Enhance Safety and Reduce Costs by Permanently Marking Buried Plant

Abstract

We examine the benefits of using an electronic marker system to aid future location of valuable and dangerous buried utility plant or other "underground treasure". We summarise the advantages of knowing exactly where plant is installed and present a low-cost system to aid this process.

By

Mark Govier, October 2020

Introduction

Many utility companies rely on burying their distribution network plant beneath the street and elsewhere for security, safety, and aesthetic reasons. However, that plant does not have an infinite life and can be subject to stresses that can cause failure in the future; knowing exactly where that plant is buried can become a challenge later. Some types of buried plant are extremely difficult to locate precisely from above ground; most notably those which are electrically non-conductive, such as gas and water pipes and communication ducts carrying only optical fibres.

We will present a system that can be used to aid the marking, surveying, geo-tagging, and future precision location of buried plant. The system discussed is relatively low cost; proven to have a lifetime like that expected of buried plant and simple to use with little training.

Buried Treasure

We all enjoy a good adventure story: Think of all those you read when younger involving ancient maps and things that have been "long lost" because their precise location is no longer known. Even when you find the ancient map you still struggle to locate the "treasure" because the context has changed; the landscape is completely different to when it was buried. Stories like this recall secrets, pirates and maps and the story today is not very different, buried assets are critical to the success of utility companies and their records are often considered a commercial secret.

Humans have been improving their cities since the earliest days, burying water pipes made from wood, lead and copper for over 5,500 years with street drains and sewers made of moulded bricks and clay pipes for almost as long. Large brick drainage systems complete with access holes, similar to modern manholes were in use 4,000 years ago in Babylon.

Between 3000 and 1500 BC the island of Crete had sewers and drainage systems similar to those of today up to 3.5 m (10 ft) below ground often made with tapered clay pipes fitted together to form some of the earliest spigot and socket pipes.

In Greece many houses were equipped with a latrine that emptied into a sewer below the streets. The Greek cities also buried their water aqueducts up to 20 m (60 ft) below ground level to protect their water sources from enemies.

It was during the post-Roman era that much of this technology was forgotten for as much as 1,000 years. Lead pipes were first recorded in London in 1235 and by the 16th century, piped water supplies were re-introduced to the city using a mixture of wooden and lead pipes.

In the early 1800s, gas lighting was introduced; in some areas surplus rifle barrels from the Crimean war were screwed together to form gas pipelines. The earliest electrical supplies in the UK were in Godalming in 1881 where public supply and street lighting was installed. The introduction of the telephone in 1877 resulted in further growth, the first underground trunk cable was laid in the 1880s.

Many buried utilities that are in use, are well over 40 years old and often as old as 100 years, therefore any records, should they exist are completely out of date; where for instance, a pipeline or duct was installed a certain distance from the kerb of a road, that was when the road was just two lanes and no longer relates to the modern four lane highway that may have also changed direction and position relative to the centre line.

Even if plant was buried only a decade ago and precision geographical tags noted for its location from highly accurate GNSS; returning to the same spot in the landscape can still be troublesome, especially in continents subject to faster tectonic movement. Plant could be a metre or more from its original location meaning relying on GNSS alone without reference to the buried plant itself or building precision offsets into the location detector could lead to digging in the wrong location.

Friend and Enemy

The ground, in the case of buried utilities can be both their friend and enemy: Soil can protect, support and hide otherwise ugly ducts, cables and pipes. But in burying them, it makes knowing exactly where they are troublesome. Take for one example where a new service is to be installed, perhaps using a modern "trenchless" technology, can the contractor be 100% certain that there is nothing beneath that roadway they are trying to avoid digging?

Lost in the Undergrowth – Do not Let Your Adventure Story Turn into a Tragedy

No doubt you will have heard of many incidents of buried utility plant being damaged during excavation either of itself or a nearby different service. Usually the damage is minor but still causes hassle and costs that were not expected, at the very least, annoying residents with additional traffic restrictions whilst the other utility's team attend and fix the damage. Occasionally, implications of damage are far worse, gas mains rupturing and causing fires, water mains causing extensive flooding etc. In the worst examples, lives are lost, or major injuries caused.

Following on from the above example where a contractor is proposing to install a new service using a "trenchless" technology; what happens if they "missed" the presence of a gas pipeline part way across that road? If the horizontal drill or other device disturbs or even directly impacts that pipeline; what could the implications be? At the very least the need for emergency excavation and repair of the pipeline.

This is not a new problem and governments around the world have legislated to ensure that as a minimum, before breaking ground, contractors contact a central database or the other utility companies likely to have plant in the area AND then conduct an above ground survey to mark where buried plant is to be found.

The important questions that must be answered before digging in the ground are:

1. Where is it?
2. What is it?
3. Does it tally with the known records?
4. Can you see everything?
5. Am I safe to dig?

Is it Just the Treasure That is Valuable?

Here are some numbers to put the costs of street works in perspective; in the UK it is estimated that £1.5 billion is spent annually on street works with a further £150 million spent repairing damage that those works caused (McMahon, Burtwell, & Evans, 2006). It is further estimated that the general cost to society and the economy amounts to a further £5.5 billion due to the manifold impacts of street works, such as traffic congestion and delays.

Mine Detectors

Until the 1970s most services, were installed with some form of metallic conduit or conductor, wastewater the only exception often being carried through terracotta pipes. Cables, metal pipes and metal conduits are detectable using various technologies most of which are variations on simple metal detectors which respond to the change in reactance of a tuned circuit when the inductive component (search coil) is brought near metal. Alternate systems induce a signal onto the electrically conductive material and then detect the presence of that signal further along the conductor.

But, increasingly since the mid-1970s ducts and pipelines, especially smaller ones that are commonly found in urban areas, have been made using plastic materials such as polyvinylchloride (PVC) and polyethylene (PE, MDPE and HDPE). In the case of ducts that are themselves carrying metallic wires and cables this is less of a problem as inductive cable tracing systems will work with these. But water, gas and fibre optic systems can be "invisible" to most cable location systems, so contractors may need rely on expensive technologies such as ground penetrating radar that require considerable training to interpret the results and often a special radio transmitter license to operate.

Results of "blind" trials to locate services in the late 1990s showed that then existing survey methods could only provide a 50% success rate: A site at a road junction in the UK was chosen and all surface was removed and all utilities accurately mapped. These included four sewers, eleven telecommunication cables, fifteen electricity cables, three MDPE and two cast-iron water mains plus two HDPE gas pipes. The surface was reinstated and three surveying contractors invited to use their own equipment and spend as long as necessary to map what they could find (Ashdown, 2000).

The brief was to show what was present. In this case much was missed. With the results of such surveys being used for a simple "yes or no" decision on whether safe to dig, clearly considerable danger remained.

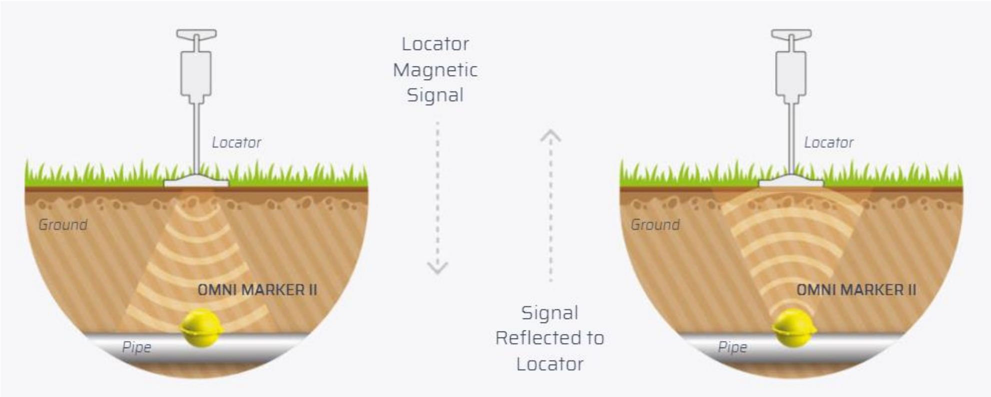
That Idea Resonates with Me

What could be done to "mark" such "non-conductive" buried plant? Well, the most obvious option is to add a conductive "trace" wire or like within or alongside each duct. This works well, for a time. After a while, perhaps following other excavation, trace wires alongside plastic pipes became damaged, corroded and disconnected during other maintenance and even trace wires in items like fibre optic ducts began corroding and becoming disconnected, often due to the fact that even the best ducts without ventilation will be damp.

All these trace wires, being entirely passive and often not having continuity end to end of a "run" meant that disconnected sections could only be traced by remote induction, where a signal is applied to the conductor from above ground and then followed using a receiver for a few tens of metres at a time.

What was needed was a system for marking buried plant that was reliable, simple to use, both at the time of installation and when being traced and low cost. Thinking about variations upon theme of the "metal detector" mentioned above, the technology was expanded to a system where devices are buried that resonate at key electrical frequencies. By choosing a range of frequencies that are offset from each other sufficiently relatively standard electronic components can be used to create these resonant circuits leading to a relatively low-cost solution. They also contain no "active" electronics that may be more susceptible than simple "passive" components. To further protect these from environmental damage when installed they were enclosed in sealed plastic enclosures, made of the same HDPE as the ducts and pipes they are "protecting".

The equipment used to locate these resonant markers resembles other locating devices but differs in the fact that it both transmits and receives. First a magnetic field is set up that is at a key marker frequency for a fraction of a second, this will cause any nearby marker that is tuned to that frequency to resonate in sympathy. When the transmitter is switched off, the buried marker continues to resonate for a fraction of a second, the decaying signal from this resonance can be detected and used to indicate presence of a marker of that key frequency on a display; often accompanied with an audible warning.



The Tempo EML-100 can sequentially scan all current industry standard frequencies so quickly whilst remaining sensitive, that it appears able to detect all types of industry standard marker concurrently.

Simplicity is Key

If any application is to be used successfully, all barriers to efficient use must be removed or made as small as possible. When installing the buried markers themselves there must be no complex requirements or installation instructions, the trench is a hostile environment, and no-one wants to be doing awkward work in such a confined space. Therefore, the ideal solution is a marker that can be installed in any orientation and simply tied to the buried service.

With this basic requirement in mind Tempo created the Omni Marker™ II which contains a gimballed tuned coil assembly that always self-levels. When activated by a locator, this horizontal coil creates a near perfect vertical dipole response, meaning that installation orientation is not related to position accuracy or sensitivity. The peak of response is always directly above the marker.

Tempo have recently complemented the Omni Marker II with Spike Marker that is a much more compact shape, like a pencil, that the user pushes into the soil alongside or above a service. These are ideal for use with shallower services or to be placed above services installed by HDD (horizontal directional drilling) as the drill is followed.

Future Security of the Network

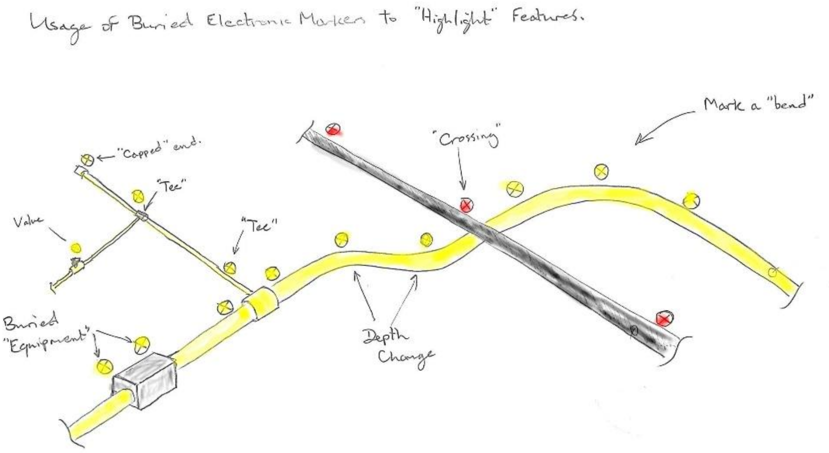
Consider the situation where the presence of passive markers can quickly confirm the consistency of plans sometime in the future. These clues all aiding contractors and planners avoid clashes with existing services.

Additionally, should there be an emergency, the presence of markers at key points is extremely useful, allowing a quick and easy search of all the nearby networks helping to avoid playing of dice resulting in further costly maintenance of your or other networks. Plus allowing your team to pin-point the location they need to dig rather than excavate a larger trench.

Locate Interesting Points in Your Network

Whether gas, electricity, telecommunications, district heating or water, a network typically includes notable points, which also represent points of weaknesses:

- Buried “dead ends” e.g. water connection points or optical fibre ducts to be connected later
- Junction boxes or buried branch
- Repairs or splices
- Crossover Network
- Change of direction or depth and degree of change



These points are usually difficult if not impossible to spot from above ground by the field teams unless they were recently excavated. The positioning of passive markers in key locations allows stakeholders to identify these locations quickly and positively, differentiating them from the rest of the network.

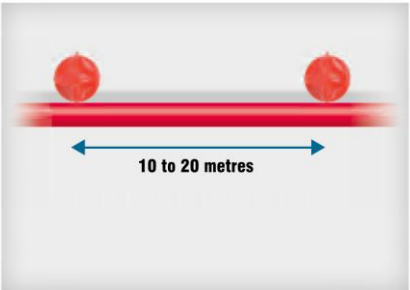
Tagging Accessories and Features in the Network

Boxes, Chambers and Accessories

To aid attachment to accessories and other hardware installed below ground or at ground level (that can become overgrown later) we also produce a smaller Spike Marker electronic marker, which can be supplied with clips that can be attached to the sides of ducts, cables or flat surfaces, such as the side of a polymer box using a cable tie, the marker then simply pushed onto the clip.

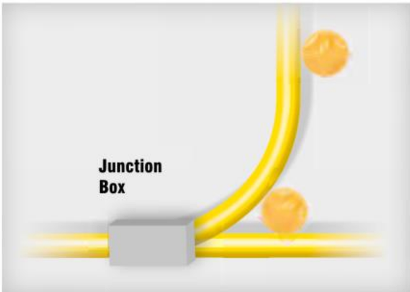
Suggested Uses

Mark at regular spaces along straight runs, perhaps every 10 to 20 m.



Create a scheme within your company and stick to it. When markers are spaced differently to the normal "plan" then contractors should be aware that "something is happening" underground.

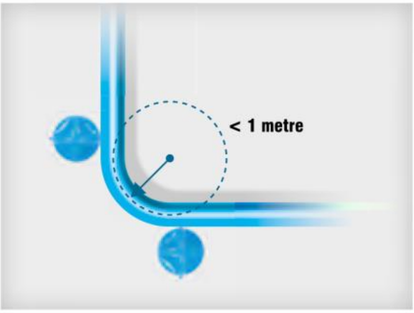
Mark at splices and junctions



Optionally add a marker, perhaps a Spike Marker™ inside or above the junction box too.

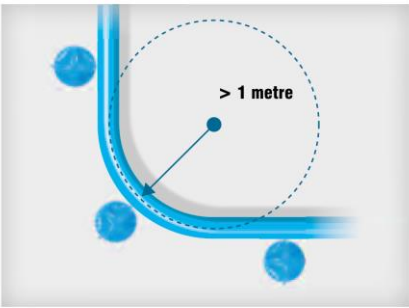
Marking bends

Either side for smaller radius curves



For smaller radius curves, where the change of direction should be detectable with the locator when directly above one marker; you only need to mark either side of the bend.

Follow the curve for larger services

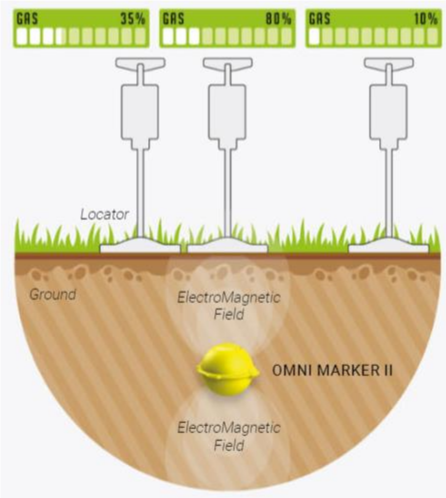


For larger radius curves, where the final change of direction is not detectable with the locator when directly above one marker; you should mark at points around the bend. With each marker being detectable from the last. Perhaps no further than 1.5 m apart horizontally.

Marker Fields

The coils of markers are designed so their maximum response is vertically directly above the product. The “ball” style markers have the coil on a weighted gimbal that self-levels under gravity. The Spike Marker is long and thin being designed to simply be pushed into the soil/backfill alongside a buried service. The Omni Marker II and Spike Marker which both have this simple dipole field form are easy to pinpoint. The OM-II is detectable to a depth of at least 1.5m (5 ft), Spike Markers when installed vertically achieve almost as great a depth, 1.2 m, despite being very compact.

Directly above each marker the locator will find a “maximum” response or “sweet spot” that can be relied upon for guiding digging to that key point in your network. Equally, other services will have a very good guide of places to take great care when digging.



Precision Mapping Options

When markers are buried with utility plant or during repairs there is another advantage: Namely, records and maps need not be updated immediately.

Contractors need to take a few “as installed” photographs including visible position references, e.g. lamppost, gatepost, or tree. Then, as the new or repaired services are now marked precisely and can easily be detected from above ground later; it is simple for a surveyor to follow a short time after the contractors have finished on site and create or update a detailed precision digital map of the area. This can allow the surveyor to have access to a clearer site and perform their job more quickly, when more convenient and without causing further delay to the street works contractors.

Precision mapping of “the underworld” is increasingly being demanded by new legislation in several countries, states and major cities to actively reduce the risks to the public and contractors when street works are undertaken. Combining a marker locator with a precision GNSS receiver system can provide results of sufficient accuracy to meet these new requirements.

Summary

Electronic Marker Systems provide a long-life, reliable, yet low-cost means to accurately mark buried plant: This may be done for a multitude of purposes in many industries but the primary reason is to improve safety, for the buried plant, contractors working on it or nearby and the general public. Precision tuned devices are simply placed in the trench along with the utility plant during installation or repair. If a standard pattern is followed for installation, these can enhance the precision for future excavation, saving time, resources and money whilst greatly improving safety.

References

Ashdown, C. (2000). Mains Location Equipment – A State of the Art Review and Future Research Need. *UKWIR report 01/WM/06/1*.

McMahon, W., Burtwell, M. H., & Evans, M. (2006). The Real Cost of Street Works to the Utility Industry and Society. *UKWIR report 05/WM/12/8*.

For further information:

http://getomnimarker.com

Other useful web-links:

https://commongroundalliance.com/Publications-Media/DIRT-Report

http://streetworks.org.uk/

https://www.utilitystrikeavoidancegroup.org/strike-damages-report.html

Glossary of Terms

EML – Electronic Marker Locator

EMS – Electronic Marker System

GNSS – Global Navigation Satellite System, e.g. NAVSTAR (GPS), GLONASS, Galileo, Beidu etc.

GPR – Ground Penetrating Radar

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