9TH PIPELINE TECHNOLOGY CONFERENCE
Berlin, 12-14 May 2014
Session 6

TRENCHLESS PIPELINE REMOVAL (TPR)

Alfredo Frassinelli[1] and Benedetta Furlani[2]

[1] ENERECO (Fano, Italy)
[2] ENERECO (Fano, Italy)

ABSTRACT: Trenchless Pipeline Removal (TPR) is a new technology meant for pipelines who have reached their service life end. The TPR method can be applied where it is not possible or not allowed trenching for the removal, in the same way as it is for new installations.
Currently if a pipe cannot be removed by open cut method, it is abandoned. For the pipeline owner the removal of a pipeline is necessary to relieve him from any obligation towards land owners and Authorities; additionally, from the environmental point of view, a pipe which is left buried can be considered as a waste.
The trenchless pipeline removal starts from the helical cut of the pipe, using waterjet cutting. In this way the pipe can be pulled out, because the cut pipe behaves as a spring thus reducing its section and the pipe-to-soil friction as a consequence.
On-site tests have demonstrated the feasibility of trenchless removal, which at present can be applied to pipe sections of about 200 m, for diameter greater than or equal to 10 in.
This year the TPR method will be used for removing critical sections of old pipelines of the national gas network.

1. INTRODUCTION

In Italy, as well as in other Countries, it is often necessary to install new pipelines to replace the old pipes that have reached the end of their service life and are to be abandoned or removed.
The decommissioning of a pipeline requires a series of activities to fulfil safety requirements: pipeline evacuation, cleaning, inerting or cement mortar filling (if any). However, over time, the abandoned buried pipe requires maintenance of all pertaining restoration (such as morphological / hydraulic restoration where necessary), since the owner of the service is held legally responsible to third parties such as Local Authorities and private owners.

When a non-operational pipeline is removed, the advantage for the pipeline owner is the termination of all right of way, related obligations and responsibilities. On the other hand, the removal activity has many problems (as well as costs) which are typical of the construction phase - not only related to the construction site arrangement but even for the mandatory final site restoration.
Pipeline removal is usually carried out by open cut excavation. The pipe is first cut into pieces for transportation, then the trench should be backfilled by excavated soil compaction and all restoration must be implemented in terms of soil stability and vegetation, reinstating the pre-existing condition.

In many cases, the removal with open cut excavation can be difficult; in some cases not advisable or even allowed. These include: road crossings, river crossings, areas with unstable soil, channels with dikes and environmentally protected areas. Therefore the pipe in these sections can only be abandoned.

2. ENVIRONMENTAL CONTRADICTION

During the design stage of a new pipeline to replace an old pipeline, it is very common to run into a strong environmental contradiction:
In particular sections such as water channels, vineyards, environmental protected areas, etc., where the pipeline for various reasons cannot be laid using the traditional open cut method, the use of trenchless technologies make possible to maintain the routing. One of the major advantages of the trenchless installation technologies is to ensure that the construction will have the as minor as possible impact from the environmental point of view on the surrounding areas.
On the other side, at a distance of a few meters from the new pipeline to be installed, in the same environmental situation, the pipe to be replaced can only be removed by open cut method, thus leading to the same consequences that for the new installation are strongly avoided.

It is up to the relevant Authorities to authorize the removal by open cut method, but for the same reason for which the installation is allowed only without trenching, in the same way to dig for removing the old pipe cannot be authorized, therefore the alternative is that the pipe is left buried in that section, filled with concrete.

But this cannot be considered the optimal solution, because any buried material, such as a piece of pipe that is not anymore part of a buried infrastructure, can be classified as a waste.
The environmental laws are recently more restrictive and are prescribing the removal of any “out of service” facilities as an old pipeline is. On this purpose, from 2013 in Italy any new project is authorized only if the investment cost includes also the budget, as well as detail procedure, for the final dismantling at the end of the operating life. The owner shall mandatory give a financial guarantee for such activity.

Additionally, for pipe sections that are left buried due to the technical or legal impossibility of their removal, since from the design phase, during the Environmental

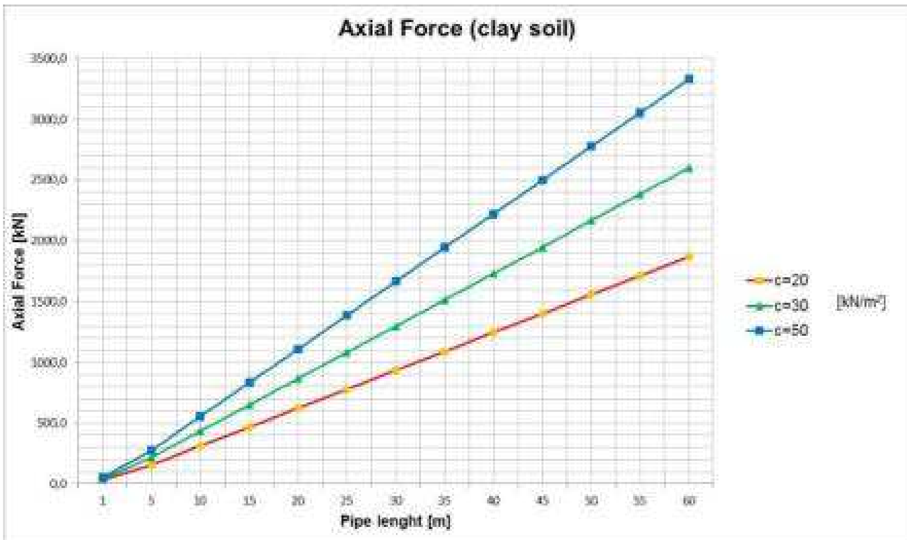
Impact Assessment procedure, it is becoming quite common the Authority request to have a long-term monitoring of any releases in the ground of iron oxides and pollutants caused by the abandoned sections of pipe.
It is clear that leaving a section of pipe abandoned does not relieve the pipeline owner from his obligation towards third parties (land owners, Authorities), remaining legally and economically responsible in terms of restoration of the involved areas and for complying with statutory requirements, even though the pipeline is no longer in operation.

For all the reasons above, the relevance of the pipeline removal issue was the inspiration and the starting point for the study of a possible trenchless alternative solution.

3. DESCRIPTION OF THE TPR METHOD

The soil-to-pipe friction depends on the soil type, the burial depth, the pipe coating material roughness, etc..
The necessary pulling force to extract an old buried pipeline without trenching can be calculated considering the soil-to-pipe friction and the pipe geometry (diameter and length).
The resulting pulling force is very high and it is generally impossible to move a buried pipe, except for very short sections (few meters) and in particular favourable conditions.

Figure 1 - Pulling force to extract a pipe of different length and in different soil conditions.



To facilitate the removal operation, the new Trenchless Pipeline Removal (TPR) system is based on the principle of reducing the pipe diameter, thus leading to a drastic decrease of the friction force between pipe and soil.
To achieve that, a helical cut is carried out on the pipe to maintain the stability of the hole, until the pipe is left in its original position. This helical cut along the section to be

removed lets that the pipe behaves as a spring when pulling and rotating forces are applied on it.
As far as helical cutting of the pipe is concerned, there are various methods of cold cutting, including the waterjet system.
The cut must be done from inside the pipeline. Therefore, a cutting machine has been designed and assembled to be inserted in the pipe hole. The cutting machine consists of a rotating head with a waterjet nozzle. The body of the cutting machine consists of two trolleys which allow longitudinal movements along the pipe, as shown in **2**, **Figure 3** and

Figure 4.

Figure 2 - Cutting machine design.

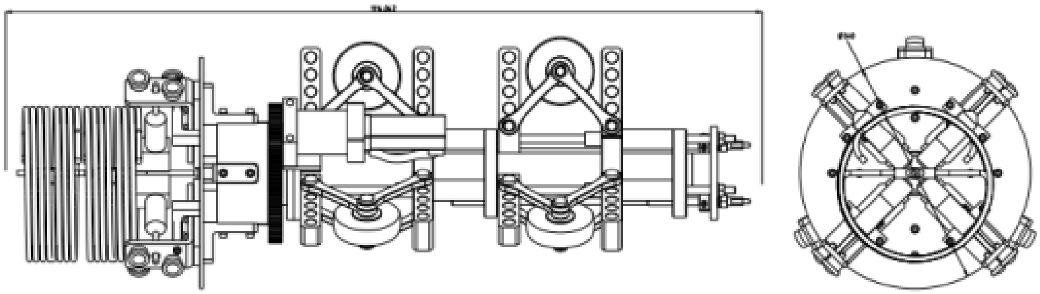


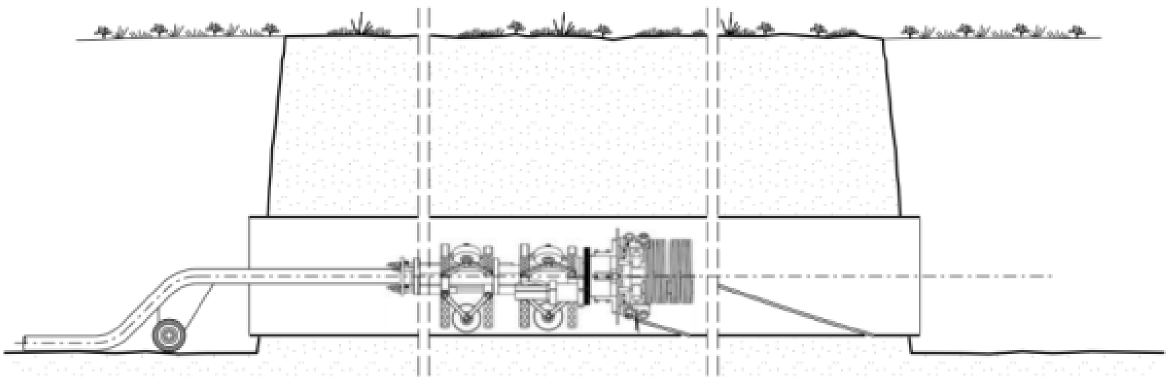
Figure 3 - Cutting machine.

Figure 4 - Cutting phase (workshop test).

The waterjet technology has been selected among other possibilities for the great benefit in terms of safety, because it is a cold cutting method without the risk to generate sparks which could trigger to explosions in presence of residual gas or hydrocarbons.
This solution has been widely confirmed as appropriate for this kind of application during workshop tests and site tests both from a qualitative (continuity of the cut) and quantitative (cutting speed estimated at about 20 cm/min) point of view.

In the following **Figure 5** it is represented how the cutting machine operates inside of a buried pipe to be removed, making a helical cut along the whole length by waterjet cutting.

Figure 5 – Schematic section of the on-site cutting phase



Once the cut is completed, for the extraction of the pipe it is necessary to use an equipment capable to generate pulling force and torque. Due to the particular situation of a long pipe section to be removed, the use of an HDD rig (see **Figure 7**), not in the traditional way it is meant to operate, seem to be the appropriate way.
In fact, a pulling head is to be welded to the pipe, to be connected with the rods of the HDD rig.

The combination of pulling force and rotation, as shown in **Figure 6**, activate the spring effect along the pipe which starts its elongation. The reduction of the pipe section is propagated along the entire length, when the reduce friction is lower that the pulling force the extraction begin.
By means of the HDD rig the extraction continues until the entire pipe is pulled out from the soil where it was buried.

Figure 6 – Schematic section of the extraction phase

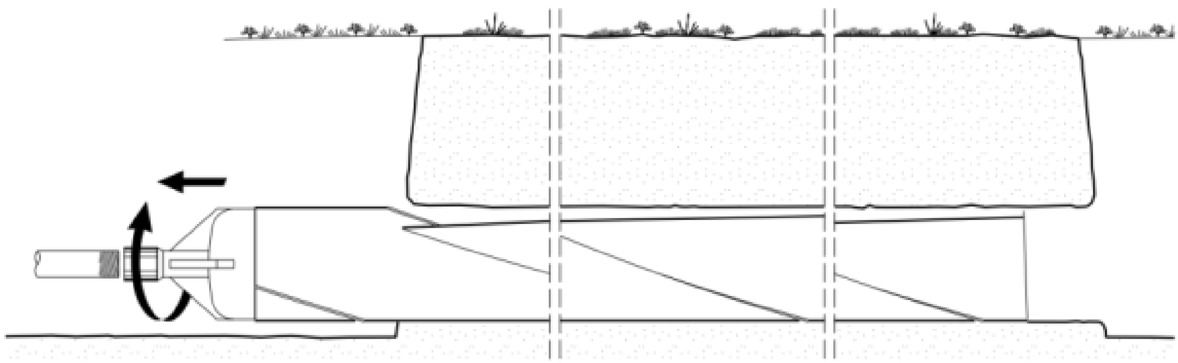


Figure 7 – HDD rig.

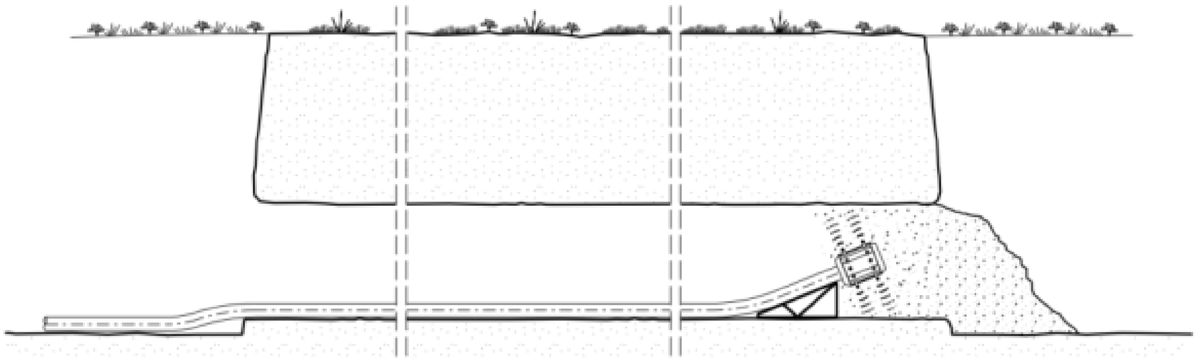
In order to complete the intervention, it is not to be underestimated the filling of the remaining hole with suitable material.
The filling phase can be contemporary to the extraction phase, when the soil characteristics do not guarantee the stability of the hole; otherwise, the filling can be carried out as final phase after the extraction.

When it is necessary to stabilize the hole before extracting the pipe, it is recommended to use a suitable mixture of water and clay that has the dual purpose of facilitating the extraction phase and compensating for the gap left. In fact, it is necessary to fill the hole in order to avoid soil collapse once the pipe has been removed.

In other cases, if the soil collapse is not envisaged for the characteristics of soil, for example in cultivated areas and where the groundwater level is not intercepted at the pipe laying elevation, another simple alternative can be used, such as pipe filling with expanded clay aggregates or sand that can be insufflated in the cavity (see **Figure 8**)..

The filling procedure is still under evaluation, in particular for selecting the appropriate material and optimizing the operational sequence.

Figure 8 – Schematic section of the filling phase (after the extraction)



4. FIELD TESTS

The TRP method has been already tested on site with positive results.
The first pipeline cutting and removal field test on a ND 500 (20") pipeline section of about 30 m has been performed in September 2012.
The second test has been completed in August 2013, on a ND 550 (22") pipeline section of about 50 m, including cutting, removal and filling phases.

In the following
the main characteristics of the two tests are summarized:

Table 1: Field tests summary

	1st TEST	2nd TEST
Location	***Cremona (Italy)***	***Minerbio (Italy)***
Diameter	***20''***	***22''***
Length	***30 m***	***50 m***
Pipe material/ Wall thickness	***Carbon steel, 11.1 mm; polyethylene coating***	***Carbon steel, 10.3 mm; Coal tar coating***
Soil	***Silty sand***	***Clay***
Waterjet cut pressure	***6000 bar***	***4000 bar***
Helical cut pitch	***3 m***	***3 m***
Cutting Length - Duration of the cutting phase	***32 m - 4 hours***	***45 m - 5.5 hours***
Pulling Force - Torque	**-**	***500 kN - 30 kN·m***
Filling	**-**	***Expanded clay***

In the following pages some images of the main phase of the Trenchless Pipeline Removal method (cutting, extraction, filling) are shown:

Figure 9 (a-b)– Cutting phase during site tests

Figure 10 (a-b-c-d) – Extraction phase during site tests

Figure 11 (a-b-c) – Filling phase with expanded clay during site tests

The expectation from the future field applications is to gather the site data necessary for the assessment of the TPR method.
In particular the objectives are:

- To evaluate the effect of different helical pitch on the same pipe length (about 40/50 m).
- To investigate the behaviour, applicability and reliability of different filling material (i.e. expanded clay aggregate, eco-compatible bentonite mixtures, dry sand, etc...) for the different application, in particular when it is requested soil stability after removal, for example at road crossings.

- To evaluate the effect of the length to be removed and determine the maximum limit of this application, considering that each section can be divided in two, operating from both ends.

In addition, a study of the theoretical model of the cut pipe during extraction is being carried out (considering length, helical cut pitch, diameter, soil characteristics, etc..) for comparison with the site results.

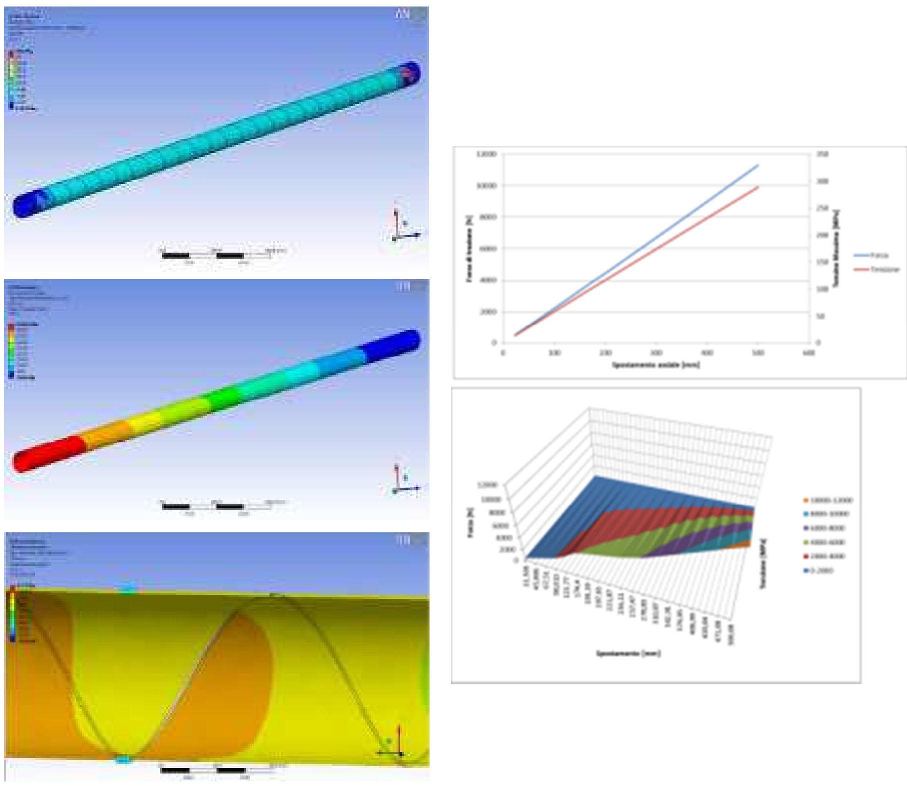
5. THEORETICAL MODEL

The mathematical simulations of the cut pipe behaviour during the extraction are being carried out.
The parameters that affect the model are:

- Pipe characteristics (diameter, wall thickness, length, external coating, material)
- Soil characteristics
- Spiral cut pitch

The expected pulling force and rotation necessary for the extraction shall be compared with those recorded during the site tests. This will allow a proper set up of the model.

Figure 12 – TPR simulation screenshots.



6. OTHER APPLICATION OF WATERJET CUTTING IN THE OIL AND GAS FIELD

Other uses of the waterjet cutting in the oil and gas field can be envisaged considering the benefit of this cold cut technology.

Possible different uses of the waterjet cutting system are:

a) Pipeline external cutting on site for valves installation, tees for branch connection or other special tools (see **13**)

Figure 13 – Pipeline external cutting.

b) Bevelling end preparation for steel pipes with very high wall thickness.
The waterjet cut technology will be used for the prefabrication of pipes with about 80 mm wall thickness (see **Figure 14**), with good results in terms of quality of the cut and time compare to other methods.

Figure 14 (a-b-c-d) – Bevelling end on very high wall thickness steel pipes.

c) Realization of holes on very high wall thickness steel pipes for weldolet, sweepolet and other special pieces to be welded to the pipes.

7. CONCLUSIONS

The positive results of the site tests have demonstrated that the helical cutting of the pipe is the optimal solution for the removal of pipeline sections without trenching.

The real potential of this new system, in terms of applicability in different scenarios, is to be verified in the future with the implementation of this method in those areas where the impact of a traditional pipeline removal by trenching is not allowed.
With additional site data and further experience the system will be set up and all the operations will be optimized, in order to reduce the time and costs of this application.

For the time being, the TPR method can be utilized for pipes with diameters greater than or equal to 10”.
At present, the TPR system can operate on straight line or elastic bend sections of a pipeline.
With regard to the maximum length of the pipeline to be removed, the current goal is to remove up to 200 m that can be obtained by the extraction at both ends.
Like all trenchless technologies, TPR is in constant evolution.
Hopefully the TPR system, like other trenchless technologies, could evolve over time and could be the solution for the removal of increasing pipeline lengths, thus safeguarding particular environments and making it possible to remove pipelines in certain situations where, to date, abandoning the underground pipe is mandatory.

8. REFERENCES

Chirulli, R. - Manuale di tecnologie No-Dig, Le tecniche e le metodologie di progetto e di calcolo (*No-Dig manual: No-Dig Technologies Manual: techniques and methods for design and calculation*)

Vescovo, C. and Lazzarini, U. - La costruzione di condotte in acciaio nel segno del rispetto ambientale: le Tecnologie Trenchless (*Steel pipe construction respecting the environment: Trenchless Technologies*)

AIW: Associazione Italiana Waterjet (Italian Waterjet Association) http://www.aiw.polimi.it/