in chemical and cement plants, power stations and other industries where continuous concentration measurements of gases and liquids are imperative.

Nevertheless, many industrial plants still do not even pursue a preventive maintenance strategy. Equipment runs until it fails. This trend is, however, on its way out as new and stringent regulations command compliance with quality standards or, in its absence, closure of the unit.

ABB's AO2000 gas analysers offer state-of-the-art technology for operational reliability. The design's unique communication network facilitates easy overview of the complete system. Standard interfaces allow simple integration into higher-ranking PC, measurement and control, or distributed control systems. These make it possible to centrally monitor decentralized systems.

Structure of a modern process gas analysis system

What is condition-based maintenance?

Maintenance is a strategy for the preservation or restoration of the operative readiness of plants, machinery, etc. Maintenance strategies can range from **reactive** (maintenance after damage/failure); **preventive** (prophylactic, regular/periodic) to **condition-based** (oriented towards predicting actual wear and tear).

To understand how effective condition-based maintenance can be, it is necessary to pose two crucial questions: how long is the interval from the first possible detection of an incipient failure until functional failure occurs? Is there sufficient time for counter-measures?

This can be illustrated by considering the air-filter of a car. In a preventive maintenance scenario, this filter is changed after a specified mileage, regardless of whether or not it needs to be changed just then. A condition-based approach would use the measurement of the pressure drop across the filter. There would be a limit value that, when surpassed, would generate the "Change Filter" message. Additional recording of the pressure differences over time would create a trend-curve on the basis of which the optimum time for changing the filter would be predicted. Precisely such data are of immeasurable value in the environment of industrial maintenance, as only in this way can equipment availability be maximized and the costs of maintenance minimized.

The sensitivity of a gas analyser drifts slowly from the day of manufacture.

When does condition-based maintenance make sense?

The air filter example makes it clear that problems and failures can be prevented with the provision of an adequate number of sensors in combination with data collection and analysis. Greater integration of data sources (such as process control data and condition-based monitoring data) is possible through the use of interfacing systems.

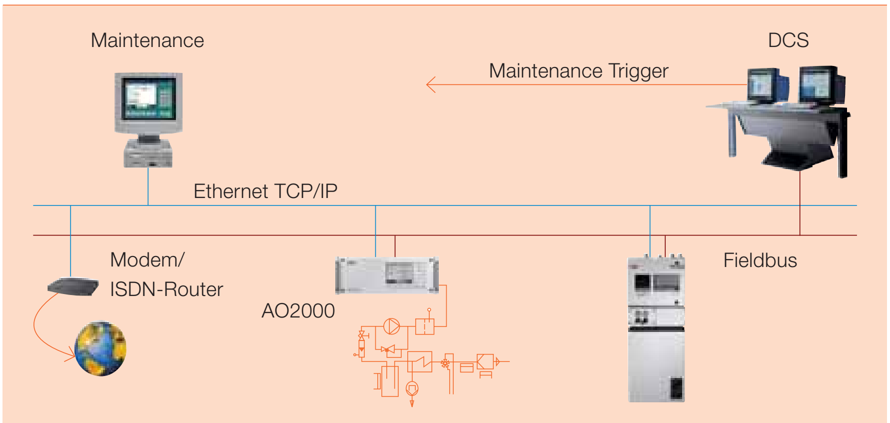
Whether condition-based monitoring is appropriate, necessary and affordable depends on the individual case. Condition-based maintenance is imperative when critical components are concerned and their failure has sustained negative effects (on safety, environment, production, etc.) and/or when wear and aging are involved.

Aging and wear are inevitable and can be irrelevant, provided they do not adversely affect the functioning of the overall system. Thus, the sensitivity of a gas-filled detector in a gas analyser drifts slowly from the day of manufacture. This is unavoidable and the effect is compensated for by regular calibration. At some time or other, however, the measured values will become unreliable. Can this moment be predicted? Yes, it can! The right data and information can be acquired and analyzed (permitting diagnosis), and the "residual lifetime" can be determined.

Enabling compliance with environmental Standard EN 14181, QAL3 requirement

Strict environmental regulations are an on-going challenge for continuous gas analysis (CGA). The European Standard EN 14181 "Stationary source emissions – Quality assurance of automated measuring systems" was promulgated in September 2004. It ensures that automated measuring systems for continuous emission measurement comply with specified requirements for the reliability of measured values. The quality assurance levels QAL1/2/3 were introduced for this purpose. These quality assurance levels comprise the suitability of a CGA for the measuring task (QAL1), validation after installation (QAL2) and monitoring during operation (QAL3). With the introduction and implementation of EU Directives 2001/80/EC and 2000/76/EC, emission monitoring is subject to this quality system. Besides using performance-tested instruments, plant operator

1 Schematic representation of analyzer including gas conditioning and remote coupling structure of a modern process gas analysis system



must comply with QAL3 requirements. Failure to do so can result in heavy fines.

What are the challenges of compliance?
Intensive use of modern communication technology is necessary for specialized service technicians to be able to monitor the operation of the CGAs. The measuring capability of the CGAs and their availability can be continuously evaluated via remote access (phone line, intranet). Each analyzer reports its health status when the system detects irregularities. As a result, statutory requirements with respect to the quality of the measuring results and their availability can be centrally met despite the distributed nature of the system.

Service experts are, at any time, able to carry out remote diagnoses and, perform remote troubleshooting.

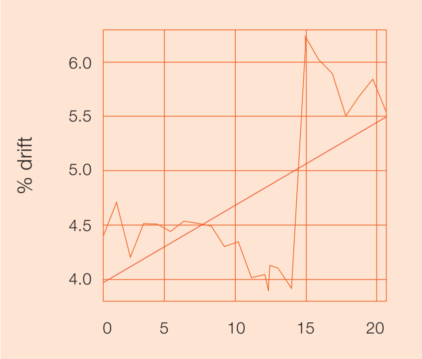
What does Analyze IT offer?
The Analyze IT Explorer is a software tool that helps operate the installed process analysis technology more effectively. ABB's gas analyzers are equipped with an Ethernet port that allows continuous access to data from the connected instruments 1. Data from all sub-systems can be logged – from gas sampling to gas conditioning and gas analysis. Signals such as flows, temperatures, pressures, status signals and also the measured data from different types of analyzers can be integrated in the AO2000 gas analyzers either directly via the internal system bus or via additional I/O-cards.

The Analyze IT Explorer processes all data in such a way that the status of an analyzer system can be provided at a glance. This includes graphical representation and the storage of data. An event signaling system sends detailed error messages and maintenance requests to the service team. Such messages can be sent by SMS directly to a mobile phone.

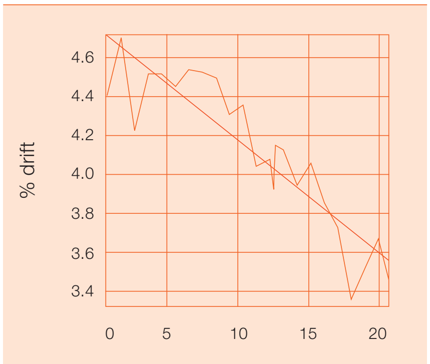
Thus, ABB analyzers form the intelligent nodes in this process, permitting

2 Condition-based maintenance based on intelligent data preparation

a Drift data includes an outlier: the extrapolation results



b The remaining service life can be calculated from the cleaned-up drift data



the Analyze IT Explorer to access the data of the measuring chain. The operator can use this setup for central monitoring and data transmission. The operator can also gain systematic support by allowing ABB after-sales service staff remote access to the analyzer.

Global service – global expertise
Despite regular inspection and maintenance of the analyzer system, the operator is often unable to identify or prevent errors and failures through lack of the necessary expert knowledge of the system.

In consequence, ABB offers operators a series of service products assuring optimum support and safeguarding the measuring process – so achieving improved availability of the measured value.

Remote service technology plays a central role here. Service experts are, at any time, able to carry out remote diagnoses and, perform remote troubleshooting. During such sessions, all status messages, conditioning components and statuses of calibration and detectors are evaluated, and, if required, compared with historical data.

In this way, a complete overview of the system can be obtained without recourse to field service. Malfunctions and unreliable data are recognized in good time as are the effects of aging. This transforms field service from an on-demand to a systematic activity. A costly spare part inventory at the operator's premises, can, in many cases, be dispensed with. Remote service technology contributes to high system availability, cost optimization and optimal planning of service activities.

How are higher alarms generated?
Since mid-2004, ABB has been examining new methods of statistical data evaluation in a project, in conjunction with the most advanced coking plant in the world in Schwelgern near Duisburg (KBS GmbH). One finding of the pilot project with KBS GmbH was, that problems that arise through human intervention in the system should not be underestimated. If a technician briefly switches off an instrument, the subsequent data evaluation is affected

by a malfunction. Therefore the preprocessing of data, such as denoising, detrending, detection of outliers and cleansing are indispensable. 2a shows the raw drift data of an AO2000 at the coking factory. A shift – provoked by human intervention – is conspicuous in the data record. Data preprocessing filters out the shift 2b and the remaining service life of the detector can then be predicted from the cleaned-up data.

In addition to the alarms generated by simple infringement of the threshold limits, Higher alarms were generated in this project through statistical data analysis. Principal Components Analysis (PCA), for example, can combine several signals to form a new "virtual" signal, which can then be accessed as if it were the single signal of a threshold evaluation. The advantage of such a process is that critical system statuses, which cannot be read in single signals, are also detected.

The changes in the performance of a device can also be analyzed over time and extrapolated. The simplest form of extrapolation is linear. Unfortunately, a large number of mechanical and chemical aging effects are not adequately described by linear behavior. Higher dimensional extrapolation models must be used. This opens up a wealth of possibilities. A suitable alarm can be generated before a possible failure occurs. Prognosis horizons of several months are already being achieved, reliably predicting failure. Consequently, any pending plant downtimes can be used to combine maintenance tasks into a single equipment shutdown.

A large number of mechanical and chemical aging effects are not adequately described by linear behavior. Higher dimensional extrapolation models must be used.

Gas analyzer systems in the future

The expert obtains requisite data from the data history. He thereby has a view to the past and knows the history of the instrument. Automatic evaluations help to solve the problems that arise effectively. More importantly, they enable predictions to be made about when which problems will occur, and with what probability.

Condition-based maintenance relies on the knowledge of how component statuses change and deteriorate over time. Future equipment for continuous gas analysis will have more and more intelligence and use a variety of data that was not used in the previous generation of gas analysers. The systems will learn to make predictions from the data history about aging, ie, the loss of useful life contingency. The following types of diagnosis will play an important role:

- Signal-based (eg, alarm value infringement)
- Data-based (statistical evaluation, data mining)
- Model-based (comparison of the actual data with the data supplied by a model)

The possibilities of remote diagnosis and remote maintenance will ease the burden of the end user. Critical changes in the mechanical system, optical system and electronics will be detected early on so that necessary measures can be taken. Experts will be able to mobilize at any time.

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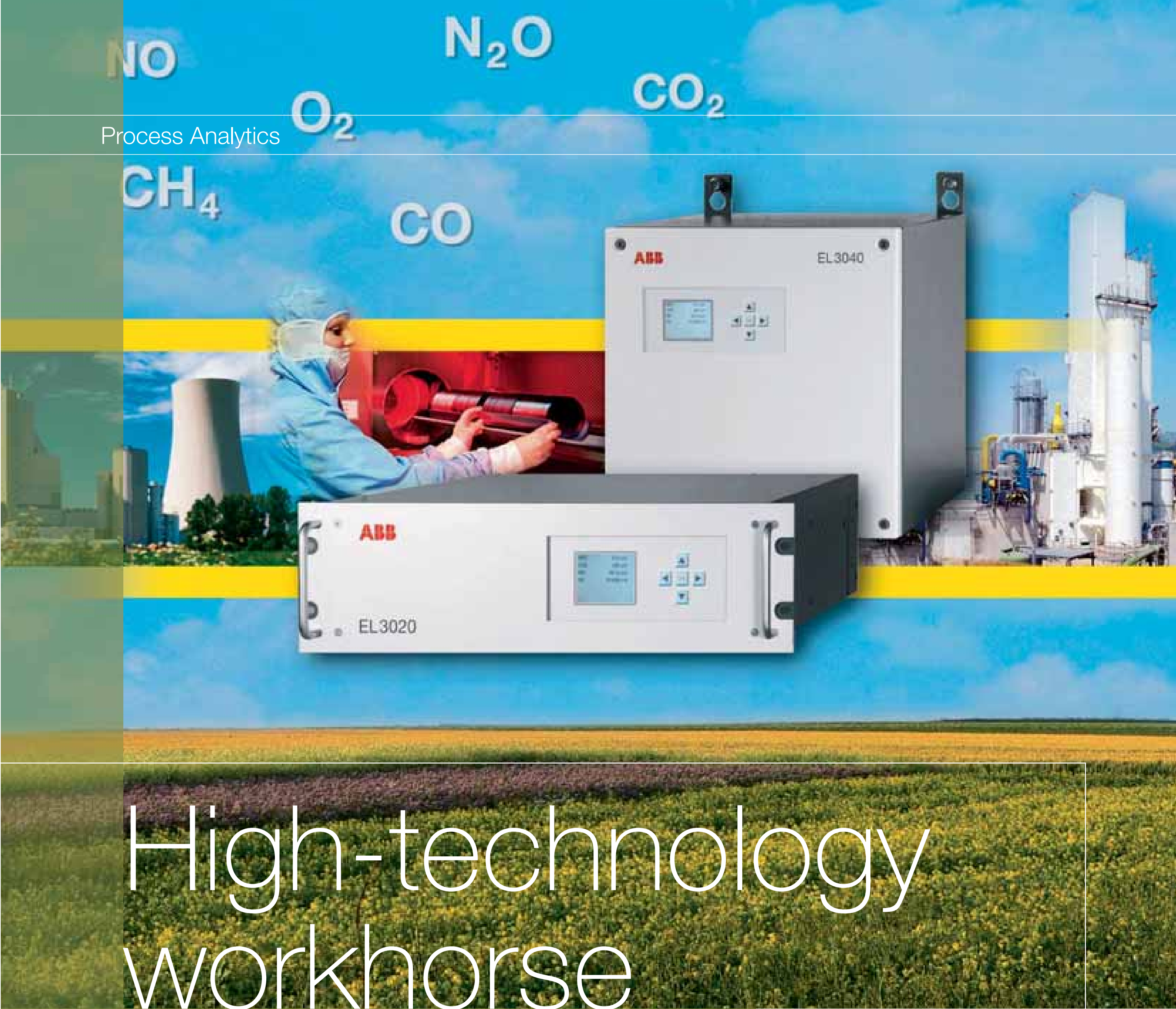


High-technology workhorse

Advancing contemporary modular gas analyzer technology with the Uras26 photometer

Werner Rüdiger, Carsten Rathke, Michael Ohland, Mario Crevatin

Worldwide environmental awareness and tightening industry regulations are leading to tougher emissions standards. These in turn are calling for greater accuracy in measurement technology. At the same time, the drive for greater productivity in industrial processes means that single installed devices must be able to monitor as many different gas components as possible as accurately as possible while minimizing down-time and human intervention through auto-calibration functions and intelligent filtering of data-output. Ideally, such a device should be built on a flexible platform, facilitating future upgrades and the integration of new functions, and so protecting the customer's investment.

ABB's continuous gas analyzer module like Uras26 uses high performance measurement technology and has the ability to quantify ultra-low concentrations of gas. It can simultaneously monitor four different gases. The advanced algorithms running on its digital signal processor eliminate much of the guesswork and imprecision that is associated with traditional instruments – while additionally assuring these algorithms can easily be upgraded to meet future needs.

Environmental protection, process optimization, quality assurance and cost reduction are key issues for processing industries today. Owing to their flexibility, gas analyzers are used in a wide range of measuring tasks in almost every industrial process: in chemical and pharmaceutical production, in gas production, in the processing of metals, minerals, paper and wood pulp, in power generation and in environmental applications.

Contemporary modular analyzer technology introduces state-of-the-art module electronics, intelligent algorithms and continuously improved measuring physics. ABB offers two different product lines, Advance Optima and EasyLine, both of which are highly flexible and provide optimum results at low cost. The Advance Optima product line is based on an integrated system design. It permits multi-analyzer and complete analyzer systems to be set up cost-effectively. The EasyLine product range is distinguished by simple gas analyzers of reliable design.

Spurred by the need for standardization and simplification of the control of gas analyzers, a new electronic "Common Platform" that forms the innovative core of the module, was developed.

The common platform

The common platform provides a standard interface for all analyzer types, thereby overcoming the considerable functional differences between measurement techniques, from the measurement of a Wheatstone bridge voltage to measurement through complex modules, such as a photometer. At the beginning of the development phase, it was, therefore, necessary to identify what all analyzers have in common and to model these shared characteristics in hardware and software.

All analyzer types are characterized by the fact that they use a complex method to convert a physical effect into an electrical signal – this was therefore taken as the underlying principle on which further investigation and validation rested.

A raw digital measured value is generated from the analog electrical signal in an analyzer-specific electronic system. If the common interface is now programmed for the transmission of this raw measured value, a standard analog/digital converter is created for all analyzer types. The raw signals can then be further processed by means of a common hardware and software platform (common controller), which is virtually independent of the measurement technique 1. At this stage, the raw measured value is scaled, linearized, pressure or temperature corrected, filtered – or "refined" by some other means.

A serial hardware interface was selected, which besides transmitting data to the analyzers, also integrates the 24 V DC power supply. All other required voltages are generated in the modules. Besides the performance requirements, an important criterion for the serial interface was that it can be supported from the simplest controllers to high-grade signal processors.

The software model is also characterized by the greatest possible compatibility with all analyzer types. The analyzer model was developed from a detailed analysis of all requirements. All analyzer data and functions were mapped in software components – a "virtual analyzer" covering all different analyzer functionalities was developed.

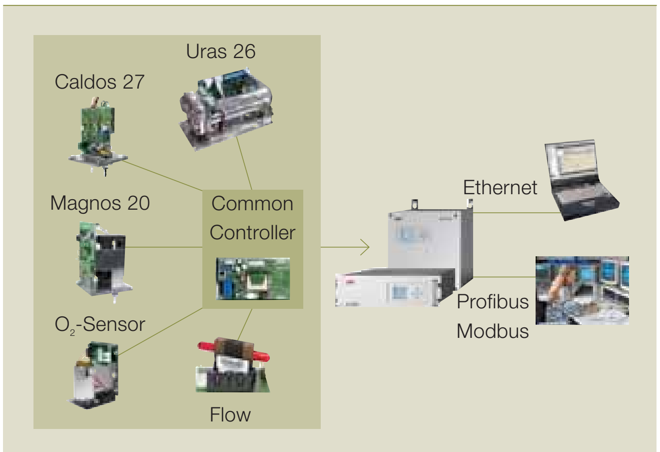
Basically, an analyzer consists of 1...n detectors (thermal conductivity, infrared etc.), each detector measuring 1...n components (CO, CO_2 and so on) and each component having 1...n measuring ranges. If this data is modeled and combined with modular signal processing and corresponding correction functions, a virtual analyzer, suitable for most analyzer functionalities, is obtained.

The common platform affords many advantages, such as reduced integration time for new measurement techniques, reusable hardware and software components and the common use of external interfaces such as Ethernet, PROFIBUS, Foundation Fieldbus digital and analog Input-Output (I/Os). In addition, the same software tools can be used for all instruments. The end result is a higher degree of production automation achieving further process simplification.

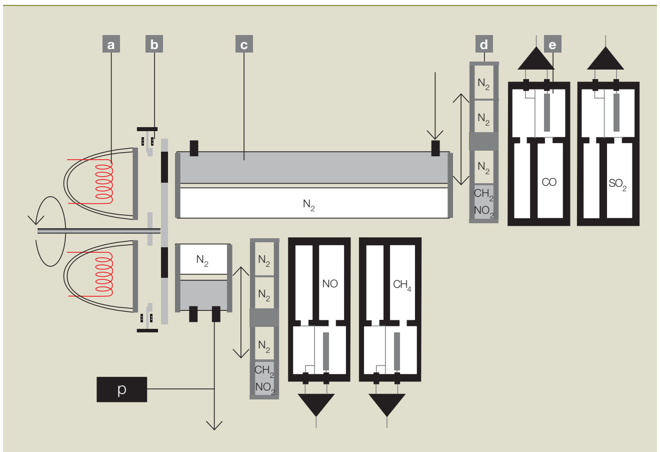
The Uras26 Gas Analyzer Module

In connection with the launch of the new common platform, an ABB frontrunner was upgraded: the Non-Dispersive Infrared (NDIR) Uras photometer. The tried-and-tested optical construction of the Uras14 2 was com-

1 Overview of Common Platform-compatible modules of the new EasyLine product range



2 Schematic representation of the optical structure of the Uras.
a Infrared lamp, b Chopper wheel, c Sample cell, d Calibration cell, e Opto-pneumatic detector



bined with the new Sensor Specific Interface (SSI) modular electronics, making it compatible to the "common platform" technology.

The measurement principle of the Uras is based on the capability of gas molecules to specifically absorb infrared (IR) radiation. This means that energy is removed from a light beam within a certain frequency range, depending on the gas concentration. In most infrared gas analyzers a photo detector is used to detect this effect. This is not the case with the Uras: It contains gas-filled, so-called "opto-pneumatic" detectors, in which the sample of interest is held. The radiant energy absorbed by the fill gas causes a change in temperature and thereby a change in pressure in the detector. This change in pressure evokes an electrical signal via a membrane capacitor. The correlation between the detector gas and the sample gas provides an extremely high selective sensitivity with regard to gases such as CO, CO_2, SO_2, NO, CH_4 and N_2O – to name but a few.

The measurement principle of the Uras is based on the capability of gas molecules to specifically absorb infrared radiation.

In the Uras26, the concentrations of up to four process gas components can be reliably determined by connecting detectors in series. The length of the sample cells installed upstream of the detectors determines the provable concentrations, which range from a few parts per billion by volume (ppbv, $<10^{-5}$% Vol.) to 100% Vol. The Uras26 also has integrated calibration cells, which automatically move into the optical beam path [1]. These supply a reference signal and ensure long-term stability. Maintenance costs are markedly reduced because built-in calibration dispenses with the need for expensive test gas cylinders.

A low-noise measurement is provided by periodic modulation of the IR radiation source with an interrupter disk ("chopper wheel") and subsequent frequency – and phase -selective amplification. This type of signal processing is generally referred to as a "lock-in" process [2]. Up to four Application Specific Integrated Circuits (ASICs) were used for calculating the amplified lock-in signal in the previous model, Uras14. The development of a "digital" lock-in amplifier for the Uras, with extended functionality, was also undertaken during the development of the new Common Platform-compatible module electronics.

The development stages

Development of the module electronics for the Uras26 was carried out in three phases. In the first phase, the existing preamplifier was extended from a purely analog principle to an independent hardware unit with a digital interface. On the basis of this preamplifier and its compatibility with the existing sensor, digital measurement values could be acquired very quickly and made available for further evaluation.

In the second phase, new algorithms for the "lock-in signal" were tested 3 .

In parallel the hardware, which had so far been based on an ASIC, was reworked. A flexible and high-performance Digital Signal Processor (DSP) enabled a far more accurate phase correction, a higher dynamic range of the "lock-in signal", a more accurate monitoring of the motor speed, as well as the implementation of new instrument functionalities. The modulator, which includes the motor, the chopper wheel, a light barrier, as well as the infrared lamp, was simplified at the same time 4 .

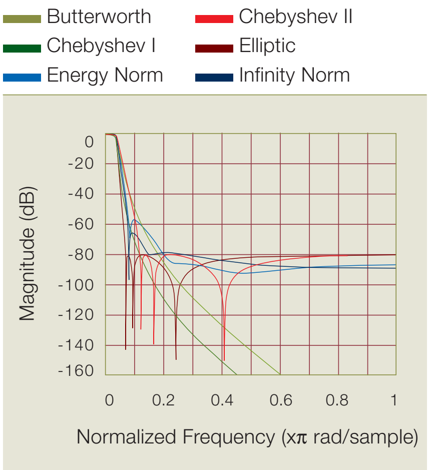
An overall simulation of the instrument enabled further verification of the solutions found, and tested the behavior of the instrument for a future extension of functions. The physical generation of the signal within the sensor is a fitting example 5 .

In the third phase, new algorithms were tested on the developed Uras26 unit with a view to offering further instrument functionalities for low-maintenance operation and reasonably priced service in future.

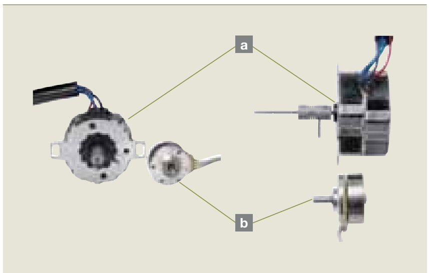
New potential with the use of DSP

Improving or adding new features in an ASIC based system involved redesign of the ASIC and the rest of the hardware – a very expensive and time-consuming proposition. An important advantage of replacing ASICs with DSP is that integration of future functionality and performance improvements can be achieved without

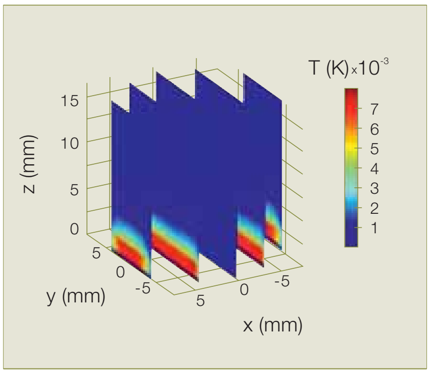
3 Frequency responses of various new signal processing algorithm



4 Size comparison of the old motor a and the new motor b of the Uras modulator



5 Physical signal generation (temperature change) at various locations in the Uras detector; red for strong, blue for weak changes



altering the hardware design. For instance, extended diagnostic features of analyzer components for the purposes of "remote maintenance" or "predictive maintenance", and the new intelligent shock suppression are of particular value to the customer.

The shock sensitivity of the sensor results from its high measurement accuracy. Its acute sensitivity to the lowest gas concentrations also makes it sensitive to other influences, such as temperature changes or shocks. To reliably detect shocks, a clear distinction must be possible between signal changes caused by modifications in the gas concentration, and signal changes caused by shock. The DSP achieves this by looking at both the digital measured values over time, and their frequency components – with and without shock.

When a shock is reliably detected, it is necessary to correct its influence on the actual measurement signal. The DSP carries out this calculation in real-time. Taking a series of shocks as an example, 6 illustrates their suppression.

Uras26 is an advanced system that eliminates much of the practice and guesswork associated with conventional instruments.

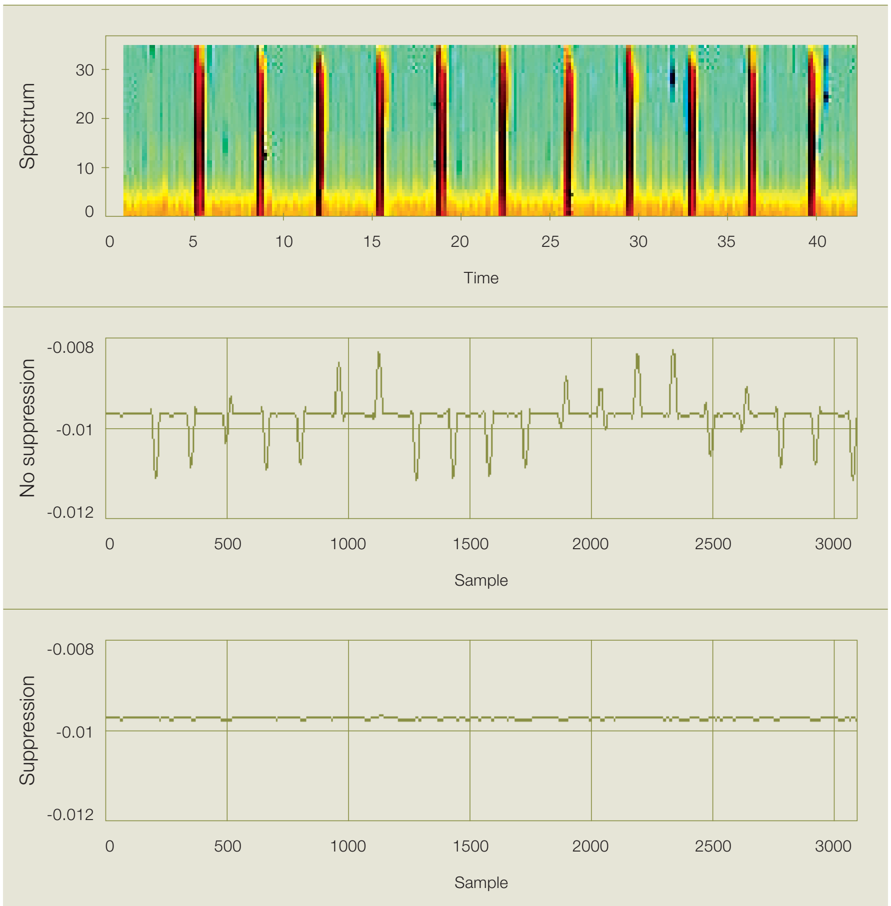
Key Benefits

Thanks to its DSP-based electronics, the Uras26 analyzer module offers extended signal analysis capabilities, such as signal filtering, diagnostic functions and cross-sensitivity optimization. The most notable benefits of the Uras26 – placing it ahead of the field – are: its ability to simultaneously analyze four gases and its integrated calibration cells that significantly reduce downtime. Uras26 is an advanced system that eliminates much of the practice and guesswork associated with conventional instruments.

As a result of the measurement performance and high stability, EasyLine analyzers can be used for emission monitoring according to the new European Directive 2001/80/EC.

Acknowledgement
We would like to thank the following colleagues for their contributions: Richard Bloch, Walter Fabinski, Frank Kassubek, Gerhard Klein, Olof Liberg, Thomas Liedtke, Markus Nägele, Olivier Steiger, Thomas Weyrauch.

6 Digital measured values; Top, broken down into the frequency components (red = strong, blue = weak frequency components) – Center, without shock suppression – Bottom, with shock suppression



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[2] **J.H. Scofield:** A frequency-domain description of a Lock-In-Amplifier. American Journal of Physics 62 (1994), 2, 129–133.

Acknowledgement
We would like to thank the following colleagues for their contributions: Richard Bloch, Walter Fabinski, Frank Kassubek, Gerhard Klein, Olof Liberg, Thomas Liedtke, Markus Nägele, Olivier Steiger, Thomas Weyrauch.

Infrared absorption

Safe and stable measurement of gas concentrations in the ppm range with ACF-NT

Christoph Becker, Bernd Hielscher, Norbert Will

FTIR (Fourier Transform Infrared) technology has the capability to measure more than 100 of the 189 Hazardous Air Pollutants (HAPs) listed in Title III of the Clean Air Act Amendments (USA) of 1990. In fact, when these Amendments were passed, existing measurement methods could only measure 40 of these HAPs.

In 1306 Edward I of England prohibited the burning of sea coal in craftsmen's furnaces because of the foul smelling fumes it produced. Centuries later, for similar reasons, Elizabeth I banned the burning of coal in London when Parliament was in session. In the 1600s, writer and scientist John Evelyn reported that industries were obviously the cause of pollution in London, noting that pollution almost vanished on Sundays. London became famous for its "pea soupers" and "great stinking fogs".

In 1952, more than 4000 people succumbed to respiratory and cardiac diseases during the infamous "London Fog", when a five-day temperature inversion trapped deadly acid aerosols. Air pollution was no longer just an aesthetic concern, but a recognized hazard to health and safety. In 1956 the first Clean Air Act was passed.

While England was slowly coming to grips with the very real risks of industrial pollution, in neighboring France, Jean Baptiste Joseph Fourier was swept up in the tide of events surrounding the French Revolution. One of 12 children from his father's second marriage, Fourier joined Napolean's army as Scientific Advisor. When he returned from the conquering wars, he was appointed Prefect of Grenoble. It was in Grenoble, in 1807, that he completed his most important treatise, "On the Propagation of Heat in Solid Bodies". Like many great works that continue to impact the world today, Fourier's treatise was mired in controversy. No one, at the time, could have guessed at just how critical it would be to monitoring one of mankind's most pervasive problems – pollution.

Fourier Transform Infrared (FTIR) Spectroscopy is a measurement technique. The Fast Fourier Transform (FFT) is a mathematical operation performed on the signal obtained by interferometry Textbox to extract the infrared (IR) spectrum.

FTIR technology has proved mission critical in the environmental field. In 1995, scientists from the United States Geological Survey (USGS) mounted a FTIR spectroscope on a plane to measure gases being discharged from the caldera of one of the most active volcanoes on earth – Kilauea in Hawaii.

In the last few decades, with more and more regulation coming into force, ambient air quality has markedly improved in most Western countries. However, the "Global Burden of Disease" program of the World Health Organization (WHO) estimates that worldwide, 6.4 million lives are lost every year from long-term exposure to Ambient Particulate Matter (APM). Thus, environmental regulations continue to tighten.

Stricter environmental regulations and advanced technologies ensure that the emissions of harmful substances from domestic waste, hazardous waste and sewage sludge incinerators, cement plants and power stations continue to decrease. As the concentrations of harmful substances in waste gases fall, the demands on the measuring technology rise.

In addition to this, demand on the stability of an instrument over its entire operating lifetime increases at the same time as maintenance costs are being minimized. The ABB multi-component measuring system ACF-NT is an example of how innovative technologies enable the safe and stable measurement of gas concentrations in the parts per million (ppm) range.

The imperatives of Automated Measuring Systems (AMS) for continuous emission measurement

Legal provisions for the limitation of emissions have a long tradition in Germany whose standards have been setting the trend in Europe since the '80ies.

Operators of refuse incineration and processes with co-incineration are presently preparing for the implementation of new directives in Europe.

With the introduction of EU Directives 2001/80/EC and 2000/76/EC, emission monitoring is subject to EN 14181, "Stationary source emissions – Quality assurance of automated measuring systems". This was promulgated in September 2004. Compliance with the EN 14181 standard is a legal requirement under both the Large Combustion Plant Directive (LCPD) and the Waste Incineration Directive (WID). All vendor-supplied equipment must be EN 14181-compliant.

The quality assurance levels QAL1/2/3 were introduced to ensure this compliance. Quality level QAL3 obliges the operator to carry out regular checks for precision and drift at the zero and end-point of his analyzer measuring range. These checks are typically carried out during the maintenance interval. Longer intervals between routine maintenance minimize costs .

ACF-NT capabilities for reducing downtime and hence, cost of operation

The range of application of the ACF-NT measuring system, which is based on the FTPA 2000 FTIR spectrometer, includes complex applications for emission monitoring in domestic waste, hazardous waste and sewage sludge incinerators, and in cement plants and power stations with co-combustion. These are pursuant to European Directive 2000/76/EC, and incorporate its quality demands pursuant to EN 14181. The loss-free measurement of the lowest concentrations of water-soluble components is achieved by seamless heating of the system to 180 °C – from the probe element to the analyzer.

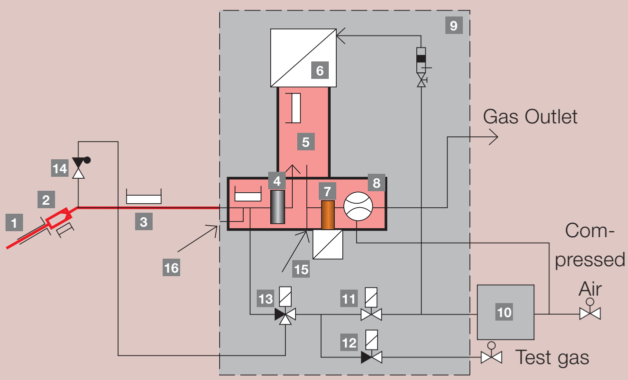
Seeing inside air with infrared interferometry

All molecules in the air – including pollutants – leave a "fingerprint" in the infrared by absorbing certain frequencies. The resulting infrared spectrum not only permits the molecules to be identified, but also permits their concentrations and temperatures to be evaluated. Fourier Transform Infrared (FTIR) Spectroscopy is a measurement technique that extracts this spectrum from incoming infrared light.

FTIR combines the Fast Fourier Transform (FFT) with the Michelson interferometer. The physicist, Albert A. Michelson, performed several experiments to measure the speed of light. He developed an interferometer in 1881, with which together with E.W. Morley in 1887, he showed that the speed of light is independent of the movement of the reference system (The Michelson-Morley experiment is often quoted in conjunction with Einstein's Special Relativity Theory). It is a development of this device that is used in FTIR today[1)]. The FFT is a mathematical operation performed on the signal obtained by the interferometer (the interferogram) to extract the infrared (IR) spectrum[2)].

1 Flow diagram of the working of the ACF-NT

1 Probe tube
2 Heated filter
3 Heated sampling line
4 Stainless steel filter
5 Heated meas. cell
6 FTIR spectrometer
7 ZrO_2 Sensor (option)
8 Aspirator pump
9 Spectrometer purge
10 Compressed air cleaner
11 Zero gas solenoid
12 Test gas solenoid
13 Switch test gas local or probe. Emergency purge
14 Check valve
15 FID port
16 Hg° port



Footnotes

1) For an explanation of the interferometer, see textbox "Principle of the interferometer" on page 53

2) For more background on Fourier Transform spectroscopy see the textbox "From waves to data: a quick guide to Fourier Transform spectroscopy" on page 60.

A low-maintenance electronically controlled air injector system conveys the sample gas from the chimney stack to the analyzers at constant pressure. In order to avoid pressure dependencies, which could arise if an uncontrolled feed pump were used 1, no moving parts are employed.

The spectrometer measures gaseous pollutants such as HCl, CO, NO and SO_2 as well as NH_3, H_2O, CO_2, HF, N_2O and NO_2. Measurements at very high moisture content are possible using a chemometric model optimized for refuse incineration processes. For measurements of O_2 a zirconia sensor and organic C_{tot} with a Flame Ionised Detector (FID) are optionally integrated in the system and are supplied with sample gas from the same sampling system.

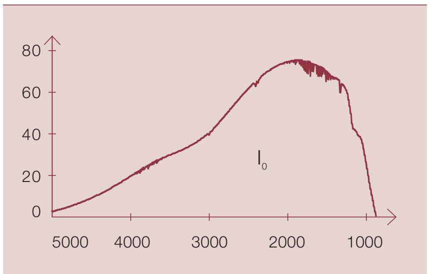
In addition to the use of conventional analog and digital interfaces, a modern interface concept offers the possibility of serial transmission of data. This can be effected by Modbus or PROFIBUS, for instance, for a simplified connection to an emission analysis computer or control system. Data can also be transmitted via standard Ethernet – familiar from office technology – and remote maintenance can be carried out via a telephone modem connection, in order to minimize maintenance costs.

The long intervals between maintenance and the resultant low operating costs are a particular advantage of the ACF-NT. Significant costs are incurred for adjustment during the maintenance interval, especially in multi-component measuring systems. The operating costs are estimated to be approximately 70 percent of the life-cycle costs of an analyzer system. In particular, checking water-soluble sample components such as HCl, NH_3 or HF means an increased outlay for the provision of a calibration gas generator for the test equipment. Typically the time taken for complete adjustment of a measuring system with up to 12 sample components is approximately eight hours.

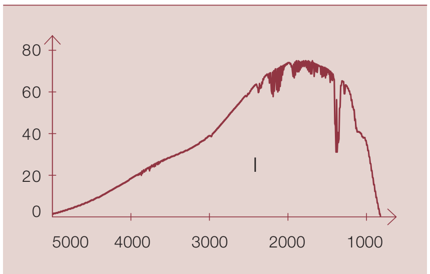
2 Schematic of processing principles of a raw spectrum to an absorption (extinction) spectrum

Lambert-Beer: $I/I_0=e^{-\varepsilon c l}$

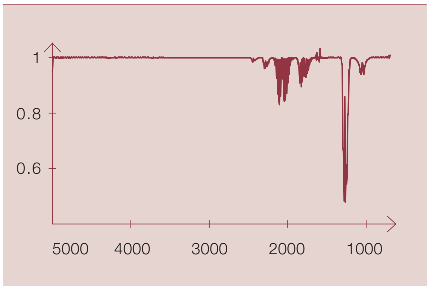
Reference spectrum (I_0)



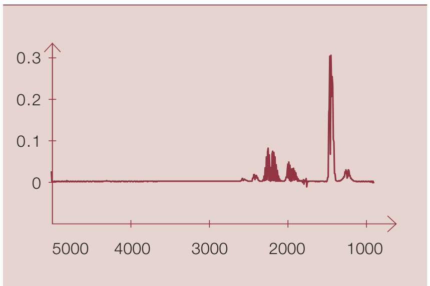
Sample spectrum (I)



Transmission spectrum ($T=I/I_0$)



Absorption spectrum (E=-ln T)



The Lambert-Beer Law applies:
$I/I_0 = e^{-\varepsilon c l}$

With
- I Beam intensity, weakened by absorption in the sample cell
- I_0 Beam intensity, unweakened
- ε Extinction coefficient (molecule-specific constant)
- c Concentration of the sample component
- *l* Effective cell length

The signal I, attenuated by the absorption in the sample (spectrum of the sample), is divided by the unweakened signal I_0 (reference spectrum of the zero gas) and thus receives the transmission spectrum. The negative logarithm of the transmission spectrum supplies the extinction or absorption spectrum, which includes the qualitative and quantitative basic information on the composition of the sample. The height and area of the absorption bands (the absolute absorbance) of the individual substances is the dimension of the concentration. Using the Lambert-Beer Law equation, it is easy to see that this absolute absorbance is only dependent on the number of molecules in the measuring cell (ε and *l* are constant)

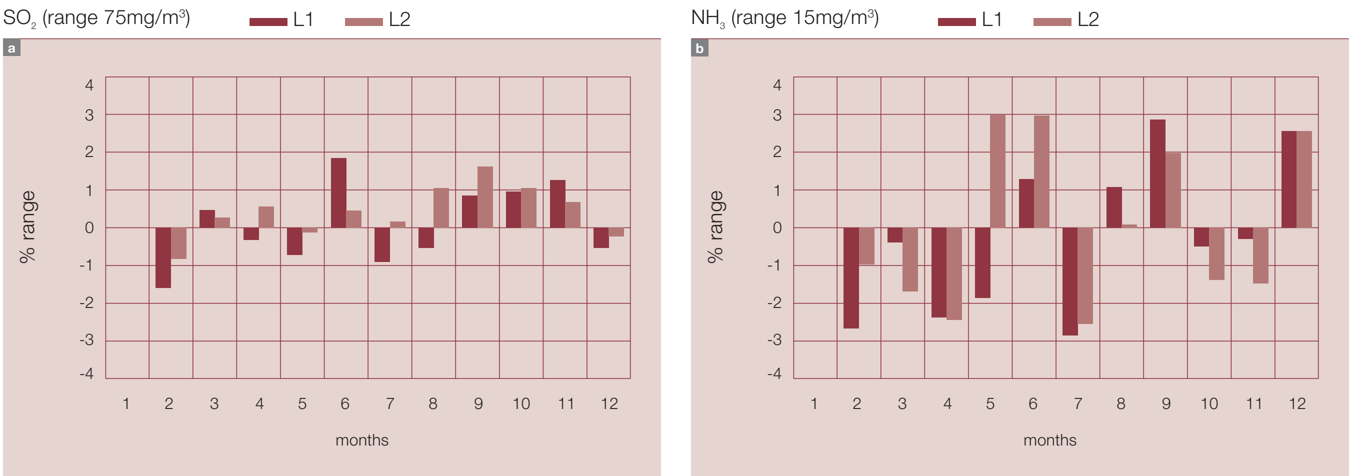
The quotient formation I/I_0 provides a decisive advantage for the stability of the analytical functions of the spectrometer, because the aging processes of modules such as the emitter and detector, as well as any changes in the transmission value of the sample cell (which would manifest themselves as drifting) are automatically compensated for. The basic requirement for this is that a new reference spectrum is a regularly input; this is automatically carried out every 12 hours in the ACF-NT.

FTIR measurement technique with emphasis on optimum signal processing and stability

FTIR spectrometry is a full-spectrum method. This means that absorption processes in a wide spectral range are used for analysis of the substances and not just narrow wavelength ranges, as is the case for interference filter, gas filter correlation or dispersive photometry.

In the Michelson interferometer in the FTIR instrument, each individual wavelength is modulated in extremely small sections, corresponding to the resolution of the instrument by means of interference. The modulated infrared radiation, as a sum of all the modulated (encoded) wavelengths, known as an interferogram, undergoes selective changes in the intensity distribution during interaction with the material, as it passes through the measuring cell filled with gas. The complete IR spectrum is calculated from the interferogram by means of a Fast Fourier Transformation. All the individual selective changes in intensity, based

3 Span deviation for two gases



on emission absorption in the sample, can be qualitatively and quantitatively evaluated as a result.

The processing of a raw spectrum to an absorption (extinction) spectrum is shown in 2.

Theory put to the test

The applied theoretical stability considerations are confirmed by the experience gained from more than 600 systems that have been installed throughout the world since 1993.
It has emerged from scheduled tests with test gases in the maintenance interval that the ACF-NT permits adjustment intervals of over a year.
All the deviations identified so far can be attributed to incorrect handling in the test, incorrect adjustment, or the use of test gases of incorrect concentrations.

ABB's own experience concerning the stability of the FTIR spectrometer is borne out by two independent long-term studies carried out by the German Technical Inspection Authorities (TÜV) of the Rhineland region. The latter study tested the predecessor of the current ACF-NT for the first time in 1995, and the current ACF-NT system in 2004–5. Two systems were tested in parallel in each of the field tests. The first long-term study ran for six months, the second for 12 months. Both field tests met the respective requirements with regard to stability and availability.

The results of a test on two lines of a refuse incineration plant – which ran for a year, taking the components NH_3 and SO_2 as example – further validate the findings on stability 3. The end-points of all sample components tested by the TÜV (CO, NO, SO_2, HCl, NH_3, H_2O) were validated at monthly intervals. The deviations of all components were always within permissible limits.

The statistical scattering of the data for ammonia 3b clearly shows the problematic nature of this gas (the same as for HCl and HF). As a result of adsorption and desorption processes on the gas-bearing surfaces, a lengthy waiting period is required till equilibrium is reached. This clearly shows that special care is called for in the adjustment and validation of these components.

Field test results for two lines of a refuse incineration plant

The new European Standard EN 14181 defines the maintenance interval as the maximum permissible period within which compliance with the stated values of the process variables is guaranteed, without external maintenance requirement, eg, refilling, calibration or adjustment. According to this definition, a maintenance interval of 12 months results for the current ACF-NT on the basis of the field test of 2004–5, ie ACF-NT is a measuring system with proven stability in field tests of one year. Tests with test gases only have to be carried out once a year.

Remote maintenance with the Analyze^{IT} Explorer

The Analyze^{IT} Explorer can be used in Ethernet TCP/IP networks to display all available data in a suitable manner and make it available for remote maintenance. The extent of servicing work can, therefore, be reduced, and reliability increased by means of "look-ahead" maintenance. This results in increased system availability through rapid troubleshooting and reduced cost through planned, predictive maintenance.

Operational stress can accelerate deterioration of equipment in a corrosive environment and move both equipment and processes to the brink of failure. Limiting stresses within the operating environment maintains reliability. Hence, predictive maintenance is a crucial feature for leading environmental monitoring instruments for air quality and industrial emissions.

The ACF-NT is a leading environmental monitoring system. It is proven to be safe, stable, industry-compliant and capable of detecting gases in the lowest ppm concentrations.

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Energy measures

ABB's NGC 8200 marks a breakthrough in micro chromatography

Paul Kizer

The modern world would be quite unimaginable without a secure energy supply. This supply in turn depends on the trading activities of energy providers. In the face of rising energy prices, these companies are increasingly focused on cutting unwanted giveaways and wastage – and for this, they are seeking better metering technology.

Whereas traditional gas-metering is content with measuring the volume of gas moved, both supplier and customer should be more interested in the energy value of the gas. This value depends on its chemical make-up. On-line gas chromatography permits an exact analysis of the composition of the gas – data that can be used to accurately establish the heating value. The principle is not new, but the challenge is to produce a device that meets the demands of mass-deployment – robust and safe yet practical and accurate. Just the job for ABB's NGC 8200!

ABB has made a technological breakthrough in on-line gas chromatography – a technology that is very useful when analyzing the heating value of natural gas.

Most natural gas custody transfer contracts today have a heating value rather than gas volume specification – often measured in MMBtu Textbox.

The financial benefit for keeping track of energy rather than just flow rate is substantial. Most major (large volume) interconnects have on-line Btu measurement of some sort today. It is anticipated, that in the future a larger number of smaller volume stations will use this technology as the costs of GC's (gas chromatographs) are reduced by new developments.

The general philosophy of ABB Totalflow has been to work toward a standardization of chromatographic techniques so that the GCs can be manufactured as instruments rather than hand-built requiring trained technicians in their installation, operation and maintenance. Several manufacturers have targeted such standardization, and various approaches tried. The analytical team at ABB's Bartlesville, OK, plant in cooperation with ABB's corporate R&D department effected a thorough study of micro-electro-mechanical system (MEMS) methods. As a result of this, the decision was taken to develop a highly integrated manifold-based[1] module using conventional materials – raising on-line chromatography to the next level of technology in terms of modularity and field repairability. The result is a new GC, the NGC 8200 that is just as powerful and innovative as it is small in size.

Extensive testing on the prototypes and pre-production units has shown unmatched linearity, repeatability, temperature stability as well as low-level component detection ability.

A pedigree of excellence

The foundation for this revolutionary new on-line GC was laid over a decade ago when the Model 8000/8100 Btu/CV Transmitter was developed 1.

This product has a time-proven track record that boasts over 1200 units working as natural gas analyzers all over the world. The design included several breakthrough innovations that were unmatched in the industry until recently. Some of these placed chromatographic analysis into applications with the natural gas industry where its use was not previously practical. The Windows-based user interface, which has since become common-place, permitted ease of use despite the complexity of the underlying instrument. The self-contained computer controller lowered installation costs while allowing the GC to be deployed in explosion prone hazardous locations. The weatherproof enclosure and air-less oven permitted the GC to be installed close to the sample point, reducing sample transport tubing and dew point problems. The four serial digital communication ports enabled multiple participants at gas custody transfer sites access to vital quality and heating value data. These data links also made the on-site calculation of energy flow possible by linking to computerized flow computation units. The built-in stream switching solenoids allowed the monitoring of several gas sources without calling for additional hardware.

However, all these engineering "firsts" are insignificant when compared to the modular concepts that were developed with this product. For the first time in history, the "chromatography" part of the GC became a "spare part". This means companies can stock spare GC modules locally permitting analyzer repair to be effected in hours rather than days. The key to this GC Module was a highly integrated manifold containing the columns, valves and detectors. This module could be used on any Model 8000 ever produced. Such modularity had never been achieved before.

This product has a time proven track record that boasts over 1200 units working as natural gas analyzers all over the world.

Once proven, the manifold concept on the GC Module was expanded to include the other mechanical parts needed to make a multi-stream GC

1 The model 8000/8100 Btu/CV Transmitter

2 The model 8000/8100 Type M

Btu

The energy that can be obtained by burning gas depends on its chemical composition. The greater the energy per unit volume (calorific value), the smaller the volume of gas needed to heat a home hot water tank. Total flowing energy is defined as:

$$E = H * Q$$

Where:

E = Energy flow rate (MMBtu's)

H = Heating Value/unit volume or mass (Btu or CV (calorific value) per unit volume or mass.

Q = Volume or mass flow rate (SCF or cubic meters or mass flow rate)

One Btu is the quantity of heat required to raise the temperature of one pound of water from 58.5 °F to 59.5 °F (equivalent to about 1055 Joules in SI).

In North America, the prevalent unit for energy measurement is the MMBtu or the dekaTherm (in Europe Joules are often used). The thermal energy stored in gas is calculated by:

thermal energy (MMBtu) = calorific value (Btu/cf) * gas volume (MMcf)

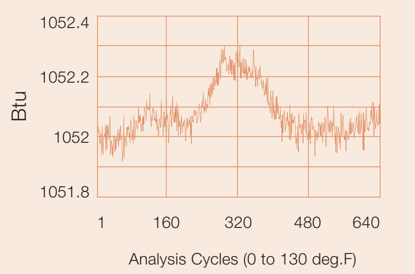
1 MMBtu = 1 dekaTherm

Footnotes

[1] A manifold is a device that regulates flow in a hydraulic system.

3 Development of integration (left to right), from 8000/8100, through 8000/8100 Type M to GC 8200

4 Repeatability over temperature for NGC 8200



5 Low maintenance needs are key to effective field applications

work. This led to the development of the Model 8000/8100 Type M, which was slightly smaller, but whose specifications were roughly equivalent to the previous model 2.

Drawing on the experience gained through these two models, ABB developed the next generation of explosion-proof, on-line GC – the NGC 8200 3. This features an even higher degree of integration than its predecessors. Despite the uniqueness of the replaceable GC module of the Model 8000, its greatest advantage lies in the manifold. In fact, the entire analytical module on the NGC 8200 can be replaced with the use of a single hex-wrench. The design incorporates the strength of its predecessors further. The built-in controller has much more capability without consuming more power. The device is smaller but retains the explosion and weather-proof durability of its predecessor while gaining in ruggedness. Like the earlier models, it is still a multi-stream device, but can additionally handle multiple calibration streams.

With the addition of a multivariable transmitter to provide inputs, the GC is a flow computer and a chromatograph in one.

It also has some features that have not previously been developed on an explosion proof on-line GC Table 1.

3 illustrates the stepwise development of integration in this design. It shows the internals of the Model 8000/8100 on the left, the Model 8000 Type M in the middle and the analytical module of the new NGC 8200 on the right.

The true value of this new design lies in the powerful combination of improved performance at a much lower installed cost. Regarding this improved performance, for example, the repeatability over a wide range of ambient temperatures sets a new industry standard. 5 illustrates this precision over the 0 to 130 °F temperature range:

Operational testing

The result of operational testing allows a published specification of +/– 0.125 Btu at 1000 Btu at ambient, +/– 0.25 Btu at 1000 Btu over 0 to 130 °F.

While the Model 8000 made it practical to interface an analyzer to a flow computer to provide energy measurement, the NGC 8200 integrates both functions into the same instrument. With the power of the GC controller's 32-bit microprocessor and the object oriented *X*Series software framework (ported from Totalflow RTUs and

Table 1 Features of the NGC 8200

- Internal interactive graphical display
- Windows CE software operating system
- Oven mounted pressure sensors
- Completely digital analytical signal processing section
- Two independently programmed carrier pressure regulators
- Ethernet and USB communication ports
- True "transmitter-like" design (looks and installs like common multivariable transmitters)
- Integral flow computer with addition of multi-variable transmitters
- Many other general purpose applications; such as:
  - Data loggers
  - User-configurable alarm monitoring
  - User-programmable math/logic functions
  - Industry Standard IEC 61131 programming language for more complex applications

Flow Computers), direct energy measurement is a reality. With the addition of a multivariable transmitter to provide inputs, the GC is a flow computer and a chromatograph in one.

The entire analytical module on the NGC 8200 can be replaced with the use of a single hex-wrench.

5 shows a field example of an integrated energy measurement system using ABB's multivariable transmitter (on right) and the NGC 8200 (in center with display) as both the flow computer and the chromatograph.

The NGC 8200 does more than provide first rate on-site analysis. It presents a highly versatile platform integrating many of the functions that pipeline operators need to deliver greater productivity.

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An eye on the field

Remote natural gas measurement and automation systems

Brent Berry

Progress in automation is changing the way oil and gas producers operate. The ability to efficiently meter remote activity at low cost opens up new opportunities for real-time optimization of control systems, raising the overall efficiency and productivity of processes.

In the gas industry, many older wells are declining – the consistency of the gas (presence of liquids) makes it increasingly difficult to extract. Newer wells are increasingly being drilled into fields that pose similar challenges. This calls for a tighter control of the extraction process, which in turn places demands on remote monitoring.

Accurate measurement, improved productivity, and increased natural gas production are the fundamental reasons for continued growth in the use of remote natural gas measurement and automation systems.

These areas of endeavor represent key business drivers. The successful exploitation of these set stronger companies apart from weaker ones. The decline rate of wells is increasing and automation is an important option to extend the lives of these wells. The gas produced in many new wells is mixed with associated liquids, requiring artificial lift methods from the start of production.

Given that it might take an hour or more to drive to any given location, it is desirable that the system minimize the number of required site trips.

From the producer's perspective, there are numerous operational and economic bottom-line advantages associated with deploying advanced measurement and automation technologies, including lower operating costs, increased labor productivity, increased production, improved custody transfer accuracy, reduced equipment and well downtime.

The topics treated in this article provide an inside look at remote measurement and automation systems using ABB's TotalFlow metering technology.

Characteristics of remote systems

Besides their coexistence with prairie dogs, coyotes and the like, what other characteristic(s) are important for instruments and systems used in markets and environments such as the one shown in 1.

Autonomous power supply

It is unusual for an electricity supply to be available in remote locations, hence rechargeable batteries fed by solar panels are the preferred technology. In locations where adequate solar radiation is not available (far north/south latitudes) thermoelectric generators are preferred.

Harsh environment

Field equipment should not be too particular about its environmental conditions. The equipment is often exposed to the elements, and hence prone to significant variations in temperature, moisture, wind, dust and electromagnetic radiation. Despite this, remote technology must continue to deliver stable performance around the clock.

Accurate Measurement

It is not enough for the equipment to simply maintain stable operation in a harsh environment. The custody transfer metering market demands exceedingly high performance in such environments. Accuracy is of prime importance.

Sensors must remain stable despite temperature and pressure variations. For differential producing meters (which integrate a rate equation to derive the quantity volume), it is important that the **real-time clock** that drives integration time-slices, remains stable. **Computational accuracy** is vital. The equations used, which include sophisticated numerical methods involving complex polynomials with fractional exponents, conform to standards of organizations such as AGA, API and ISO. Determinism to within 50ppm is the accepted norm for floating point math accuracy.

Minimize site visits

Given that it might take an hour or more to drive to any given location, it is desirable that the system minimize the number of required site trips.

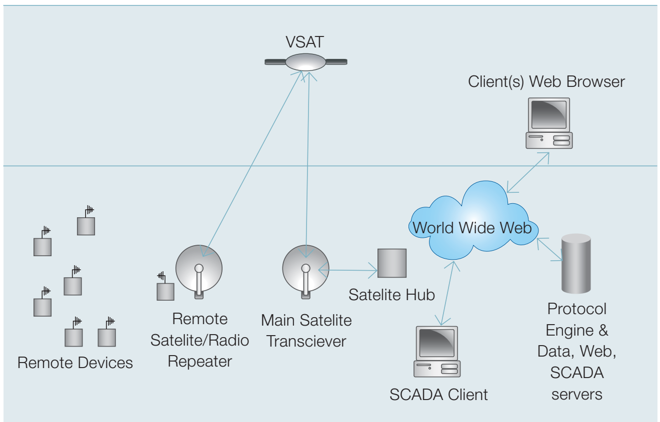
The derivation and collection of custody transfer totals ideally occurs without visiting the metering site. Therefore being capable of remote data telemetry is of significant benefit 2. If telemetry is not available, the optimum system requires only one trip per billing cycle.

Hazardous Area Operation

Electrical safety certification is usually required for equipment in proximity of a natural gas source. Freestanding equipment, not enclosed within another structure, is usually considered DIV 2 (Zone 2)[1] if five feet (1.5 metres) or more away from the meter run. If within five feet or if enclosed inside a non-vented structure, then

1 Live information feed from remote location in harsh environment

2 Hybrid satellite and radio communication network structure



DIV 1 (Zone 1) 2) is usually indicated.

Secure Against Intrusion

Given the goal of unattended operation, it is also important that the equipment remains secure against intrusion. This includes both physical and digital entry.

Integrated functionality

The ability to integrate measurement and automation functions within the same device reduces the number of devices required in remote applications. Initial system cost and cost of ownership are reduced. It also improves the user experience as training on one device applies to all the applications.

Data Types of Remote Systems

On many of today's oil and gas production, transmission and distribution systems, data exists in four principal categories.

- EFM (Electronic Flow Measurement) gas accounting database
- General-purpose trend files
- Near real-time polled data
- Exception-based alarming data

Custody transfer EFM databases support transaction records, which can be edited and audited. American Petroleum Institute (API) standard 21.1 specifies the details of EFM data requirements for custody transfer.

In order to evaluate such data as fluid level control versus well production, compressor condition, well casing pressure, dehydrator temperatures and delivery line pressure, it is beneficial for the system to support remote trending (data logger trend files derived in real time by the remote device).

Generally, near real time polled data is comprised of only a few variables (registers) polled on a frequent basis (ranging from every few seconds to a few times a day). The polling frequency depends on the use of the data, the communications system bandwidth, and the ability of the remote power system to maintain battery autonomy.

At times, the system should provide exception-based alarm detection capability – especially when polling and data collection cycles overrun an acceptable time limit in obtaining status of critical equipment. In order to filter out spurious, unwanted alarms the field equipment must be capable of using alarm filtering and detection logic. Detected alarms must be queued for automatic status transmission to a host system. This technique is often referred to as "alarm cry out" or "exception reporting".

Examples of remote systems

A few examples of remote systems representing different applications in different segments (production, gathering, transmission and distribution) of the oil and gas industry are given below.

Energy Metering and Blending System

Landfills produce an inexpensive consumable gas that is sometimes used as an energy source. However, the heating value of the gas is low and varies significantly as a function of temperature (seasonal and day/night cycles). In order to produce a stable fuel of consistent heating value, higher quality natural gas is blended with it. The goal of such a system is to maintain acceptable heating value, yet consume as much of the landfill gas and as little of the higher quality gas as possible.

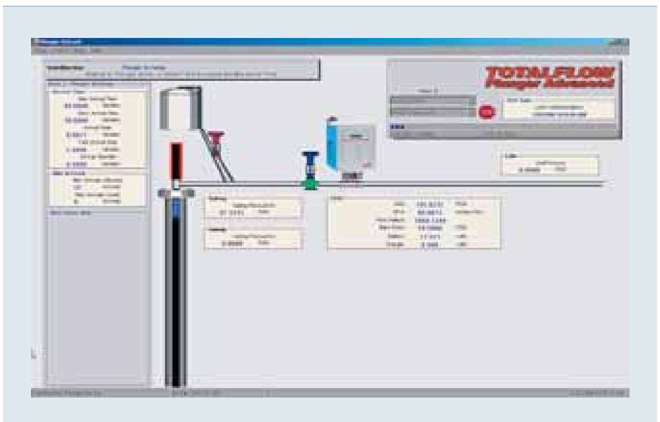
Remote measurement and automation, are helping the oil and gas industry operate more efficiently, more safely, more accurately and productively

Such a system is made up of two subsystems; the first being an energy metering system comprised of a primary element, a flow computer and a natural gas analyzer. The flow computer acts as the system master extracting composition and heating value from the analyzer. The flow computer then combines this data with the volumes derived from the primary meter in order to integrate both energy and volume.

The same basic elements of a natural gas energy metering system provide the building blocks of the blending system. In this case, two streams are measured. Additionally, the flow

3 Energy metering and blending system based on ABB Totalflow natural gas analyzer

4 The plunger GUI based on ABB Totalflow plunger lift application



computer performs feedback control, dictating the proper blend need to obtain the desired energy from the fuel gas 3.

Plunger lift (for liquids removal)

The production of natural gas often produces liquids (oil and water). When the down-hole pressure cannot lift the liquids through the production tubing, artificial lift methods are adopted. These methods can be subdivided into three main categories, within which several variations exist. The three main types of artificial lift are intermitting, pumping and injection. Basic intermitting involves closing the production line by shutting a valve. The down-hole gas pressure rises until it pushes liquids through the production tubing. With the liquids removed, gas can flow again, but as it flows, the liquids build up again and choke gas production repeating the cycle.

Plunger lift is a form of intermitting where a device (the plunger) is inserted into the well's tubing. The plunger provides a more efficient mechanical seal, thus helping to maximize utilization of down-hole pressure to life the liquids. It rises when gas in the well begins to flow and falls when the well stops flowing. When the plunger rises to the top of the tubing, the flow computer detects it and the plunger's transit time derived. This information is used to adapt the intermitting control algorithm and so tune the valve-shutting decision in real-time 4.

Liquid measurement custody transfer using tank level

In the production field, produced liquid is usually stored in tanks as the title picture of this article depicts. Liquid product is either transferred from such tanks into a pipeline or loaded into tanker trucks. By interfacing tank level sensors to a flow computer or RTU the foundation for automated measurement is in place.

When loading a tanker truck, such a system can produce an electronic run ticket. The RTU constantly monitors tank level and detects when loading begins, based on a rapid drop in the level. The RTU remembers the starting level. Based on the level readings, fluid temperature, fluid density and an electronically stored strapping table, the RTU integrates the volume transferred, throughout the loading process.

When the tanker load is completed (detected by a stable liquid level) an electronic ticket is finalized and made available for electronic transfer.

The ability to integrate measurement and automation functions within the same device reduces the number of devices required in remote applications. Initial system cost and cost of ownership are reduced.

Indispensable technology

Remote measurement and automation, including field technology, wireless communications networking and host system software, are helping the oil and gas industry operate more efficiently, more safely, more accurately and productively. These systems continue to mature and increase in functionality, providing enhanced capability for managing important assets.

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Footnotes

[1] An area in which explosive substances can occur but do not do so under normal operating conditions.

[2] Explosive substance likely to occur under normal operating conditions.

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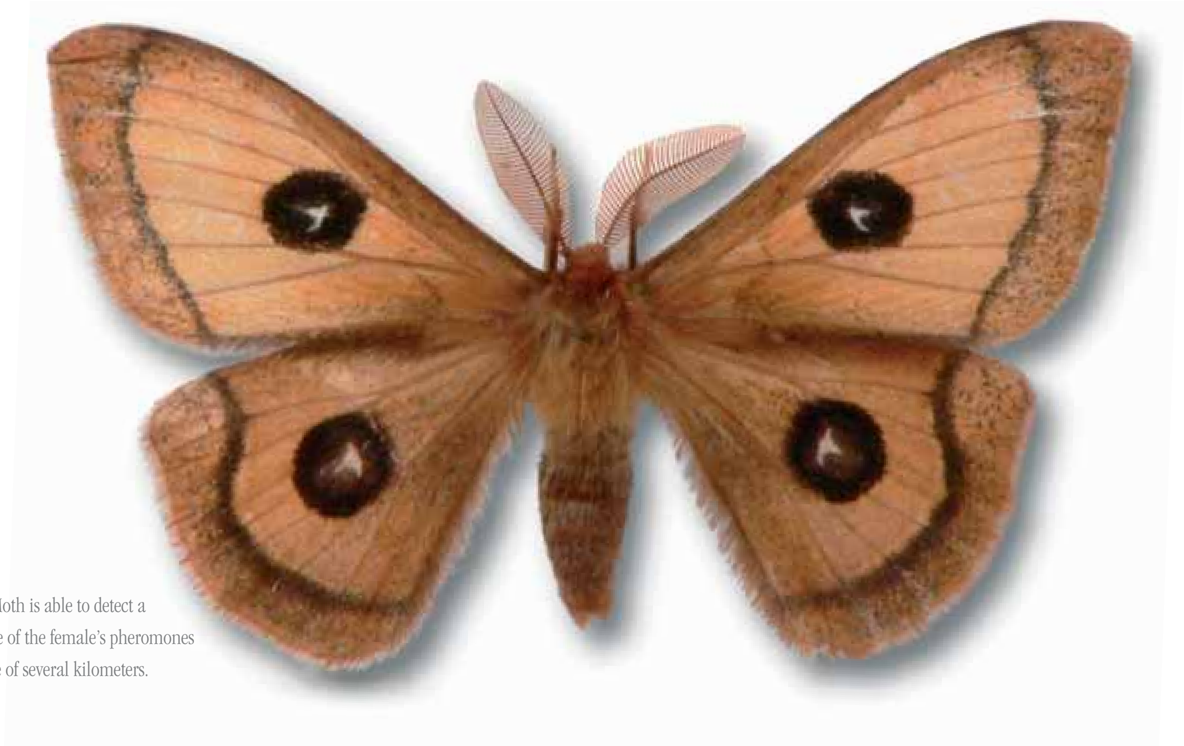

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