Introduction and development of trenchless technology to reduce the environmental impact of gas construction work

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1. Abstract

Toho Gas is actively introducing and developing trenchless methods and restorative repair methods for the installation and restoration of gas pipes. The use of trenchless methods and restorative repair methods is characterized by smaller excavation/construction areas, compared to traditional open-cut method. Because of this, traffic congestion is eased, the number of times to remove the soil is reduced, and the time to use heavy machinery is shorten, all of which decreases the amount of CO_2 emitted due to the construction work. Additionally, restorative repair methods are able to prolong the life of the gas pipes, which reduces the associated life cycle costs. Thus, the active use of trenchless methods and restorative repair methods is an extremely important part of performing gas construction work in a sustainable, environmentally friendly way.

Using the examples shown below, this paper will outline the track record of environmental impact reductions achieved by Toho Gas (particularly related to the reduction of excavated earth) through the introduction of trenchless methods and restorative repair methods, as well as the development and improvement of the methods in order to increase the application rate of these methods and increase their performance and reliability.

Development of trenchless methods
- Development of a trenchless replacement method (Wire Blade Method) for galvanized steel pipe
- Development of a trenchless replacement method for ductile cast iron pipe

Development and improvement of restorative repair methods
- Development of a supply pipe restorative repair method for galvanized steel pipe
- Improvement of a restorative repair method (Phoenix Method) for ductile cast iron pipe and steel pipe

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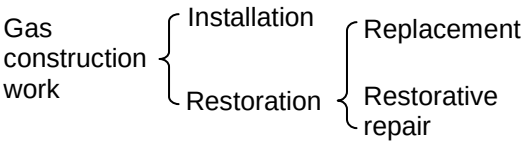
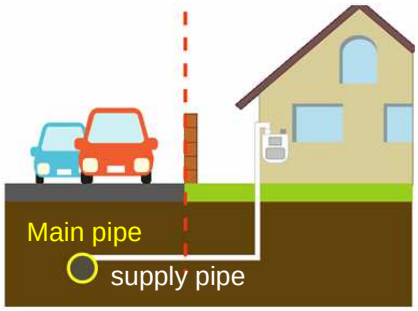
2.1. Types of gas construction and types of gas pipes

Gas construction work can be divided into installation, in which new gas pipes are laid, and restoration, in which existing pipes are renewed. Also, restoration can be divided further into replacement, in which a new gas pipe is laid in the same position as an old gas pipe, and restorative repair, in which the inner surface of old gas pipe is lined with resin or hose.



[Fig. 1] Types of gas construction

In Japan, the gas pipes buried in the road are called *honshikan*, or main pipes, and the gas pipes that branch off of the main pipes and supply gas to houses are called *kyonaikan* (supply pipes).



[Fig. 2] Main pipe and supply pipe

Today, polyethylene pipe is used for these purposes because it is flexible and lightweight. However, traditionally, cast iron pipe and galvanized steel pipe were used for gas mains and small-diameter galvanized steel pipe was used for supply pipes. Because a long time has elapsed since the cast iron pipe and galvanized steel pipe were laid, restorative repairs using polyethylene pipe is currently being carried out.

[Table 1] Types f gas pipes

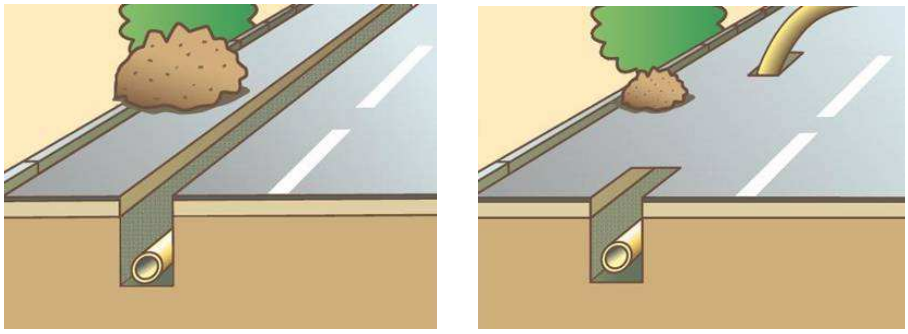
	Before	Today
Main pipes	Cast iron pipe Galvanized steel pipe	Polyethylene pipe (PE pipe)
Customer-side supply pipes	Galvanized steel pipe	Polyethylene pipe (PE pipe)

2.2. Characteristics of trenchless methods and restorative repair methods

In the past, open-cut methods were used in gas construction works in which a trench was dug along locations where the gas pipe was to be laid.

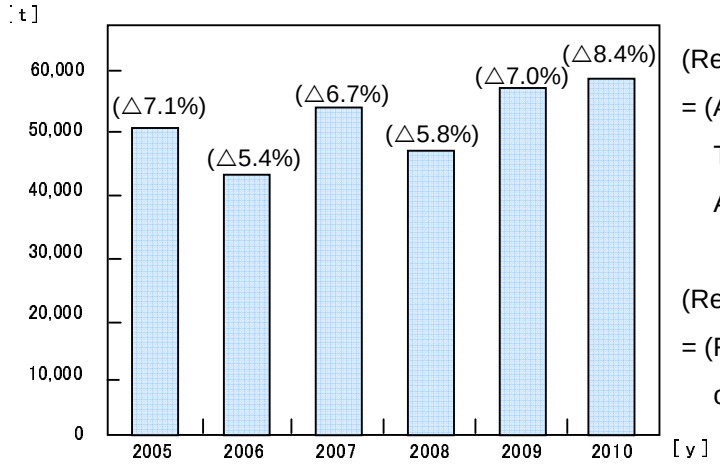
In recent years, however, there has been an increased use of trenchless methods, in which both ends of the construction area is excavated and the gas pipe is pulled into the ground from one end. Similarly to trenchless methods, restorative repair only involves excavating just the two ends of the construction zone.

Because of this, the application of trenchless methods and restorative repair methods allows the excavation area to be dramatically decreased, which leads to reduction of excavated earth. The use of trenchless methods can result in 60% less excavated earth than open-cut method.



[Fig. 3] Open-cut method and trenchless method

By actively introducing these methods, Toho Gas is working to reduce the amount of earth excavated during gas construction, and to reduce the CO_2 emissions by using heavy machinery for shorter periods. In FY2010, Toho Gas succeeded in achieving a reduction of 57,800t in the amount of excavated earth (corresponding to 9.2% of the total amount of earth excavated).



(Reduction)
= (Amount required with open-cut method: Theoretical value) - (Actual amount: Actual value)

(Reduction rate)
= (Reduction) /(Amount required with open-cut method: Theoretical value)

[Fig.4] Reduction in the amount of excavated earth (Reduction rate)

As the chart shows, the reduction rate in the amount of earth excavated through the use of trenchless methods and restorative repair methods is not high enough yet. This is an indication that the application rate for trenchless methods and restorative repair methods was not as high as it could be for all gas construction works. To increase the application rate, it is necessary to develop new trenchless methods and restorative repair methods, and work to improve existing methods.

2.3. Development of trenchless methods and restorative repair method

Toho Gas is introducing and developing trenchless methods and restorative repair methods that are suited to different types of pipe, pipe diameters, and purposes (newly installed or replacement). This includes proprietary methods that we have developed as well as technology obtained overseas that was improved according to Japan's construction work environment.

2.3.1. Development of trenchless methods

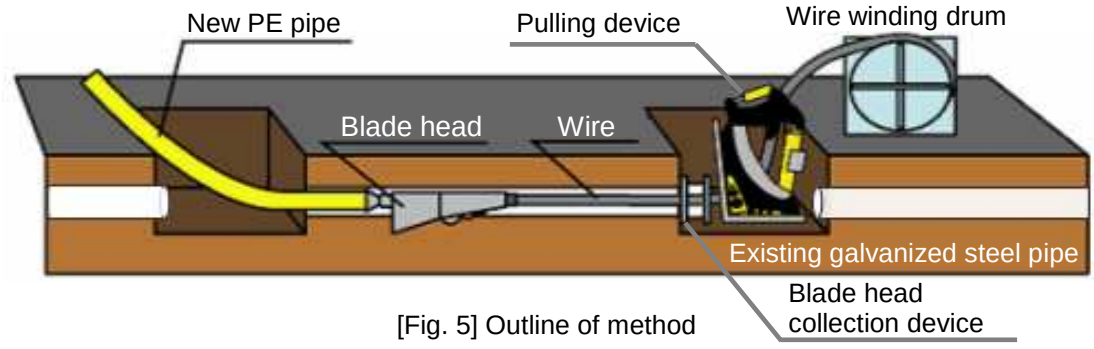
2.3.1.1 Development of a trenchless replacement method for galvanized steel pipe (Wire Blade method)

(1) Outline of method

This is a replacement method that involves cutting open galvanized steel pipe (50A, 65A) and inserting new PE pipe inside. This method was developed based on the Porta Burst PB30 manufactured by Earth Tool Co. LLC.

(2) Construction method

1) A pit is excavated on each end of the construction zone.
2) The pipe is severed at each end of the construction zone, and the gas inside is purged.
3) A wire is passed from one pit to the other through the existing pipe.
4) A blade head to which new PE pipe has been attached is connected to the end of the wire that was passed through.
5) The blade head is pulled through the existing pipe, and the PE pipe is inserted as the existing pipe is cut open.



[Fig. 5] Outline of method

(3) Key points for development

・ Improved work efficiency through the use of wire

In Japan, Pipe Splitter method has been widely used as a trenchless method for replacing galvanized steel pipe. Instead of wire, rods are used in Pipe Splitter method to pull in PE pipe, which requires attaching and detaching short lengths of rod according to length of pipe worked on during construction (for example, when working on a 40m length of pipe, rods weighing 5kg must be attached and detached about 100 times).

Because the Wire Blade method does not require anything to be attached or detached, it is more efficiency, resulting in an average of 36m/day that can be completed (compared to 31m/day for Pipe Splitter method). This means that fewer pits are required for replacement work, in turn means that less earth must be excavated.

- Improved safety through the development of peripheral devices

  We developed a blade head recovery device to make it safer and easier to collect the blade head. Also, we developed a wire winding drum to make it easier to handle the wire and to improve the work environment.

- Reduction in the amount of earth excavated through the use of a miniature blade head

  We developed a miniature blade head that is able to reliably cut and push open galvanized steel pipe. By modifying the shape to reliably push open the galvanized steel pipe and by miniaturizing it (making it shorter), we also succeeded in decreasing the size of the pit required.

(4) Future plans

We plan to fabricate and improve jigs so that this method can be applied to larger-diameter galvanized steel pipes such as 100A and 150A.

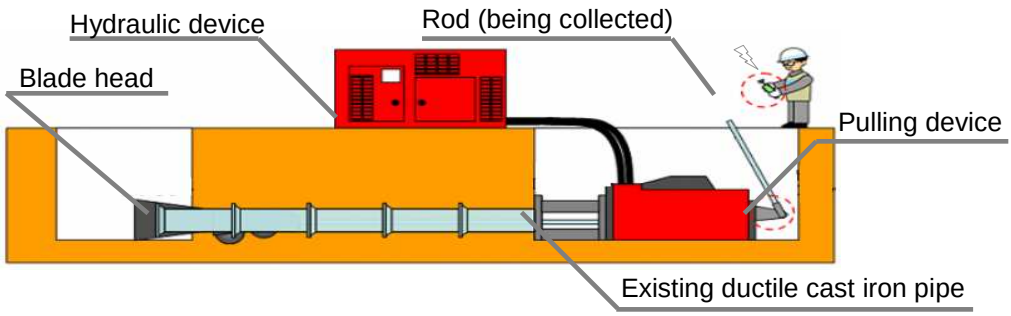
2.3.1.2 New development of trenchless replacement method for ductile cast iron pipe

(1) Outline of method

This is a replacement method in which existing ductile cast iron pipe is cut open and new PE pipe is inserted inside. It is being developed jointly with Earth Tool Co. LLC in the US.

(2) Construction method

1) A pit is excavated on each ends of the construction zone.
2) The pipe is severed at each end of the construction zone, and the gas inside is purged.
3) Rods are pulled through from one pit to the other through the existing pipe.
4) A blade head to which new PE pipe has been attached is connected to the rods that have been passed through.
5) The blade head is pulled through the existing pipe, and the PE pipe is inserted as the existing pipe is cut open.



[Fig. 6] Outline of method

(3) Key points for development

- A strong pulling force for cutting open ductile cast iron pipe

  Ductile cast iron pipe is harder and tougher than galvanized steel pipe and gray cast iron pipe, making it extremely difficult to crack. We increased the pulling force of the hydraulic unit that pulls in the blade head (91t max.) and fabricated a unit that can reliably cut open ductile cast iron pipe.

- The blade head shape that protects PE pipe from damage

  The shape of the expander (the part that pushes open the cast iron pipe) in the blade head was modified so that the PE pipe is not damaged on the edges of the ductile cast iron that is spread open. Currently, we are further improving this method.

[Fig. 7] Cut open cast iron pipe and PE pipe

- Automation and the use of remote control for devices to improve safety

  To improve work safety, we made it possible to attach, detach, install, collect, and add rods both automatically and semiautomatically. We made it possible to operate the device by remote control to allow the worker to operate the unit from the surface.

(4) Future plans

Development of this method has finished for the most part. Going forward, we plan to make smaller improvements and put in peripheral technology such as improving the shape of the blade head and developing way of taking out supply pipes effectively.

Up until, we have been using traditional trench methods to perform replacement construction on ductile cast iron pipe. By developing and applying this trenchless replacement method, we expect to reduce amount of earth excavated at work areas.

2.3.2 Development of restorative repair methods

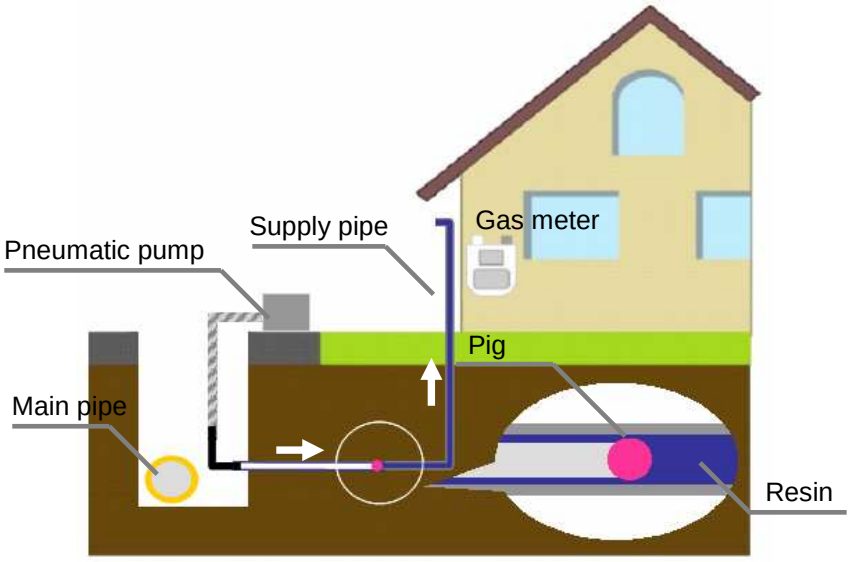
2.3.2.1 Development of a supply pipe restorative repair method for galvanized steel pipe

(1) Outline of method

This is a method of lining the inside of existing galvanized steel pipe (supply pipe) with urethane resin. This prevents gas leaks from cracked, damaged, or corroded gas pipes.

(2) Construction method

1) The gas meter is removed.
2) The point where the supply pipe connects to the main pipe is excavated.
3) The supply pipe is cut off where it connects to the main pipe.
4) The resin is put inside the supply pipe.
5) The supply pipe is lined with the resin by pneumatically pushing the pig.



[Fig. 8]Outline of construction method

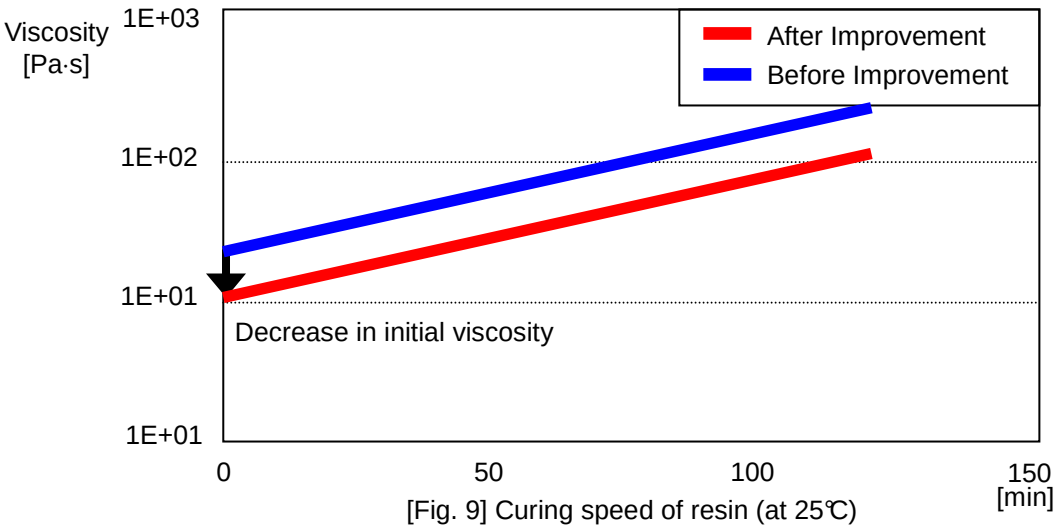
(3) Key points for development

- Urethane resin with both high elasticity and strength

  We are currently developing a 2-part urethane resin with both high elasticity and strength (development is mostly complete). This method allows the lining resin to function as a gas pipe and continue to provide a stable supply of gas even if the pipe breaks or the pipe develops holes due to corrosion and the resin lined come out,

- A urethane resin with a long cure time that does not run

  Generally, 2-part urethane resins take a long time to cure after it is mixed together. This means that not very much time is available for lining the pipe, which may result in the failure of this method (because the resin hardens during the lining process). To address this issue, we decreased the initial viscosity after mixing, to delay the cure time in relative terms, and we succeeded in increasing the lengthening the time available for the lining process. An appropriate level of viscosity was left to prevent the resin from running and collecting at the bottom of the pipe after the lining process is complete, which can block the gas pipe.



[Fig. 9] Curing speed of resin (at 25℃)

(4) Future plans

Once this method has been fully developed, it will be applied to galvanized steel pipes for which corrosion is a concern. By using this method in place of open-cut methods used traditionally to replace existing pipe, we believe that it is possible to significantly reduce the amount of excavated earth and waste resulting from the construction works.

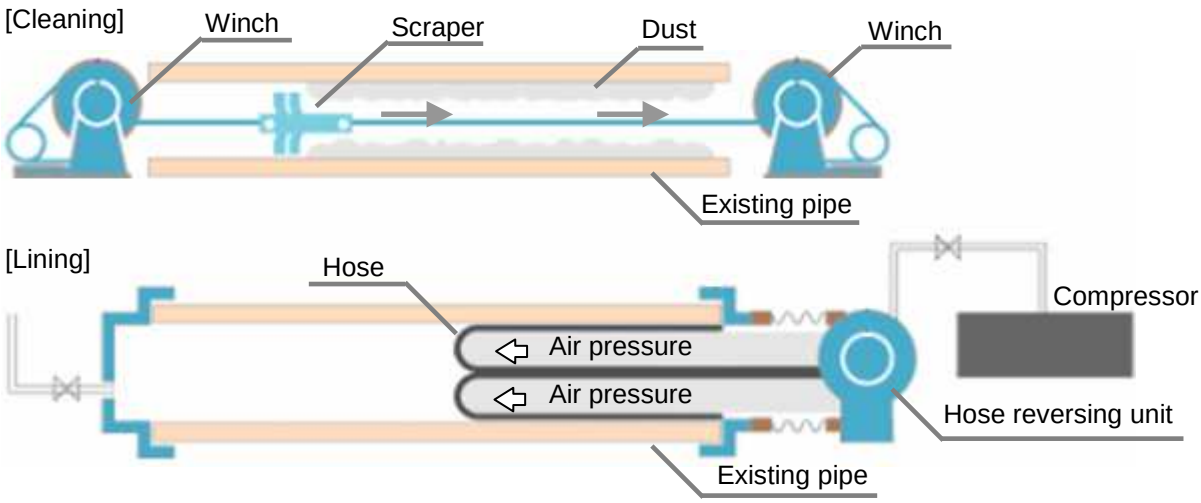
2.3.2.2 Improvement of a restorative repair method (Phoenix method) for ductile cast iron pipe and steel pipe

(1) Outline of method

This is a method of lining the inside of existing cast iron pipe / steel pipe (gas mains) with highly elastic fiber hose. By using method, it is possible to prevent gas leaks from joints, gas leaks caused by cracks and damage in the existing pipe, and gas leaks caused by shaking and damage during earthquakes.

(2) Construction method

1) A pit is excavated on each end of the construction zone.
2) The pipe is severed at each end of the construction zone, and the gas inside is purged. The pipe is also cleaned.
3) The existing pipe is lined by passing the hose through from one pit to the other while reversing it.
4) Each end of the hose is cut, and resin is applied at each end to prevent the hose from unraveling.



[Fig. 10] Outline of construction method

(3) Key points for development

・ Hose with both elasticity and strength

Conventional hose have excellent elasticity and softness to prevent breakage in the event that an earthquake shakes the gas pipe. However, when such hose is used for low-pressure pipes

that have a low internal pressure, and a major disconnection occurs in pipe joints, this causes the hose to be exposed to the ambient underground water pressure and soil pressure for long periods; because the hose is soft, the hose may be crushed by the underground water pressure etc. To address this issue, we strengthened the hose and changed the adhesive to maintain the elasticity and softness of conventional hose, but also made it deform less in case it is ever exposed to underground water pressure etc.

- Existing construction materials and methods maintained

  So that existing construction materials and methods can be maintained, we have improved performance just by improving the hose and adhesive. Because of this, construction companies do not have to change equipment or learn new construction methods; they can use this method immediately.

(4) Future plans

When there are any bends in the existing pipe, it cannot be replaced with PE pipe by applying trenchless replacement methods, but this method has the advantage that it can be used even if there are bends in the existing pipe. We believe that by applying this method in cases where conventional trenchless methods cannot be applied, it can be used to reduce the amount of earth excavated during construction.

2. 4. Conclusion

In order to reduce the environmental impact of construction, Toho Gas is actively involved in the improvement and development of trenchless methods and restorative repair methods. This paper introduced examples of trenchless methods and restorative repair methods that we have improved and developed.

The social demands faced by the gas business are becoming more diverse every year, and even in gas construction works there is an increasing need for lower costs and lower environmental impact. To respond to these demands, we believe that it is important to increase the application rate of trenchless methods and restorative repair methods, and going forward, we will continue our development and improvement of these methods.

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