New technologies can save time and money and change the way we perform tasks. But some challenges demand ingenuity. Such is the case when a simple pump replacement project is impeded by an underground obstruction. For these types of projects, adaptable pipe support layouts are a money-saving, low-tech alternative.
When purchasing an oil and gas terminal, a new owner rarely receives complete records of all construction activity performed at the site over its history. Because these facilities can often change hands, documentation often goes missing between acquisitions. Even if a site plan is available, it is likely to be incomplete. Some underground obstructions may be missing from drawings or located in places other than where documents indicate. This becomes a problem anytime a new owner wants to install underground pipes, replace a pump or perform other small construction projects at a terminal. The discovery of an unexpected obstruction mid-project may require structural redesign and possibly the need for additional supports, which can lead to major delays and cost overruns.

Thanks to advances in technology, owners now have several ways to identify potential underground obstructions and mitigate these risks.

3D LASER SCANNING
Using a 3D laser scanner, it is possible to create an above-ground model of an oil and gas terminal. The scanner collects data on all the structures at a site, and can be used to construct a digital three-dimensional model (Figure 1). While offering great value on large projects, laser scans can have a relatively large impact on schedule and budget for smaller projects. Because the resulting model only indicates where piping enters the ground, it also offers less value on smaller repair and replacement projects. A surface laser scan cannot be depended upon for underground locations since piping does not always run in a straight line and there may be other obstructions unrelated to piping.

GROUND PENETRATING RADAR (GPR)
GPR uses radar pulses to image the subsurface and identify underground obstructions. This nondestructive method can be used in combination with 3D laser scanning to create a more complete above- and below-ground model of an oil and gas terminal.
HYDRO EXCAVATION
Another nondestructive alternative, hydro excavation, uses pressurized water to excavate soil in the area where the construction is to be completed. It can be performed either on an exploratory basis early in the design phase or later, during construction, to ensure existing underground obstructions are not impacted.

THE ENGINEERING ALTERNATIVE: ADAPTABLE PIPE SUPPORT LAYOUTS
Because technology-based solutions can add significantly to a project’s budget and schedule, it can be more economical, in some circumstances, to use engineering — rather than technology — to address underground obstructions. Specifically, on smaller projects that require few pipe supports, it often makes better economic sense to design structures and foundations that address the possibility that obstructions may exist than to use GPR or hydro excavation to locate them with certainty.

Consider how foundations and pipe supports are typically designed: In most cases, designers specify the precise locations where supports should be installed. Should construction crews encounter an unexpected obstruction in the field, they must return to project engineers for direction on how to proceed. That may involve redesign and other budget- and schedule-busting alterations.

With an adaptable pipe support layout approach, structures and foundations are sized to accommodate a range of scenarios. Engineers then use advanced piping design and analysis software to calculate a range of locations on a pipe where supports might be placed. This provides field personnel the flexibility to relocate a support if an obstruction is encountered — without needing additional engineering approval.

While this approach requires more upfront engineering, it typically saves significant time and money compared to other alternatives, especially on smaller projects or in cases where the owner prefers not to invest in surveys or scans.

EVALUATING DESIGN CONSIDERATIONS
For these projects, structures or foundations are conservatively designed to meet the requirements for the maximum allowable span. Under certain circumstances, however, the maximum span alone will not necessarily yield the most conservative solution. Consider a pipe that can span 20 feet between supports. When designing its support system, engineers should not only consider the span length, but also the pipe’s weight — both empty and when filled with product — as well as thermal expansion, wind load, seismic load, snow load, and ice load, and how each of these loads affect the system. A pipe system with many turns that undergoes thermal expansion, for example, acts differently than one with long, straight runs.

Some pipe sections also provide fewer alternatives for support placement than others. Precise dimensions, for example, are needed near pumps and at piping elbows, as well as where piping undergoes an elevation change or transitions below grade.

In cases where load tolerance is small, pipe supports must be placed at specific locations to meet the allowable nozzle loads. To allow more flexibility around equipment, an entire pump assembly — including the supports adjacent to the pump — can sometimes be relocated.

To reduce pipe deflection and stress at piping elbows on smaller piping, it is standard practice to place supports at a maximum specified distance, as well as within a specific distance from every elbow. This rule of thumb for adaptable pipe supports may need to be adjusted, depending on project requirements and piping size.

Designers can alert field personnel to their pipe support placement options by including a note on the drawing to indicate the maximum adaptability allowed in the field without engineering involvement. This span and location criteria, of course, should be modified to address the individual requirements of each project, as well as to provide specific guidance on the supports adjacent to the specified equipment.

WORKAROUNDS WHEN NO SURVEY EXISTS
A survey can significantly increase the design duration of a small project. The engineering team’s ability to move the design forward is limited as it awaits survey results. Without a survey, however, engineers must find other
ways to complete necessary measurements or assess elevations, especially when the site has few existing landmarks to use as benchmarks.

**ARC VERSUS LINEAR DIMENSIONS**

One strategy is to use arc dimensions instead of linear dimensions to locate a foundation. With this approach, an engineer simply specifies an arc dimension to the corner of a foundation or center of a pier that will be measured from two existing site landmarks. The new foundation is located by the intersection of the two arcs (Figure 2).

This measurement can be accomplished in the field by connecting a string to an existing landmark, such as a bollard, and marking the ground at the lengths specified on the drawings. The arc approach can speed work in the field and eliminate skew errors that may occur with linear dimensions.

**BENCHMARK ELEVATIONS**

Without a survey, accurate elevations can also be difficult to attain. To reduce costs, arbitrary benchmark elevations may be used instead.

If a new project ties into existing piping, for example, a good benchmark elevation can be achieved by setting the centerline of the tie-in piping to an arbitrary 100 feet and base all other elevations relative to that elevation.

If a new project is isolated from existing site features, the top of concrete for a new foundation can be set at 6 inches above grade, for example, and designated at an arbitrary elevation of 100 feet. All other elevations can then be based relative to that elevation.

**SUMMARY**

Technology has transformed many of the activities involved in design and construction. But technology is not the best answer to every design challenge. It is important to understand all the options available to execute the design, and to discuss them with the owner while scoping or kicking off the project. Smaller oil and gas terminal projects are excellent candidates for flexible engineering approaches that greatly diminish or eliminate the need for time- and cost-consuming exploration of existing conditions.

**BIOGRAPHY**

**BLAKE SHADID, PE,** is a structural engineer for the Terminals & Pipelines Group at Burns & McDonnell. His responsibilities include the design of tank and equipment foundations, pipe racks, cable tray supports and electrical equipment racks. Since beginning his career at Burns & McDonnell, he has focused on the civil and structural design of electrical substations, and is currently specializing in liquid terminals and structural design.