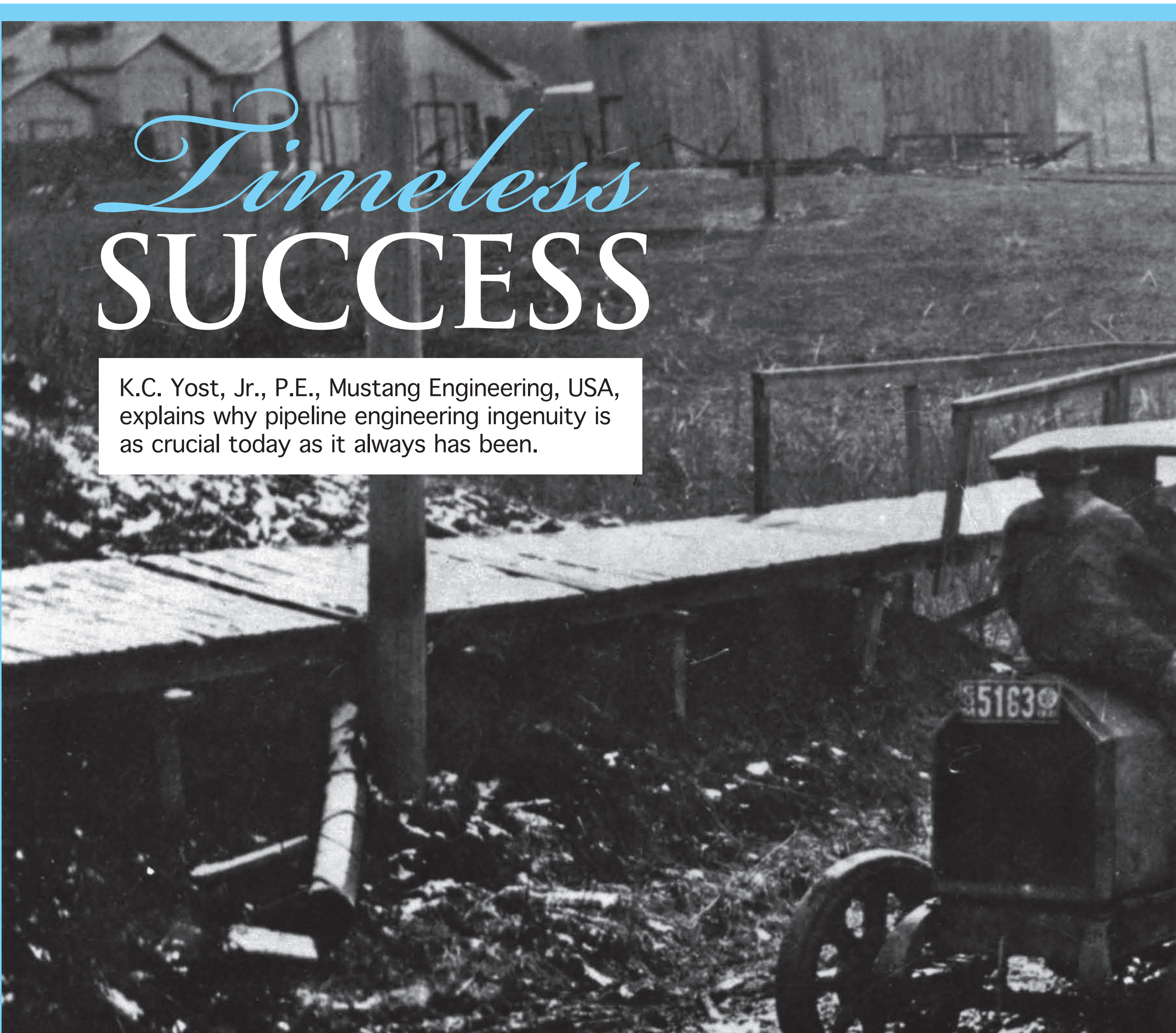
Timeless SUCCESS

K.C. Yost, Jr., P.E., Mustang Engineering, USA, explains why pipeline engineering ingenuity is as crucial today as it always has been.



The engineering and construction of crude oil pipelines has been successfully undertaken for more than a century, commencing when producers realised that there were more economical means to get the crude from the wellhead to the refinery or storage terminal other than by horse-drawn wagons. The earliest pipeline engineers had to address materials specifications of the pipe, geography of the route, logistics of equipment mobilisation and demobilisation, infrastructure development and understanding of line pressures. To some degree, engineers also had to consider relations with the communities along the route, co-operation with all project stakeholders, preservation of the environment, security of the equipment and personnel, and safety of the pipeliners.

The world has long been energy driven, relying on production from known sources of crude oil in areas that have been drilled extensively. Increasing global demand and a per barrel price of US$ 70 or above, however, have augmented the search for crude and increased the economic incentives to get it to markets. Developing nations are not only trying to increase their own production, but are becoming net exporters to other developing countries as well as the traditional global importers, including the United States. Easily accessible resources have already been exploited, often leaving newly discovered or identified, but previously not viable, reserves to be produced in remote regions with little or no infrastructure and few local technological resources. In today's world of pipelining, while the technologies, materials and expertise are far more sophisticated than they were in the early years, many of the same challenges remain and require at least the same level of ingenuity.

Figure 1. Condensate tank being moved (slowly) through Sistersville, West Virginia, circa. 1921. *Photo courtesy of Maurice Yost family archives.*

Understanding specifications and tolerances

In the US, crude oil pipeline specifications are enforced under regulation 49 CFR 195 by the Pipeline and Hazardous Materials Safety Administration (PHMSA), an agency of the Department of Transportation (DOT). The standard specifies the maximum allowable operating pressures (MAOP) of the pipeline based on its diameter, pipe wall thickness, and the strength of the steel. At one time, steel pipe mills produced a limited variety of standard pipeline wall thicknesses, such as 0.375 in. and 0.500 in., from which engineers would select based on the calculated pipe thickness and diameter, offering a sufficient safety factor, to accommodate hoop stress, the internal force on the pipe generated by the fluid and external loads placed on the pipeline.

Today, mills around the globe have the ability to customise the wall thickness to more closely align with the calculated hoop stress and operating pressures, including safety factors. Tailored thicknesses of 0.600 in. or 0.425 in., for example, are possible to manufacture within tolerances. Since pipe costs are a large economic consideration on any project, the possible wall thickness reduction of 0.100 in. on a 24 in., 200 mile pipeline can be a significant cost savings to the operating company. While safety standards are being met, the emphasis on pipe mill quality assurance and tolerance control in their production are paramount. It is often prudent that the engineering company or third-party specialists conduct mill inspections, including ladle samples to ascertain that the specified steel chemistry is correct for the project requirements.

Assessing constructability

Mustang personnel have engineered and managed pipeline and facilities projects in numerous remote regions of the world, from the frozen arctic to desert heat and seemingly impenetrable jungles. Understanding the existing infrastructure of the region is imperative even before front

Figure 2. Pipe specifications can be tailored to close tolerances that require an increased emphasis on quality assurance at the pipe mill.

Figure 3. Many oil-producing regions are remote, presenting infrastructure challenges for pipeline engineers.

Figure 4. Rights-of-way can be in congested regions, requiring ingenuity to create suitable work areas.

regions, across mountains and rugged terrain to coast ports. The oil-producing region is isolated with little existing infrastructure. While there are some roads and existing rights-of-way, engineers are challenged to determine how necessary equipment can be mobilised and transported to the work site to construct pipelines and facilities.

Decisions regarding access for pipe joints, steel plate, tanks, pumps and construction equipment delivery have to be considered. The extent of modularisation needed to construct remote pumping stations to boost output, and storage facilities to store crude in several locations throughout the country must also be taken into account. Much of the crude is considered highly viscous, requiring additional storage and capabilities for adding diluents. Tools such as geographic information systems (GIS) and global positioning systems (GPS) can be employed to assist in the fastest and best route determination. Logistics experts can assist engineers in this effort. Alternatives for demobilisation also need to be analysed, with cost estimates completed as thoroughly as possible during the detailed design phase. As in any remote region, personnel and facilities security are also necessities for engineers to factor into the design.

Sustaining the environment

Ingenuity is often required for engineering urban pipelines or those traversing environmentally sensitive terrain. Workpad constraints can limit the ability to maneouvre pipe and equipment, necessitating the creation of temporary work areas. During a Houston (Texas) ship channel deepening project, 96 existing pipelines had to either be removed or relocated. To relocate almost 60 lines under the one mile-wide channel, a suitable work area for the horizontal directional drilling (HDD) rig and support equipment was created by using spoil from the channel dredging and a 45 ft circumferential Geotube. The 10.5 acre artificial island protruded into the water adjacent to the dredged channel and was later converted to a wildlife habitat and bird sanctuary.

A northeastern US project required the construction of a raised wooden platform to accommodate an HDD rig needed to run a new natural gas pipeline under six rail lines. With operating space confined to a right-of-way less than 15 ft wide and with a major highway and airport on one side, engineers designed a platform to straddle a tidal ditch adjacent to a pristine wetland and migratory bird sanctuary. Engineers had to consider the location of the rig site as well as the containment of any drilling fluids used in the HDD procedure. The unique logistics required permits from six local, state and federal regulatory agencies.

Push ditches can be engineered to accommodate long pipe strings that have to traverse beneath sensitive wetlands or environmentally protected areas. The water-filled ditch or channel, adjacent to the HDD exit, can be used to float the pipe away from the HDD site after being welded and inspected. On a US Gulf Coast project, Mustang accommodated up to 5000 ft of pipe in a 'borrow ditch' converted from a canal near the HDD exit. The entire string could then be hydrostatically tested in place and pulled back through the HDD hole without the need for pipe rollers or a large work area. In certain instances, where environmental considerations are not foremost, the ditches themselves can readily be constructed as a less expensive alternative to HDD.

Figure 5. Stringing wagons haul pipe to the right-of-way, circa. 1900.
Photo *courtesy of East Ohio Gas Company.*

Figure 6. Stringing wagons have been replaced by trucks, but their purpose is the same, circa. 1924.
Photo courtesy of Maurice Yost family archives.

Advocating for the client

Understanding the client's requirements and translating them into cost savings is a prime function of an engineering firm. Planning early and thoroughly, presenting cost effective alternatives, and providing innovative solutions leads to project success. This success begins with good communications among all stakeholders and assuming the position of being good stewards of the client's resources. Maintaining good relations with landowners along the proposed route is another important facet of protecting the client's interests plus facilitating a successful project outcome. In most project decisions, there are tradeoffs between costs and timing. With the global demand and attractive market price for crude oil, it is important that decisions take into consideration the payback of on-time or early project completion. This might require considerations of alternatives during project execution that might add incremental project costs, but significant time savings and earlier payback.

Conclusion

The role of pipeline engineers continues to change with greater project complexity, higher pressures and increased flowrates. Despite the assistance from technological tools, support software and systems and dedicated specialists, engineers have to be adept at a broad range of skills- assessing materials, understanding specifications and pertinent regulations, facilitating logistics, resolving constructability issues, preserving the environment, and communicating with all project