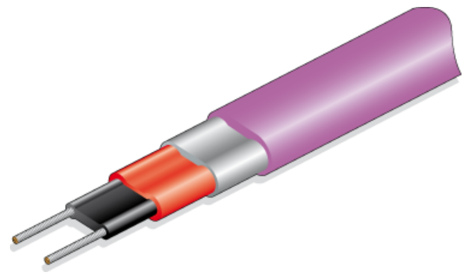
SAFETY AND LONGEVITY OF SELF-REGULATING HEATING CABLES

- *The Advent of IT-S Technology*



ABSTRACT

Ensuring temperature safety is the major obstacle for the designer of a heat tracing system.

Optimising performance service life is a further important objective.

This paper will demonstrate how IT-S (Inherent Temperature Safety) Technology provides the best solution to both these considerations.

Inherent Temperature Safety - Definition

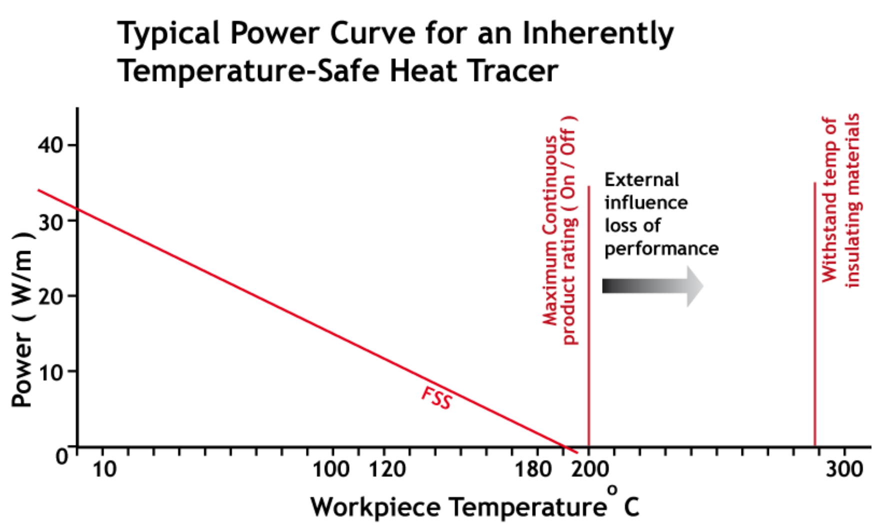
" The inherent ability to self-regulate at a temperature level below the maximum product rating and withstand temperature of the insulating materials, without the use of temperature controls."

INTRODUCTION

Self-regulating semi-conductive heating cables have become the most popular generic tracer type used to provide winterisation or temperature maintenance of pipework and equipment in industrial applications.

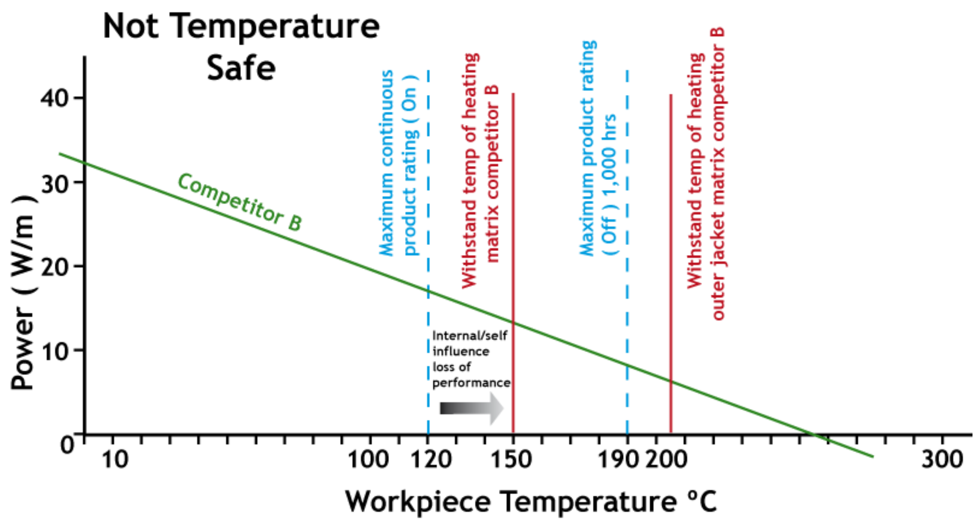
Their popularity has evolved to a large extent because they are often perceived to be incapable of overheating, and thus, temperature control, where provided, is for energy efficiency purposes, rather than to ensure temperature safety. This is often true of ***low*** temperature winterisation self-regulating tracers.

However, many tracers, particularly when higher temperature capability is required, are not inherently temperature-safe, needing controls to ensure temperature safety. In such cases they have no advantage over constant power tracers, and indeed, may also be considered to have disadvantages when taking into account their high cold start-up currents, which often necessitate larger switchgear and power cable sizing.



Until recently, these ***medium*** temperature self-regulating tracers have been accorded a “maximum un-energised exposure temperature” limit of around 200 deg. C, and a “maximum energised temperature” limit of, for example, 120 deg. C. As stated, such tracers require the provision of temperature control to ensure temperature safety.

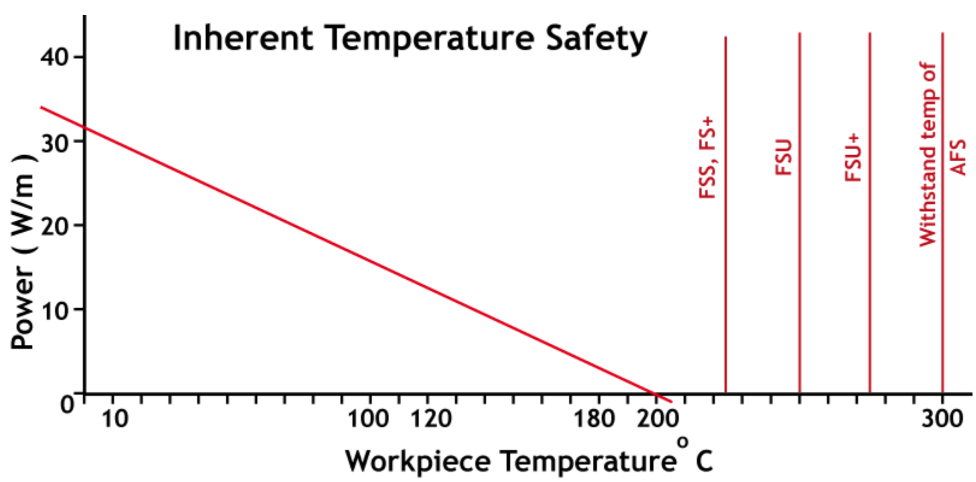
Further clouding the issue, some makers accord their heating cable products a “maximum intermittent energised temperature” limit, where ‘intermittent’ may be defined as ‘1000 hours cumulative’. It will be recognised that this equates to only 41 days, and, as such, does not sit comfortably when heater longevity is a prime consideration.

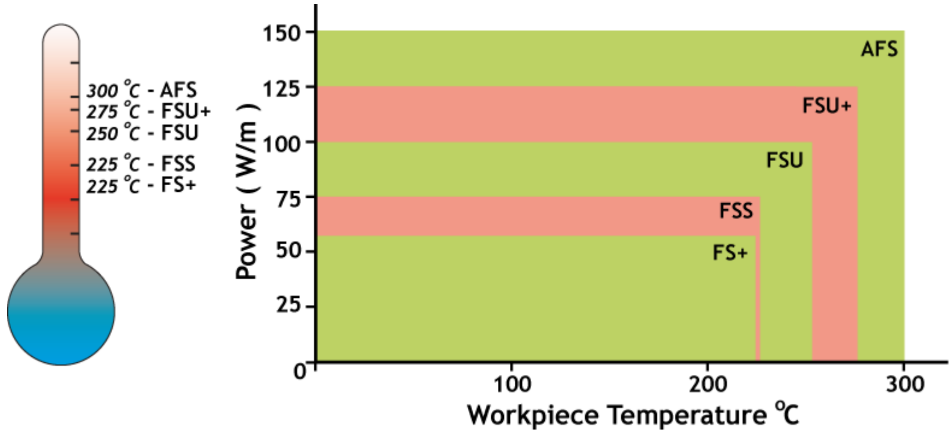


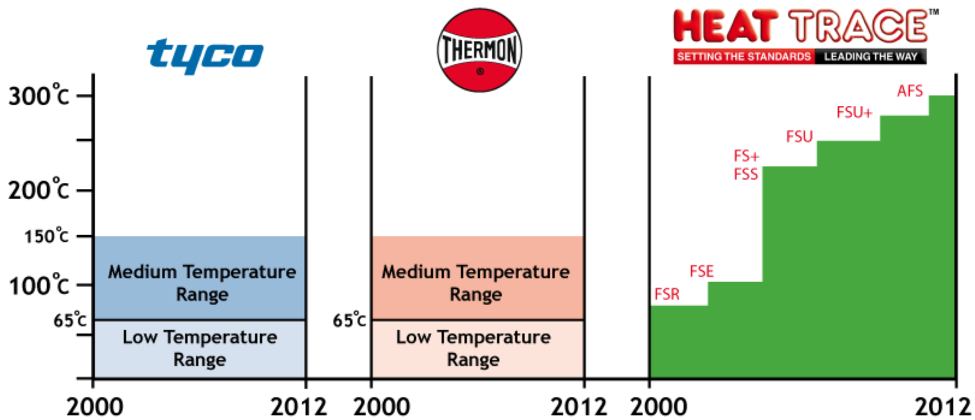
Thus, the subjects of temperature safety and performance service life are of real concern in considering heating cable selections. The need for ***high*** temperature self-regulating tracers providing inherent temperature safety has become an industry need.

NEW, HIGH TEMPERATURE, IT-S TECHNOLOGY

Those following the progress of Heat Trace in becoming the Industry’s Technical Leader, may have become aware that each of the five product ranges of self-regulating tracers recently developed or upgraded, have a temperature capability significantly in advance of anything available from a competitor manufacturer.







More importantly, ***ALL these heating cables exhibit Heat Trace's IT-S (Inherent Temperature Safety) Technology.***

IT-S occurs when a self-regulating tracer, energised under the most onerous conditions, e.g. coiled up in a substantially adiabatic enclosure, has surface temperatures, when stabilised, at a level below the limiting temperature of the materials of construction. In other words, the tracer is incapable of overheating or burn-out.

Thus, when using IT-S Technology self-regulating tracers, the designer needs only check that the T-classification of the hazard or any limiting process temperatures are not exceeded. In that event, the system will always remain temperature-safe, without the need for temperature controls
This is extremely important as the ensuring of temperature safety is the biggest hurdle faced by the trace heating system designer, who is faced with three possible choices. These are spelt out in IEC60079-30, the electric trace heating industry's standard for hazardous area applications. They equally apply in IEC62395, for safe area industrial use and commercial applications. Thus explosions or fires resulting from hot surfaces are avoided.

ENSURING TEMPERATURE SAFETY

The designer's three options are:-

- IT-S Technology self-regulating tracers
- A stabilised design, by calculation, or
- Temperature Control

Stabilised design calculations are extremely complex and should be attempted only by those competent to do so. The soft option is often Temperature Control, which clearly provides the least safe form of protection.

Temperature Safety – 'a safe system that performs'

- **Inherently Temperature-Safe Heaters (IT-S) - Safest**
- **Stabilised Design - Usually Safe**
- **Controlled Method - Least Safe**

- **All HTL's Self-Reg. Cables are IT-S - Competitors cables are not.**
- **Evolution performs Stabilised Design Calculations automatically for every pipe length.**

This is because the temperature sensor must be correctly positioned on the equipment at it's hottest point, which, when thermally insulated, is often difficult to predict. And, every piece of pipe having differing flow conditions must be individually controlled. In practice, due to commercial pressures, this does not happen, and the *system temperature safety is compromised.* Even then, should a temperature sensor become removed, or damaged, or disconnected, control is lost and *safety is further compromised.*

In Heat Trace's opinion, ***Temperature Control as a means of ensuring temperature safety should be a last resort.***

Typical Complex Pipe System

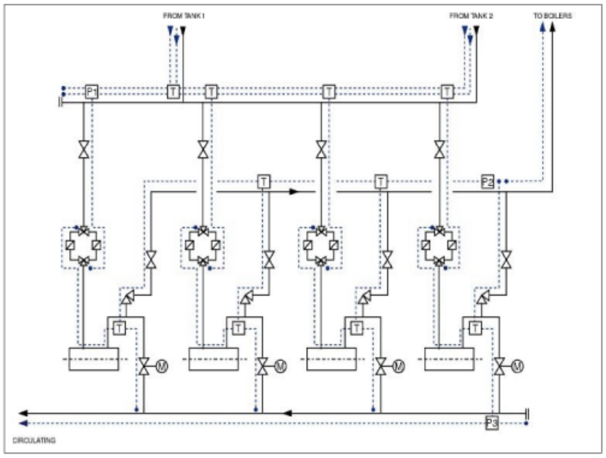
Multiple flow possibilites…

…means,

30 thermostats / Circuits

or

1 PowerMatch Micro



The importance of IT-S inherently temperature-safe tracers will therefore be understood. In addition to providing the highest level of temperature safety, IT-S tracers offer commercial advantages, in the form of fewer or simpler circuiting, as flow patterns carry less significance.

TRACER LONGEVITY

The subject of service life of a semi-conductive self-regulating heater has been addressed for many years by citing the Arrhenius equations used to determine the temperature ratings for polymeric dielectric cable insulation materials.

Accelerated aging tests resulted in reduced elongation capability, with typically 50% elongation representing a failure point. Whilst perhaps appropriate for assessing the dielectric materials of self-regulating tracers, Arrhenius has zero relevance to the main failure mode of such tracers, and is therefore considered of little value to this paper, which is more interested in practical, rather than theoretical tests.

IEC60079/30-1 includes a 'Thermal Performance Test'. This is an accelerated aging test whereby tracer samples are subjected to 15 minutes at room temperature followed by 15 minutes at their maximum temperature rating in the energised condition. After 1500 cycles, the heater must not have a power output variation (when compared with the start power output) of more than +20% and –25%. This test incorporates a high degree of the expansion / contraction that can affect the heater matrix / power conductor contact bond causing a reduction in power output.

Modes of Failure

In considering potential failure modes, it is perhaps prudent to first clarify misconceptions brought about by other papers produced in relation to this topic. Two such papers, the authors of whom represent major manufacturers, might almost have been a collaborative effort. So closely aligned are they, that even the misnomers appear to have been copied! These papers each cite 3 possible early failure modes due to manufacturing or process defects:-

1) Non homogenous heater matrix
2) Loose fitting insulation jacket
3) Contact resistance between bus-wires and the extruded matrix

1) Non homogenous heater matrix

We would not dispute that non-homogeneity of the heating matrix compounding process could result in degradation. However, it would equally be true that such a defect may also result in hotspots, dead shorts or an increase in power output.

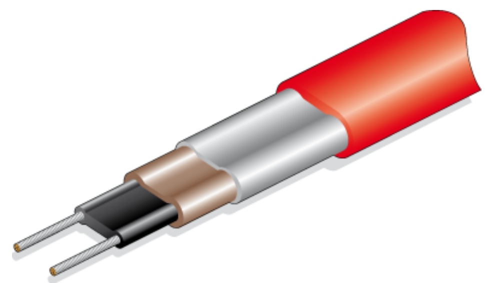
It is surprising that a leading maker would volunteer that some of his company's product failures are due to their inability to carry out the compounding or extrusion processes to the requisite quality. This issue which could be a compounding or extrusion problem, could also cause hotspots/dead shorts/increases in output. Certainly, this is not a recognised failure mode at Heat Trace Ltd.

2) Loose fitting insulation jacket

Here the inference is that an air gap between heater matrix and primary electrical insulation will result in the matrix operating at a higher than necessary temperature, causing a reduced life expectancy; and certainly, it is obvious that the greater the difference between the operating temperature and the withstand temperature of the materials of construction, the greater the longevity of the heating matrix.

However, with respect, few if any failures are the result of an ill-fitting primary jacket. Firstly, it is inconceivable that a recognised cable maker is unable to evacuate air when extruding the jacket. Next, usually a metal braid and a further over-jacket are then applied to the cable. These processes include a degree of air entrapment, which can further cause an increase in matrix temperature. Then, on installation, there are air gaps between the tracer and the pipe. Or the heater may be fixed to a plastic pipe having poor thermal conductivity. All these are factors in the resultant operating temperature of the heating matrix.

Heat dissipation is aided by the degree of heat-sinking provided by the cable itself and the emmisivity of the heater materials and the workpiece to which it is affixed. For this reason, a metal-jacketed heater will run cooler than a polymeric one, given like cable geometry and heat output. Hence it will have an extended service life. For this reason, Heat Trace are able to provide metal-jacketing as an option for it's complete range of heating cable products.



The reality is that, for a long service life, the heating compound formulation should be devised such that self-regulation occurs whereby the matrix is effectively non heat-producing at a temperature that is substantially below the limiting withstand temperature of the constructional materials *i.e. the heater is inherently temperature-safe (IT-S).*

Hence, we reject a loose fitting primary insulation jacket as a major cause of early failure.

3) Contact resistance between bus-wires and the extruded matrix

This is, without doubt, the most common cause of heater function degradation. At Heat Trace, a proprietary process ensures a good bond with the bus-wires during extrusion of the heater matrix. The contact value is measured and re-measured at every process through manufacture. Samples of <u>every</u> batch are retained (yes, really) for 10 years, and can be compared at any time with post service samples to assess the degree of degradation, if any.

Increase in Contact Resistance

This is most commonly brought about due to expansion and contraction during service, causing a relaxation of the bond between the bus-wires and heating matrix. This loss of bond may be significantly exacerbated by tracers which exhibit high currents when started from cold.

Improvements in service life may therefore be achieved in the management and minimisation of start-up currents, and this is an area in which Heat Trace has focused a great deal of it's R & D efforts. Two major breakthroughs have been made:-

i) Directional Conductivity*

The heating matrices of most self-regulating tracers comprise spherical carbon black particles randomly, though uniformly, dispersed within a polymeric carrier. This produces electrical conductivity equal in both the 'x' and 'y' planes.

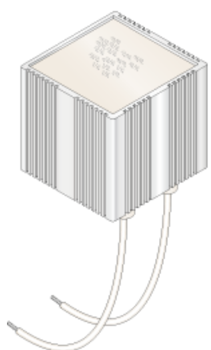
Heat Trace have developed a processing method, whereby the conductivity laterally is 300% of that of the longitudinal conductivity. This reduces the effects of the cold start-up currents and the high temperatures / rates of expansion which occur in the moments at start-up, and which are the major contributor towards a relaxation of the contact bond.

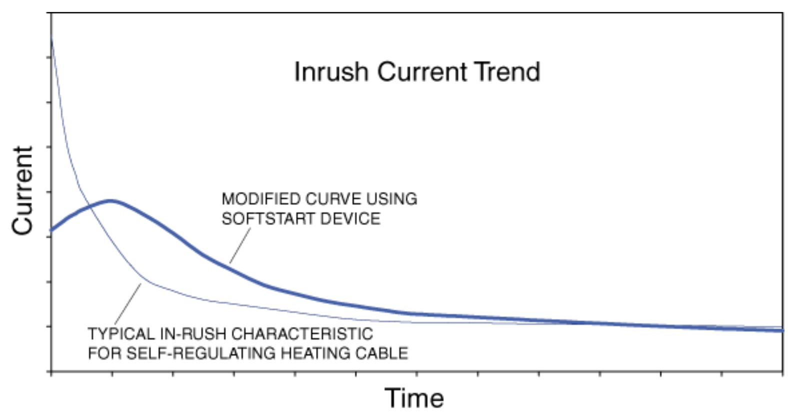
* - Heat Trace has patents granted protecting it's Directional Conductivity technology

ii) SSD Soft Start Device

SSD is a simple, small, low cost device having no moving parts which can fail. It has been developed by Heat Trace to further limit in-rush currents at cold start-up. The SSD device, which is series connected to the self-regulating tracer, further reduces the currents at start-up, typically by 50%.

The NTC (negative temperature coefficient) of the SSD neutralises the PTC (positive temperature coefficient) of the tracer, thereby smoothing start-up loads, and limiting the potentially damaging expansion / contraction and resultant increase in the contact resistance from a reduced bond strength.





The combined effect of Directional Conductivity and the SSD Soft Start Device is to increase the longevity of Heat Trace's self-regulating heating cables. This provides Heat Trace with a significant technical advantage over it's competitors.

SUMMARY

ENSURING TEMPERATURE SAFETY

From the foregoing, it will be appreciated that the limitations of *medium* temperature self-regulating tracers which have required temperature controls to ensure the temperature safety of a trace heating installation, and which provide a questionable degree of safety, particularly for hazardous area locations, no longer apply.

Heat Trace's new and upgraded *high* temperature self-regulating tracers **ALL** feature Heat Trace's **IT-S Technology**, and are inherently temperature-safe, requiring no temperature control, unless required for energy efficiency or process purposes. The *high* temperature product range referred to comprises:-

High Temperature Self-Regulating Heating Cable

- **FS+ 225°C On or Off - up to 60 W/m.**
- **FSS 225°C On or Off - up to 75 W/m.**
- **FSU 250°C On or Off - up to 100 W/m.**
- **FSU+ 275°C On or Off - up to 125 W/m.**
- **AFS 300°C On or Off - up to 150 W/m.**

IT-S inherently temperature-safe tracers provide the highest levels of temperature safety, are now available for virtually all trace heating duties, and **should be specified for all in-plant applications.**

Where temperature safety is provided by a Temperature Controlled installation, this clearly provides the least safe form of protection. Therefore, ***Temperature Control as a means of ensuring temperature safety should be a last resort.***

TRACER LONGEVITY

It has been demonstrated that the most likely limitation to a long service life from self-regulating heating cables, is the potential of relaxation of the contact bond between the bus-wires and extruded heating matrix; and it has been shown that the this relaxation is most likely to be caused by the high temperatures generated, and the high currents and rapid expansion of dissimilar materials during start-up from cold.

The start-up current, which can be many multiples of the operating current, can be severely moderated by employing tracers having Directional Conductivity, and the application of SSD soft start devices.

In doing so, tracer longevity will be improved by an order of magnitude out of keeping with costs.

N.S.Malone
4 April 2012