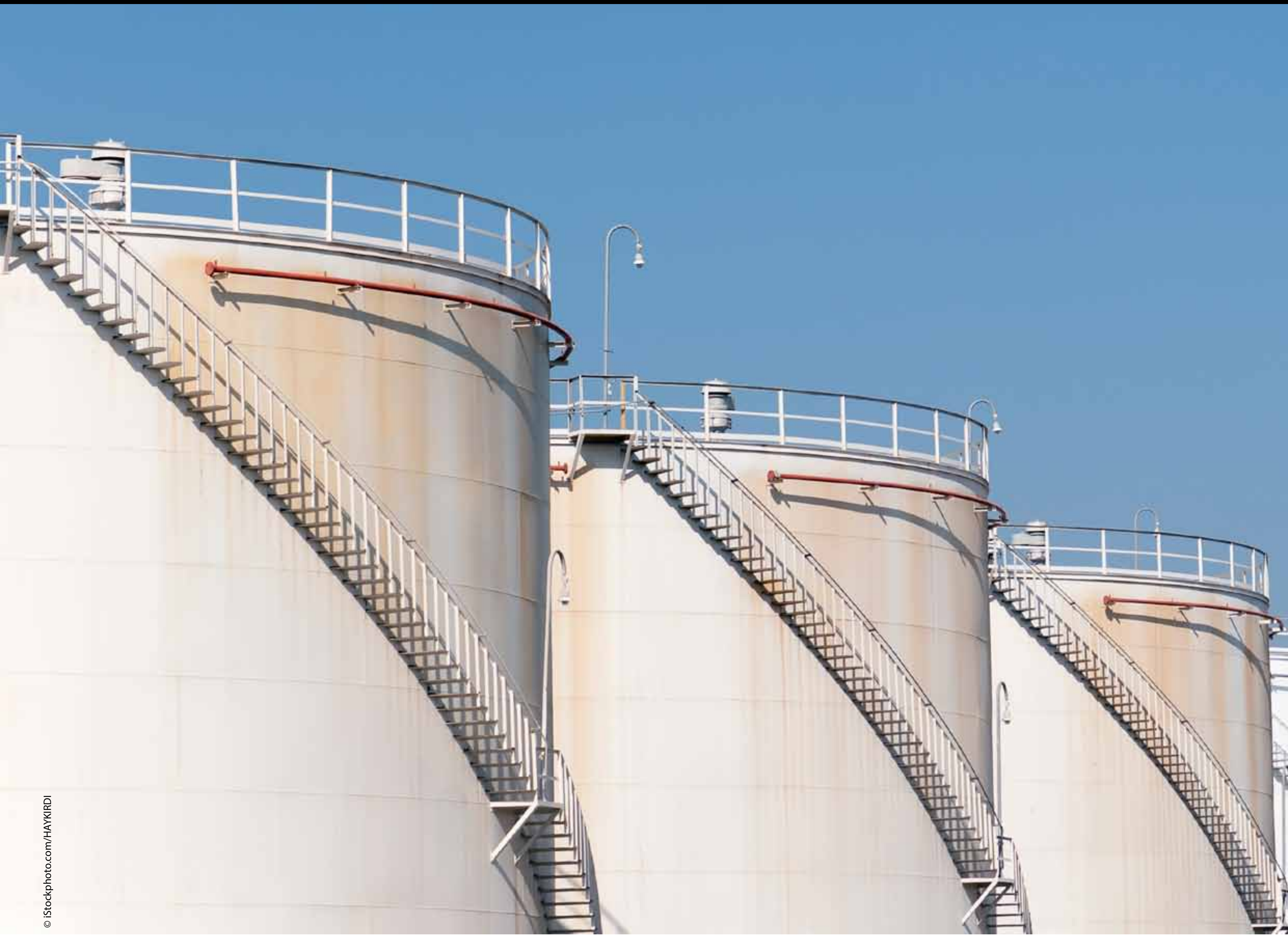
Tank farm monitoring

Meeting Australia's fuel reserve needs



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Meeting Australia's fuel reserve needs

Glenn Johnson

Meeting Australia's IEA treaty obligations will require refinery, terminal and storage operators to establish automated tank farm monitoring and inventory management solutions.

In April 2015, the Department of Industry and Science published its Energy White Paper 2015, "to provide an integrated Australian energy policy framework" that will be "consistent with the Government's vision for economic reform and future competitiveness"[1]. The main focus of the white paper was on improving competitiveness in the energy sector, more productive use of energy and investment in innovation.

Unfortunately, transport energy security did not get much attention in the white paper. Australia is not meeting its obligations for fuel stockholdings under the International Energy Agency (IEA) treaty, but this only received a passing comment in the white paper.

At the same time a Senate committee on energy resilience and sustainability was releasing its findings[2], which included the following three recommendations:

1. The government should undertake a comprehensive whole-of-government risk assessment of Australia's fuel supply, availability and vulnerability.
2. The government should require all fuel supply companies to report their fuel stocks to the Department of Industry and Science on a monthly basis.
3. The government should develop and publish a comprehensive Transport Energy Plan directed to achieving a secure, affordable and sustainable transport energy supply.

What is the risk?

A quite comprehensive analysis of Australian fuel supply chain risk, conducted by the National Roads and Motorists Association (NRMA) in 2013[3], stated that:

The very small consumption stockholdings of oil and liquid fuels in Australia, combined with what appears to be a narrow assessment of our fuel supply chain vulnerabilities, does not provide much confidence that the strategic risks to our fuel supply chain are well understood and mitigated by our nation's leaders, the business community or the population at large.

The report also quoted an ACIL Tasman Fuel Vulnerability Assessment 2011[4] as saying that as of 2011 Australia received 55% of its petroleum shipments from Singapore, with Japan and Korea also being significant sources. Singapore acts as a regional supply hub for South-East Asia and in turn sources 40% of its supply from the Middle East. In a world of instability in the Middle East, and potential conflict in the South China Sea, disruption of supply via Singapore could have a significant impact on Australia's fuel supply.

Australia's high dependence on petroleum fuels for the transport of essential products such as food and pharmaceuticals makes this a significant problem for the country as a whole.

Australia is not meeting its reserve obligations

As a member nation of the IEA, Australia is obliged to meet the requirements of membership. One of those requirements is that fuel storage reserves must equal at least 90 days' worth of consumption. Australia is the only IEA member country among 29 developed economies whose reserves are not meeting that obligation.

The Energy White Paper stated that meeting IEA obligations would mean an investment of several billion dollars over a decade.

The challenge that will arise for fuel storage facilities and terminals in the future will be a potential need to increase capacity — including perhaps for new tank farm facilities to be built — and to achieve a more accurate and timely method of measuring fuel stocks. To date, most fuel storage facilities in Australia rely on manual tank gauging measurements, and therefore there is never an accurate understanding of available stock.

Today's low oil prices are also impacting oil and gas company profits, making investment in technology that may not at first seem essential to business operations unattractive. However, tank farm and terminal operators are now also faced with having to comply with international safety standards, so the challenge becomes investing in the right areas to not only improve safety and meet regulatory requirements, but to take advantage of the expenditure to maximise the business value of any tank monitoring technology that may be deployed.

How we got here

According to the Australian Petroleum Production & Exploration Association (APPEA)[5], Australia's production of oil, condensate and LPG peaked in 2000 and has been trending down ever since, while the production of natural gas more than doubled between 1998 and 2014 (see Figure 1).

There have been a number of refinery closures in recent years. As recently as 2012, Australia had seven oil refineries, but now only has four — New South Wales has lost all its refining capacity and Victorian capacity has halved.

As a result of reduced local production and refining, Australia has been a net importer of oil since 2004. In fact, Australia's dependency on fuel imports has increased from 60% in 2000 to over 80% today.

According to the Senate committee:

Australia is a net importer of crude oil and refined petroleum products. In 2013–14, 82 per cent of the crude and other feedstock required for domestic refining was imported, with the balance supplied from indigenous production.[6]

It is also predicted that refining capacity may completely disappear by 2030, leaving Australia completely dependent on an overseas supply chain. In a world of increasing political instability, this leaves the country even more vulnerable to fuel supply disruption.

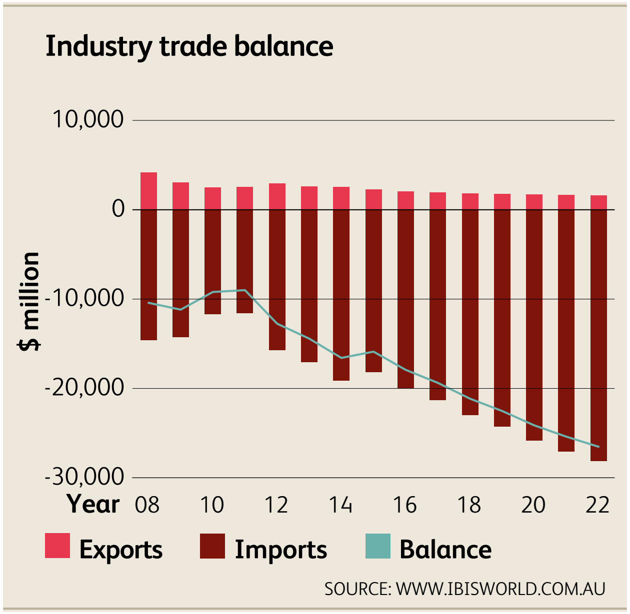

Figure 1: Imports and exports of petroleum products ($ billion). Source: IBISWorld Market Research.

How much do we have?

How much fuel reserve Australia has is not accurately known. All fuel storage in Australia is held commercially and is dependent on the business requirements of the organisations in the supply chain. The closure of refineries has resulted in them being converted to storage facilities and terminals, somewhat increasing storage capacity.

How much is available in terms of 'days of stock' depends on whether stocks of fuel are expressed in days of net imports or in terms of historical average daily consumption.

According to the Senate committee, as of December 2014, Australian Petroleum Statistics (APS) reported that there was 4275 kt of crude oil equivalent stocks, representing 52 days' cover of daily net imports. In terms of historical average daily consumption, the committee was informed that Australia has 34 days of fuel stocks.

"The 34 day figure is calculated on the average daily consumption of fuel in Australia divided by what is believed to be the volume of fuel available to the market."[7]

The discrepancy seems to be that the 52-days figure includes fuel in transit at sea. IEA requirements only count fuel actually held in stock, which means that as of December 2014, Australia only had about one month of reserve transport fuel.

The main reason that the actual reserve is not accurately known is that the majority of fuel storage locations have no accurate way of measuring stock at any point in time.

Many refineries, storage facilities and terminal facilities in Australia have ageing tank infrastructure, which was built without any form of automated tank monitoring. Storing commercial stock, the organisation owning the tanks may have historically not been specifically interested in accurate or continuous measurement of inventory, and the costs associated with measuring it. Many will also have operated on a 'just in time' basis — keeping only enough stock to meet customer requirements — in order to minimise business overheads.

Manual tank monitoring

Where tanks are not instrumented, manual methods of measurement need to be used. The American Petroleum Institute's Manual of Petroleum Measurement Methods[8] defines standardised methods of manually measuring tank levels. The two methods are to measure either the ‘innage’ or the ‘ullage’ using a bob and gauge tape dropped from the top of the tank. Innage refers to measuring the actual fluid level from the bottom reference point of the tank, while ullage means the indirect method of measuring the distance to the fluid level from the tank’s top reference point. In terms of accuracy, neither method can take into account volume changes caused by temperature fluctuations.

There are also other obvious deficiencies in manual measurement methods, not the least of which are the risks to worker health and safety. Workers are, of course, required to work at heights — with the obvious risk of falls — and are likely to be exposed to flammable and toxic hydrocarbon vapours.

It is understandable that these factors alone mean that manual tank gauging is a process that does not occur at frequent intervals, and inventory may change significantly between measurements.

Manual methods also mean manual recording. Workers need to record their measurements at the tanks, and then at a later time enter them into whatever system is used by the facility to log the data. These are often simple spreadsheets. The scope for human error and inaccuracies is obvious.

Another downside of long manual measurement intervals is that tank overfill prevention is quite weak. In order to lower the risk of overfill, the acceptable upper level limit defining a full tank has to be at a lower level than if continuous measurement is used — effectively reducing a tank farm’s maximum capacity.

Safety as a driver for tank monitoring

While the Australian Government may well legislate for mandatory reporting for all fuel storage facilities, a major pre-existing driver for automated tank monitoring has been safety concerns following the Buncefield incident in the UK in 2005[9].

After the accident, representatives from the Control of Major Accident Hazard (COMAH) Competent Authority issued a report entitled Safety and environmental standards for fuel storage sites[10].

Figure 2: Buncefield Oil Storage Depot, Hemel Hempstead, Hertfordshire. (Source: buncefieldinvestigation.gov.uk)

The report makes safety recommendations for incident prevention in flammable and hazardous material storage sites.

As stated above, manual measurement methods are not reliable in preventing hazardous tank overfilling, and attempts to minimise the risk involve tolerating lower inventory levels. Today, modern overfill prevention systems that incorporate API 2350 (United States driven guidelines) and IEC 61511 functional safety standards are available. These systems can operate autonomously to not only alarm of potential overfilling, but to close emergency shutdown valves automatically.

An automated overfill prevention system (AOPS) also has a fast reaction time, which means that tanks can be safely filled to capacity, increasing overall inventory capacity.

Inventory visibility for business processes

The management systems of many tank farm and storage terminals rely on manual field measurements supported by tools and systems that are not very sophisticated and are often in-house developed, out of date and no longer supported.

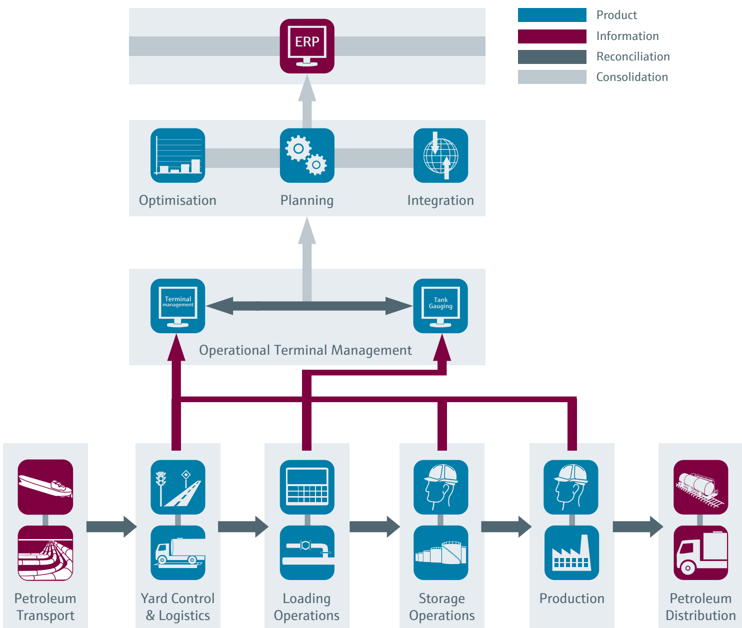

Figure 3: Integration from process to ERP.

Using Excel spreadsheets to generate reports, or relying on the tools that come with tank level gauges, results in the generation of isolated information that is difficult to put into context and which therefore provides limited value to operations. With manual measurements, the risk of error increases, as does the time to discovery of faults and failures — both of which can have a major impact on safety and performance.

In the interest of maximising business returns from automated tank monitoring, business process automation is as important as the automation of the physical process. Replacing a manual or legacy tank farm monitoring process with an optimised system can improve business returns. Eliminating the separation between the automation of physical processes and business automation systems such as ERP is not just 'Internet of Things' hype, but can provide real business benefits in terms of improved operational planning and control.

Integrating tank monitoring systems with the plant DCS and ERP systems also eliminates deviations between the availability of product and delivery schedules that can be caused by manually collected and out-of-date data — and can also have a large impact on the efficiency of downstream operations.

The main impact of access to real-time data from start to finish is that everyone involved in the operation of the facility, from operators and technicians, right through to planners in the boardroom, has access to accurate information to enable their day-to-day decision-making.

Types of tank monitoring application

Bulk fuel storage terminals can be split into three types: pipeline, marketing and storage terminals:

- Pipeline terminals are found at the beginning or end of a pipeline and receive products directly from a refinery or from tankers.
- Marketing terminals are for temporary storage prior to distribution and usually store a small variety of products, such as gasoline and diesel.
- Storage terminals may be used for storage of final product for a particular industry, such as jet fuel for an airport, or may store a wide variety of different products.

Measurement of product volume or mass is necessary for both inventory control and custody transfer.

Inventory control measurements are important for understanding exactly how much product is in stock, and reliability and repeatability are important considerations.

Safety overfill prevention systems use a point level sensing solution, since their only purpose is to detect the high level and prevent overfilling.

Accuracy challenges

The application of instrumentation creates opportunities to measure inventory far more accurately than any manual method. Manual methods essentially involve only measuring the level of the liquid surface — and possibly an oil/water interface — and as accurate as these measurements may be, they are not necessarily an accurate indicator of the actual quantity of product, for a number of reasons.

Various deformations and variations to tank dimensions can occur over time. The dimensions of a tank can change through deformation caused by the varying mass of liquid in the tank, and by temperature variations. Due to their weight, tanks can move or tilt over time, and both the bottom of the tank and the roof can move. All these deformations cause variation in the liquid level for a given volume of liquid. Some but not all of these variations can be compensated for by tank correction and capacity tables.

Hydrocarbons also vary in volume depending on temperature — a variation in temperature of 1°C typically causes a volume change of around 0.1%. Varying amounts of water are normally present as well, which need to be measured to calculate the correct quantity of the stored liquid.

It is the volume or the mass of the stored material that is of interest. There are two main methods of tank monitoring — a mass-based method and a volume-based method. The mass-based method is based on measuring the hydrostatic pressure of the liquid column using pressure instruments. The volume-based method combines a level measurement with a temperature measurement. In either case it is also necessary to measure the free water volume in the tank.

In addition to these two main methods there has also been an increase in the growth of hybrid tank measuring systems (HTMS), which use highly accurate level measurement combined with hydrostatic pressure measurement for mass. This is often the preferred method, particularly for product that is often measured based on mass. Furthermore, for crude 'water bottom' can be a very critical measurement as many or most crude tanks intentionally have water at the bottom of the tanks that will need to be deducted from overall volume.

Recommended technologies for volume measurement

Servo level gauges

Servo tank gauges operate on the principle of displacement measurement. A small displacer with a higher specific density than the liquid is suspended on a measuring wire that is unwound from a drum and positioned in the liquid medium using a servomotor. A resolver coupled with the wire drum is used to measure variations in the weight of the displacer, according to Archimedes Law.

Figure 4: A servo level gauge.

When the displacer is lowered and touches the liquid, the weight of the displacer is reduced due to the buoyancy of the liquid. As a result, the torque in the drum is changed, and this change is measured by the resolver along with the distance the displacer has been dropped.

The displacer can also be lowered through the liquid until a new change in buoyancy is detected, enabling the servo gauge to detect an oil–water interface.

Servo gauges are one of the most accurate methods of level measurement, with an accuracy of within ±0.4 mm over a depth of 40 m. They also inherently measure the density of the fuel, since it is directly related to the buoyancy.

Radar level instruments

Radar level instruments are a non-contact method of measurement in which the instrument is mounted at the top of the tank and transmits microwave pulses down into the tank.

For high accuracy liquid level measurement in storage and process applications, radar gauges operate based on the frequency-modulated continuous wave principle (FMCW). The radar emits a precise crystal-oscillated, continuously varying frequency wave from the antenna. The wave is reflected off the product surface and received again by the radar system.

The reflected energy is dependent on the fluid's dielectric constant, which is significantly different from air for both water and hydrocarbon liquids. Due to the further difference in dielectric constant between the fluid and water, the interface level can also be detected.

Radar level instruments typically provide an accuracy of ±0.5 mm, and have the added advantage of low maintenance, having no moving parts as servo gauges do. However, they do not measure density, and this will need to be determined by additional instrumentation.

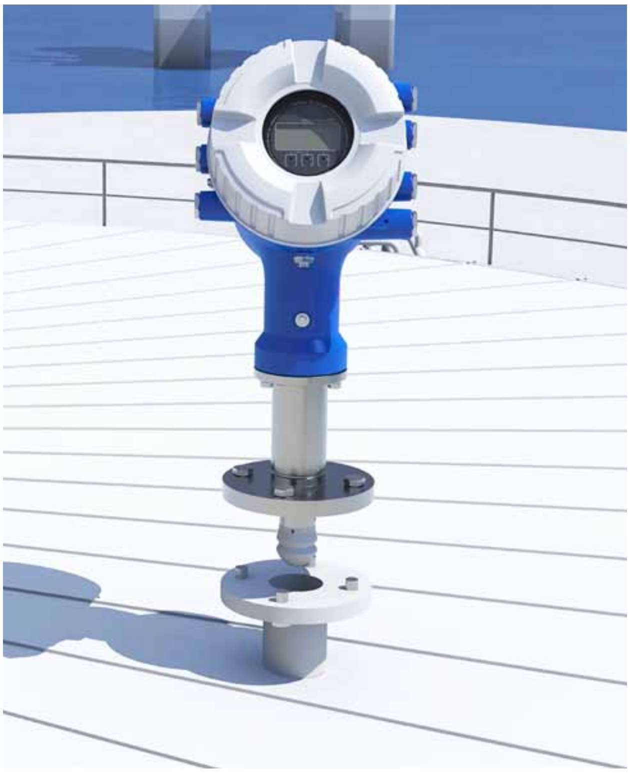

Figure 5: A radar level gauge.

Vibrating fork level switches

For safety overfill detection, the recommended level-switching instrument is a vibrating fork instrument. Such instruments consist of a fork with tines that are vibrated by a piezoelectric crystal oscillator at a resonant frequency of about 1 kHz in air. When immersed in a liquid, the vibration rate will slow down by about 20%.

The advantage of vibrating fork level switches is that they are maintenance-free and highly reliable — essential qualities for a safety application. They are not affected by material build-up on the tines, nor by turbulence, bubbles or other liquid phenomena.

Figure 6: A vibrating fork instrument for level detection.

In addition, there is now an industry trend towards favouring continuous radar, since it allows ramp alerts prior to an overfill 'panic'. This means the operator is given an early warning that if the tank continues filling at its current rate it will overfill in a predicted time.

Tank safety systems

To meet safety requirements and at the same time maximise tank capacity, it is essential to implement an independent Safety Instrumented System for this purpose.

Automated IEC 61511-certified systems are available that make the detection, indication and prevention of overfill simple to implement. Such systems offer complete functional safety loops covering safety integrity levels SIL2 and SIL3.

Such a system (Figure 7) takes its inputs from point level switches at the top of the tank and acts as a system independent of all other controls, automatically closing a safety shutdown valve if required to prevent overfill.

Networking

Implementing or extending a tank farm inventory monitoring system will, of course, require implementing an infrastructure to integrate the tank instruments into a control system, and many legacy tank farms have obsolete or non-existing signal wiring from the tank storage area. Traditional methods of running cables or optical fibre over large tank farms would normally form the largest part of the cost of deployment, and in many cases may be cost-prohibitive.

In recent years, industrial wireless technologies have all but eliminated the wiring cost, replacing cable runs with wireless instruments.

Overfill prevention system

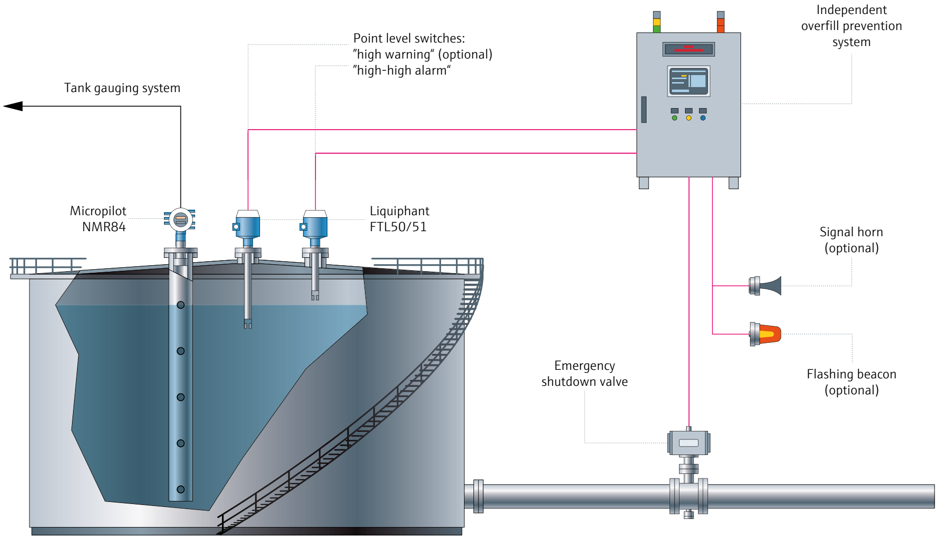

Figure 7: Automated overfill prevention system.

A secure, wireless infrastructure can halve the cost of deployment over a wired solution. Where existing instrumented tank monitoring exists, but improved connectivity is required, wireless adapters or gateways are an option. Wireless tank monitoring means that precise inventory data for tanks that was previously out of reach can be made available.

Automated inventory management

A precise calculation of net volumes is key for accurate business accounting purposes. A 5 mm level measurement error plus a temperature error of 0.6°C in a large fuel tank can cost tens of thousands of dollars per tank per annum. But accurate measurement is not the only thing to consider — it is also important to get best business value possible from the tank monitoring system.

By replacing a manual or ageing tank farm monitoring system with an up-to-date automated one that runs closer to constraints, an optimised system can generate higher returns. Closing the gap between planned and actual schedules is a key objective, since deviations between the availability of product and the product delivery schedules not only impact the tank farm process but can also have cost implications for downstream operations.

Automated processes are better able to monitor what's going on in the field to help improve the management stock and of all activities and workflows — making interoperability important. Fortunately, by networking the tank monitoring systems, data can be integrated with SCADA, DCS and ERP systems via commonly available technologies such as OPC.

Software for non-refinery storage terminals

Where a tank farm is used for only storage and terminal purposes, a separate inventory management system may be appropriate.

An inventory management platform can support users in collaborative demand planning, event-driven replenishment planning and scheduling as well as the reconciliation and consolidation of

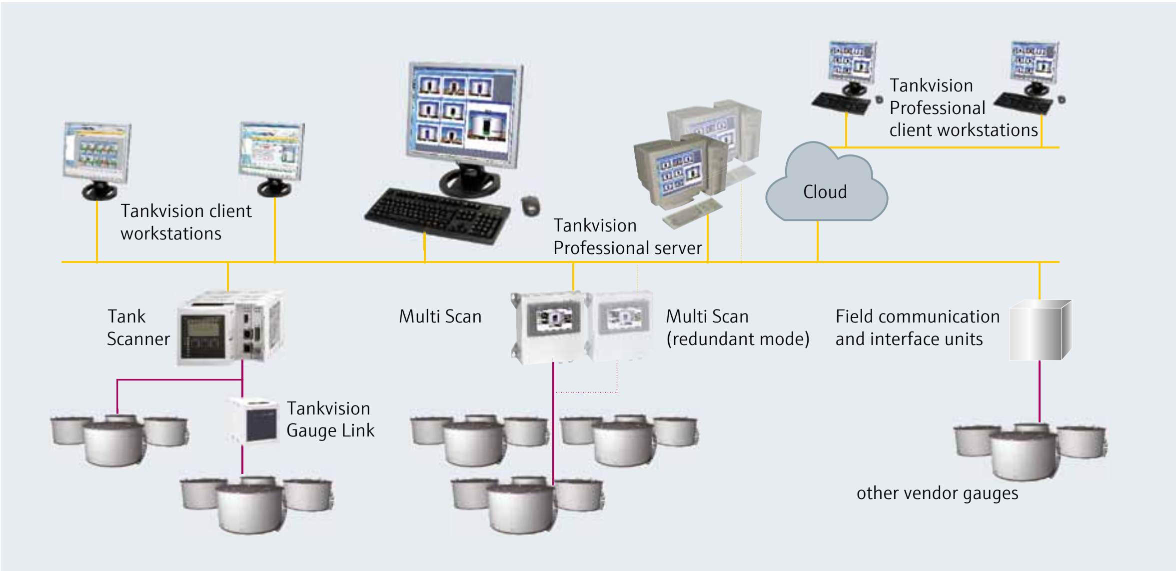

Figure 8: Implementing or extending a tank farm architecture.

Figure 9: A radar gauge fitted into an existing stilling well with a vibrating fork for overfill prevention.

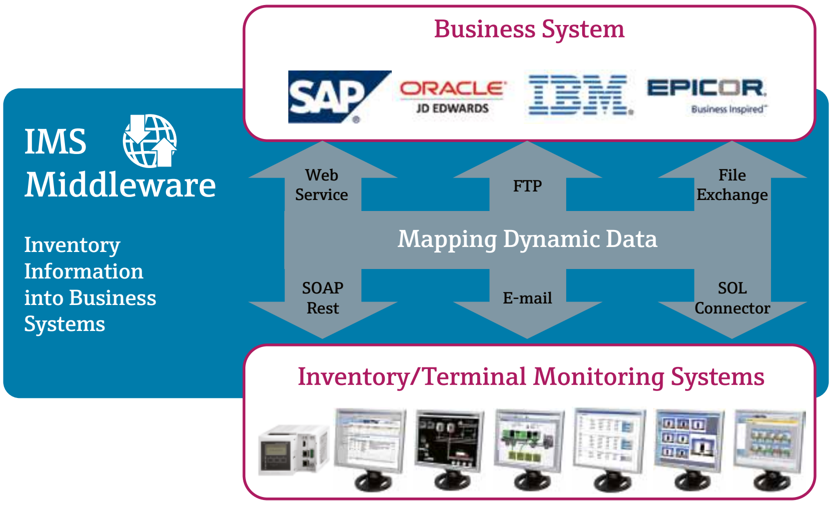

Figure 10: Integrating inventory information into business systems.

geographically distributed inventories. It is also possible to involve partner organisations for further improved supply chain operations.

Today, organisations can choose to implement an inventory system on their own computing infrastructure — suitable for larger operations — or to use cloud services (software-as-a-service) where the operation is smaller, further reducing business costs. Cloud services also make the management of multiple sites easier and more cost-effective.

System commissioning and integration

In a tank farm operation that was previously manually operated, the implementation and integration of the monitoring and safety systems may present challenges — all of which can be overcome with the assistance of an experienced vendor that can also provide engineering and integration services.

By involving a competent partner right from the start, fuel refinery, terminal and storage operators can be sure of smooth project handling and the seamless handover of a fully operational plant, with increased safety, reliability and availability.

A partner should be selected that has the expertise to ensure the overall performance of the tank monitoring network and integrate into any existing DCS, SCADA or ERP system, as well as provide all necessary training and ongoing support.

Figure 11: Inventory management for multiple sites.

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