GAS DISTRIBUTION
MAINS AND SERVICE REPLACEMENT
BY LIVE SLIPLINING TECHNIQUES

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1. ABSTRACT

1.1. Introduction

Many gas companies around the world have an aging metallic distribution network which is in the process of being renewed with polyethylene. Slip lining is probably the most common method of renewal and is widely acknowledged to be the most cost effective.

The technique of live slip lining is still relatively little known worldwide, but the earliest system known to the author was developed some 25 years ago. Currently there are systems to allow the live slip lining of both metallic mains and services and where utilised are perceived as a valuable addition to the range of replacement techniques available. In the UK alone an estimated 3000km of low pressure iron gas mains and 350,000 metallic services have been replaced using live slip lining techniques.

1.2. Aim of the study

The aim of this paper is to identify the methods currently available to gas engineers to undertake the live slip lining of metallic mains and services and to assess their value in comparison with “traditional dead” slip lining or other replacement techniques. The paper seeks to assess the merits of these techniques under the headings of health and safety, environmental impact, productivity and costs, operational factors, impact on the consumer and the general public.

1.3. Study Method

Three techniques of live slip lining, or live insertion as it is more commonly known, are examined by this study, two for the replacement of mains and one for the replacement or repair of services.

Over the past 25 years gas companies in 10 countries have used these techniques and their experiences have been taken into account in this study. More specifically, this study draws on the recent experiences of four companies in the UK and two in the USA.

4. Results

It was found that very large cost reductions are to be gained by the use of live sliplining techniques for gas services together with enhancing the safety of operatives and reducing the impact on the environment.

As regards mains replacement, the cost differences between traditional and live sliplining were found to be relatively small but cost advantages could be gained by informed choice of method based on factors such as length of main inserted in each discrete operation and its diameter. With less time off gas and less excavations open at any one time, live relining improved the relationships between the gas company and both the consumer and municipalities.

One new specialist live technique was found to promise very large cost reductions over alternative traditional methods.

5. Conclusions

By informed selection live relining techniques can yield safety, cost, customer and environmental advantages. There is a lack of knowledge worldwide that it is hoped this paper will go some way to addressing.
2. PAPER

2. 1. INSERTION TECHNIQUES

2. 1.1. Live Mains Insertion

The first system of live mains insertion known to the author, originated in the USA in the late 1970's. The complexities of this system limited its appeal but when it was introduced into the UK in 1979 a significant innovation (Reference 1) led to widespread adoption of the modified technique through the then unified British Gas distribution network. This technique is used for the replacement of low pressure cast or spun iron pipes with polyethylene, also operating at low pressure. This method is currently the one in most common usage and it is estimated that in the UK in excess of 3000km of low pressure distribution mains have been replaced using it.

The essential steps of the technique are as illustrated in the Figures 1 and 2 below. A full description of the technique is given in References 2 and 3.

Fig. 1 Essential Steps of the Live Mains Insertion Technique – Inserting PE

- A section of the main to be replaced is cut out while gas supplies to the isolated section are maintained with a bypass
- A simple gland is attached to the end of the section to be replaced and the new PE pipe inserted through it
- Gas is allowed to flow into the PE pipe before the insertion proper commences. Once purged and fully gassed up, the new PE is pushed into the old main
With the new PE fully inserted and connected into the network, customers are supplied with gas via the new PE and the annular space.

Consumer services are transferred to the new PE sequentially using polyurethane foam to block the annular space.

There is a variation of the technique in use, initially developed in the UK (Reference 4) and subsequently adopted in both France (Reference 5) and the USA (References 6 and 7). This variation is designed to allow the inserted polyethylene pipe to be commissioned at medium pressure, typically 4 bar, while the main to be replaced continues to be operated at low pressure, typically 20 mbar.

Apart from the countries mentioned above, the technique has been used to a greater or lesser extent in Belgium, Denmark, Germany, Ireland, Italy, Portugal and Spain.

2.1.2. The Sealback technique

The Sealback technique was introduced in the UK in mid 2004 following a two-year development programme. It enables the ‘live’ replacement of low pressure iron mains, on sites of engineering difficulty, to be carried out from a remote location, typically 10 m to 13 m away from where the pipe joins the parent main. The technique is used in locations where access to the main is restricted because of particular traffic conditions (such as on a light controlled junction), where traffic disruption would be unacceptable because of the volume of vehicles, or in sensitive locations such as in the proximity of hospitals, police stations etc.

The principle of the method is illustrated in Figure 3 and is more fully described in References 8 and 9.
An excavation is made in a suitable location on the iron pipe to be replaced (Figure 3). A camera inspection is then carried out on the section of main to be replaced to check for obstructions, such as bends or siphons. Following a positive survey, a flow stop operation is carried out, a section of pipe removed and a valve and gland seal fitted to the iron pipe.

A “nose cone”, as illustrated, is fitted to end of the PE pipe which is then inserted through the old iron pipe to its connection with the parent main. The annular space is then filled with a polyurethane foam to effect a permanent abandonment of the old iron pipe.

Currently the system has been developed for the insertion of 55mm, 75mm and 125mm diameter PE pipe into (3") 75mm, (4") 100mm and (6") 150mm diameter iron pipes respectively.

At the present time, four to five Sealback projects are being carried out per month in the UK and it is expected that this will increase to 12 per month during 2006. The technique has not, as yet, been used outside the UK, although several countries have already expressed interest in adopting it.

2.1.3 Live Service Insertion Techniques

The technique of inserting live gas services was pioneered in the UK in the late 1980s. The method enables steel services in the range of diameters from 25 to 50mm operating at low pressure, typically 20 mbar, to be inserted with appropriately sized polyethylene from a suitable location on the consumer’s property to the connection with the main. The chief attraction of the technique is the avoidance of excavation in the public highway with its associated costs and traffic disturbance. The technique is currently the preferred method of repairing leaking services in the UK and has also been used for the bulk replacement of services selected on the basis of condition. Currently in the order of 15,000 services per year in the UK are repaired or replaced using the method. The essential steps of the technique are illustrated in Figure 4 with a full description being given in References 10 and 11.
An excavation is made on the consumer’s property to gain access to the steel service (Figure 4). A flow stop operation is carried out on the service and a section of pipe cut out to allow the fitting of a valve and gland on the upstream side. This enables the new PE, fitted with a finned “nose cone” to be inserted through the old service with the aid of a manual pushing machine.

The new PE pipe is pushed through the old steel service until the connection with the main is reached. Once this is achieved, the annular space is filled with an appropriate sealant, such as polyurethane foam, as a means to permanently abandon the old steel service. The reconnection of the consumer’s supply to the interior of the property is then achieved using conventional methods.

Following its development, this technique was trialled in various European countries but as yet has not been adopted as a routinely used technique, as is the case in the UK.

In a slightly modified form, however, it has been adopted in the US where it is routinely used by some gas utilities.

Trials are currently underway in Argentina and the author hopes to be able to report feedback verbally at the time of presentation of this paper.
2.2. STUDIES

2.2.1. Live Mains Insertion

In the UK, the techniques of live mains and service insertion have been in regular use for many years by the operator of the gas distribution network. Until June 2005 there was one single operator, known until that date as National Grid Transco. The author has drawn on the experience of that operator from whom relevant statistics have been obtained. In particular, the author has used the detailed study carried out by National Grid Transco in 2004 (Reference 12) as a source of valuable information. Since the sale of three of National Grid’s regional distribution networks in June 2005, the author has spoken to the new network owners to obtain their views on the relative merits of live mains insertion.

In the US, two utilities were questioned on their use of the technique and useful statistics were obtained from both National Grid USA (formerly Niagara Mohawk) and Fitchburg Gas & Electric, part of the Unitil corporation (References 6 and 7).

2.2.2. Sealback

To assess the merits of this technique the views of the UK gas distribution network owners have been sought and case studies in two of them have been evaluated.

2.2.3. Live Service Insertion

Statistics have been obtained from National Grid in the UK on the usage of live service insertion and its costs as compared to other replacement methods. The remaining three network owners have also been consulted for their views on the uses and benefits of the technique.

In the US, the company providing the equipment and sealant for the technique was contacted for their views on the technique.
2.3. RESULTS

2.3.1 Live Mains Insertion

2.3.1.i. The UK Experience

The study carried out in the distribution network of National Grid in 2004 (Reference 12) yielded some very interesting results which are summarised in Table 1 below with amendments drawn from the views of operational engineers from the other three UK distribution network operators.

It is convenient to consider the benefits, limitations and disadvantages of live mains insertion as a technique under the following headings:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Sub-topic</th>
<th>Benefit</th>
<th>Limitation</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health &amp; Safety</td>
<td>Excavations</td>
<td>• Minimum number of excavations open.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Excavations backfilled before new excavations dug</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Work Practices</td>
<td>• Teams not under additional pressure of getting all services transferred on insertion day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Teams usually only work standard length day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Excavations on services for transfer carried out when services already decommissioned</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Customer time off gas</td>
<td>• Only off gas once while services are transferred</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Impact</td>
<td>Excavations</td>
<td>• Excavations open for less time, therefore some excavated material re-used as backfill</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Minimises use of fresh backfill and landfill disposal.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Productivity and Costs</td>
<td>Projects with up to 100m of main to replace</td>
<td>• More cost effective than dead insertion for diameters up to and including (6&quot;) 150mm. See Figure 5.</td>
<td></td>
<td>• Less productive and more expensive than dead insertion</td>
</tr>
<tr>
<td></td>
<td>Projects with between 200-300m of main to replace</td>
<td>• Each insertion operation (“push”) must be of at least 150m to achieve productivity parity and cost savings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational Factors</td>
<td>Projects with between 300-400m of main to replace</td>
<td>• More productive and more cost effective</td>
<td>• Each insertion operation (&quot;push&quot;) must be of at least 150m to achieve productivity parity and cost savings</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>-----------------------------------------------</td>
<td>--------------------------------</td>
<td>-------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Service Connections</td>
<td>• Services can be transferred at a time that is operationally convenient</td>
<td>• Services must be transferred sequentially</td>
<td>• Obstructions can involve additional excavation to prepare a new launch site</td>
<td></td>
</tr>
<tr>
<td>Contingency</td>
<td>• If problems are encountered, push can be suspended as customer supply not affected</td>
<td></td>
<td>• Technique requires greater degree of operative training compared with dead insertion</td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td>• Equipment very simple</td>
<td></td>
<td>• Use of insertion depends on sufficient network capacity to allow downsizing</td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>• Use of insertion depends on sufficient network capacity to allow downsizing</td>
<td></td>
<td>• Live insertion is limited to size combinations that give sufficient capacity in the annular space – see Table 2</td>
<td></td>
</tr>
<tr>
<td>Impact on Customers &amp; Public</td>
<td>• Minimum time off gas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public</td>
<td>• Fewer excavations open at any time</td>
<td>• Reduced traffic disruption</td>
<td>• Better relationship with public and municipalities</td>
<td></td>
</tr>
</tbody>
</table>

*Table 1* Benefits, Limitations and Disadvantages of Live Insertion as a Technique
**Fig. 5.** Difference in Cost Between Dead Mains Insertion and Live Mains Insertion per Project Length. Cast Iron mains up to (6") 150mm diameter. *Source: Stephen O'Reilly (2004). Report Comparing Live and Dead Mains Insertion*

**Table 2** Capacity of Annulus Expressed as the Nearest Equivalent PE Pipe Diameter (for common combinations only)
(Network analysis will determine if this equivalent pipe is adequate to maintain gas supply)

<table>
<thead>
<tr>
<th>PE Ø</th>
<th>Diameter of Main</th>
</tr>
</thead>
<tbody>
<tr>
<td>55mm</td>
<td>63mm</td>
</tr>
<tr>
<td>63mm</td>
<td>90mm 125mm 160mm</td>
</tr>
<tr>
<td>75mm</td>
<td>75mm 110mm 140mm</td>
</tr>
<tr>
<td>90mm</td>
<td>63mm 90mm 140mm</td>
</tr>
<tr>
<td>110mm</td>
<td>75mm 125mm 180mm</td>
</tr>
<tr>
<td>125mm</td>
<td>90mm 180mm</td>
</tr>
<tr>
<td>140mm</td>
<td>63mm 160mm</td>
</tr>
<tr>
<td>160mm</td>
<td>140mm</td>
</tr>
<tr>
<td>180mm</td>
<td>90mm 200mm 250mm</td>
</tr>
<tr>
<td>225mm</td>
<td>125mm</td>
</tr>
<tr>
<td>250mm</td>
<td>200mm 355mm</td>
</tr>
<tr>
<td>268mm</td>
<td>160mm</td>
</tr>
<tr>
<td>315mm</td>
<td>268mm 355mm</td>
</tr>
<tr>
<td>355mm</td>
<td>250mm 500mm</td>
</tr>
<tr>
<td>400mm</td>
<td>250mm 500mm</td>
</tr>
</tbody>
</table>

Note: Combinations in the shaded area are possible but rarely undertaken

*Source: National Grid Gas Main Laying Manual, Section B, Live Mains Insertion*
2.3.1.ii. The US Experience

The two companies questioned in the US have commenced using live mains insertion over the past two years. It should be noted that when using insertion techniques, they are upgrading the pressure in the newly installed HDPE main to medium pressure, generally to 4bar.

National Grid USA have been using live mains insertion as part of their “low dig” programme for mains replacement. Over the past two seasons, some 8.5km of iron mains have been replaced in the size range (4") 100mm to (10") 250mm diameter. They find the reductions in labour costs to be modest, at around 10%, with the major saving coming from the 50% reduction in restoration costs. They also report savings in the purchase of backfill material and the costs of removing spoil. In total they are reporting project cost reductions of 30% compared to open trench main laying.

Fitchburg Gas & Electric have now completed two seasons of using the technique. Just less than 3km of (4") 100mm diameter cast iron has been replaced by (2") 50mm diameter HDPE in that time. An analysis of projects carried out in 2004 and 2005 show total project cost reductions of 37% and 38% respectively compared to the alternative of open cut main laying. Similar to National Grid USA, they find that the largest cost reductions are associated with reinstatement, or restoration costs. As much as an 80% reduction was reported for the work carried out in 2005. In comparison, the savings in labour costs are much lower, around 10%.

2.3.2. Sealback

Case studies from two of the UK’s distribution networks revealed the following information:

A project in the network of Scottish and Southern Energy, located near Brighton, yielded an estimated cost saving of 65% compared to conventional methods. An 11 metre section of (4") 100mm diameter iron main was inserted with 75mm PE to its junction with an (8") 200mm diameter main which was located in the middle of a major trunk road. Excavation costs in such a location would have been very high, not to mention the traffic disruption caused.

A project in Barnet (North London) in the network of National Grid involving the same pipe combinations as above yielded an estimated cost saving of 80% as compared to opening a trench on the junction of the two pipes. Such a large cost saving was attributed to the fact that opening a trench would only have been permitted overnight on the three lane highway in which the parent main was located.

Two further projects in the Birmingham area of the National Grid network involving the insertion of short lengths of (6") 150mm diameter iron mains with 125mm PE, yielded approximate cost savings of 70% and 25% respectively. The larger saving was made due to the avoidance of excavation in a traffic sensitive location, while the smaller one was made where electricity cables lying on top of the parent main would have made excavation work difficult.

All networks report a proportion of planned work not being possible due to bends being identified in the section to be replaced during the camera survey stage.

2.3.3. Live Service Insertion

In the UK all four network owners reported usage of the technique for repair or replacement work, with a desire at senior management level to increase its deployment, both on economic and safety grounds.
Two of the network owners, National Grid and Scottish and Southern Energy, are making a determined effort to dramatically increase live service insertion, principally on the grounds of safety. They are adding the operation of cutting off of service pipes (for non payment of gas consumption or non use by the customer) to the uses to which the technique is put. For this latter use, the new PE pipe is installed and commissioned, but left capped at the point where the old service pipe was cut. This leaves the option to re-connect the consumer at a later date if required.

The rationale is to keep the operators off the public highway as much as possible for several safety related reasons:

Firstly, if an intervention is to be made on a service pipe, then access to it is best made on the consumer’s property where the depth of cover is likely to be least and where a larger excavation can be made for ease of working without a major cost penalty. Such a shallower, larger excavation is safer to work in where the risk of gas escaping could occur when the service pipe is cut.

Secondly, making the intervention in that location avoids exposure of the operatives to the hazards from traffic that are associated with excavations in the highway.

All UK network operators reported significant cost savings in using the technique, with the average unit cost saving in 2006 terms being reported as approximately £114 (166€ or $200), this saving being the reduction in the average cost of reinstatement.

The usage varies from network to network but currently a total of approximately 15,000 services per year are being repaired or replaced with the use of live service insertion. The current pattern of usage in National Grid in 2005 for operations where the technique is potentially suitable is outlined in Table 3.

<table>
<thead>
<tr>
<th>Type of usage</th>
<th>Replaced by Live Service Insertion</th>
<th>Total</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic service relay following a gas escape</td>
<td>3,617</td>
<td>66,704</td>
<td>5.53%</td>
</tr>
<tr>
<td>Domestic service relay changed meter position</td>
<td>18</td>
<td>446</td>
<td>4.04%</td>
</tr>
<tr>
<td>Domestic service renewal based on condition</td>
<td>631</td>
<td>1,693</td>
<td>1.93%</td>
</tr>
<tr>
<td>Domestic service renewal – urgent</td>
<td>754</td>
<td>10,339</td>
<td>7.29%</td>
</tr>
<tr>
<td>Total for all types where live service insertion can be used</td>
<td>5020</td>
<td>79,182</td>
<td>6.3%</td>
</tr>
</tbody>
</table>

Table 3 Usage of Live Service Insertion

Note: The table above omits the category of service replacement linked to the replacement of mains. This is a huge workload in National Grid amounting to some 565,000 re-laid services in the period to which the table relates. It should be noted that this category of work rarely necessitates the use of the live service insertion technique as most mains replacement in the UK is by insertion and an excavation must then be made at the service connection point to affect the service transfer to the new inserted PE main. This operation being necessary negates the advantage of the live service insertion technique whose chief benefit is the avoidance of excavation at the mains’ connection. It may sometimes be used, however, as a
means of reducing the workload of renewing services during a dead insertion project, helping to minimise the time consumers are off gas and the length of the operator’s working day.

A recent study by National Grid has identified that of the total of some 80,000 operations in the above table, the potential number where the live service insertion technique could be used is some 16,000. This total takes into account the circumstances where the technique can not be applied, for example where a service is found to be leaking at its connection to the main. The study has highlighted the potential to increase from some 5000 to 16,000 operations per year, yielding a saving of approximately £1.25million (€1.8million or $2 million) annually. This would translate to a national saving, if all UK networks increased usage, of at least twice that figure.

As regards the US experience, to the date of publication of this paper no response has been received from the sources questioned but the author hopes to report verbally at the time this paper is presented in June 2006.
2.4. CONCLUSIONS

2.4.1. Live Mains Insertion

The results obtained from the UK distribution network operators, the most mature users of live mains insertion techniques, compared the benefits of the technique against the very cost effective and equally “low dig” alternative of dead insertion. From these results the main conclusions that can be drawn are:

1. Independent of the pipe diameters and length of individual project there are distinct health, safety and environmental advantages to using the live technique as laid out in Table 1.
2. For projects over 200 metres in length, providing each insertion “push” exceeds 150 metres, the live technique is more cost effective in the most common diameter range for replacement (up to 6” 150mm), by between 5-14%.
3. For projects 100 metres in length, or less the live technique is more costly by between 9-13% for the same diameter range.
4. The use of the technique is limited to pipe combinations where the annular space between old and new pipes has sufficient capacity to temporarily support the gas load during the insertion operation – see Table 2.
5. The impact on the consumer and general public of mains replacement work is minimised by the use of the technique.

The results obtained from the US were comparing the use of live mains insertion with open trench main laying and therefore the cost benefits reported are high, between 30-38%. The author has no figures similar to the UK results comparing live and dead insertion.

Fitchburg Gas and Electric reported similar health, safety, environmental and consumer, advantages as the UK companies.

2.4.2. Sealback

Although the technique is still in the roll out stage in the UK, it is already clear that there are very substantial cost savings to be made in using the technique; up to 80% was reported by one UK network. Another major benefit is the reduction in exposure of the distribution network owners to the risk of incurring traffic management fines associated with any work that takes place on the highway in the UK.

The chief limitation of the technique is the small range of diameters that can currently be tackled and the inability of the nose cone to negotiate bends. Both these aspects are the subject of further development work, already underway.

2.4.3. Live Service Insertion

The views of the UK gas distribution network owners are that this technique offers the safest means currently available for operatives to repair or replace a service pipe by keeping them out of excavations on the highway.

In addition to this major benefit is the fact that National Grid UK estimates between 14-23% overall cost reduction can be made on the average cost of service repair or replacement compared with using all other currently available methods. Nationally, if used to its full potential, the technique could yield savings of £2.5 annually in today’s terms.

The limitation of the system is it can only currently be applied to steel services and depends on the network being capable of supporting reductions in diameter of services.

In general, where applicable, the above techniques offer considerable cost benefits to distribution network owners and increase the safety of their operational staff. The author trusts this paper helps to bring these benefits to a wider audience in the worldwide gas industry.
3. REFERENCES

11. Steve Vick International Ltd. How to Carry Out Live Service Insertion
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3. Usage of Live Service Insertion
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