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Transforming refining best practices with 3D virtual models

The technology, from laser scanning to management of change, is mature, functional, cost-effective and proven

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For every type of business, there are certain techniques, methods, processes or activities that are more effective than others. They deliver optimal outcomes with fewer problems and a minimum of unforeseen complications. This is the concept of "best practices;" it is simple and powerful. Best practices are based on efficient and repeatable procedures that have proven themselves over time for large numbers of people.

Technologies that support these best practices have a history of steady evolution punctuated by discrete step changes. Computing technologies have resulted in a new level of efficiency and effectiveness within the refining and processing industries. For example, today we take e-mail and information sharing over networks for granted, however, imagine the regression in current work processes if we had to suddenly revert to voice messages and physical mail.

Such technological step changes or breakthroughs play a dual role in the progression of a company's best practices. Not only do they provide better ways to execute existing work practices, these breakthroughs are often significant and strong enough to loosen the natural tendency of established practices to persist unchallenged. This allows practices and methodologies to be re-examined, re-defined and improved. Therefore, it is doubly important that technological breakthroughs be embraced as soon as they are viable and cost-effective.

For plant operations and asset management, the "next big thing" in support of best practices may be a surprise, because much of the underlying technology has been in use in product design and entertainment arenas for years. This technology—involving 3D virtual models of production facilities and assets—is transforming the way we work, replacing 2D abstract representations such as isometric drawings that are more difficult to read and can diverge from reality.

In this article, we take a look at the role of 3D virtual models in best practices, where visualizations that precisely match a plant's actual facilities and assets are presented and navigated on computers in your offices, in the field or over the Internet. This article starts by describing some actual applications in refining and then discusses how 3D virtual models are constructed, maintained and applied in support of plant engineering, turnarounds, maintenance, inspection and operations.

3D virtual models in engineering. The process industries have completely adopted 3D technology in computer-aided design (CAD) systems for initial plant design and engineering. However, the models and documentation created in these processes do not serve operating and maintenance tasks over the productive life of the assets. This is because the "as-designed" CAD representations often deviate from "as built" or field conditions and, over time, become less representative of the actual plant and equipment. (The 3D virtual models typically are not updated as modifications are made to process equipment, nor is it cost-effective to maintain these CAD models.)

A refinery requiring a major upgrade of its blending and shipping facilities recently faced a similar situation. Documentation for the tank farm, marine terminal, product blending area and other facilities was out of date. To support the upgrade project, a high-fidelity, location-accurate 3D model of the facilities and equipment was created by onsite laser scanning and subsequent modeling that identified and labeled every object in accordance with the actual plant. This model served the project in many important ways:

- Engineers "walked" the scanned images of the as-built model and identified discrepancies in existing process and instrumentation diagrams (P&IDs). The P&IDs were then corrected and made suitable for engineering work at a fraction of the labor otherwise required for field inspection, redlining and updating. Reducing staff exposure to the operating plant was an additional important safety benefit.

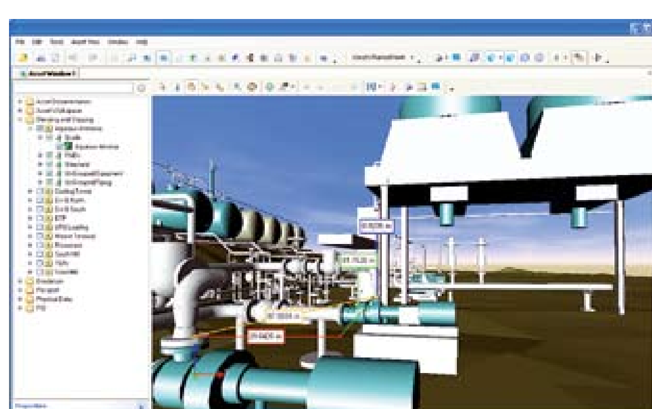

FIG. 1 Taking field measurements using a 3D virtual model.

• Documentation for the tank farm was also out of date. Using the 3D virtual model, engineers were able to identify and accurately number all piping and equipment for clearer communications in the upgrade process.

• The blending and shipping upgrade project required upgrading manual valves to motor-operated valves. This meant identifying and locating all the power lines, power poles and junction boxes that fed them. These were captured in the 3D model, enabling very efficient planning and design. The 3D virtual model was also used to achieve similar benefits of accuracy, reduced manhours and quicker completion for line-ups, crossovers and other required piping improvements.

• When it came time to configure the automation system, the virtual plant model was found to be of tremendous assistance in determining optimal lineups, sequencing of actions, back-flushing volumes, etc.

With accurate 3D virtual models, many engineering tasks were transformed from a field exercise with paper and pencil to an office task where field conditions can be explored, accurate measurements taken and general productivity dramatically improved. Fig. 1 depicts taking field measurements using the 3D virtual model.

Turnaround planning and execution. Plant turnarounds are distinct projects that often involve significant numbers of internal staff, contractors and suppliers. A typical turnaround consists of many work packages that have to be planned, coordinated and executed on a tight schedule.

Turnaround planners must take into account many considerations when developing work packages that provide clear documentation and instructions to each responsible team. The 3D virtual model of the affected facilities provided tremendous value by enhancing communications and ensuring team familiarity with tasks and their environment. Time-consuming walkthroughs were only taken as a final confirmation of the plans. This saved many hours in preparation while improving the quality of the plans and minimizing plant exposure.

Specific views to support and inform each individual work package can be easily isolated from the clutter of the real world and the full 3D virtual model. These are shared with the turnaround staff, supporting workers and contractors. We refer to these as "knowledge views" as they capture and share knowledge about the plant and planned work tasks. These views are used in combination for added perspective. For example, structural steel views were combined with piping views so that proper access and routing could be planned and communicated to turnaround staff. Figs. 2 and 3 are examples of documented work packages, keeping in mind that each of these views are not static but full 3D screens that can be panned, zoomed and navigated to gain a full perspective. When needed, scaffolding plans can be overlaid on the views to ensure suitability.

Plant maintenance. In one refinery project, the issue of temporary leak repairs was addressed. Specifically, the question was: "How to assure that the permanent leak repairs would be completed in the most efficient manner by taking full advantage of both planned and unplanned shutdowns?" Before having a virtual model, it was very challenging to identify all eligible leak repairs in every situation in a timely manner. With a virtual model that is dynamically connected to the temporary repair database, opportunities were immediately identified for permanent repair within the physical boundaries of any turnaround activity or work order involving a shutdown.

Applications of the 3D virtual model for plant maintenance are many and varied, and the impact on best practices is significant. Maintenance personnel are able to quickly locate lines, equipment and instrumentation, and familiarize themselves with the location before going to the field to perform their work. Work orders are precisely linked to the target equipment or system and, through that connection, to the most current asset data. The model is a natural tool for organizing and visualizing maintenance history, operational data, test results and analysis.

Work order planning is greatly facilitated by the 3D virtual model. Maintenance planners can develop libraries of work packages for routine maintenance tasks, supported by their respective knowledge views of the 3D virtual model. Physical conditions can be readily assessed and necessary support equipment scheduled for the task, such as a fork lift or scaffolding. Work crews can be assigned so that they do not interfere with each other. Even the seemingly simple

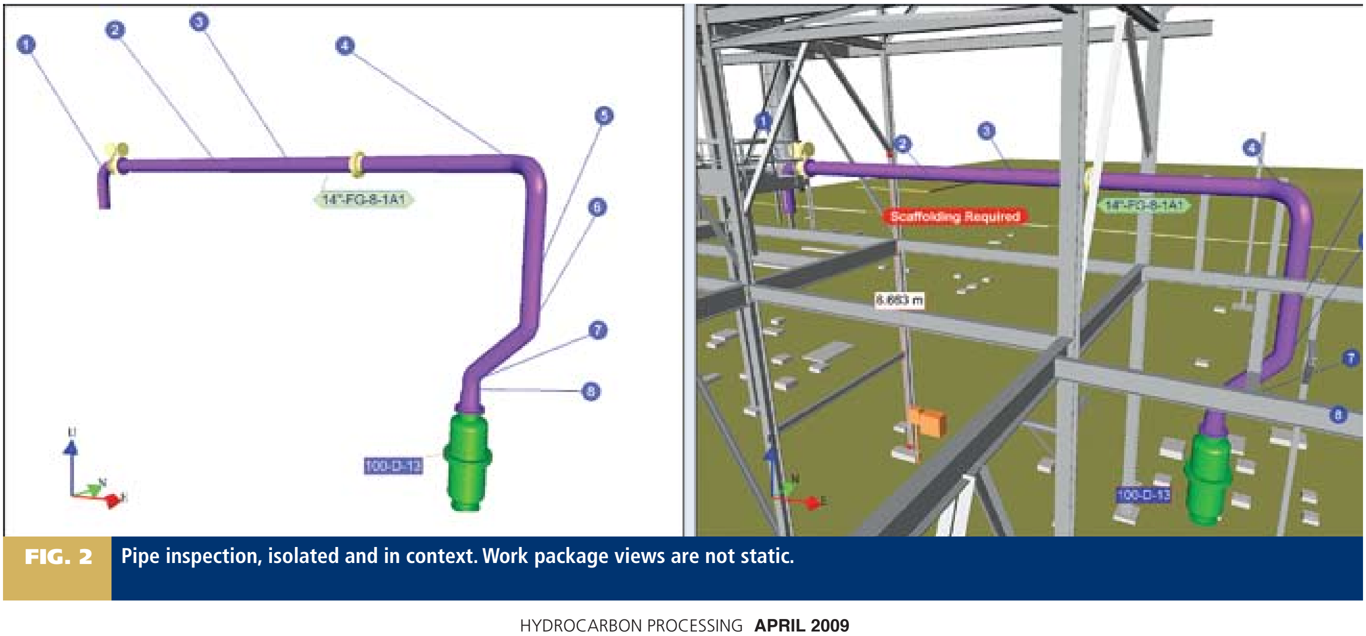

FIG. 2 Pipe inspection, isolated and in context. Work package views are not static.

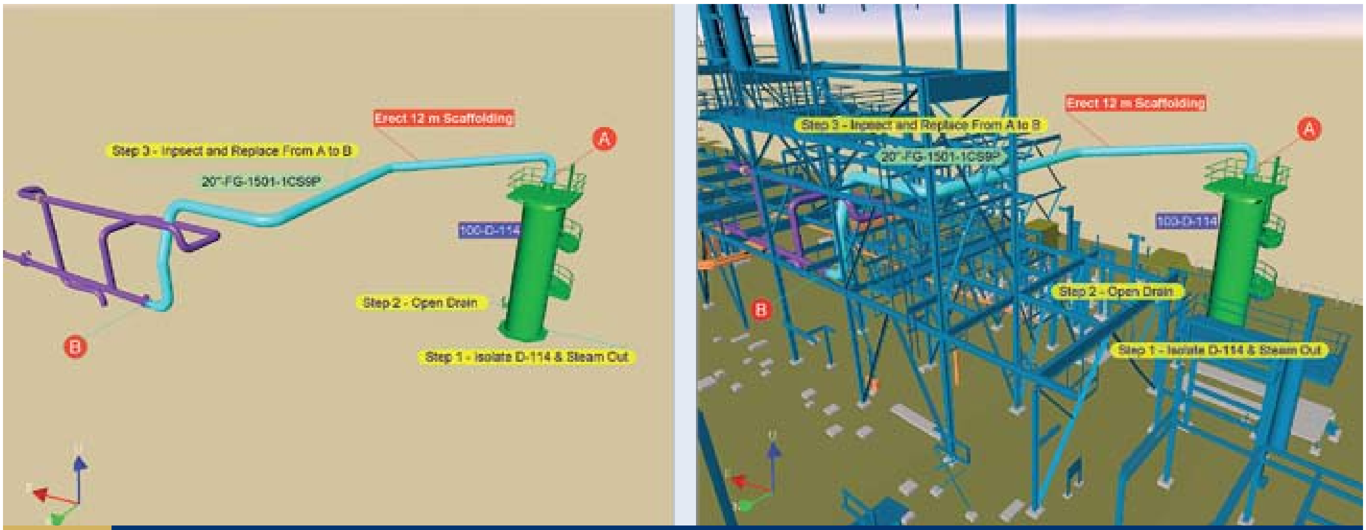

FIG. 3 Pipe replacement, isolated and in context. Views can be panned, zoomed and navigated.

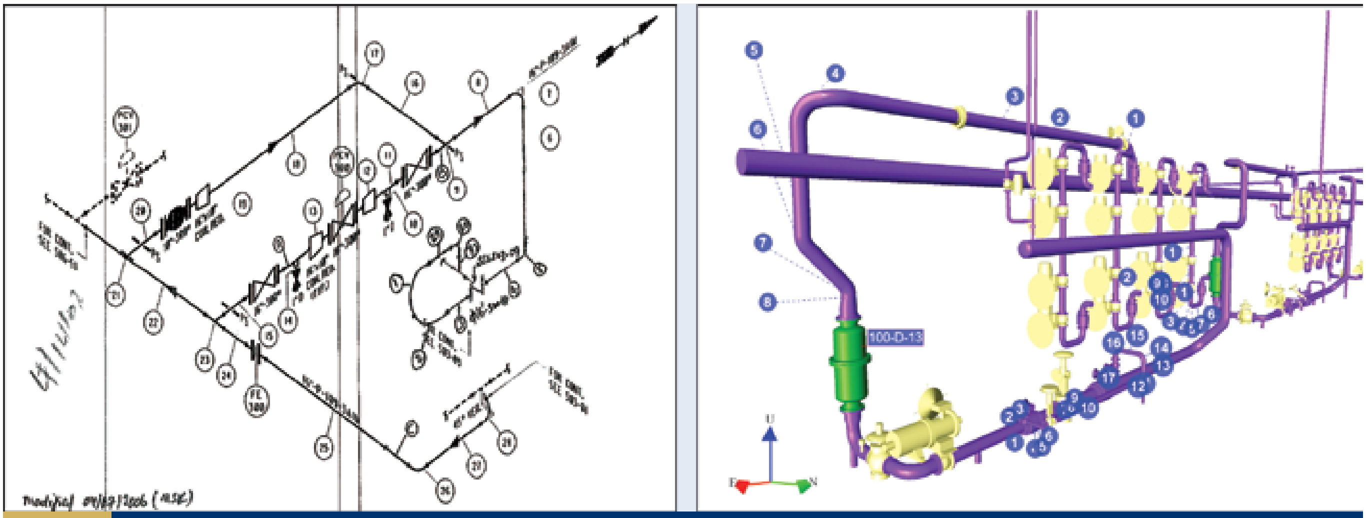

FIG. 4 Legacy 2D method contrasted with new 3D document of the inspection circuit.

task of locating the equipment becomes easier and unambiguous. The net result is greater productivity and quicker repairs, resulting in shorter downtimes and greater plant utilization.

Inspection and plant integrity. A common practice in refineries is to document inspection circuits using 2D isometric drawings with manual placement of the thickness monitoring locations (TMLs). In parallel, an "inspection" database is kept with corrosion rates, inspection dates, and other data for each circuit and TML. The challenges in coordinating and maintaining accuracy under this system should be obvious. In contrast, inspection circuits documented in a 3D virtual model can be subset into individual views with TMLs clearly called out in their exact geospatial location while linked dynamically to the source data.

With such "active isometrics," personnel can virtually walk the area before inspections, adding or subtracting detail to understand what they are dealing with. The model accuracy enables scaffolding design and other preliminary set-up work. And since the 3D virtual model always shows true placement and measurements, so do the isometric circuits. This avoids the possible and time-consuming inconvenience of inaccurate inspection circuit documentation. Fig. 4 shows the legacy 2D method contrasted with the new 3D document of the inspection circuit.

In a bitumen upgrading facility, the focus was on identifying and monitoring locations and conditions that could adversely affect plant integrity and reliability, especially vessels and pipes under pressure. The plant staff used the 3D virtual model to identify the physical boundaries and components for all corrosion inspection circuits. Seeing the "big picture" in 3D enabled them to select the best locations based on access and corrosion potential. The model became the organizing tool for all the TMLs and linked with the inspection software to display their baseline readings, test schedules and results.

The virtual model provides inspection planners with access to actual field conditions without actually having to go there. Inspectors can use the 3D virtual model to determine scaffolding needs, access limitations and safety requirements. Also, the model can be used to effectively communicate and coordinate with technicians and maintenance staff. Corrosion histories, kept in the inspection software, are accessed from the 3D virtual model for analysis, root cause determination and communication with subject-matter

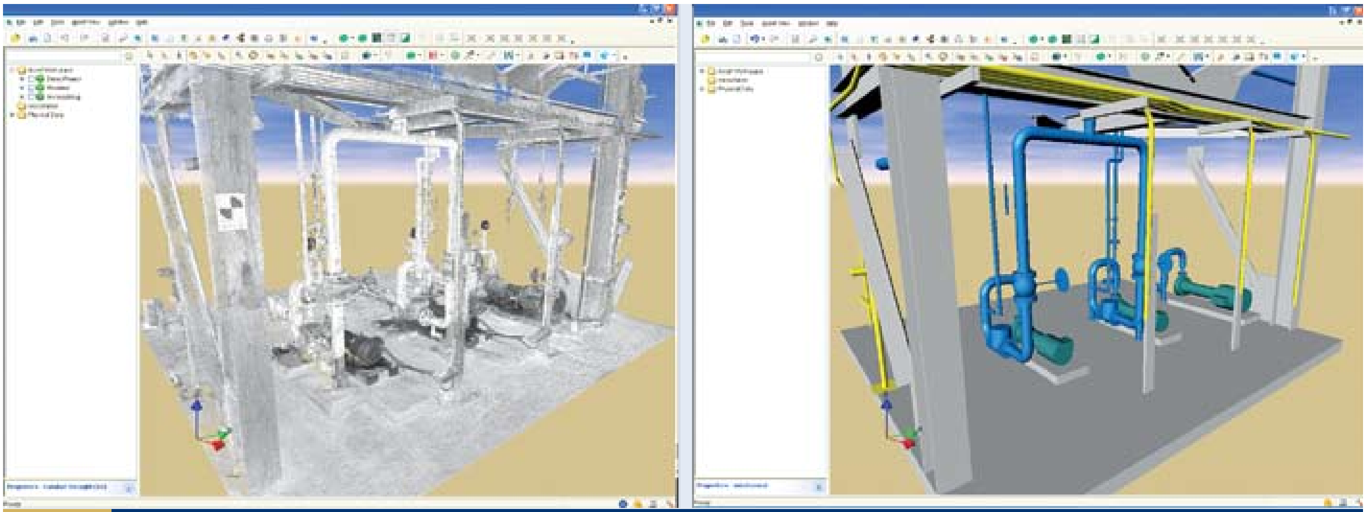

FIG. 5 Section of a process unit as captured by a laser scanner, and the same unit fully modeled as 3D objects.

experts. As one inspector put it, "One hour using the 3D virtual model saves me eight hours in the plant."

Plant operations. There are many opportunities to utilize the 3D virtual model in the operations department. For example, in the offsite area, determining the optimal routing for an ad hoc oil movement had relied on memory and potentially lengthy multiday site walks and investigation. With the 3D virtual model, routings are easily defined and, more importantly, the routings can often be optimally lined up and determined in just minutes.

Operating procedures can be more easily created and reviewed because the model provides a true "in plant" perspective at the user's desktop. Familiarizing personnel with facilities and procedures is greatly simplified. Procedures and training materials can be linked and accessed from within the 3D virtual model and an isolated view can be shown.

Safety procedures, including isolation device locations, can be documented in full 3D and full context. HAZOP analysis can be performed with greater clarity and with accurate asset documentation. Location of persistent alarms can be visualized in their physical context. Creating work orders is a much more precise activity because the virtual model provides an easy way to tie the work order to the equipment piece of interest instead of at the process unit level. The virtual model also provides a 3D common basis for communication between operations and maintenance.

How the model is created. The path to an "as-built" 3D virtual model of plant facilities and assets is surprisingly easy. If a 3D design model does not already exist, laser scanning technology is used. The scanning services are widely available. The process is similar to conventional surveying in that scans are taken from multiple perspectives, each from known coordinates.

Modeling software can combine the scans into a coherent "as-is" model or point cloud. Where CAD data exist for equipment and systems, it can be imported and integrated into the model. Otherwise, software is used to convert the point cloud data derived from laser scanning into 3D objects. The end result is a visual, navigable, multiperspective 3D virtual model that accurately and precisely reflects the actual facilities. Fig. 5 depicts a section of a process unit as captured by a laser scanner, and the same unit fully modeled as 3D objects.

The next step is to "intelligize" the model by adding identifying tags and other asset information. By tagging objects, components, structures, circuits and subsystems, the model shapes gain context and can be used for searching, sorting and linking to relevant data from all other plant information systems. The result is an asset management environment that we call "asset virtualization."

Management of change is a very important aspect of any 3D virtual model because much of the model's benefit results from model precision and it representing the actual production assets and facilities. Therefore, the 3D virtual model software must be capable of accepting updates at any time via new laser scans, altered CAD information and direct model changes to reflect field conditions. Furthermore, changes must be automatically propagated (or inherited) to views, documents and integrated systems to ensure that all asset information and the 3D virtual model accurately reflect the plant.

Features, functions to consider. Despite the seemingly complex services provided by such software, the users should find the application as intuitive and as easy to use as a video game. Training for nonpower users should require only one or two hours, not days. It should run on standard office computing platforms. The software should understand roles and be able to assign and manage authorizations, permissions and security based on the organization structure, command and control levels, and plant security policies.

The model should represent the actual plant with detailed precision and dimensions. Equipment is not always perfectly vertical; piping is not always orthogonal; valves and other devices rarely end up precisely where they were designed. In the 3D virtual model, it is reasonable to expect and demand accuracy tolerances of all details to within 5 mm (3⁄16 in.).

The 3D virtual model should support the creation of any number of subviews that isolate and emphasize individual processes, equipment and work tasks. It should be possible to layer these views (show two or more together) for more precise planning, documentation and communication of work tasks in the appropriate detail and context. Also, look for the ability to incorporate 3D views of dynamic assets such as cranes and scaffolding that may be temporarily deployed in the plant.

In addition to providing true graphical representation of the plant on the desktop, the 3D virtual model must be easily integrated with the various systems of record for plant and asset data so that operations data, maintenance records, asset documentation, safety data, etc., can all be accessed quickly without awkward searches or time-consuming requests and responses. Information should not be replicated but instead directly accessed as needed from native sources and put into appropriate context for the user and task at hand. For example, it should support a query—pulling the required data from several databases—requesting to see all pipes containing sour gas, having a corrosion rate greater than 5 mils/yr, and an operating temperature greater than 260°C (500°F).

■ 3D virtual models introduce a fundamental and significant change—a breakthrough—in the way people perform work.

Also very useful would be simulation and playback functions that create movie-like depictions of scenarios and events. These would help support training, learning and reviews of upsets and recovery processes. The model also should allow user annotations that persist in context for developing procedures and advancing best practices.

3D virtual models are a perfect foundation for collaboration, coordination and collective knowledge capture that extends across plant disciplines and to the plant's network of service and product suppliers. In the future, look for exciting developments that meld these 3D virtual models with Web-accessible virtual meeting rooms, forums, subject-matter wikis and other emerging Web/Enterprise 2.0 and 3.0 concepts.

Value proposition. There is no shortage of software products that propose to save time and money, reduce downtime and increase plant utilization. The 3D virtual models, however, do this by introducing a fundamental and significant change (a breakthrough) in the way people perform work.

Because the industry workforce is aging, the capture, documentation and transfer of their know-how using asset virtualization is essential. Future plant workers will greatly benefit from this knowledge and thrive in a more modern 3D virtual model environment.

Plant owners and operators also must consider that environmental issues and corporate responsibility are in the governmental spotlight. Sarbanes-Oxley requires internal awareness and proper controls over information and processes that relate to the business's financial health, including asset documentation. The 2007 investigative report commonly referred to as the "Baker Report" draws attention to leadership's role in making safety in industrial processes and equipment "a core value" of any company. OSHA 1910 calls on companies to meet standards of safety for workers and the local environment. 3D virtual models facilitate these efforts in important arenas while delivering the operational excellence that distinguishes world-class companies. **HP**

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