In considering electric heat tracing of long pipelines, we must first define – what constitutes a long pipeline? In essence, this may be construed as any pipe having a length longer than can be accommodated by (until now), convenient, cut-to-length, parallel resistance tracers. Such lines must be individually designed, and the heating systems made specifically for that pipeline. A number of different types of system are available, the type usually determined according to how long the long pipe is.

**Long pipelines in plant areas**
Industrial electric heat tracing (or trace heating) in, for example, refineries, chemical or power plants, comprises in-plant pipework and equipment, together with interconnecting pipelines between plant areas. However, the systems offered for the in-plant and interconnecting pipes vary considerably.

In-plant piping is usually complex, comprising many short pipe lengths connected together and valved to produce a myriad of flow permutations, making temperature control difficult – a correct design would often require a separate thermostat on every piece of pipe, which may be commercially prohibitive. Systems have evolved that, wherever possible, utilise semi-conductive self-regulating heating cables that are usually inherently temperature-safe. This alleviates the temperature control issue, with controls employed for energy efficiency rather than temperature safety.
Areas are often classified hazardous, and inherently temperature-safe heaters provide the greatest degree of safety. The ensuring of temperature safety by means of temperature controls should be as a last resort. Whereas in the past, self-regulating heaters were limited in temperature, the author’s company, Heat Trace Limited, has developed and now manufactures, self-regulating heaters capable of withstanding temperatures in excess of 300 °C. This means that now, almost all in-plant heat tracing can be achieved with inherently temperature-safe self-regulating heating cables without the need for generic types that require controls to ensure temperature safety.

Compared with complex in-plant piping, interconnecting lines from area to area are usually simple, single pipes of up to, for example, 1 km in length. These can be either static or flowing according to process requirements. This simplifies temperature control, often to a single device. Unfortunately, until now, inherently temperature-safe self-regulating heating cables have been unsuitable for interconnecting lines, as they connect to a single phase supply, and their parallel resistance principal results in a maximum circuit length of, typically 100 m, due to volt drop along the power conductors. In order to avoid the need to provide electrical supply points along the pipe route, systems have evolved that utilise existing supplies at the ends of the interconnecting pipe. These are always of the series resistance type, with each heater being designed specifically for the individual pipe to be traced, and each being temperature controlled, often for temperature safety as well as for energy efficiency.

Now, Heat Trace have developed a three phase self-regulating heating cable capable of circuit lengths up to 750 m. This means that lines up to 1.5 km between supply points can now be heat traced with inherently temperature-safe self-regulating heaters, eliminating the need for specifically designed systems.

### Longer pipelines to plants

It is not uncommon for much longer pipelines to run to a plant, from, for example, an on/off-loading berth into a refinery, or power plant. The line may only be used occasionally, for example when fuel oil is being delivered to a power plant. Again, transfer lines of this type are usually simple, single pipes of anything up to 10 km long with power supplies at the pipe ends only. Temperature control is simple, often using a single control device.

Pipe runs from 500 m up to 2 km can normally be most economically satisfied by a three conductor ‘Longline’ series resistance style of heater (Figure 4) whilst longer runs may require three runs of single conductor ‘Longline’ series heaters (Figure 5). A 10 km transfer line would typically comprise 2 x 5 km ‘longline’ heating circuits fed from the plant and jetty ends of the pipeline.

For very long pipelines, Skin-Trace systems, (as described below) become a viable option. The breakeven pipe length at which Skin-Trace becomes the most economical solution depends to some extent on the location and cost of labour. Skin-effect heat tracing is both labour intensive and craft sensitive, so a skilled workforce in a low cost region will have a lower breakeven point than areas in which labour is expensive.

Additionally, ‘Longline’ series heater systems are now available from the author’s company comprising heating conductors of special low resistance alloys rather than conventional copper. This can substantially reduce the ‘Longline’ system cost, now often switching the balance away from Skin-Trace for other than extremely long circuit lengths.
Pipelines may be above ground or buried. When buried, thermal insulation in the form of pre-insulated pipe sections is usually specified.

**Cross-country pipelines**

Long distance pipelines that are required to be heated, for example, for the transportation of oil, though sometimes for freeze protection of water, will often require a skin-effect heat tracing system to meet the power requirements where supplies may be many kilometres apart.

The system comprises a ferro-magnetic steel heating tube, typically 25 mm, attached to the pipe to be heated, the heating tube containing an insulated power conductor. The heating tube and conductor are connected together at one end and to the power supplying transformer at the other. Heat is produced by skin and proximity effects, mostly in the heating tube. The current is concentrated towards the inside skin of the tube, to the extent that the potential at the outer skin is effectively zero.

The tube and conductor sizes, length and supply voltage determine the power generated by the system. The system has a power factor of approximately 0.85, thereby having a 15% inefficiency when compared with other systems for long pipelines.

The insulated conductor is pulled into the tube via ‘pull’ boxes, which are welded to the heating tube at intervals along the line. It is critical that all welding of tubes and fabricated items are pressure tight and are free of weld spatter that could damage the insulation of the conductor during the pulling operation. Hence the need for a skilled and experienced installation team is of paramount importance.

For long distance pipelines that are buried, a pre-insulated piping system is usually specified and pipe stalks are assembled at site prior to burial. Cables are pulled through pre-formed channels fitted to the pipe.

**Oil well production tubes**

Oil wells commonly have production problems as heavy crude oil flows from the reservoir through the production tube towards the surface. The hot oil cools as it rises until its viscosity increases, and, commonly, wax is deposited on the tube walls, reducing production rates until the tube must be scraped.

Numerous ‘solutions’ have been tried such as steam injection, hot oil treatments, chemical additives, and electrical heat tracing. Electric tracing efforts have included self-regulating, series resistance tracers and skin effect systems. The lack of space between the tube and annulus will often militate against the latter. Series constant power heaters have suffered from ‘chimney effect’, whereby the heat produced rises, causing the heat tracer to run progressively hotter towards the surface, creating a potential for failure.

Early attempts with self-regulating tracers comprised a complex power cabling arrangement. Clearly, self-regulation is a
desirable feature for an ‘oil well’ heating system, as the ‘chimney effect’ is avoided.

The oil leaves the reservoir at a temperature where heating is unnecessary, however, as the oil rises and cools, heating becomes necessary to prevent waxing and eventual blockage. With the use of self-regulating cables the power produced by the tracer is at its minimum towards the bottom of the heated length where the oil is hottest. The close contact of heater to pipe ensures the cable ‘self-regulates’. However, not all heat generated by the tracer is delivered into the oil line. The annulus is uninsulated and the heat generated by the exposed surface of the cable that is not in contact with the pipe will generate warm air currents that will rise, creating a ‘chimney effect’. With self-regulating cables this is minimised, since the tracer output at lower pipe level is reduced. As the warm air rises in the annulus, it reduces the temperature difference between oil line and outer skin, reduces heat loss and contributes to warming of the oil line around other parts of its surface. Unlike series constant power cables, self-regulating cables will adjust their output based on the conditions to which they are exposed. The oil will attempt to cool on its journey to the surface, yet the heat in the annulus will increase towards the surface due to chimney effect. Self-regulating cables adapt to the changing conditions without fear of overheating or burnout as some conventional series systems have experienced.

As described earlier, the authors company have developed a three phase self-regulating heating cable capable of circuit lengths up to 750 m, a length ideal for most wells. Typically, the heater will be applied only to the uppermost half of the production tube – the crude oil is allowed to cool from its reservoir temperature to, say, 60 °C, before the temperature is boosted and maintained by the heat tracing system.

The ‘oil well’ self-regulating tracer is provided with a continuous aluminium outer sheath thus providing an extremely robust and mechanically resistant, yet light heater. Its nominal output of 40 W/m maintains the flow preventing the need for wax scraping and expensive downtime. And compared with other electrical heat traced methods, this is the only one that comprises a standard heater cable that can be cut-to-length from reel stock. So now, individually designed, and manufactured heating systems made specifically for that pipeline are no longer necessary.

Sub-sea pipelines
A subsea pipeline, or flowline, usually describes a submarine pipeline carrying oil or gas products from a wellhead to either a production platform, or a Floating Production, Storage and Offloading vessel (FPSO). It can also refers to a pipeline that carries product from the shore to a tanker on/off-loading point for transferring product from a shore storage facility to a tanker for transportation, or from a replenishment tanker to shore - for example fuel oil to a power station.
The variation in subsea pipeline requirements, range from relatively short tanker on/off-loading pipelines, to extended tie-backs on the sea bed from oil fields to a production platform. The depth of the pipeline can also vary, from relatively shallow water, such as around 20 - 30 m depth for a tanker off-loading system, to deepwater subsea applications in water depths in the region of 3000.

Shallow water tanker offloading pipelines can usually vary between 500 m to 5000 m or more in length. They can generally be satisfied with heat tracing systems similar to those used on above ground long pipelines. Utilising one or more series resistance heating cables fitted to a sealed, pre-insulated, pipe-in-pipe system, between a pipe line end manifold (PLEM) located on the sea bed and the on-shore tie-in to existing pipe work. Pipelines are generally fabricated and assembled on shore and, depending on the length of the pipeline, can be either be dragged into position using specialised equipment, or floated and towed to position then sunk to the sea bed. As the tanker only off-loads infrequently, there is usually a need for sufficient power to be installed for heat raising the pipework to the correct temperature over a period of several hours prior to the tanker arrival. Due to the inaccessibility of the pipeline on the seabed, redundant heating circuits are frequently specified.

In deepwater applications with water depths approximately 3000 m or more, it was necessary to develop ultra high quality and reliable heated pipe-in-pipe systems. These systems can usually employ several heating cables placed around the inner flowline. When using conventional heaters, the reeling process of the pipe-in-pipe system onto the pipe lay vessel, caused the heaters on the pipe to stretch or compress, depending on their position on the inner flowline. When the pipeline was unreeled and laid on the sea bed, this resulted in contact between the heater and the inner pipe being intermittent and heat transfer was very poor and unreliable. Therefore a new style of heating cable, DUOFLEX LongLine, was developed by Heat Trace Ltd, having the ability to stretch and compress by a proportion of its length, yet return to its original position on the pipe. Working in close partnership with Technip UK, a major subsea services company, the joint development produced a unique reelable, heated pipe-in-pipe system, capable of multi-directional flexing. This greatly improved contact between the heater and the flowline and improved heat transfer, resulting in a very efficient and reliable heating system. Joint world patents were awarded for this reelable, heated, pipe-in-pipe system.

**Summary**

Clearly, the designer will wish to avail himself of inherently temperature safe, convenient, cut-to-length tracers wherever possible. But whereas, until now, specifically engineered heat tracing systems became necessary at around 200 - 300 m, now it is possible to move that break point towards 1000 - 1500 m.

The choice of system type will often be determined by the pipe length. The chart in Figure 12 provides some idea of how the pipe length and system type compare in terms of installed cost. 

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**Figure 10.** Subsea pipeline configuration - reproduced by kind permission of Technip UK.

**Figure 11.** Laying of subsea pipeline - reproduced by kind permission of Technip UK.

**Figure 12.** Chart showing cost effectiveness of different heating systems.