Expanding Pipeline Repair/Replace Options

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Abstract

Developed countries face an aging pipeline infrastructure with an increasing need for more and more maintenance. At the same time, burgeoning development places limits on access and restricts working areas, making maintenance more difficult and expensive. The natural gas industry is no exception to the challenges of aging infrastructure and choking development. The natural gas industry faces an additional challenge—population sprawl that converts formerly rural areas to Class 2, 3, and even 4, reducing Office of Pipeline Safety (OPS) Maximum Allowed Operating Pressures (MAOP). All the while, increasing demands require more throughput and higher MAOPs to satisfy it. The industry is desperate to maintain the infrastructure at the very time open trenching to repair or replace pipe is becoming more difficult and expensive. While not a panacea, technology transfer has over the years given the industry valuable tools to improve safety, reliability, and efficiency. Advanced inspection devices and pipe-boring equipment are just two examples of improved tools, but more are needed to allow the natural gas industry to keep pace with demands.

Pipe expansion technology, in the guise of solid tubulars developed and actively used in the well drilling industry, is a likely candidate for transfer to the pipeline industry. Solid expandable tubular technology uses proven well drilling methods to insert a specially designed and manufactured steel pipe inside an existing pipe. The inserted pipe is then expanded to mate against the existing pipe. In the ultimate iteration, both the new and the old pipe are expanded until the final composite of old and new pipe has no loss of the original pipeline's inside diameter (ID). Initially, the refurbished pipe would use only the new wall thickness to calculate a new MAOP. Additional testing could result in using the combined wall thickness for pressure calculations.

While expansion practices and required metallurgies are well understood, several technical and economic hurdles must still be overcome. Some of the technical challenges include cathodic protection of the newly installed and expanded pipe, corrosion prevention of the annular space between the two pipes (if any), and how to install taps to the internal pipe. The primary economic issue is cost—can the technology be deployed in a cost-effective manner. As with past technology transfer, these issues must be overcome through multiple parties working collaboratively.

The Challenge

The U.S. gas industry operates approximately 290,000 miles of steel transmission main and 1,200,000 miles of distribution main. Over 99% of the transmission lines are coated and cathodically protected with approximately 210,000 miles 12-inch or larger in diameter, this is in comparison with distribution mains where less than half are steel. Of these steel mains, approximately 24,600 miles are 10-inch diameter or larger. Because of internal pressures, distribution mains are typically less cathodically protected and less stressed than the transmission mains.

Both transmission and distribution mains need to be monitored and sometimes refurbished due to corrosion or other damage. Figure 1 shows examples of mains that have failed and needed to be taken out of service for repair. The picture on the left shows previous mechanical damage to a main that later failed via a rupture at high pressure. The picture on the right shows a failure due to excessive corrosion.

Figure 1 – An aging infrastructure needs new technology for cost effective repair/replacement.

Repairing or replacing aging infrastructure becomes more complicated as obtaining permits for critical crossings (river and major road crossings) become more difficult. Population increases and the resulting development drive up the cost of open trenching and increase opposition due to environmental concerns, which occasionally make open trenching nearly impossible.

Adding to these challenges is the fact that the demand for natural gas is projected to increase 25% by the year 2020. This higher demand pushes operating pressures. One of the key factors fueling demand, population growth, means more development along right-of-ways that increases the likelihood of excavation damage. The increase in population also has an impact on the classification of gas pipelines. The OPS limits the allowable operating stress of pipelines based on the building density and population of the area near the pipeline. A Class 1 main, which would be in a low populated area, is allowed to operate at 72% of the pipe's specified minimum yield strength (SMYS). A Class 2 main, which would be in a more populated area, is allowed to operate at 60% of SMYS. Class 3 and 4 mains are allowed to operate at a SMYS of 50% and 40%, respectively. As the population increases along right-of-ways, pipelines are subject to more stringent operating restrictions, sometimes losing the ability to deliver full supplies to customers unless costly upgrades are performed.

In the last decade the OPS has instituted integrity management (IM) requirements for mains operating in high-consequence areas. IM requirements necessitate that operators inspect their mains for integrity and mitigate deficiencies found. These IM programs and the development of new technologies for IM, such as smarter pigs and assessment tools, have uncovered additional areas of pipeline concern that need remediation. Figure 2 shows a modern smart pig used for pipeline inspection.

Figure 2 – Smart pigs are typically used to inspect high pressure pipelines.

Current main replacement or repair technologies typically involve boring to install a new pipe, excavating an open trench to install a new pipe or repair device, or excavating to insert a flexible or plastic liner. The attendant improvement and cost reductions that come with more frequent use increase the technical and economical viability of these new tools. Figure 3 shows two of the present trenchless technologies.

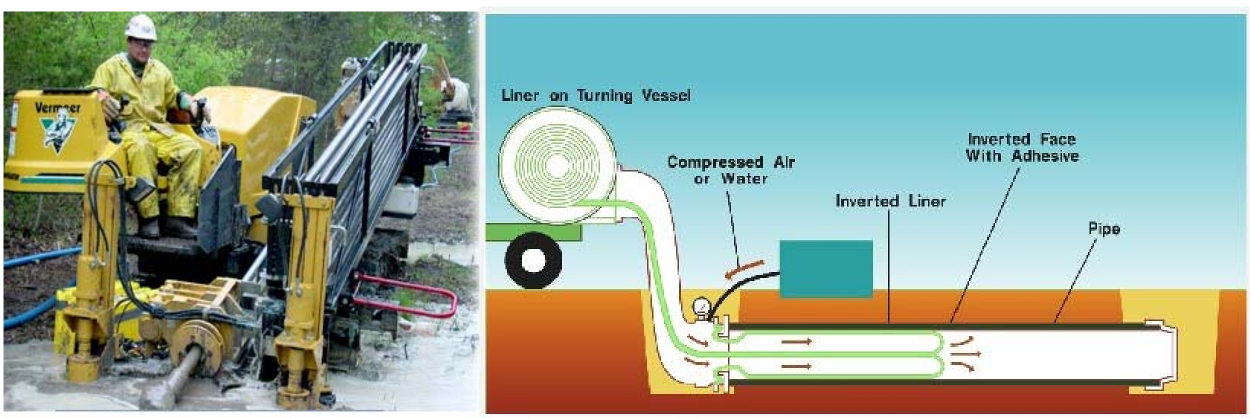

Figure 3 – Trenchless technologies, such as a boring machine (left) and a hose liner (right), are technically and economically viable for various applications.

Constant improvement and innovation are keys to remaining competitive in this energy-distribution industry, and continued research and development are keys to improvement and innovation. One of the most important components of new solutions is finding technologies that have already been developed by other industries then further developing the technology for transfer to new applications.

Technology Transfer

Note: This section of the paper is based on a report recently released by PRCI and others titled *The Role of Energy Pipelines and Pipeline Research in the U. S.,* by Cheryl Trench and Tom Miesner.

Technology transfer, broadly defined, involves taking what was not “invented here” and applying it to local needs. Much of what the pipeline industry uses today was developed in other industries and then modified (if needed) to fit pipeline applications. Plastics and plastic pipe, for example, existed well before its use in the pipeline industry. In the early 1970s the pipeline industry started a technology transfer program to discover how to use different types of plastics. Today, plastic pipe and many developed installation methods play an extremely important role in the distribution industry's new and renewal piping work. This technology transfer totally and positively changed the integrity and cost effectiveness of the entire industry.

Technology development involves effort and capital, and considers end user benefits and risk. Fledgling technologies typically involve high-risk research. These concepts need to be matured via knowledge building and small technical successes to prove them viable and relevant. After initial research funding many technologies are identified as unviable and do not survive past conceptualization. Technologies that survive the concept stage mature and begin to build a legacy of success as additional effort and capital are invested in them. Even so, technical and economic challenges usually still need to be overcome at this stage.

At this point the risk decreases and the potential for benefits from each dollar invested increases. If the technology is fully successful, a relatively small investment in the form of deployment is used to reap large benefits from the technology. Once the technology is fully deployed and the benefits are actualized, additional benefits (diminishing returns) may be achieved by the investment of additional funding and effort. This relationship between risk, effort (including capital investment), and benefits are illustrated in the improvement S-curve shown in Figure 4. As can be seen on the diagram, transferring a technology at a point near the end of the knowledge-building stage eliminates the need to do much of the basic research required to prove the concept as viable. Transferring the technology at this stage allows the new user to reap the greatest benefits with the least amount of effort.

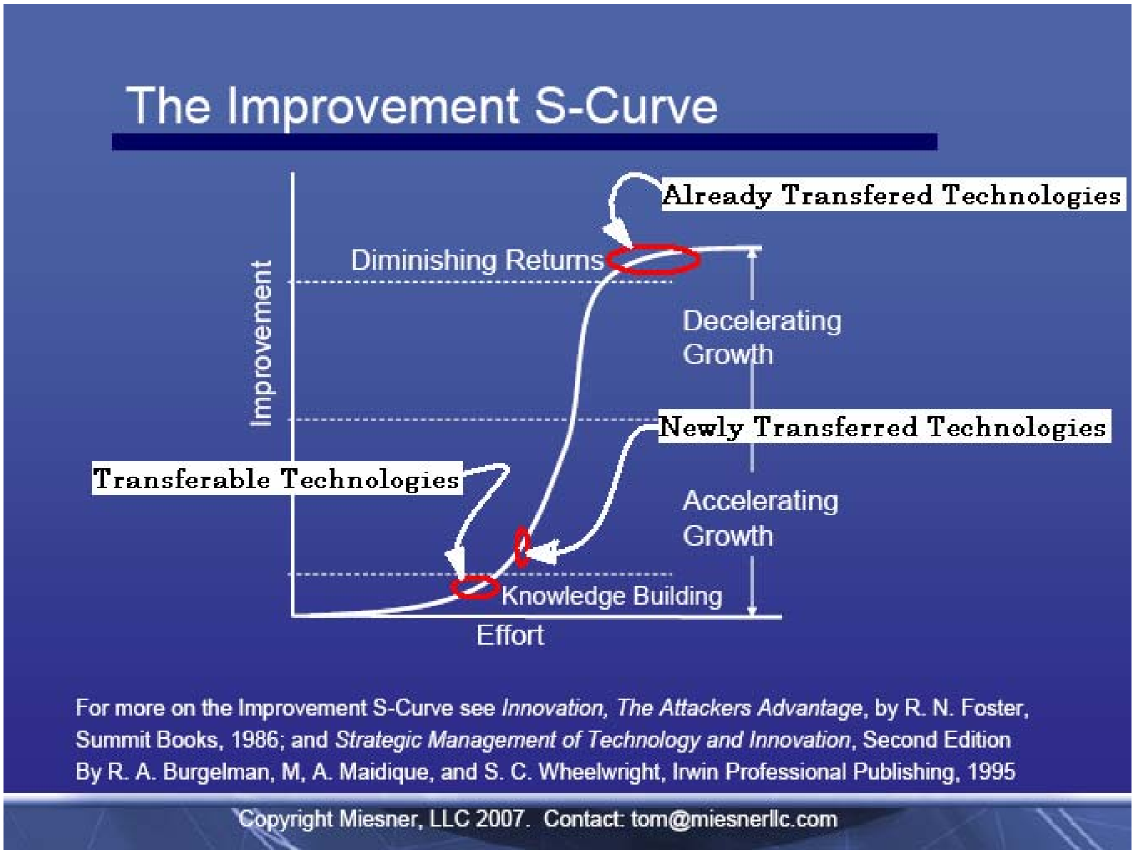

Figure 4 – Technology S-Curve. Transferring a technology from one industry to another after it has passed the knowledge-building stage allows the end user to realize the maximum benefit for the effort expended. (Courtesy Tom Miesner, Miesner, LLC)

The benefits of technology transfer are numerous. When one industry transfers a technology from another, they receive the benefits of the new technology without taking on the expenses for the basic research and development that were expended in initial development. This is not to say that the technology transfer will always succeed. Sometimes it is both a technical and economic success. Sometimes it is a technical success but cannot be economically deployed. A hypothetical example of a technology that might be a technical but not an economic success is expanding gold pipe inside corroded steel pipe. This approach could become a technical success as gold is malleable and won't corrode; however, it would not be cost effective.

Technology Transfer of Solid Expandable Tubulars

To meet the ever-increasing demand for hydrocarbons, the drilling industry had a need for deeper and longer wellbores for oil and gas production. Traditionally, the depth of a well was limited by the tapering effect—using smaller drillpipe further downhole because these pipes needed to pass through the previously set pipe, as shown on the left in Figure 5. To solve this problem, solid expandable tubular technology was developed to place a smaller pipe downhole and then expand it after it was in place as shown on the right in Figure 5. The end result is a deep well with minimal or no reduction of pipe diameter, depending on the expandable system used. This innovation resulted in lighter drillstrings and larger diameter holes, thereby saving cost and improving flow rates. This technology and adapted processes are what are being considered for transfer to the pipeline industry.

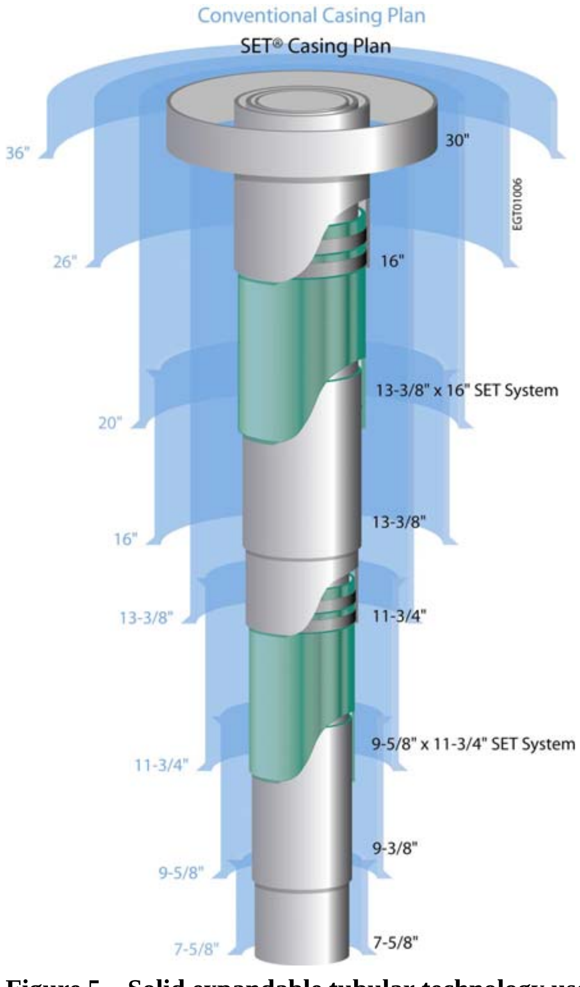

Figure 5 – Solid expandable tubular technology used in the well drilling industry. Expanding pipe sections at extended depths avoids loss of diameter as depth increases.

A technology transfer of solid expandable tubulars would create a system to insert a new pipe of carefully-controlled metallurgy into an existing pipe. The new pipe would either snug up against the existing pipe with limited loss of ID, or the expansion would expand both the new and old pipe so that no loss of ID would be realized. Initially, the refurbished pipe would use only the new wall thickness to calculate the new MAOP. Additional testing could result in using the combined wall thickness for pressure calculations. The expansion process would expand the new pipe and the old pipe with the interface between the pipes being a tight-press fit. The amount of expansion typically done with this technology can increase the pipe diameter by 30%, so it may be possible to even upsize the final ID of the line as compared to the original diameter.

The application of this technology to the pipeline industry for the renewal of pipelines is shown in concept in Figure 6.

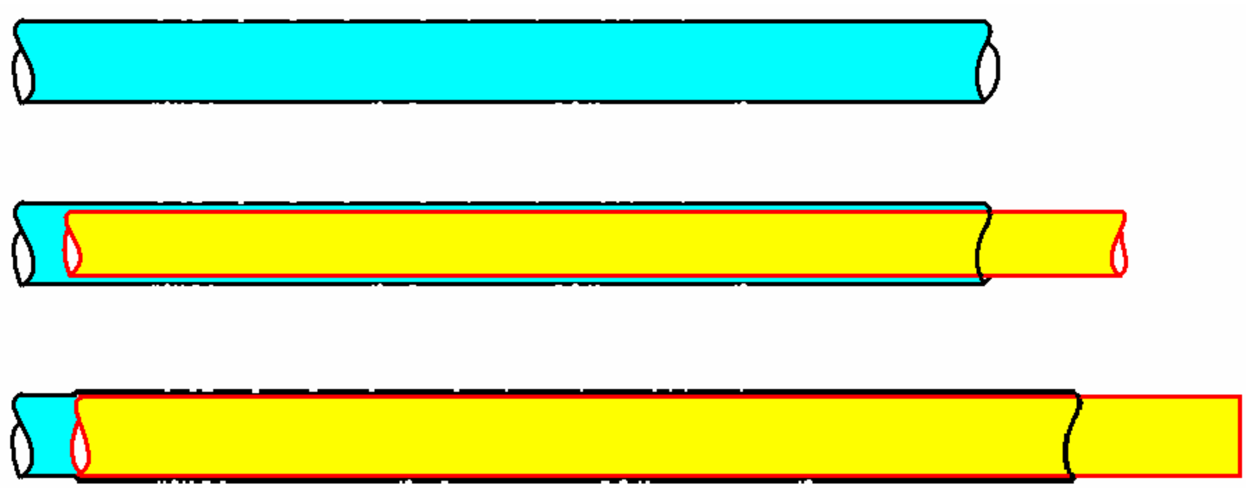

Figure 6 – Conceptual drawing of how solid expandable tubular technology would be applied to the pipeline industry. This figure illustrates the existing pipe (top), the new pipe inserted in the old pipe (middle), and the expanded new and old (bottom).

Additional Challenges in Pipeline Applications

The application of solid expandable tubulars in the well drilling industry is aided by a number of factors that do not exist in the pipeline industry.

Insertion Forces

In drilling applications, pipe travels downhole assisted by gravity. Doing the same installation in a horizontal application of pipe that may have bends and miters becomes more challenging. A mile of 12-inch schedule 40 pipe weighs about 148 tons. That weight is a great help in pulling pipe downhole. The same weight in a horizontal application creates a large friction drag between the inner pipe and the outer pipe. Extensive work has already been performed to model insertion forces, test various insertion techniques, and develop environmentally friendly lubricants that significantly reduce insertion forces. Insertions up to one mile at a time in pipelines with up to 20 D bends and limited internal obstructions should not be problematic, but procedures must be developed to understand the geometry of the original pipe prior to insertion to avoid any surprises.

Expansion Impacts

Expansion procedures have been developed and proven, but some work remains to fully understand whether the liner pipe expansion should be controlled such that its OD post expansion is slightly under the ID of the existing pipe, or if a slight expansion of the existing pipe could be allowed. In the first-phase approach, if expansion is controlled such that no expansion of the existing pipe occurs, only the wall thickness of the liner pipe could be used for pressure calculations and the coating on the existing pipe would not be affected. If a slight expansion of the existing pipe can be tolerated, the full wall thickness of both pipes could be used. Preliminary studies indicate that most pipelines coated with fusion-bonded epoxy could be expanded slightly with no impact to coating. Those protected with coal tar or other certain coatings are most likely not prime candidates for expansion.

Corrosion and Cathodic Protection

Corrosion control in the pipeline industry is not only critical but is mandated by law. The research and development needed to successfully transfer solid expandable tubular technology from the well drilling industry to the pipeline industry must consider how to assure protection from corrosion and how regulators would accept that assurance. Furthermore, the end-product would need to be delivered at a cost that provides enough incentive for the end users to apply this technology in lieu of tried and time-proven older technologies.

In the area of corrosion, several problems arise. Assuming the line would need to be coated, preventing damage to the coating during insertion is an issue. Assuming the 148 tons of weight previously mentioned, scraping the coating could result as the expandable pipe traverses the inside of the existing pipe. Weld beads protruding into the original pipe, miters, and other internal anomalies present opportunities to damage the coating. Assuring protection is doubly important as there is no ability to "jeep" the pipe after insertion. Protecting both the host pipe and the expandable pipe from corrosion is another issue. While it seems logical to assume current would flow between the new pipe and the existing pipe since they would be in close metallic contact, whether or not this current would cathodically protect both pipes or rather set up corrosion cells between the two pipes needs to be tested. Answers to these issues and others would need to be vetted with additional research.

Welding Processes

Welding processes to successfully join joints of liner pipe have been developed and proven to perform effectively through the expansion process. Post-expansion mechanical properties of the weld have been demonstrated to comply with existing welding specifications such as API 1104. The next step is to develop quality specifications and testing protocols beyond strength and ductility to include allowable defect sizing post-expansion and post-expansion testing requirements. These specifications and procedures are particularly important as the liner will be inside the existing pipe with limited ability to test following expansion.

In-Line Inspection

The ability to perform internal line inspections is a key tool in the integrity engineer's tool box. Any repair concept must be designed to allow continued internal inspection. Conversations with tool vendors indicate that as long as the presence of liners is known in advance and the liners are sufficiently robust to survive the tools passing through them physically, passing through the liner is not a problem with the ID changes needed to accommodate the liner. Still to be developed are the processes that enable effective anomaly detection when pipes are in close contact. Intuitive magnetic flux technologies should be effective as they measure total flux leakage. Again, as long as liner specifications are known, development of interpretation algorithms is possible. Ultrasonic may present more challenges. In either case, effective inspection processes must be developed.

Operational Process and Interfaces

The final step following the work previously defined is to develop processes, interfaces, and tools to provide a smoothly deployable integrity solution. For example, welding standards, expansion techniques, and quality control procedures must all harmonize and be supported with the effective tools to ensure safe, reliable, and efficient installation.

Economics

Initial indications reveal that considerable economics exist to deploy this technology in a number of areas. Potential applications include installation in congested areas where the cost of excavation is quite high and directional drilling is difficult due to geology constraints, as well as in areas where permitting difficulties or the concentration of other facilities limits the ability to drill. Another promising application is in an area where transmission lines would otherwise have to be de-rated due to population encroachment. But the technology needs to stand on its own merits based on what it delivers at what cost.

Previous experience indicates that expandable solutions would first be considered as a niche solution—such as in a scenario where no other solution would work and the reward of success would be high and the risk of failure would be low. Initially, costs could be significant, but as the number of projects per year increase, the unit cost of each system would quickly drop and level off. As efficiencies are discovered and developed, costs are amortized.

Transferring Solid Expandable Tubular Technology to the Pipeline Industry

The ability of solid expandable tubulars to provide a permanent, steel, pipe-in-pipe solution prompted interest from the pipeline industry as a method to improve structurally at-risk or de-rated pipelines with minimum loss of ID. Sufficient development has already been performed to identify, understand, and address issues such as the post-expansion metallurgy required to ensure the pipe continues to meet API 5L/X-grade specifications, how to control the expansion process to limit wall loss, and which coating can be expanded with no loss of coating properties. Using the trenchless process enables pipeline restoration with minimum disruptions due to repairs—a significant benefit in heavily congested areas and geologically sensitive environments. Research indicates that prime candidate applications of solid expandable technology exist in situations where traditional excavate-and-repair techniques are difficult to use, cost prohibitive, or would disrupt public movement.

Based on work done to date, solid expandable tubulars are a viable technology and can add significant value to the pipeline industry as an integrity tool. Various processes and procedures have already been developed, but funding is still needed to realize the full commercial potential of this robust technology. The challenge now consists of developing a cost-effective means to deploy this technology and convincing the pipeline industry that solid expandable tubulars are indeed a viable solution to address the challenges of an aging pipeline infrastructure.