Heating long, heavy oil pipelines

Dean White, Heat Trace Limited, UK, provides a comparison between the benefits of a series resistant heat trace cable vs skin effect heat tracing.

A Greek construction company headquartered in Athens – Terna S.A., – were approached by Greece's Public Power Corporation (PPC) to design and build a much-needed second power station for the island of Rhodes, powered by heavy fuel oil (HFO).

The chosen site for this new project was in the south of the island, located approximately 5 km north of Prasonisi Beach.

As with several of the power stations located on the Greek islands they are oil-fired. In order to meet the requirements of the Greek Government to reduce harmful emissions, the use of low sulfur content fuel oil was preferred. This low sulfur content fuel oil is a very heavy and waxy oil, resembling shoe polish when at low temperatures. It is therefore necessary to heat the oil to above 50˚C in order to lower its viscosity and to facilitate efficient pumping.

The oil is delivered by sea to an offshore pontoon tanker offloading point, approximately 600 m from

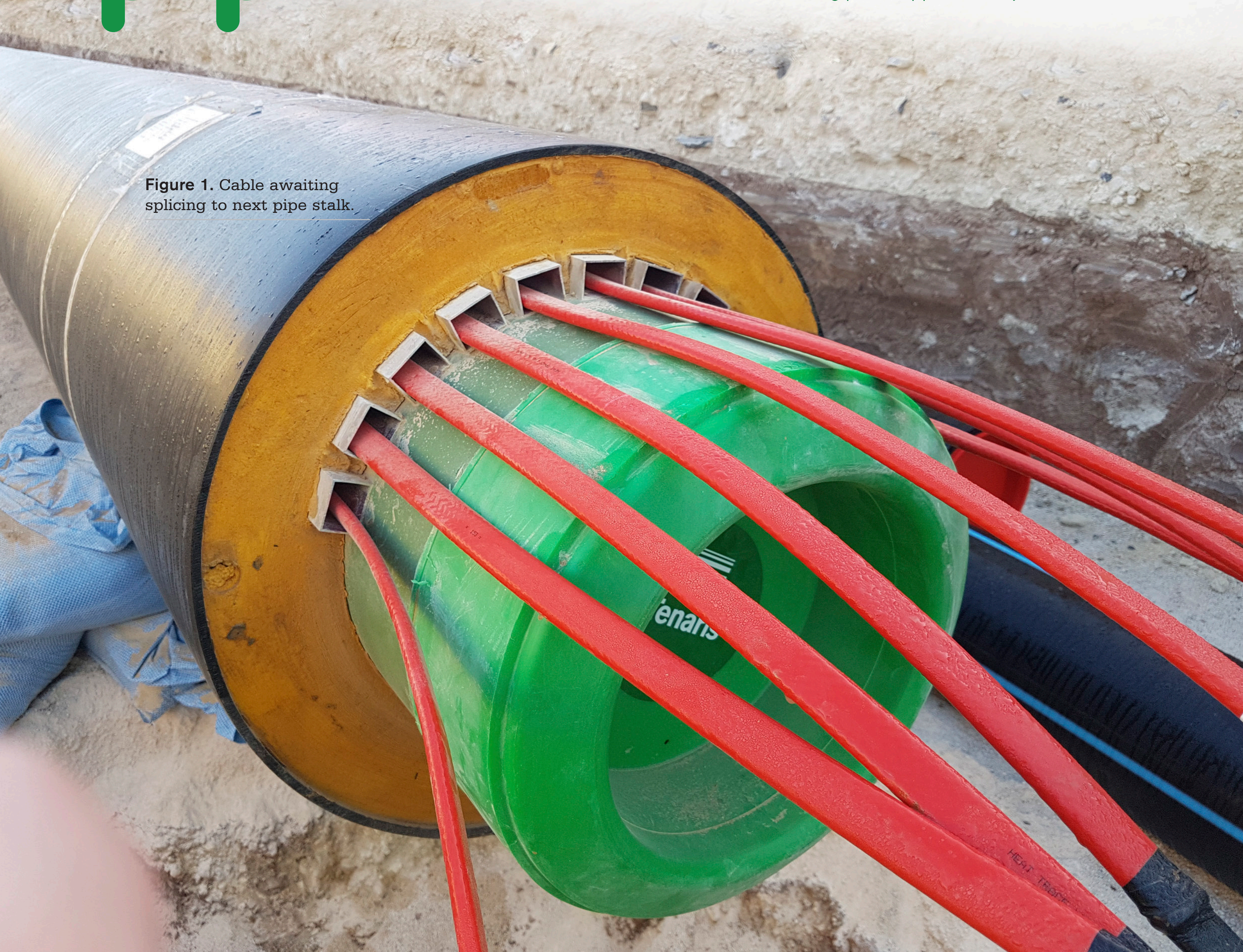

Figure 1. Cable awaiting splicing to next pipe stalk.

the shore, in relatively shallow water. Therefore, a 600 m subsea section of pipeline was required in order to deliver the fuel oil from the offshore pontoon to a small oil storage terminal located onshore. The oil would then be pumped approximately 4.5 km to the main fuel oil storage point. This long, buried, cross-country pipeline would also require heating along its entire length, until it reached the main storage tanks.

Terna S.A. selected Socotherm S.p.a. (Adria, Italy), a pipeline coating and pre-insulated pipe manufacturer, to provide the coated and pre-insulated pipes, together with an electrical heat tracing system for the pipeline.

The original pipeline heating system specifications were designed around the provision of a 'skin effect' heat tracing system. This type of electric heat tracing system has been in use for many years and, since its patents expired many years ago, several heat tracing vendors can offer this type of heating solution.

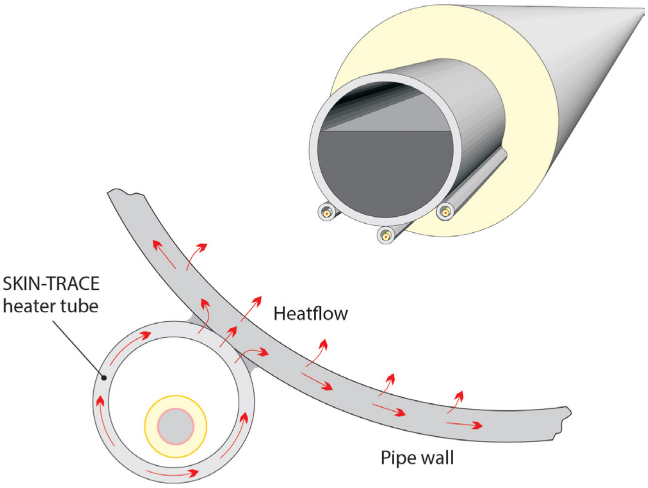

Figure 2. Skin trace system.


Figure 3. LONGLINE series pipe stalk storage area.

A pipeline heating system

Skin effect heating, as a solution for providing heat to a long pipeline, is very robust once it is installed. However, the cost to install and operate the system is very expensive in relation to both the time and skilled labour requirements.

Skin effect heating is installed by inserting a skin tracing cable into carbon steel tube(s) attached to the main production flowline (Figure 2). This tube can either be strapped to the production pipeline or, more often than not, welded to the pipeline. Strapping the tube to the pipe is only efficient when low power outputs and low temperatures are required, such as for freeze protection applications. Where higher power outputs are required to maintain elevated temperatures, or a higher thermal efficiency is required, it is normal to either stitch-weld the tube to the flow pipeline or, in extreme cases, the tubes will be 100% fillet welded to the flow pipeline.

The problem with welding the tubes to the flow pipeline is that skilled labour is required, to ensure that the tubes are not damaged in any way by the welding process and that no damage occurs to the actual flowline either. In addition, any corrosion coating on the pipeline will need to be fully restored after welding operations are completed. It is after this stage is completed that the thermal insulation is applied to the pipeline, followed by a final outer cladding layer on the finished pipeline.

When the pipes and tubes are all joined together at site, a non-magnetic current carrying conductor is pulled into the tube. The conductor, together with the tube itself, is connected to the power supply. The current flow is concentrated on the inner surface (or skin) of the tube.

The subsequent heat generated in the tube is transferred into the main flowline by conduction. This phenomenon is called skin effect heating. A small proportion of the heat generated is also produced in the current carrying conductor. However, one of the downsides of a skin effect heating system is that it is only approximately 80 - 85% efficient, due to reactive and inductive impedances that are induced.

The pre-fabricated sections of pipeline, referred to as 'pipe stalks' are delivered to site where they will be welded together to form the long pipeline. The protruding skin effect tubes would then need to be coupled together. This further compounds the labour issue, as all of the tubes need to be welded together during the pipeline assembly at site, in order to provide a completely airtight seal. In addition, carbon steel pull boxes are welded to the pipe at distances between 80 - 150 m apart, to allow the actual skin effect cable to be pulled through the carbon steel tubes.

All of this welding, pneumatic testing and subsequent repair to the pipe's anti-corrosion coating results in a slow and laborious installation. The completed pipeline is then laid on the seabed, buried in a trench or routed overland to its final destination.

An alternative system

As an alternative solution to the skin effect system, Heat Trace Limited proposed that a series resistance LONGLINE heat trace cable would provide a less expensive system – both in the purchase of materials and components and, more importantly, significantly reducing the installation costs (Figure 4).

Instead of welding carbon steel tubes to the pipe, a number of rectangular steel box sections would be strapped (not welded) over the anti-corrosion coated pipe during fabrication at the factory. Following this, a polyurethane foam thermal insulation and final outer cladding would be added.

When the fully assembled pipe stalks arrived at site, they were welded together as normal and the anti-corrosion coating repaired as necessary. No further welding operations were required.

A total of nine rectangular box sections were used on the flow pipeline for this project, to accommodate 3 × 3 phase heating circuits (Figures 1 and 3). The box sections do not act as part of the actual heating system and are simply used as a method to get the series resistance heating cables onto the pipe, beneath the thermal insulation layer.

The methods for pulling, or pushing, the cables through the box section can vary from project to project. This can be undertaken either by feeding pulling ropes inside of the box section and pulling the cable through, or by pushing the cable through (Figure 5). This project allowed an installation rate of 20 m/min. of cable to push the cable through the box section by hand, with 400 m lengths being successfully installed in a single operation.

On other projects, a capstan winch and pulling ropes have been utilised. This increases the installation rate to over 40 m/min. of cable.

Socotherm S.p.a. requested many physical tests and computational FEA studies to prove that the technology would provide the required solution of heating the HFO pipelines up to the required temperature over a 48 hr period. After successfully completing a number of different tests, Socotherm S.p.a. concluded that the series LONGLINE solution being proposed had many commercial, technical and installation benefits and advantages over a skin trace system.

For this particular project, due to the tourist season, the installation team were limited to only installing approximately 400 m of pipe at a time. However, the cables were easily installed within half a day.

Once all the the LONGLINE cables had been installed into their respective box sections, tests were undertaken on each cable section before splicing to the next cable (Figure 1). This was followed by further electrical insulation resistance tests.

Once all of the tests had proved positive, the heating cable field joints, together with the sections where the cable transited the pipe joint (Figure 6) were covered over with thermal insulation, then cladding was applied and the pipe trench backfilled.

In a similar fashion, the cables on the subsea section of pre-insulated pipeline were installed through the box sections and water-stops. Once completed, the 600 m subsea section of pipeline was towed out to sea and lowered into position. The pipeline was then further protected with a concrete cover to protect and secure it in place on the seabed.

The completed fuel oil tanker offloading system was commissioned in April 2018 and successfully received the first oil deliveries to the site in May 2018.

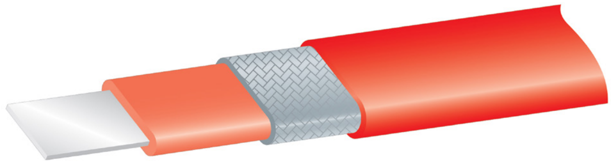

Figure 4. LONGLINE series resistance heater.

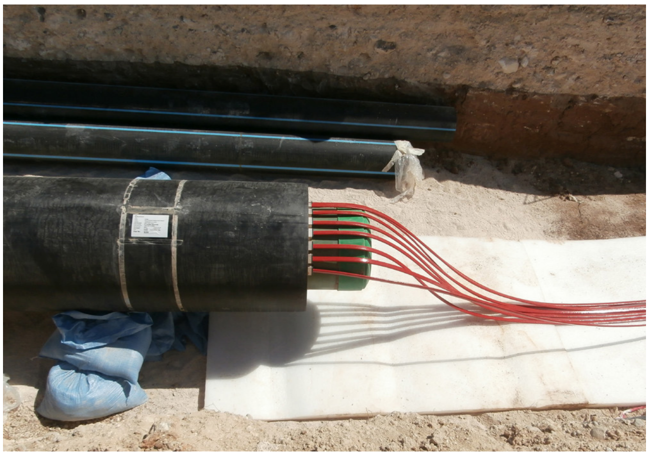

Figure 5. Cable feed point.

Cost comparison between heating systems

Selecting a typical 5 km sample pipeline and designing both a LONGLINE heating system (using box section traceways) plus a skin effect heating system (using the ferrous tubing), the following comparisons can be drawn.

Regardless of the size of the pipe, both systems were targeted to provide a minimum power output from the heating system of 30 W/m along the length of the pipe. Both sets of results include for the provision of a transformer and control package. A skin effect heating solution also requires an additional load balancing unit that is not required for the LONGLINE solution.

Figure 7 illustrates that the CAPEX of the LONGLINE heating system is approximately 80% of that of a similarly costed skin effect heating system. This alone is a significant saving. Other real savings are in the installation time and cost.

Installation and commissioning for a LONGLINE solution accounts for approximately 4% of the total

Figure 6. Cables transiting pipe joint.

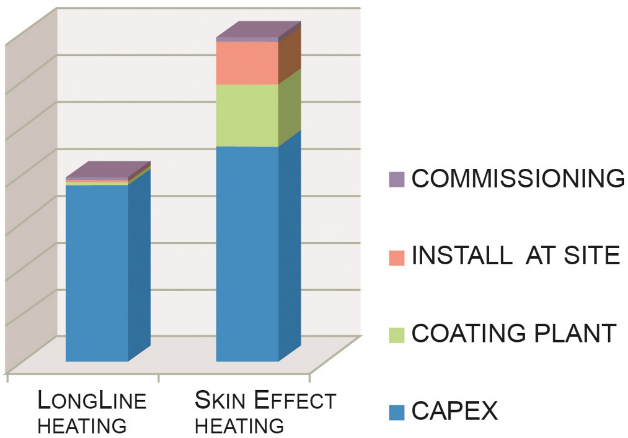

Figure 7. LONGLINE vs skin effect – cost comparison.

heating system cost. For skin effect heating systems, this rises to approximately 33% of the total heating system cost.

Overall, considering CAPEX and installation costs, an installed LONGLINE solution can result in real savings of around 40% of the cost of an equivalent sized and installed skin trace solution.

Other applications

Applications may include, but are not limited to:

- Subsea tiebacks.
- Offshore/onshore tanker offloading pipelines.
- Oil storage and distribution facilities.
- Multi-kilometre cross-country pipelines.
- Offshore crude oil export terminals.

The LONGLINE system can be used in many applications, where elevated temperatures are required in order to mitigate flow assurance problems in multi-kilometre pipelines. A similar system was used on the world's first electrically trace heated, reeled pipe-in-pipe system (ETHPIP) for a 6.5 km heated subsea gas condensate tieback, from the Islay wellhead to the Forvie manifold in the North Sea, at a depth of approximately 120 m.

One of the earliest LONGLINE heating systems used with pre-insulated pipe sections was installed in the 1980s in New Zealand. This was for approximately 30 km of buried, pre-insulated crude oil pipelines from onshore wellheads to a central gathering station.

With the savings that are achievable with the LONGLINE system, when compared with a skin effect heating system, many pipeline heating applications exist in upstream, midstream and downstream areas.

The capability of LONGLINE heaters changed when, to meet the demands of long pipeline operators, the trace heating world's first continuous metal extrusion facility was designed and built. This unique facility can produce virtually endless lengths of low resistance profile conductors, as well as continuous metallic over-jackets. It is now possible to produce heating circuits much longer than existing systems, at significantly lower costs. The metallic over-jacket results in a heating cable with massively increased mechanical strength when compared with the relatively low strength of alternative systems. This enables the LONGLINE cables to be pulled greater distances without damage, thus minimising the number of field cable joints. Now, a single electrical power supply point may feed LONGLINE circuits of approximately 50 km, such that power supply point intervals of 100 km are possible for centre-fed heating circuits. To achieve these longer circuit lengths, supply voltage capabilities now extend up to 6.6 kV. Investment has also continued in conductor jointing techniques, recognising that joints are the potentially vulnerable point of any heating installation.

The capability now exists for insulated and heated pipelines for both onshore and offshore pipelines that transport hydrocarbon products over multi-kilometre distances. Also, long heating circuits ensure a minimum number of power supply points, resulting in significant CAPEX savings. Additionally, the LONGLINE heating system is easy to install without damaging or affecting the corrosion resistant pipe coating.

The original LONGLINE heating system, launched by Heat Trace Limited more than 30 years ago, has been refined, improved and upgraded into a variety of heating cables, from which the most appropriate type may be selected to suit any particular application.

In conclusion, these ongoing developments provide wax and hydrate mitigation systems that provide operators with efficient heating solutions for future long pipeline developments. This means optimising hydrocarbon transportation systems by providing a solution that offers significant CAPEX and OPEX savings when compared with alternative heating solutions.