

## Instrumental to Success

**Jonas Berge looks at how remote monitoring services can augment the value of instrumenting assets in plants.**



**Smart Pump**  
An instrumented pump alarms operations when cavitation arises and maintenance if service is required.



**Smart Heat Exchanger**  
A connected heat exchanger notifies maintenance when it is fouling.

When I was a child, we only took photos at birthdays, major holidays, and during vacation. A roll of 24 or 36 frames could last a long time. The film was brought for development and the prints glued in albums to be shared with visitors. Digital technologies have completely transformed how we go about our daily lives, including how we are taking photographs.

Today, we take digital photos several times a day to help us in ways that were not possible before: of where we parked the car, of the directory map at the mall, a beverage we liked, or the spare part, or produce we need to buy. Originally, we did not envision use of digital cameras is this new way. There are many other examples of how digital technology has transformed our lives. Digital technology is also transforming how work is done in plants. Plants are now made smarter by instrumenting and digitally integrating assets to make our work easier. This article looks at how remote monitoring services can augment the value of instrumenting assets.

In the past, energy and water was cheap, waste disposal carried little cost, emissions did not incur fines, and labor willing to work in a plant was abundant. On the down side, instrumentation & controls were costly in the past because of hardwired signals, computers and software were also costly back then. Now the cost of energy and water is high, waste disposal is expensive, emission fines are high, and labor with the right skills is hard to attract and retain. These are challenges impacting many departments in all plants. These challenges are the same across all industries and it is only going to get more challenging. On the bright side we now have inexpensive digital instrumentation & controls, inexpensive cloud computing and *software*

Asset	Instrument Count
Pump	1 – 6
Heat exchanger	6 – 12
Air cooled heat exchanger	5 – 10
Blower	5 – 10
Cooling tower cells (health and optimization)	4 – 16
Non-process compressor	3 – 13

Table 1: Complex assets require multiple instruments

as a service (SaaS), and inexpensive telecommunications.

To date automation has delivered better and better process control and safety. However, in addition to that, a second layer of instrumentation enables a Pervasive Sensing™ approach to tackle the other challenges. Plants are constantly innovating with new ways to use their digital infrastructure. Originally plants did not envision use of instrumentation in this new way. Many departments in the plant can benefit from modernization with a second layer of automation as well as asset monitoring as a service.

### Plant modernization

The industry has aspired to futuristic fully automated plants for a long time. But when existing plants were first built all those years ago they were only instrumented for production and safety. Plants were not instrumented for long-term reliability, maintenance and field operator productivity, energy efficiency, or to reduce safety and environmental incidents. These aging plants are now being modernized with additional instruments; that is, by instrumenting hundreds or even thousands of assets around the plant. This enables aging plants to be turned into smart plants.

Monitoring complex assets such as pumps, air cooled heat exchangers, blowers, cooling towers, compressors, and heat exchangers requires multiple instruments.

Monitoring simple assets requires only a single instrument, although one instrument may include multiple sensors such as acoustic and temperature or vibration and temperature. These assets include steam traps, relief valves, rupture disks, control valves, as well as pipes and vessels where corrosion is an issue. Energy management requires a flowmeter for each of water, compressed air, fuel gas, electricity, and steam (WAGES) flow at each plant unit or piece of equipment.



Asset	Asset Count	Instrument Count	Total Instruments
Blowers	10	5 – 10	80
Cooling tower cells	4 – 15	4 – 16	15
Non-process compressors	10 – 50	3 – 13	200
Air cooled heat exchangers	50 – 100	5 – 10	525
Heat exchangers	5 – 10	5	45
Pumps	100	1 – 6	300
Steam traps	2,000 – 10,000	1	2,000
Relief valves	200 – 1,000	1	200
Pipes & vessels (corrosion)	20 – 150	1	20
Control valves	1,500 – 2,500	1	150
Maintenance round points: vibration, temperature, etc.	150 – 500	1	100
Energy metering points: WAGES	200	1	50
Emergency safety shower & eyewash stations	10 – 15	1	10
Bypass and manual valve feedback	100 – 200	1	50
Operator round points: gauge, sight glass, VA meter, dip stick, grab sampling	150 – 500	1	200
<b>TOTAL</b>			<b>3,945</b>

Table 2: Additional instrumentation for Pervasive Sensing solutions

A refinery could deploy 4,000 instruments or more to cover currently missing measurements. Most of the sensors first deployed on a large scale will be non-intrusive sensors or sensors reusing existing process connections as these are the easiest to deploy.

Plants do not fully instrument right away. Instead they start with easy sensors on critical and essential assets. Over many years a refinery could theoretically deploy perhaps as many as 18,000 additional instruments if fully instrumented.

**Instrumenting for energy efficiency**

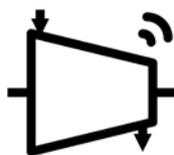
Plants have hundreds or thousands of steam traps. They are typically only inspected once a year because there are so many of them, and the work is often outsourced to a service company. Given the relatively short life span of a typical steam trap a large percentage of them may have failed, blowing steam for many months undetected. With only a few dollars’ worth of steam per day per trap in a refinery this can still add up to as much as US\$ 4 million per year in wasted energy from steam traps alone.

Fouling in heat exchanger bundles over time reduces efficiency requiring fuel to fire burners to makeup heat, unnecessarily driving up energy cost, in addition to impacting production throughput. Cooling towers may have fans running unnecessarily at night or even the during the day at certain times of the year, wasting electricity. Relief valves not seating properly cause product to leak into a shared flare system resulting in loss for which plants are unable to tell which valve is passing. Plants are unable to run internal energy



**Smart Air Cooled Heat Exchanger**

Instruments on air cooled heat exchanger detect vibration and schedule repair.



**Smart Compressor**

Large turbines and compressors have been monitored for years but now the small ones are digitally networked too.



Wireless power meter.

management programs according to ISO 50001 as there is no consumption measurement for each of the plant units and equipment. These are challenges the plant energy manager faces where additional instrumentation can help.

By deploying acoustic transmitters on steam traps, and using special steam trap analysis software, inspection is automated. With automated inspection, plants have the ability to detect blowing of steam within minutes instead of months, allowing the energy loss to be stopped by replacing the faulty steam trap much sooner. By deploying an array of instruments on heat exchangers in conjunction with analytics software, plants get the ability to track fouling and to schedule cleaning at the optimum time to reduce the need for makeup heat thus improving energy efficiency and ultimately reducing energy cost.

Similarly, instruments on cooling towers provide the plant the ability to detect excess cooling capacity, allowing fans to be managed to save electricity. Acoustic transmitters on relief valves have the ability to detect if it is not seating properly allowing product to pass. Service can be scheduled accordingly to stop flaring of good product. Additional flowmeters and electricity meters together with an Energy Management Information System (EMIS) give plants the ability to monitor and report consumption of energy in the form of water, (compressed) air, (fuel) gas, electricity, and steam (W.A.G.E.S.) for water balance, energy balance, and to alarm on overconsumption to drive energy management practices with energy accounts on a plant unit or at the equipment level such as a heater or reactor. Note that this information does not go to the operators, but is rolled-up into simple dashboard KPIs to those responsible for energy efficiency and loss prevention.

Instrumenting them is the most practical way to deal with the huge number of assets in a plant. Essential plant systems such as the water system, compressed air system, fuel gas system, electrical system, and steam system are all fully monitored to ensure their integrity.

**Instrumenting for reliability**

Plants were originally not instrumented for real-time condition monitoring for most equipment. Only the large turbines and compressors had condition monitoring. Plants therefore periodically had to manually collect and type in data for other assets.

Traditional maintenance rounds with vibration, temperature, and acoustic testers are not productive, and a retiring workforce and limited number of people joining the heavy industries makes such manual tasks a challenge.

Plants need a small army of skilled people to do it – but they don't have it anymore. Moreover, manual testers cannot get inside equipment enclosures on fans and cooling towers so manual testing is not possible during operation. Plants have hundreds of processing equipment including pumps, blowers, air cooled heat exchangers, non-process compressors, cooling towers, and valves etc. Plants need to correctly schedule maintenance because when equipment fails because the early indications of problems went unnoticed for days or weeks, they cause costly process downtime or slowdowns, plus repairs are expensive.

With permanently installed vibration, temperature, and acoustic transmitters plants gain the ability to reduce maintenance rounds and instead assign personnel to service the equipment that really needs attention, before they fail catastrophically. Arrays of instruments mounted on processing equipment in conjunction with asset management software or add-on applications to the historian which plants already have give the ability to detect impending problems early so equipment can be serviced before a failure causes costly process downtime or slowdown. At the same time, the plant also gets the ability to tell when an asset does not need maintenance, thus avoiding unnecessary planned downtime and cost of preventive maintenance.

Corrosion monitoring instruments on pipes and vessels give plants the ability to track and manage corrosion that could inhibit chemical injection, and service problem areas before leaks occur. This maintenance information also does not go to the operators in the control room. The new information goes to the offices of the maintenance and reliability engineers as a tool for correctly scheduling maintenance; to know what equipment to schedule maintenance for, for instance which heat exchanger is fouling and how fast and which pumps seals or bearings have issues.

### Plant-wide wireless instrument network infrastructure

Over the past several years thousands of plants around the world have experimented with wireless instruments in multiple ad-hoc applications throughout the plant. Now having familiarized themselves with the technology, these plants are deploying a structured plant-wide wireless instrument network infrastructure that benefits all departments in the plant; reliability, maintenance, energy efficiency, safety, as well as operations. It is in the company's best interest to invest in a single infrastructure. If each team in the plant deployed a separate infrastructure using different technologies the plant would soon have a challenge to support such a fragmented approach. A single shared infrastructure serving all departments is best.

An important characteristic of digital technology is that once the initial investment in the digital network



#### Smart Blower

Fans and blowers with instruments and connectivity notify when they are in need of service.



#### Smart Steam Trap

Instruments on steam traps connect to the network and software report when due for replacement.



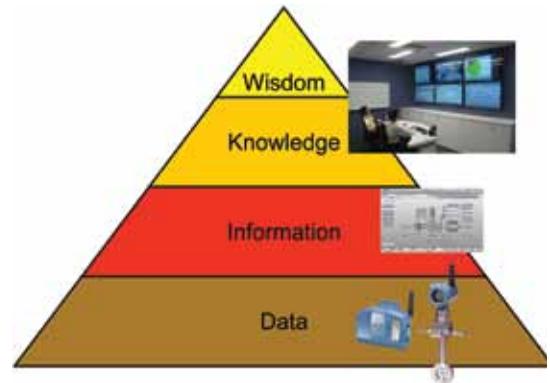
#### Smart Cooling Tower

Cooling towers communicate waterside problems and other data prompting attention.



#### Smart Relief Valve

An instrumented relief valve reports release as well as any seat leakage.



DIKW pyramid.

infrastructure has been made, instruments can be added at near zero marginal cost. For instance, a gateway may start out with only a few instruments, but it can grow up to 100 instruments on that same gateway without additional hardware.

### DIKW Pyramid preventing data overload

Displaying thousands of additional data points to operators would overwhelm them. Moreover, most of the data from the Pervasive Sensing instrumentation is related to maintenance, reliability, and energy efficiency-- only a small portion is related to process operation.

Software removes the need to have eyeballs on all these data points or to pour over reams of printouts. The software does the monitoring in the background and alarms the relevant personnel when something is beginning to deviate from normal.

Analytics software is based on the Data, Information, Knowledge, and Wisdom (DIKW) pyramid model. Algorithms in the software process the large number of raw data points and distill them into useful information and knowledge which is actionable. For instance, the instrumentation provides the raw data such as inlet and outlet temperature for product and steam on a heat exchanger, as well as the flow, and differential pressure across it. Software algorithms compute the heat transfer coefficient and duty etc. with trends and alarms which is information that is easier to grasp than the raw data from the instruments. This software can run on Virtual Machines (VM) in the cloud. Wisdom could be Root Cause Analysis which might still require a human.

Operators at the DCS console look at screens which are basically graphical animations of the P&ID. However, the new reliability, maintenance, and energy data is integrated through the Asset Management System (AMS) or plant historian which most plants already have. This information is displayed differently, in the form of a detailed diagram of an individual piece of equipment like a pump or fan, each one with its critical components like the motor and seals. This makes maintenance data easier to visualize. Energy management data is displayed in the form of KPI dashboards with dial gauges and pie charts.

**Asset monitoring as a service**

Aircraft engines are monitored by their manufacturers as the planes are in the air so that maintenance can be scheduled when they are on the ground. Why should plant equipment be any different?

Outsourcing inspection of pumps, blowers, compressors, steam traps, heat exchangers, air cooled heat exchangers, and cooling towers etc. to external service contractors is common in plants today, only that the contractor has dozens of people at site walking from asset to asset to manually collect data using portable testers. It is very time consuming, so weeks and months passes between inspections of much equipment. Infrequent inspections mean early indications of impending failure are missed and equipment ends up running to failure anyway.

Condition monitoring can optionally be extended into a remote asset monitoring service business model similar to the aircraft industry. With a Pervasive Sensing solution in place in the plant, the plant personnel can either do the asset monitoring themselves from an in-house office or an external contractor can take on much of the responsibility for monitoring certain plant assets, compiling weekly, monthly, and quarterly reports including interpretation of complex diagnostic waveforms and trends etc. from a remote location outside the plant. Instead of contractor service personnel making their rounds in the plant collecting data, equipment is instead instrumented to automatically send the data to the remote monitoring centre where diagnostics experts determine when service is required for thousands of assets around the plant. Remote asset monitoring as a service also reduces the burden on the plant personnel if there is insufficient staff able to interpret a vibration spectrum, valve signature, radar echo, or a chromatogram. For instance, the reliability department may not have sufficient numbers of level 3 vibration experts. In a full service model the service provider can also handle the administration such as spare parts ordering and dispatching service technicians to service a valve or replace a steam trap.

Instruments and network infrastructure can be owned by the plant, or in an Infrastructure as a Service (IaaS) model the service provider owns the gateways and instrumentation and also takes responsibility for ensuring the wireless instrument network is kept robust and that the batteries in the wireless devices are in good condition. The plant pays a monthly subscription fee for using the infrastructure instead of buying it.



**W.A.G.E.S. Metering**  
Energy flows can be monitored centrally for individual equipment.



**Smart Manual Valve**  
A bypass valve alarms if it has been left open after proof testing.



**Smart Control Valve**  
Smart control valves have been around for a long time but now notify the manufacturer when service is required.

Similarly, the plant can own the monitoring software and servers, or in a Software as a Service (SaaS) model the service provider owns the servers and the software and also takes responsibility for ensuring the servers and software run, typically in the cloud, administering database backup, as well as managing software updates and hot fixes etc. The plant pays a monthly subscription fee for using the software instead of buying it. There are no local servers or software at site.

For instance, there are more than 70 plants in Singapore’s industry cluster on Jurong Island. Many of these plants have been instrumented for sensing beyond the P&ID. As a result, early adopters have experienced greater energy efficiency, fewer losses, smaller carbon footprint, higher productivity for maintenance and operation personnel, greater reliability, and the plants have become a safer place to work. The availability of good 3G mobile network infrastructure, Internet infrastructure, cloud data centers, and a knowledgeable workforce makes Singapore the ideal proving ground also for remote asset monitoring, and several pilots are already on the way.

**Process data vs. equipment data**

Traditionally plants have had policies that prevent data from leaving the company which makes sense since until now automation has only been concerned with the primary layer of automation for process control and safety for which process data leaving the plant could reveal proprietary process intellectual property. However, most of the instrumentation now being deployed to modernize plants is not for process data but for the second layer of automation for energy efficiency and equipment health data which is not proprietary since it is not the core business of the plant. Therefore such data can be allowed to leave the plant, enabling the external contractor to use the data to provide better maintenance and turnaround services to enhance reliability and energy efficiency.

**Backhaul network**

From the instrument network infrastructure a backhaul network brings the data to the remote monitoring data centre. Keep in mind that these instruments do not control equipment or process; it is measurement-only.

If the remote asset monitoring service provider owns the instrument network infrastructure the data can be backhauled to the remote monitoring data centre using the 3G mobile phone network by connecting

	Infrastructure Ownership and Management	Software Ownership & Management	Asset Monitoring and Reporting	Work Order Administration	Asset Repair / Replacement
Self Monitoring (no service)	Plant	Plant	Plant	Plant	Plant
Software as a Service (SaaS)	Plant	Service Provider	Service Provider	Plant	Plant
Infrastructure as a Service (IaaS)	Service Provider	Service Provider	Service Provider	Plant	Plant
Full Service	Service Provider	Service Provider	Service Provider	Service Provider	Service Provider

Table 3: Remote asset monitoring service models



### Smart Safety Shower

Safety showers and eyewash stations alarm the operators for first aid assistance if activated.



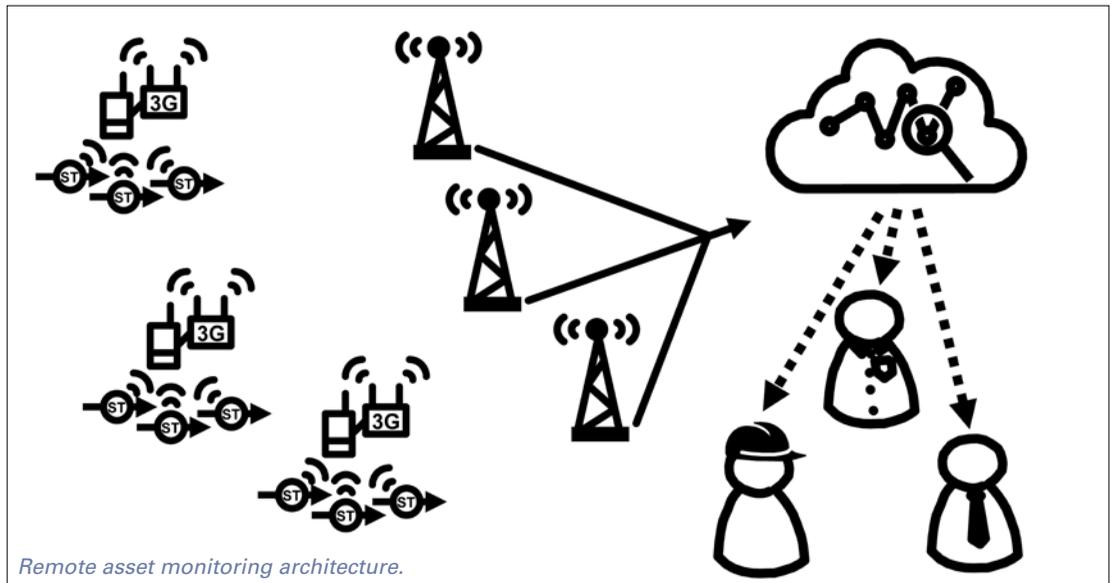
### Smart Storage Tank

Higher degree of instrumentation alarm on tank floating roof tilt and water pooling.



### Gauge Replacement

Instruments send the data to the operator instead of the operator coming to the data.



Remote asset monitoring architecture.

a 3G router. Such a Machine-to-Machine (M2M) architecture achieves complete network separation. That is, the asset monitoring infrastructure is completely independent from the system control network and the plant network. Data is transferred over private networks using a point-to-point Virtual Private Network (VPN).

If the plant prefers to own the instrument network infrastructure, remote asset monitoring by an external service provider is still possible. The backhaul network can be engineered to only transfer data from reliability and energy efficiency instrumentation to the remote monitoring data centre over a secure intranet connection using point-to-point VPN; more of Intranet of Things than an Internet of Things.

## Preparing for the Internet of Things

The Internet of Things (IoT) paradigm in the context of industrial automation refers to more instrumentation which is intelligent and digitally networked; ecosystems based on wireless or bus. This includes sensors digitizing data as well as actuators with embedded intelligence.

Many plants already use wireless and other digital communication networking at the instrument level, digital from the very first meter; from instruments all the way up to the enterprise level. Plants do not need to connect these instruments to the internet today, but it is important to prepare the fundamentals by deploying a Pervasive Sensing architecture based on digital instrumentation with digital networking now. The “Internet” connection for IoT can come later when the plant is prepared.

## Big Data analytics

The Big Data paradigm in the context of industrial automation refers to analytics software such as a plant historian collecting more information from more instruments around the plant. By analyzing historical data from more points than ever before, over long periods of time, it may be possible to discover new

insights about the plant, revealing facts about the plant that were previously unknown for decades. For instance, relief valve lifting may be found to be correlating with other process events in the plant. These new insights can then be used to operate the plant better. Operators may have a gut feeling for certain relationships but additional measurements and Big Data analytics enables such relationships to be confirmed, but other relationships that might be uncovered which we didn't know existed will surprise us.

## Successful plants

We no longer have to go to photo development shops and we no longer have to put the photos in albums. Photos are available instantly and always with us. This is just one of the ways in which life has changed as a result of digital technology.

Plants today do not have all their assets instrumented to make smart plants possible. Plants have vibration monitoring on their largest compressors, turbines, and most critical pumps – but that's it. Plants need dramatically more instruments and new software to distill the raw data into actionable information in order to improve.

Existing plants can be modernized with additional instrumentation. For a new plant, this should be planned from the very beginning of a project. With the increasing demand for reliability, energy efficiency, and from new environmental and safety regulations plant personnel are unable to cope unless they are given better tools.

Instrumenting equipment feeding data into new software tools now makes sense. By automatic condition monitoring for assets as small as a steam trap, thousands of healthy assets can be ruled out, and personnel can instead focus their attention on the assets that really need service. A Pervasive Sensing strategy is instrumental to success.

CEA