In 2015, the oil and gas industry has faced many challenges. In response to adverse conditions in the industry, oil companies have had to make some tough choices to survive the decline, which appears will continue throughout the year. Making matters worse is the fact that the average age of US refineries is 40 years, and some are almost 90 years old. The oldest still in operation is the American Refining Group, Inc. Pennsylvania Refinery, built in 1881, making it a whopping 134 years old.

Only one new refinery has been built in this century in the US. Many are growing old and decrepit, and it takes serious maintenance and upgrades to keep them going safely. With the current decline in the industry, oil companies must re-evaluate their plans to replace ageing facilities.

Rather than build new refineries, many of the existing facilities will need to be kept operational a bit longer before being replaced. More retrofit projects, revamps and expansion projects will be needed for ageing facilities to continue production.

As-built data
Plants often need to be changed, restructured or expanded due to changing market requirements, unforeseen situations, new procurement sources, regulatory updates or technical innovations. It is important for companies to manage these changes effectively and efficiently to minimise shutdown time and associated costs. However, accurate, as-built information for existing oil and gas facilities is often difficult or impossible to obtain. This obstacle represents yet another challenge to the industry.

The collection of accurate, as-built data is important for an existing brownfield asset. This is normally a tedious manual process because an engineer would have to physically inspect the facility and collect such data. Process engineers may face this problem when they begin a major maintenance and/or refurbishment project.

To overcome these challenges, current laser scanning technology can be used in combination with point cloud conversion software to expedite the creation of accurate 3D as-built plant models.

Today’s laser scanning methodology demonstrates an advanced workflow that results in a cost-effective alternative to historic field measurement techniques. This provides the EPC firm and its subcontractors – as well as the owner operator – with a new level of 3D modelling capability while improving productivity.

3D laser scanning as-built conditions
There are many reasons for needing to capture the existing as-built condition of the plant environment. Often, it is because record drawings of the plant itself are either out of date and/or have been lost since original construction occurred. Over time, changes to an existing plant may not be documented. Some plants are ageing and simply need repair and/or replacement of existing components. Sometimes, process changes throughout the plant life cycle may require a revamp of the existing facility. And, plant expansion can dictate that existing systems are modified. A brownfield plant may need to be updated so that it can be productive once again.

Historically, the approach to capturing the existing condition in any facility, such as an oil refinery or a petrochemical plant, has involved on-site manual field measurement. This approach requires the erection of scaffolding and the usage of tape measures. It is disruptive to an existing facility and may require prolonged shutdown conditions, which can adversely affect plant operations.

Manual field measurement is labour intensive, expensive, inherently inaccurate and potentially dangerous. It often results in a huge amount of field data and hand-drawn sketches of existing piping systems, equipment and various structures that represent the installed condition. This information then needs to be replicated in a CAD software environment for it to gain any usefulness as shared digital data and graphical information. Needless to say, this approach is neither efficient nor cost-effective.

3D workflows
Current 3D modelling software is the ideal tool for new plant design. However, capturing the as-built condition of an existing plant with traditional field measurement techniques can prove to be a daunting challenge and does not complement a 3D approach to plant design. In fact, traditional field measurement methodology compromises the value of a 3D workflow.
This transformation of the CAD software tools that design firms used in project execution drove the need for more sophisticated solutions for 3D as-built development to follow. The alternatives to manual field measurement today involve current laser survey and laser scanning technology.

**Laser scanning capabilities**

Creating an accurate 3D model of the existing as-built plant condition starts with laser scanning technology. There are two types of laser scanners: total stations and high definition surveying.

**Total stations**

Total stations are used for survey purposes to measure individual points of information. A total station or total station theodolite (TST) is an electronic/optical instrument used in modern surveying and construction. The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read slope distances from the instrument to a particular point. Highly accurate, total stations can measure individual point locations to within 2-3 mm.

Robotic total stations enable the operator to control the instrument from a distance via remote control. This eliminates the need for an assisting staff member, because the operator holds the reflector and controls the total station from the observed point. Total station technology requires a line of sight to the object being measured and surveyed.

Total station laser scanners can be used in the plant environment for a variety of applications. They can be used to survey or measure strategic points within the plant site to establish a local coordinate system. Similarly, a total station can measure items such as structural steel locations to establish a local grid or key features of the plant to validate positional relationships of buildings, vessels, tanks, pumps, and so on. Total stations can measure and capture the as-built condition of individual pipes, valves, equipment, and structures on a selective basis. This also allows for rapid data capture when the scope of work is small in nature, such as adding a new pipe connection to an existing piping system. Another application could be an existing pipe that needs to be replaced due to ageing and corrosion. There are numerous instances where a total station is all that is necessary.

**High definition surveying**

High definition surveying (HDS) scanners can measure large amounts of point locations in a given area of the plant environment (see Figure 1). Depending on the scanner used, they can vary in both speed and capability. HDS scanners can capture up to 1 million points per second. HDS technology is accurate to within 4-6 mm. The data collected is used to develop what is referred to as a point cloud.

Point clouds are developed to capture individual areas or systems of a plant. Point cloud files can also be registered together to provide a complete representation of an entire plant. The collected data can then be used to construct digital 3D models. HDS scanners also take photographs as they scan, which means they can create a photorealistic representation of the as-built condition, making it useful for sharing project status updates to non-technical stakeholders.

Once captured as point cloud scans, the data can be used in a variety of ways. For example, they can be used in digital visualisation software such as Intergraph SmartPlant Review or Intergraph CADWorx Design Review. Similarly, plant assets seen in the point cloud, such as equipment, can be labelled (referred to as geotagging) with vital information for use by plant opera-
tions staff as a useful reference. The data can also be used by new staff in the format of training videos.

Survey methods for creating 3D models
As mentioned previously, one method of developing accurate 3D as-built plant models is to utilise a total station for selective pipe survey needs. Using a total station with 3D software such as Intergraph CADWorx fieldPipe as an interface enables the technician to use the survey device to measure and locate pipes in the plant and create 3D piping systems in real time. By doing so, the field technician can leverage piping specifications in the software to generate piping components and pipe spools automatically from the survey activity.

While the technician surveys piping components in the field, CADWorx fieldPipe references the appropriate piping specifications. At the same time, the laser survey device measures (‘acquires’) the pipe position in the plant. CADWorx fieldPipe generates intelligent 3D piping models directly from a survey activity. The survey process can be repeated on as many pipelines as needed. This methodology supports a variety of needs and applications for as-built requirements in a myriad of industry scenarios.

Converting the point cloud into 3D models
When the scope of as-built information needed is more inclusive than just a few pipes, the post-processing of point cloud data from HDS scanners with conversion software is also possible. This methodology can produce specification based, intelligent 3D piping models on a much larger scale.

Using a HDS scanner, a field technician can quickly capture large amounts of as-built information in the field. Depending on the scope of as-built information needed, the technician can set up and scan as many times as required to capture any area of an existing plant. Once the scanning task has been completed, the point clouds can be registered together to complete the data capture activity. Upon completion of the scanning activity, the point cloud data can be post-processed off-site by a piping designer in an office. This minimises the exposure of the field technician in the plant environment.

The post-processing of point cloud data into an as-built 3D model involves using specialised software such as CADWorx fieldPipe. Together, they are a software toolset that enables a piping designer to expedite the creation of an intelligent piping model (see Figures 3 a-f).

EPCs and owner operators
Owner operators and EPCs have adopted laser scanning techniques to gain success in their own engineering workflows. Here are two examples.

Setch Design
Setch Design is an engineering design firm with a multidisciplinary team of experienced professionals providing mechanical engineering services for the refinery, mining, fabrication, manufacturing and power generation industries. Its reputation for excellence in design is renowned throughout Australia. Setch Design undertakes approximately 100 process plant and refinery projects of varying sizes each year.

The company specialises in surveying, laser scanning, as-built data capture, tie-in location and measurement, pipe replacement, and piping systems 3D modelling.

Using total stations and HDS scanners, Setch Design produces precise as-built point cloud records of an existing plant. The team has experienced many benefits of using as-built point cloud scan data to achieve accurate as-built results. These include:

- Target acquisition direct to 3D CAD space
- Limiting daisy-chain effects over long distances
- Accuracy with changes in elevation
- Speed of registration of scans
- The ability to tie scan data to plant site datum.

According to Setch, it is easy to select individual piping components for conversion into CADWorx piping equivalents or use the auto-routing utility to convert entire pipelines. This results in quality, as-built piping geometry that can be used in the subsequent design workflow. The company says that it can produce intelligent, specification based, 3D models for plant modifications, revamps and new construction requirements.

Setch Design’s clients see reduced costs in labour and equipment during installation, as well as reduced site work during shutdowns.

Williams Group
Williams is one of North America’s leading natural gas companies with gathering, processing and transmission in critical basins and markets across the US. Williams’s large-scale energy infrastructure spans from the deepwater Gulf of Mexico to the Canadian oil sands.

Today, more than 21 million barrels of storage for ethane, propane, butane, natural gasoline and naphtha can be found at Williams’s Conway, Kansas, facilities known as Mid-Continent Fractionation & Storage. Underground storage meets the needs of customers by providing rail, truck and high-volume product movements from three distinct facilities. Along with a 100 000-plus b/d fractionator, these caverns make Conway a hub for a major portion of the hydrocarbons moving through the US Midwest.

The Williams Process Safety Management (PSM) 360 effort is an initiative aimed at improving safety, reliability and operational discipline at non-PSM facilities. This initiative involves a walk down/as-built effort at approximately 20 sites per year.

It is a challenge to perform this work due to incomplete as-built documentation for the large area of piping, equipment and vessels at any given site.

When the PSM initiative was applied at the Conway facility, Williams recognised that it could address its challenges with
Intergraph software for the creation of intelligent P&ID records. This workflow involved the conversion of non-intelligent P&ID documents using CADWorx P&ID Professional software. Valve and instrument data were replaced with intelligent CADWorx P&ID symbology.

The as-built process involved both Leica Geosystems total stations and HDS scanners. All of the Conway fractionation site was scanned. PSV studies were performed with Leica TruView. HDS point cloud data conversion to AutoCAD based files is currently under way with the final goal of converting this data with CADWorx fieldPipe and CADWorx Plant Professional into 3D models on an as-needed basis for the accurate modelling of new and ongoing projects.

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