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A COST SAVING CORE STRATEGY FOR RECONNECTING SERVICE LATERALS AFTER TRENCHLESS REHABILITATION

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ABSTRACT: Pavement restoration costs to water and other utilities that need to cut through pavement to reconnect service laterals to a main that has been newly installed, replaced or rehabilitated using some form of trenchless technology, can be significantly reduced by as much as 80% by the keyhole coring and reinstatement process. Developed in the natural gas distribution industry, this process was demonstrated to be applicable and cost-effective to the water industry by a 2007 study by the *AWWA Research Foundation*

Like microsurgery in the medical field, the field proven and environmentally friendly keyhole coring and reinstatement process is a minimally invasive excavation and restoration method that enables utilities and their contractors to cost-effectively locate underground infrastructure and perform repair or maintenance work on it from the road surface through 18 or 24-inch diameter 'keyholes' cored through the pavement, thus avoiding more costly, disruptive and inherently more dangerous excavation methods. After the underground work has been completed the cored section of pavement is bonded back into the road as a permanent, almost invisible, perfectly matching, waterproof pavement repair that can extend the performance life of asphalt and concrete pavements, significantly reduce traffic delays, minimize inconvenience to the public and save the utility more than $1000 in pavement restoration costs on each excavation.

This paper will discuss the application of this technology to the reconnection of water service laterals following trenchless rehabilitation which has been identified by the American Water Works Association as the most costly and time consuming element of the trenchless rehabilitation process.

1. INTRODUCTION

The title of this paper could easily have been *"Out of Site – Out of Mind"* as much of our one million miles of drinking water infrastructure that lies beneath our streets has been allowed to decay and is nearing the end of its useful life. Like many of the roads, bridges, and other public assets on which our country depends, most of the buried drinking water infrastructure was installed 50 or more years ago, and in some older urban areas, has been in the ground for a century or more. An effective replacement program over the next 25 years will cost at least $1 trillion (AWWA, 2011). Delay is not an option. Delay will either mean deteriorating water service marked by increasing rates of pipe breakage or a wasteful expenditure of funds to repair broken pipes that will easily exceed the long-term cost of replacing them.

Although there are some local and regional differences where the need to replace or rehabilitate failing water infrastructure affects some more than others – we are all affected. As can be seen from Figure 1, the national level of investment required to replace this aging infrastructure will double from about $14 billion a year in 2012 to almost $30 billion annually by the 2040s (AWWA, 2011).

Paying for all of this will be challenging for utilities, faced with the additional need to pay for new treatment plants required to meet new standards and other investments that have to be made to accommodate growth. This cost will ultimately be borne by consumers. And for most households, water bills will go up. But before water utilities ask consumers to invest more in the replacement of aging infrastructure they need to investigate and adopt better and more cost effective ways to minimize that burden that will ultimately fall upon their customers.

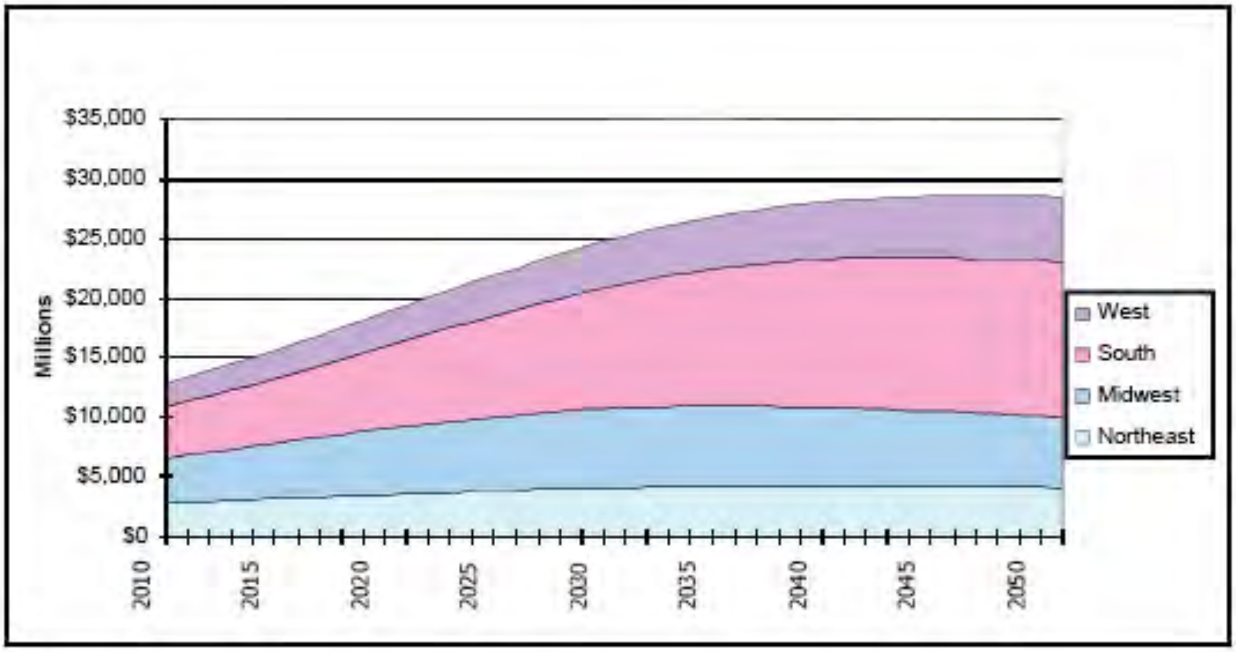

Figure 1: Water Main Replacement Costs Per Region. (AWWA, 2011)

2. LOW-DIG AND KEYHOLE TECHNOLOGY

As pointed out in the 2007 AWWA Research Foundation Study (AwwaRF, 2007) one of the ways to be more cost effective would be to use low-dig pipeline rehabilitation technologies such as slip lining, cured-in-place pipe, pipe bursting and horizontal directional drilling in combination with the cost-effective, and less intrusive, keyhole coring and reinstatement technology to reconnect service laterals.

While trenchless technology has flourished in recent times in the gas industry, cost continues to be the primary reason working against trenchless on the waterside. Bypass systems must be installed to supply customers throughout the construction period and holes generally must be excavated, often through pavement, at each service connection so the laterals can be reconnected:

> "The expense and disruptive nature of reconnecting lateral pipes has been a significant impediment to greater use of water main rehabilitation techniques. The emergence in recent decades of various pipeline rehabilitation and trenchless construction methods has raised the hope that more work could be accomplished with limited funds, but the cost of these methods when applied to water main construction has often disappointed. One of the reasons has been the added cost to reconnect service laterals. By the time that holes are excavated to tie each service lateral to a main installed or rehabilitated with trenchless technology, the project sometimes starts to resemble the open-trench projects that the water utility is trying to avoid — and so do the costs. Solving this problem is very important, as the funding for renewal has not kept pace with the growing need for infrastructure renewal." (AwwaRF*,* 2007)

But, as the study concludes, new and better methods of reconnecting services through small easily restored cored keyholes, may be the answer.

First developed in the gas industry to access and repair infrastructure buried under paved roads and sidewalks, keyhole coring and reinstatement technology emulates a procedure practiced by laparoscopic surgeons for years. By excavating a small, precisely controlled, hole 18 to 24-inches in diameter through the paved surface, gas utilities for the past 20 years have been able to access their buried infrastructure and repair it more safely, and cost-effectively, from the road surface using long-handled tools.

The major cost benefit of the process occurs at the end when the cored section of pavement, that was initially cut and extracted, is used to complete the pavement restoration process. After the underground work has been completed and the excavation backfilled to the base of the pavement, that same pavement core can be bonded back into the roadway with a special bonding agent (Utilibond) as a permanent restoration. No trenching or shoring is required, no workers are required to enter the trench and no excavation pavement spoils needs to be trucked away for disposal. No new paving materials are required to repair the road surface and the road can be safely reopened to traffic within 30 minutes of the repair, thus reducing traffic congestion and public inconvenience.

3. FIELD PROVEN AND FAILURE FREE

The coring and reinstatement process was developed and field proven by Enbridge Gas Distribution in the City of Toronto (Golder, 2003) where it was ultimately accepted and approved as a permanent pavement repair after monitoring the performance of thousands of reinstated cores in city streets from 1988 to 2003. To date, it is estimated by the Gas Technology Institute that more than 150,000 cores have been cut and reinstated using this process across North America, with no reported failures.

As part of the proof, Golder Associates, an internationally respected science and engineering firm, monitored the development of the process over ten years and tested more than 20 potential bonding products with emphasis on fast setting and rapid strength-gain to minimize traffic disruption and high bond-strength that exceeded AASHTO standards. A key factor was the ability to create a long-lasting, waterproof, mechanical joint with the remainder of the pavement that restored its pre-excavation ability to transfer traffic loading from one section to another.

In April 2003 Golder reported that:

> “The lab trials and previous demonstrations on the rotary cutting method have shown that the pavement coupon has been bonded into the slab in such a manner that the loads of traffic are effectively transmitted to the remaining intact slab. Based on trials carried out at our testing laboratory in Whitby and our in-field performance observations, we are satisfied that the equipment, procedures and materials [including Utilibond™] developed and used by Enbridge Gas Distribution over the last 10 years will ensure satisfactory long term performance of pavement reinstatement.” (Golder, 2003)

Subsequently, these impressive results were independently confirmed by the *Joint Utility Cut Study* led by the National Research Council of Canada (NRC) and the United States Army Corps of Engineers. A report of the results of a Field Investigation conducted in Toronto, Ontario, between October 2001 and April 2003, (NRC, 2004), that monitored and compared the performance of the excavation and restoration procedures involved in a conventional trench excavation and a cored and reinstated keyhole, found that the keyhole repair outperformed the conventional rectangular utility cut by a substantial margin.

Surface and subsurface data collected from sensors embedded in both excavations, and visual observations over the 18-month test period, revealed that the restored keyhole performed better and caused less damage to the road system than the conventional rectangular utility cut performed with a road saw and backhoe, and restored in a conventional manner with newly poured concrete and freshly laid asphalt.

Specifically, the study found that settlement and deflection had occurred along the wheel path in the conventional repair, and the material used to seal the joint had been lost through the action of traffic shortly after its application. These failures allowed the joint between the road and the repaired section to open and was considered to be the most likely cause of higher than normal levels of moisture at the bottom of the open cut compared with the keyhole cut.

By comparison, the keyhole repair showed no distress, remained level with the road profile, and performed well throughout the life of the experiment, with no signs of cracking or separation in the bonding compound surrounding the core. The smaller footprint of the keyhole was also credited with reducing the level of wheel load stress transmitted to the underlying sections of the roadway, compared with the standard cut, and its circular shape minimized the potential for the propagation of pressure or stress cracks in the corners of the repair.

Based on these findings, the Report on the Toronto Field Investigation concluded that the keyhole coring and reinstatement process was an effective excavation and pavement restoration technique that should be encouraged whenever feasible to minimize the need for opening large trenches in the future.

> "The keyhole cutting and restoration technique that was evaluated in the Toronto field experiment indicates that the process is practical and effective in reducing the potential for damaging the road. It is recommended that the keyhole application be encouraged whenever proven feasible." (NRC, 2004)

The fast strength-gain and overall bond-strength performance of the bonding compound was independently confirmed in 2003 by testing at the University of Illinois at Urbana Champaign (UIUC) (Lange, 2003). The comparative testing of three commercially available bonding materials concluded that:

> "The Utilibond material was the only bonding material that demonstrated satisfactory performance in the 30-minute tests [where it gained sufficient strength to support a single wheel load of more than 50,000 lb]. Since all three materials ultimately achieve high safety factors against core punch out, it is reasonable to emphasize attributes of performance such as rapid set time and workability. Rapid set time and workability [of Utilibond] are meaningful attributes in the field application, and effectively differentiate the performance of bonding materials for reinstatement of cores." (Lange, 2003).

In May 2009, the bond-strength of Utilibond underwent further testing by Construction Technology Laboratories (CTL), an AASHTO approved testing facility, which reported that the bond formed between the core and the original substrate was actually stronger than the pavement itself (CTL, 2009).

4. REDUCED CARBON FOOTPRINT

Not only can the road be reopened sooner after keyhole excavation and reinstatement (at least an hour sooner than with conventional restoration methods) but, because the initial keyhole repair is 'permanent', there is no need several months later, to again shut down traffic for two to three more hours to perform permanent pavement repairs. This can mean an average reduction in road closing duration from three to four hours which, if extended nationwide to each of the approximately 800,000 small hole utility cuts performed in our streets every year, could have a major impact on local traffic and the environment.

For example, if the coring and reinstatement process had been used in all 800,000 cases, where it was practical to do so, work-zone congestion could have been reduced nationwide by about two million hours of delay and would have saved more than 1.3 million gallons of otherwise wasted fuel (Schrank, D. and Lomax, T., 2009). Add to that the reduction in consumption and disposal of paving materials and reduced pollution levels associated with the evaporation of volatile organic compounds from new-laid pavement, and one has a prescription for both huge economic savings and significantly reduced environmental impact.

Keyhole coring and reinstatement technology significantly reduces the carbon footprint of utility cuts and pavement repair and minimizes the atmospheric emissions of greenhouse gases by simplifying and shortening the maintenance and repair process, and by reducing the consumption of millions of tons of asphalt paving materials and the disposal of millions of cubic feet of asphalt spoil every year in utility cut repairs.

This is because the use of several different types of construction equipment, including jackhammers, concrete saws, backhoes, dump trucks, vacuum excavators, asphalt and cement delivery vehicles and pavement compactors, during open-cut construction and repair invariably results in much higher greenhouse gas and other emissions into the atmosphere compared with keyhole methods, which have minimal on-site equipment requirements: a coring unit, a vacuum excavator and a hand-held pogo tamper compaction device.

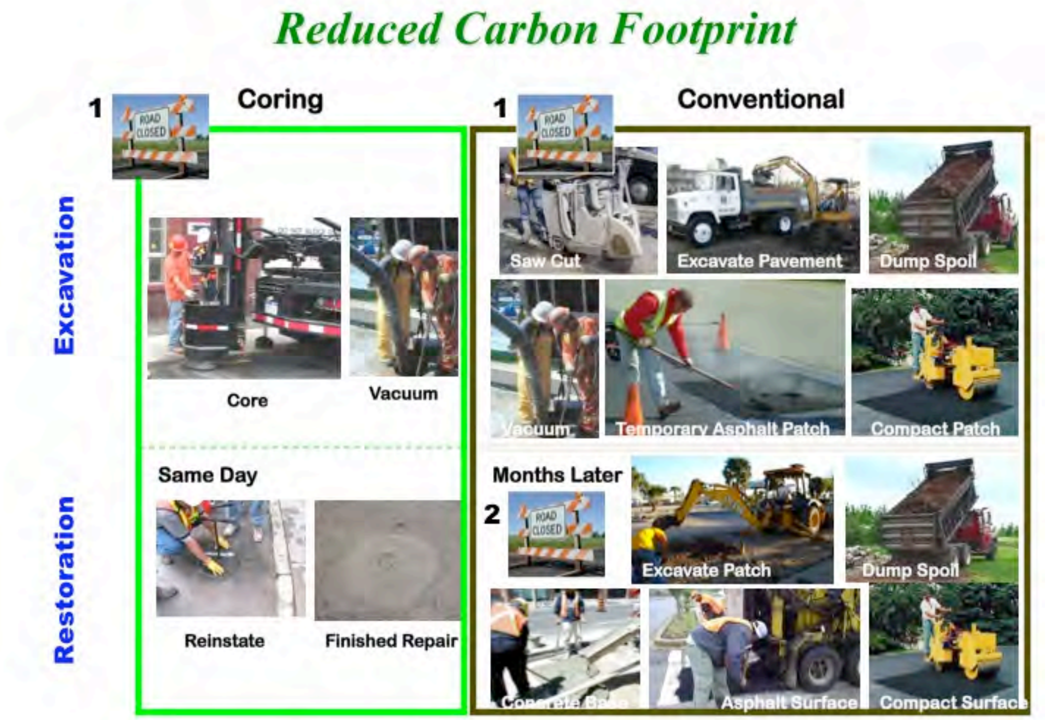

Figure 2: Comparison of equipment and timelines in coring and reinstatement and conventional excavation technology that affects the Carbon Footprint. Graphic courtesy of Utilicor Technologies Inc.

Not only does keyhole coring and reinstatement use fewer pieces of equipment but, because it reuses the same piece of pavement to permanently repair the roadway after the underground work has been completed, there is no spoil to be disposed of and no need for additional paving materials. The production of these paving materials — concrete and asphalt — is the second largest source of US carbon dioxide emissions, after fossil fuel consumption.

Moreover, because the keyhole core reinstatement is a permanent repair, there is no need to subsequently close the road again to remove and replace a temporary asphalt pavement patch with a permanent repair, thereby avoiding the emission into the atmosphere of additional volatile organic compounds from newly laid asphalt pavement.

Even if you don't count the substantial energy consumption and carbon emissions involved in the actual production, delivery and application of new asphalt concrete to conventional pavement repairs, employing the carbon footprint calculation formula developed by Ariaratnam and Savage (Ariaratnam et al, 2009) the carbon footprint from the coring and reinstatement option was found to be six times lower than that generated by conventional open cut procedures — 60 lb of CO_2 vs. 365 lb of CO_2.

5. LESS DAMAGE TO PAVEMENT

The coring and reinstatement process also results in a better pavement repair, less damage to the remaining roadway and a waterproof mechanical joint that restores the road to the load-transfer capability that existed prior to the excavation. It also minimizes the potential for groundwater penetration — the major cause of potholes.

Even the geometry of conventional repair procedures is suspect. The rectangular shape and square corners of the traditional utility cut repair causes stress to concentrate in the corners, which leads to cracks in the repaired section, permitting the infiltration of groundwater that, in freeze-thaw climates, ultimately results in potholes.

A circular keyhole has no straight edges or corners and, thus, no place for the stress cracks to form. The requirement of many municipalities that the lines of the repair be oriented in the direction of the traffic flow may help to make the repair 'look neat', but structurally can lead to differential pressures or wheel loads on either side of the cut which help to expel the sealant and open the cut. Thus, the preoccupation with rectilinear pavement restoration geometry, mandated in most jurisdictions, may be more of a problem than a solution.

Size also matters. The smaller and more precise excavation and permanent repair of a keyhole core requires no subsequent repaving or milling and overlay, performs better and is much more aesthetically pleasing than the larger rectangular road cuts that scar the landscape.

The coring and reinstatement process has been field proven and is currently employed in North America and the UK by more than 35 leading gas and other utilities and their contractors. It saves both time and money for everyone involved, and consumes far less energy and raw materials than conventional repair methods. It also reduces harmful emissions to the atmosphere, results in shorter and fewer road closings, is more convenient for the travelling public and the neighbors and causes less damage to the road system and the environment, than conventional excavation methods do.

Rather than jackhammers, pavement-breaking devices and backhoes, which disrupt or damage adjacent pavement structures, the keyhole excavation is accomplished with the surgical precision of a pavement-cutting saw. At the end of the day, the process uses the very same materials used to build the original roadway to permanently restore the utility cut in an environmentally friendly way. No pavement spoil is created, no additional paving material or resources are consumed, and no volatile organic compounds or other harmful emissions escape to the atmosphere.

Most important is the fact that this is a quick, cost-effective and easy permanent repair, which allows the road to be safely reopened to traffic again within just 30 minutes of the reinstatement of the pavement core and requires no subsequent road closing to carry out a permanent repair.

6. KEYHOLE TECHNOLOGY AND LOW-DIG WATER MAIN REHABILITATION PROJECTS

In 2007 the *Water Research Foundation*, formerly the American Water Works Association Research Foundation, (AwwaRF, 2007) undertook a comprehensive review of no-dig and low-dig pipeline replacement and rehabilitation technologies, to see if any of those techniques could be applied to water main construction.

The authors were of the view that one of the main reasons that the implementation of these less intrusive trenchless technologies lagged behind in the water industry was the added cost to reconnect service laterals (AwwaRF, 2007).

By the time that holes were excavated to tie service laterals on each side of a typical residential street to a main installed or rehabilitated with trenchless technology, both the project and the costs, began to resemble the open-trench project that the water utility was trying to avoid. It followed that if the lateral issue could be resolved, then these cost effective and low-dig technologies could take their place in the toolbox of the water industry.

> "Of these excavations, the reconnections of the service laterals are generally the most costly, simply because they are the most numerous. Consider a typical residential street, with 50-ft wide lots. If houses front both sides of the street, then service connections occur, on average every 25 feet. If the cost of re-establishing each connection averages $1000, then this adds $40 per foot to the overall cost of the rehabilitation project—a very substantial sum. This cost alone could increase the cost of the project by 50 percent." (AwwaRF, 2007)

But service lateral reconnection is not one problem to solve, but several, as the location and reconnection of the service lateral are dependent on the rehabilitation technique that is employed. And, as the study indicates, some are more difficult than others.

Drawing on more than 20 years of direct experience in the gas industry where it was first developed, and the huge pavement restoration cost savings to be derived from the coring and reinstatement process that is the centerpiece of keyhole work, this paper concentrates on the application of keyhole technology coupled with reconnecting service laterals to HDPE pipe that has been inserted with pipebursting methods. But, as the WRF study points out, similar keyhole procedures can be utilized when other low-dig or no-dig pipe insertion techniques such as horizontal directional drilling or other methods are employed to rehabilitate water mains.

7. KEYHOLE TECHNOLOGY FOLLOWING LO-DIG PIPEBURSTING INSERTION METHODS

Because it results in full structural renewal and answers both issues of utility corridor congestion (by utilizing the existing track of the original water main) and is less disruptive than conventional open trenching, pipebursting and the insertion of a high density polyethylene pipe could become the *preferred method* of replacing deteriorated water mains under pavement.

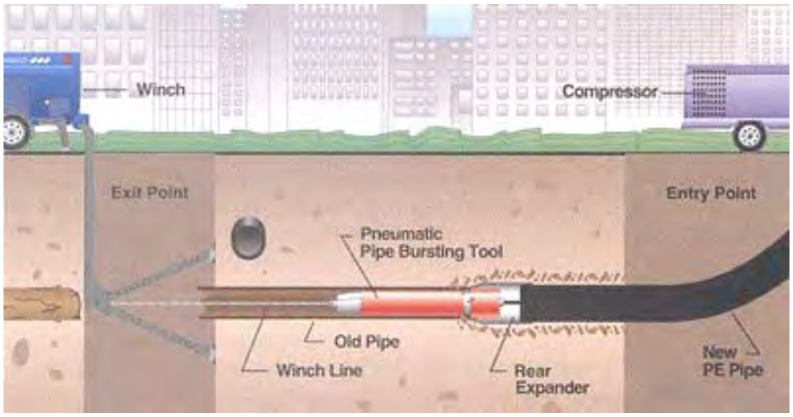

Figure 3: Pipebursting illustration. Courtesy of TT Technologies

As with the other trenchless water main rehabilitation methods, a bypass water system needs to be installed to continue service to the customer. Next, the service lines and mains need to be traced using pipe locating equipment, and the exact location of the main/lateral connections, as well as any other fittings that could impede the pipe splitting or bursting operation, marked on the pavement.

Field-testing of the keyholes concept conducted in the fall of 2003 at the Los Angeles Department of Water and Power, demonstrated that the concept can be applied by contractors and utility crews today, and is an effective way to reduce the amount of excavation required. This reduction in excavation volume should result is a cleaner project that is more quickly executed, with fewer inconveniences to the public (AwwaRF, 2007).

To commence the process, an 18-inch, circular pavement core (the "keyhole") is cut through the road or sidewalk at each of these locations using specially designed coring equipment and the core extracted and set aside.

Figure 4: Excavated keyhole showing lateral and original 6-inch cast iron main. AwwaRF 2007

Figure 5: 24-inch circular road plate for 18-inch cored hole. Courtesy Utilicor Technologies Inc

Vacuum excavation is then used to expose the lateral, corporation stop or other fittings that need to be removed.

Once those fittings (repair clamps, saddles, etc.) and the corporation stop have been removed and the service lateral disconnected from the existing pipe (See Figure 4), a small circular road plate (Figure 5) can be placed over the hole, as a safety measure and to allow traffic to resume, until such time as access to connect the lateral is required. A distinct advantage of using the keyhole method is the relative ease of placing and removing these relatively small road plates that weigh only 45-lbs. as compared with those that weigh half-a-ton or more on a conventional excavation site. Pipebursting can then proceed, and the new HDPE main pulled in as part of the process.

8. RECONNECTION OF THE SERVICE LATERALS

Once the new main is in place, the reconnection process (Figure 7) can commence and the service tee connected to the main with either a mechanical fitting or an electrofusion saddle (Figure 8). Because the orientation and position of the existing laterals is not discernable before starting the work (and could have originally been tapped on the top of the main, or horizontally or at an angle somewhere in between), an adaptable connection is needed, constructed either of HDPE or copper tubing. In the proof of process work performed as part of the study, the copper tubing device proved to be the most flexible and capable of greater adjustment (AwwaRF, 2007).

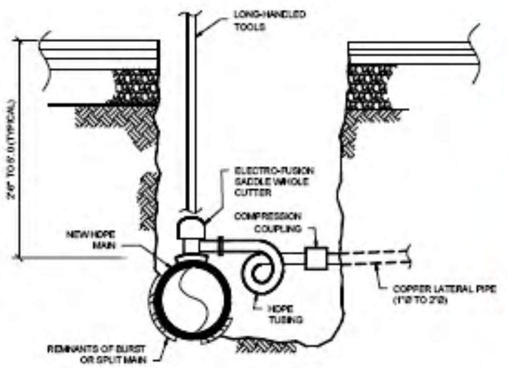

Figure 7: Connection as conceived showing plastic pigtail (AwwaRF, 2007).

Figure 8: Electrofusion saddle, with copper pipe and fittings (AwwaRF, 2007)

Using the tools shown in Figure 9 the pipe is burnished with a grinder and the assembly, complete with electro-fusion wires connected, was lowered into the keyhole and fitted to the pipe using long handled tools shown in Figure 10. The connection to the existing copper lateral was then completed, using the compression nut and bushing and the wrap-around clamp that secured the assembly to the pipe was installed to complete that part of the installation. The fusion process commenced for the specified duration, attaching the saddle tee to the pipe.

Figure 9: Long-handled keyhole tools. AwwaRF 2007

Figure 10: Keyhole tools used to clamp service tee in place. Courtesy Gas Technology Institute.

This allowed the main to be tapped by screwing down the built-in cutter that is standard in these tees, again with specialized long handled tools, cutting through the pipe wall. When the cutter was backed out, it allowed water to pass. The plastic cap was then placed over the cutter assembly and the connection was complete (Figure 11). By screwing the cutter back down it can function as a corporation stop to stop the flow to the lateral if necessary.

The excavation is then backfilled and the pavement core reinstated (Figure 12).

Figure 11: New HDPE pipe (black) connected to lateral through electrofused tee and copper connector (AwwaRF 2007)

Figure 12: Reinstated 18-inch diameter core. Courtesy Utilicor Technologies Inc.

9. REPLACEMENT OF SERVICE LATERALS WITH KEYHOLE TECHNOLOGY

Keyhole technology can also be used to great effect if it is decided to replace the service laterals as well as the main.

In 2007, Southwest Gas, which operates in California, Nevada and Arizona, first performed an excellent example of this procedure in northern Nevada using a trenchless split-and-pull technique. The entire operation was executed through 24-inch keyholes. Although this project involved replacing 1/2-inch gas service lines using a Mini-Grundotugger from TT Technologies, the operating procedures for water systems would be the same.

In the split-and-pull process, a splitting head is pulled through the existing line by a hydraulically powered winch. As the bladed rollers are pulled through, they split the host pipe. An expander attached to the head forces the fragmented pipe into the surrounding soil while simultaneously pulling in the new pipe, typically HDPE. The process can be used to split and replace house connections with diameters from 1/2 to 2 inches and up to 100 feet in length with minimal disruption. The tooling can be utilized through a keyhole in pavement applications, but also through a small hole excavation in the parkway, minimizing excavation requirements, and final restoration needs.

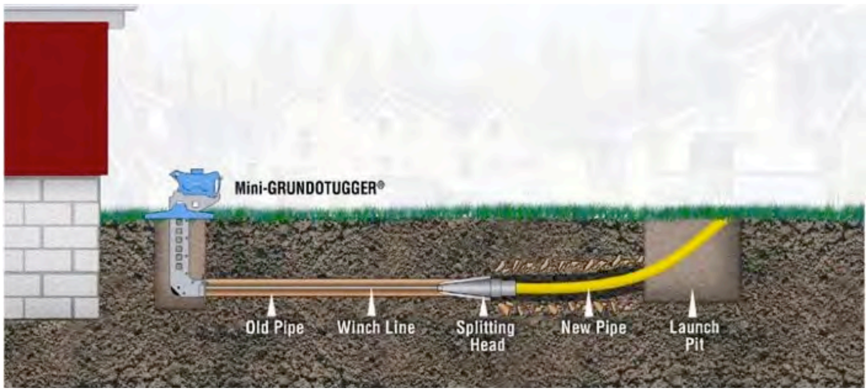

Figure 13: illustration of split-and-pull with Mini-Grundotugger. TT Technologies

Figure 14: Mini-Grundotugger winch. TT Technologies

Southwest Gas estimated that using keyhole technology and the split-and-pull method resulted in an average reduction in pavement-restoration costs of almost 87%. Compared to conventional open cut trenching, the split-and-pull technique through a cored keyhole saved more than $35 in pavement restoration costs *per linear foot* of pipe replacement (Gas Technology Institute, 2007).

10. CONCLUSIONS

The use of keyhole technology and low-dig methods, such as pipebursting, for water infrastructure rehabilitation and replacement offer significant cost savings to the utility using them and greater convenience to the public.

Water utility crews already possess most of the knowledge, tools, and equipment needed to successfully execute this kind of project, and specialized contractors are readily available to supplement those capabilities. As demonstrated every day in the gas industry and in the AWWA Research Foundation study, keyhole tools and techniques are the missing link to a cost-effective process for reconnecting services to newly laid or rehabilitated water mains in a low-dig manner.

> "Probably all that is needed for these techniques to gain wider use is a larger market. If pipebursting projects with 25,000 to 50,000 feet of water main were routinely put out to bid in large cities, the contractors who compete on this work would soon discover and innovate the tools that are cost effective." (AwwaRF, 2007)

In a future that envisages a water main replacement program over the next 25 years that will cost at least $1 trillion, it will be these innovative steps of keyhole and low-dig technology that will help to minimize the economic burden that will ultimately fall upon the consumer.

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