



*SAFE*  
**ELECTRIC TRACE HEATING  
AT OPTIMAL COST**

**SPECIFICATION**  
**+**  
**PHILOSOPHY**

Author: Neil S. Malone

## ABOUT THE AUTHOR



**Neil Malone** – has been involved with Electric Trace Heating since the 1960's.

In 1974, he established his own company, Heat Trace Limited – he remains as President and owner to this day. He became involved with the Electric Trace Heating standards development of BS6351 'Electric Surface Heating' from 1975 to its publication in 1982, and the ongoing trace heating IEC standards covering both safe and hazardous areas. He has received an award for his long term contribution in the development and maintenance of trace heating systems for industrial and commercial applications.

His approach to the safety of electric trace heating has been influenced greatly by the continuous development and refinement of these standards over almost half a century.

He was responsible for establishing ETHIC – the Electric Trace Heating Industry Council – the industry's trade association in 1986.

This document has been developed by the author as a personal and hopefully, impartial approach to trace heating, and, as such, makes no reference to his company or their products.

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**Neil S Malone asserts the moral right to  
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## PREFACE

The rise in the popularity of electrical, in preference to steam trace heating, over the past 40 years or so is due, in no small part, to the development and implementation, globally, of standards. These have not only defined the test requirements for product certification, but also brought about design and installation Codes of Practice adopted worldwide. Over this time, electric trace heating has evolved from a cottage into a burgeoning industry.

The author of this document has been involved throughout in the standards movement, having been a member of the committee set up in 1975 to develop British Standard BS6351, Electric Surface Heating, trace heating's original standard, published in 1982. This has continued, through the development of IEC standards for both hazardous and safe locations, (IEC60079-30 and IEC62395). More recently, has seen the harmonization, in 2015, of the US National Standard with IEC60079-30 to form realistically, a global trace heating standard for hazardous area use. A similar process is following for safe area use.

This document is in two parts; "Safe Electric Trace Heating at Optimal Cost – SPECIFICATION" preceded by "Safe Electric Trace Heating at Optimal Cost – PHILOSOPHY". It is intended for EPC Specification writers and Design Engineers, reflecting these Standards and Codes of Practice. The document provides an interpretation and approach to design that will result in the safest trace heating system, coupled with the most commercially attractive solution. It is intended to be an unbiased appraisal and, as such, there is reference only to generic products.

This Specification is also intended to be complimentary to the **e-Academy** Electric Trace Heating online Design tutorials, available through our industry's trade association **ETHIC – the Electric Trace Heating Industry Council** ([www.ethic-global.com](http://www.ethic-global.com)).

It is hoped that this impartial Specification may be adopted by EPC specification writers as a template from which they can develop their enquiry specifications and requisitions for tender. It is equally hoped to be of value to all electrical design engineers and students of electric trace heating.

**PART 1 - Safe Electric Trace Heating at Optimal Cost**

**PHILOSOPHY**

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# INTRODUCTION – Safe Electric Trace Heating at Optimal Cost

## Safety

Electric trace heating has matured from a niche market into an industry over the past 40 years on the back of the robust international performance standards that have been developed to ensure safe systems. These standards address the main safety issue by ensuring that limiting temperatures are not exceeded.

Temperature safety may be achieved either by means of a stabilised design or else by temperature control.

A system relying on temperature controls carries more risk in operation than a stabilised design. This is because sensors may become damaged, may not be located in the most appropriate place, or may be removed during maintenance and not replaced properly. Or the controller itself may fail. Additionally, every section of complex valved piping which can experience varying flow conditions must be individually controlled – it is the author's experience that in practice this rarely happens due to commercial pressures.

A stabilised design ensures that, under the most onerous uncontrolled and runaway conditions, the pipe and heater temperatures stabilise within safe limits. A stabilised design is therefore clearly a safer option.

The type of heater selected may also have safety connotations. For example, a constant power heating cable may cause a hazard if it is overlapped thereby creating a hotspot, whereas a self-regulating heating cable, due to its PTC characteristics, may still stabilise at a safe sheath temperature irrespective of how it is installed. Therefore, self-regulating heaters, when available, may be deemed to be a safer option.

Even so, some self-regulating heaters may pose a safety risk if they are not inherently temperature-safe. This can happen if the self-regulating power output slope of the heater is too shallow, such that a sheath temperature can occur that is beyond the withstand temperature of the heater or other limiting temperature. In this case, temperature controls are required.

Additionally, self-regulating heating cables have, until recently, been available only for freeze protection or low maintenance temperatures. This has forced trace heating system designers to resort to less safe constant power (or power limiting) heaters for many trace heating duties.

Clearly, to improve safety further, it has been necessary to address two areas:-

- I. The development of self-regulating heating cables capable of significantly higher maintain temperatures
- II. Ensure that heaters have practically no thermal output before reaching the withstand temperature limits of the heater. This is a property that may be termed '**Inherent temperature-safety**'

Whilst self-regulating heating cables may, in principle, be more temperature-safe than constant power equivalents, a further feature of this generic type, is that they can develop high currents on start-up from cold. This usually results in over-current protective devices being selected having ratings far in excess of operating loads. This clearly reduces safety – protective devices installed to protect the power wiring system and subsequently any electrical load they feed, should ideally be sized as closely as possible to operating currents to provide the shortest possible interruption time .

**In summary, optimum safety of trace heating** systems will be accomplished by:-

- i) Adopting a stabilised system design, and not relying on temperature control
- ii) Selecting a self-regulating, rather than constant power heating cable, but only if;-
  - a) It is inherently temperature-safe, and
  - b) It is capable of medium and high temperature duties, as well as freeze protection
- iii) Adopting over current protection rated for operating, rather than start-up currents.

Trace heating systems now exist satisfying all of these safety criteria in 90% of all applications, ranging from simple freeze protection to the maintenance of bitumen temperatures. Safety is further enhanced when the system can be monitored continuously for performance and fault conditions with automatic reporting remotely.

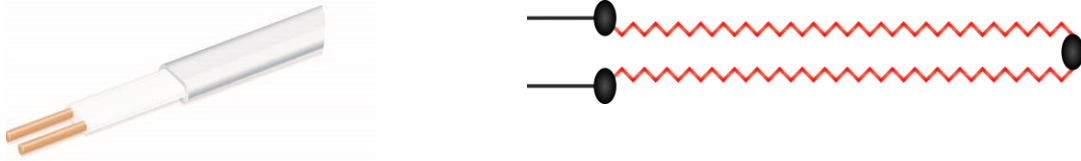
## **Capital Cost**

The capital cost of a trace heating system is affected most by the number of heating circuits, which determine the size and cost of control and distribution panels, and the power cable costs. After the thermal insulation cost these are often the two largest costs of a trace heating system.

This document discusses how inherently temperature-safe heating cables, combined with air sensing, rather than surface sensing control, can significantly reduce the number of heating circuits, which may further be reduced if circuits are soft started. In doing so, safety is increased as switching loads are more closely related to operational loads. An added benefit is the increased heating cable longevity when heat tracers are not exposed to excessive start loads. Power cabling, already reduced by fewer heating circuits, may now be further reduced, as lower start-up currents may result in smaller conductor sizes.

## ELECTRIC TRACE HEATING – Growth through Standards

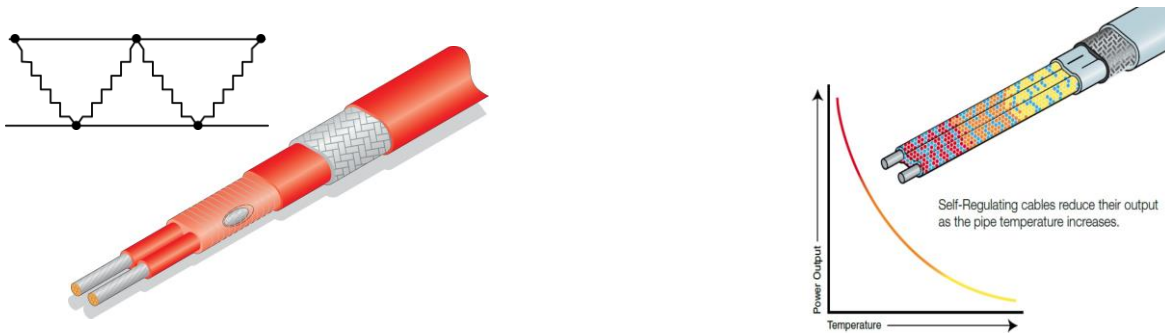
Up to the 1970's, the energy source of choice for trace heating was, more often than not, steam. Though inefficient, many plants had excess boiler capacity, so steam for tracing was deemed to be free. Conversely, electricity was expensive, and, as all heating cables were of the series resistance type, heating circuits had always to be specifically designed and manufactured for each installation – hence, electrical tracing tended to be chosen only when steam was unavailable.



**Series Resistance**

Fast forward half a century or so and we find a reversed situation, with electricity now the dominant heat tracing energy source. Steam tracing is extremely inefficient as it is rarely controlled and may typically deliver six times the quantity of heat required to provide freeze protection to a pipe. Additionally, it has high running and maintenance costs due to leaks from steam traps. Conversely, control systems can result in highly efficient electric heat tracing.

Early heating cables were all of the series resistance type, which had to be especially produced to match length, supply voltage and power output. Cut-to-length parallel type heating cables have been developed, simplifying design and installation; self-regulating heaters have improved safety; control systems have optimised efficiency and enabled continuous monitoring.



**Parallel Resistance**

Such developments have evolved due to, more than any other influence, the national and international standards that have been developed, adopted, and have driven our industry. British (BS6351) and American (IEEE515) standards were both published in 1983, adopting similar formats comprising Test Specifications, together with Design and Installation Codes of Practice. The standards addressed a complete electric trace heating system comprising heating cable(s) together with termination components, junction boxes and fixing materials, temperature controls, monitoring / alarm facilities, and power distribution and circuit protection. Even during the development of these early standards, there was cooperation between the two national committees.

This common approach of the national standards paved the way for the introduction of international standards, IEC 62395 and IEC60079-30, governing trace heating in, respectively, industrial safe and hazardous area installations. The hazardous content of IEEE515 has now been harmonised with the IEC60079-30 standard, to form a dual logo harmonized standard. The most recent development has been the removal of the hazardous area content from IEEE515. One may anticipate a similar harmonization process taking place in the near future between IEC62395, IEEE515 and IEEE515.1 covering safe industrial and commercial installations.

This almost seamless harmonization process has been possible, in no small part, due to the cooperation of the electric trace heating community. Normally competing manufacturers recognise and appreciate the influence and benefits that these standards have bestowed on the growth of our industry. The industry recognises that a safe system is reliant on not just test Specifications, but also Design and Installation Codes. It has been successful in keeping these parts together in a single standard.

**It is essential that these standards are continually updated and this document will highlight areas that may be addressed to further improve safety.**

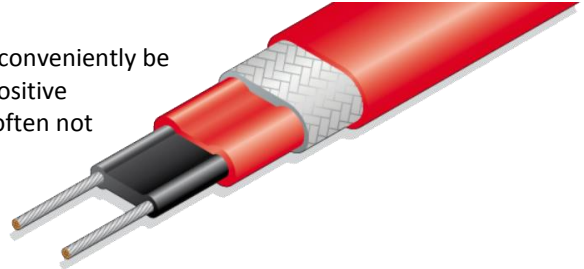
## HEATING CABLES - Generic types

There are four generic types of heat tracer

- Parallel Self-Regulating
- Parallel Zonal (Constant Power/Power limiting)
- Series Resistance
- Skin-effect Trace Heating

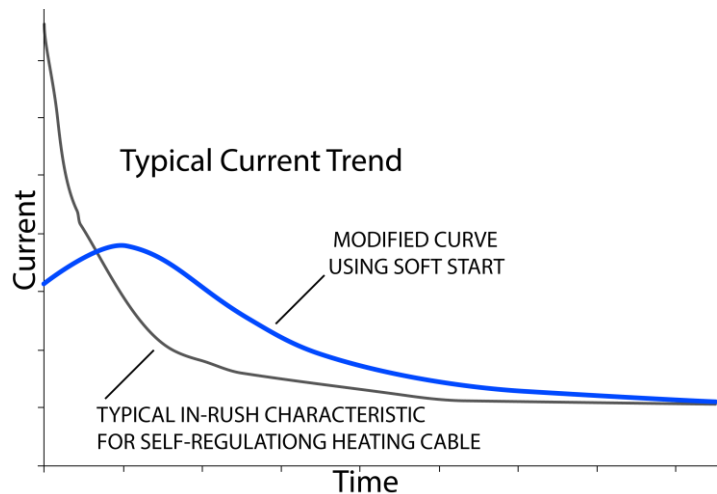
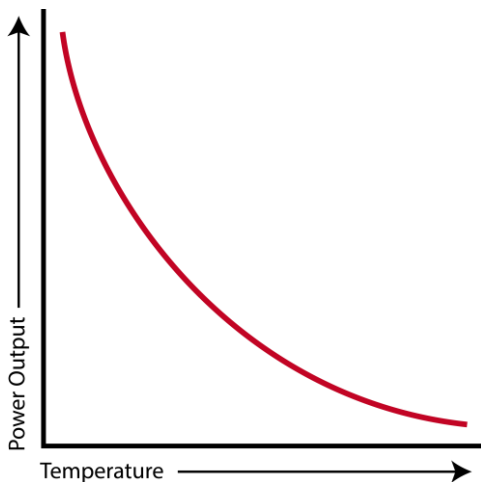
### Parallel Self-Regulating

Self-Regulating (or self-limiting) tracers are most popular, as they can conveniently be cut-to-length and are often inherently temperature-safe, due to the positive temperature coefficient heating matrix. Thus temperature control is often not needed to provide temperature safety. (See page 18 on Inherent Temperature Safety).



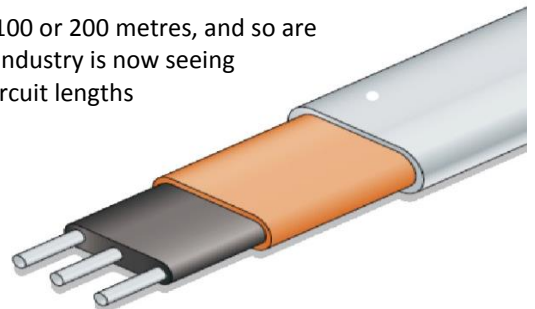
Until recently, their availability for only low or moderate temperatures limited their use. Now though, medium/high temperature semi-conductive tracers have become available able to withstand temperatures up to 300°C energised or power off. So now, self-regulating tracers are available that can fulfil 90% of all applications within industrial heat tracing.

Ever since the introduction of self-regulating tracers, the high currents on start up from cold have created a problem requiring the need for larger than necessary feed cables and switchgear. Additionally, safety was compromised, as circuit protection had to be sized in excess of operating currents. Now however, soft- starting is available improving safety, and reducing distribution costs.



A SoftStart may typically have NTC (negative temperature coefficient) characteristics which negate the PTC (positive temperature coefficient) of the heating matrix at start up. Start currents are reduced significantly (see Figure above).

Single phase Self-Regulating tracers are typically limited in circuit length to 100 or 200 metres, and so are used mainly for in-plant applications. However, as technology evolves, the industry is now seeing the availability of balanced load 3 phase self-regulating tracers capable of circuit lengths up to 600m and beyond.





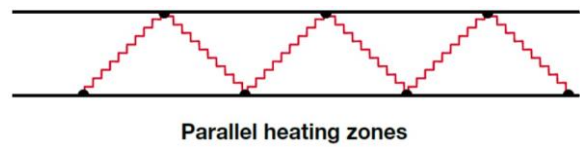
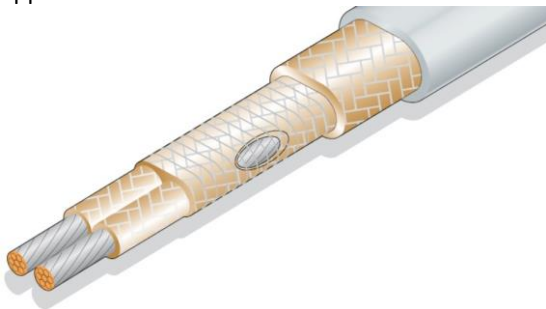
### Parallel Zonal (Constant Power/Power limiting)

Parallel Constant Power (and so-called Power limiting) zonal tracers can be conveniently cut-to-length, but are less popular than self-regulating heaters, because they often require thermostatic control to ensure temperature safety, (although sometimes a calculated temperature-safe stabilised design is possible).

Most zonal tracers are polymeric, and are limited in temperature capability. However, metal sheathed, mineral insulated constant power heaters having a withstand temperature of up to 500°C un-energised are available which can cater for most applications that the high temperature self-regulating heaters are unable to handle. Thus, cut-to length parallel tracers are now available for virtually all heat tracing applications.

This is particularly beneficial in the case of instrument lines, the lengths of which are usually unknown at the design stage of a project, and which are site run according to convenience. Additionally, it is becoming common for pipelines to be periodically steam cleaned, and these metal sheathed constant power cables can withstand most steam temperatures

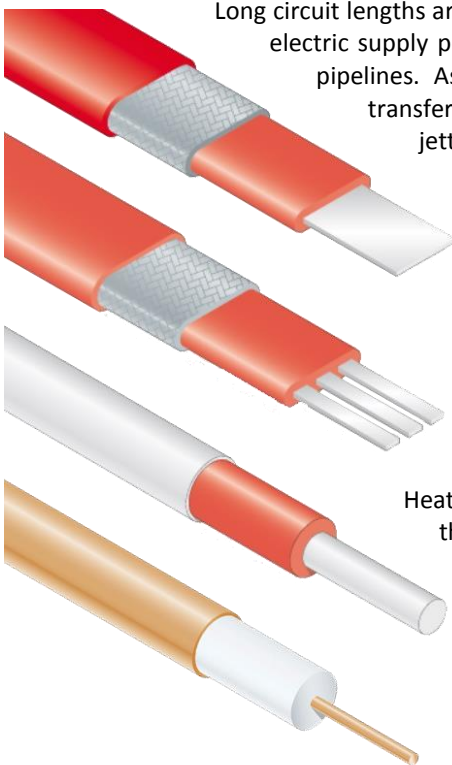
Parallel zonal tracers are typically limited in circuit length to 100 or 200 metres, and so are used mainly for in-plant applications.



### Series Resistance Tracers

Series Tracers have lost popularity to the more convenient parallel tracers because each circuit must be individually designed into its particular length/load configuration. However, series resistance heating cables continue to be commonly used in two cases:-

- For long pipes beyond the circuit length capability of parallel resistance cables, and
- Where process temperatures are beyond the limits of parallel types



Long circuit lengths are possible – typically 3 phase polymeric or elastomeric insulated tracers may require electric supply points only at multi-kilometre intervals. So a major outlet for series heaters is long pipelines. As this document focuses on in-plant trace heating, series cables are used typically for transfer lines from one area of a plant to another, or, for example, the tracing of pipes from jetty berths to the pump house of a plant.

Metal sheathed, mineral insulated (MI) series cables should only be used when process temperatures exceed the capability of the more convenient parallel tracers. This typically might occur when pipes are to be cleaned with steam which can be at temperatures exceeding, for example, 500°C.

Series Resistance Tracers usually require temperature controls to ensure temperature safety.

Heating Circuit Configuration - A 3 phase circuit configuration may comprise either, a three conductor heating cable, or 3 x single conductor heaters.



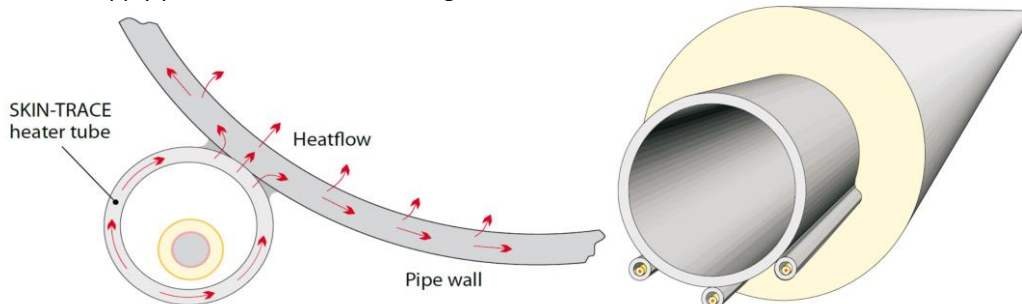
## Skin-effect Trace Heating

Skin effect tracing is induction-resistive heat tracing based on skin and proximity effects of an AC current within a ferromagnetic tube.

The heating element comprises a carbon steel tube into which is inserted an insulated non-magnetic conductor. The conductor and the steel tube are connected together at one end. At the other end an AC voltage is applied between the conductor and the tube. The relationship of conductor/tube sizes/length and voltage determines the output power developed.

The skin effect of the magnetic tube results in the current being concentrated towards the tube's inner surface, the voltage potential to the outside being zero.

The advantage of skin effect is that long circuit lengths are possible – typically a multi-kilometre pipeline may be heated from a single electric supply point. So skin effect tracing is an alternative to the series resistance tracers described above.



Depending on the heating power required and the pipeline length, skin effect tracing may consist of either of one, two, or three, heater tubes (see image above).

Whilst extremely mechanically robust and reliable, skin effect tracing is extremely expensive to install. Electrical and mechanical continuity of the system must be ensured by the welding of jointed components and more often, series resistance heating cables will produce the most competitive solution. Additionally, the system's power factor of 0.85 to 0.9 results in the need for an increased power supply capability, or alternatively localized power factor correction, at increased cost.

## HEATING CABLES – Selection Summary

Heat tracers for in-plant areas are usually selected according to the maximum temperature to which the tracer will be subjected, and the power output required from the tracer.

From the foregoing, it can be seen that the designer will choose, in order of preference the following tracer types, with temperature withstand for each generic type of tracer being typically:-

- Self-regulating tracers, which can be conveniently cut-to-length and which are often inherently temperature-safe and need no temperature control. They may be available for exposure temperatures up to, for example 300°C.
- Parallel Zonal tracers catering for higher exposure temperatures up to, for example 500°C, but usually need temperature controls
- Only exceptionally is it necessary to employ series MI cables, which must be specifically designed for a particular length and output.
- Polymeric series type might be selected for long circuit lengths

## ELECTRIC TRACE HEATING – Applicable Standards

Electric heat tracing is governed by a number of International and National Standards covering Industrial (Safe) and Industrial (Hazardous) locations. A list of the most important standards, to which products should be approved, is shown in the table below. Although other trace heating standards exist, this document focuses on the standards developed especially for electric heat tracing:-

- IEC62395 - Electric Heat Tracing for Safe Industrial locations or commercial applications, and
- IEC60079-30 - Electric Heat Tracing for Hazardous locations (formerly IEC62086)

This is because these are the most recent publications, and are truly international. The International Electro-technical Commission comprises most industrialised nations from all continents. The trace heating industry has co-operated to produce harmonised standards. Thus, the hazardous location parts of IEC60079-30 have been directly aligned into a single dual-logo standard.



Commercial Locations	Industrial Applications	Hazardous Locations
<b>IEC 62395-1, (EN 62395-1)</b> Electrical resistance trace heating systems for industrial and commercial applications - Part 1: General and testing requirements <b>IEC 62395-2</b> Electrical resistance trace heating systems for industrial and commercial applications - Part 2: Application guide for system design, installation and maintenance		<b>IEEE/IEC 60079-30-1 (BS EN 60079-30-1)</b> Explosive atmospheres - Part 30-1: Electrical resistance trace heating - General and testing requirements  <b>IEEE/IEC 60079-30-2 (BS EN 60079-30-2)</b> Explosive atmospheres - Part 30-2: Electrical resistance trace heating - Application guide for design, installation and maintenance
<b>IEC 60519-10</b> Safety in electro heat installations - Part 10: Particular requirements for electrical resistance trace heating systems for industrial and commercial applications		
<b>CAN/CSA-C22.2 No. 130-16</b> Requirements for electrical resistance heating cables and heating device sets		
<b>UL 1673</b> Electric Space Heating Cables		
<b>UL 1588</b> Roof and gutter de-icing cable units		
	<b>UL515</b> Standard for electrical resistance heating in commercial application	
<b>IEEE Std.515.1</b> Standard for the Testing, Design, Installation and Maintenance of Electrical Resistance Heat Tracing for Commercial Applications	<b>IEEE Std.515</b> Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Industrial Applications	
<b>IEEE Std. 844</b> Recommend practice for electrical impedance, induction and skin effect heating of pipelines and vessel		
<b>IEEE Std. 844.1/CSA C22.2 No. 293.1</b> Standard for skin effect trace heating of pipelines, vessel, equipment and structures. <b>IEEE Std. 844.1/CSA C22.2 No. 293.1</b> Standard for skin effect trace heating of pipelines, vessel, equipment and structures.		

## HAZARDOUS AREAS – Considerations

Electric trace heating within potentially explosive atmospheres must comprise approved equipment, designed and installed in accordance with the relevant standards indicated above. Design and equipment selection for use in hazardous areas will be influenced by:-

- the area classification
- the dust group
- the temperature classification and equipment selected providing an appropriate type of protection

As stated above, this document focuses on the international standards developed especially for electric heat tracing, IEC62395 – for Safe Industrial locations and IEC60079-30 – for Hazardous locations.

### Area Classification

The probability of explosive conditions being present is defined by zone classification:-

		Flammable Material Present Continuously	Flammable Material Present Intermittently	Flammable Material Present Abnormally
ATEX & IEC	GAS	Zone 0	Zone 1	Zone 2
	DUST	Zone 20 Cat 1	Zone 21 Cat 2	Zone 22 Cat 3
US	NEC 505	Zone 0	Zone 1	Zone 2
	NEC 500	Division 1		Division 2

### Gas and dust groups

Apparatus Groups (ATEX and IECEx)			
Groups	Environment	Location	Typical Substance
I	Gas Vapours	Coal Mine	Methane (fire damp)
IIA		Surface and other locations	Acetic acid, Acetone, Ammonia, Butane, Cyclohexane, Gasoline (petrol), Kerosene, Methane (natural gas) (non-mining), Methanol (methyl alcohol), Propane, Propan-2-ol (iso-propyl alcohol), Toluene, Xylene
IIB			DI-ethyl ether, Ethylene, Methyl ethyl ketone (MEK), Propan-1-ol (n-propyl-alcohol), Ethanol (ethyl alcohol)
IIC			Acetylene, Hydrogen, Carbon disulphide
IIIA	Combustible Dusts	Surface and other locations	Combustible flyings
IIIB			Non-conductive
IIIC			Conductive

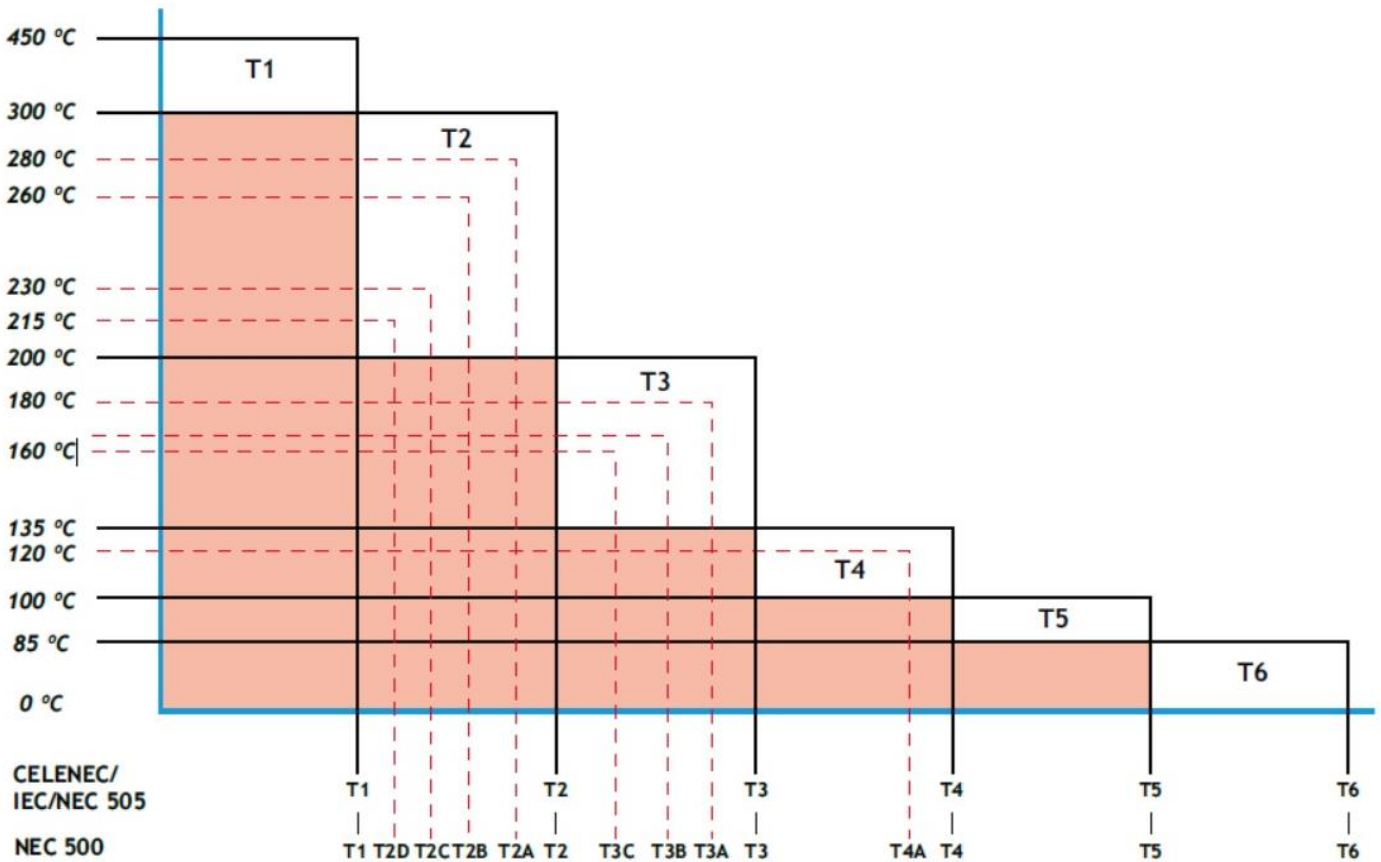
Apparatus Groups (US / CAN )			
Substance	Hazard Class	NEC 500	NEC 505
Acetylene	Class I Flammable Gases	Group A	IIC
Hydrogen		Group B	IIC
Ethylene		Group C	IIB
Propane		Group D	IIA
Methane (mining)		Group D	-
Combustible Metal Dusts	Class II Combustible Dust	Group E	-
Combustible Carbonaceous Dusts		Group F	-
Combustible Dusts not in Group E or F (Flour, Grain, Wood, Plastics, Chemicals)		Group G	-
Combustible Fibres and flyings	Class III Fibres and Flyings	-	-

Gas groups relevant to heat tracing in hazardous locations are:-

- **IIA** – Acetone, benzene, butane, ethane, methane, propane, etc.
- **IIB** - Ethylene, town gas etc.
- **IIC** – Acetylene, hydrogen

## Temperature Classification

The maximum surface temperature of the heater must be kept below the auto ignition temperature of the explosive gas or vapour mixtures which could be present. The classifications are:-



In reality, most gases encountered will have an ignition temperature of T1 or T2. **However, for electric trace heating, process engineers regularly specify a T3 (200 deg. C) T-Class as a 'catch all' for greater security.** Often, they don't recognise the additional capital costs they are adding to the trace heating installation which may require additional lower power rated heaters to meet the more stringent T3 requirements.

Additionally, it is becoming common for process pipework to be steam cleaned on occasions at temperatures which may be up to 500°C., and yet still be accorded a T3 temperature class. Clearly, it is impossible to have lines with 500°C steam in a T3 area! Better to classify it T1 if that is indeed the auto ignition risk. This minimises the capital costs of the trace heating.

Self-regulating heating cables now exist that can continuously withstand 275°C and are inherently temperature-safe. These can be left energised if required during steaming out when the steam temperature is below this limit, as, because their power output is practically zero at this temperature, they are, to all intents and purposes, switched off.

*Under such circumstances, self-regulating heaters which are inherently temperature- safe should be the preferred safety option. When this is not possible, a calculated stabilised design is preferable to a system that relies on temperature controls for the safety of the system.*

Where steam temperatures exceed the limitations of inherently temperature-safe self-regulating heating cables, safety can be ensured by employing a control system that switches off the entire trace heating prior to the steam cleaning process being activated, assuming, of course, that the tracers can continuously withstand the steam exposure temperature when un-energised.



## **Types of Protection**

As non-sparking devices, most heaters are likely to be approved to the concept of increased safety.

Sparking devices such as thermostats or circuit breakers are located within an enclosure most commonly approved to the concept – ‘flameproof’. Here it is assumed that the explosive gas mixture can be present, and that, when ignited, the explosion is contained within the enclosure.

Alternatively, sparking devices may be located within a ‘pressurised’ enclosure that prevents the explosive gas mixture from entering, and hence sparking cannot cause ignition. Yet a further type of protection occasionally encountered in trace heating is intrinsic safety. In this case, the energy levels are too low as to cause ignition.

Consideration may be given to temperature control switching by solid state relays or thyristors, rather than the more common contactors, as these are non-sparking and, as such, can be assembled within lighter and lower cost increased safety enclosures, as opposed to the flameproof or pressurised protection required by contactors.

Sometimes, distribution boards and control panels can be located outside the hazardous area to avoid the need for the additional costly protection.

## ELECTRIC TRACE HEATING – The need

Heat Tracing (or Trace Heating) is the method of applying heat to a body, or to a product (liquid, powder, or gas) contained within a system (pipework, vessel or equipment) for storage or transportation, in order to avoid processing problems or difficulties.

Heat may be applied, for example, to:-

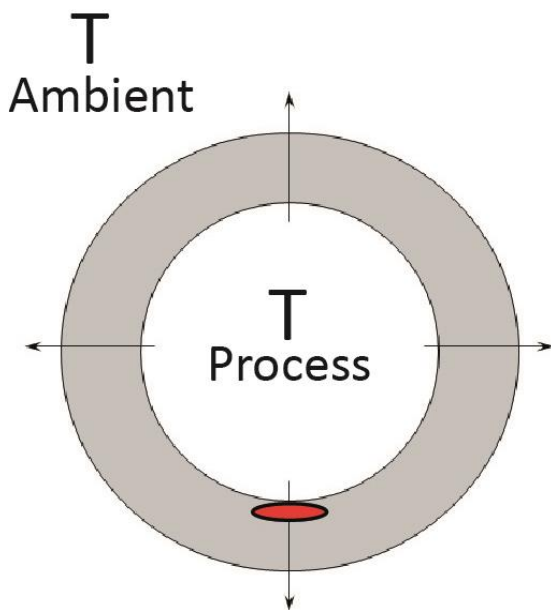
- Liquids to prevent freezing or to enable pumping by reducing the viscosity of the liquid
- Powders to eliminate condensation from the walls of equipment that could result in 'clogging' of the product
- Gases to prevent hydration due to a drop in gas pressure across pipework fittings such as valves

Heat Tracing is usually provided to maintain a product or equipment at a temperature that will prevent processing problems. But it may also be required to heat raise products or equipment from cold to the required maintain temperature. For example, a pipeline is used infrequently to deliver fuel oil from an off-loading berth into a plant area. In such a case, the pipeline and its contents may be allowed to cool to ambient temperature during periods of non-use, and raised back to the pumping temperature of the fuel oil over a period of, for example, 48 hours prior to the next delivery of oil.

Whenever the contents of a pipe or equipment are maintained at a process temperature exceeding the ambient temperature, there will be a flow of heat from the product or equipment through the thermal insulation to the external air. ***The rate of heat loss varies directly with changes in ambient temperature.***

In order to prevent the temperature of the product from falling below its required level, this ***variable*** heat loss must be compensated for by heat tracing the pipeline or equipment.

### HEAT LOSSES FROM A PIPE



If  $T_{Process}$  **exceeds**  $T_{Ambient}$   
**HEAT TRACING IS NEEDED**

\*  $T_p$  is CONSTANT

\*  $T_a$  is VARIABLE

*Therefore*

**HEAT LOSS VARIES**  
**WITH AIR TEMPERATURE**

## HEATING LOADS – Pipelines & Vessels

The design software of most manufacturers is able to automatically calculate the appropriate heating load in order to compensate for heat losses from a pipe, vessel and line equipment, or to heat raise the temperature of the equipment and its contents.

The following is a simplistic method for calculation of heating loads for pipes and vessels. It should be stressed that the heat losses from pipeline fittings, such as valves, flanges, strainers, filters, pumps, are often significant, accounting for typically an additional 25% of the pipe work heating load requirements, and that any assessment will be very approximate. Also, pipe supports, which are rarely detailed on drawings, can also account for significant heat losses unless the supports are thermally insulated, which is extremely rare.

### Heat loss compensation for pipelines

As its name implies, this form of heating is used to balance or compensate for heat losses from a pipeline to the surrounding atmosphere. The following method may be used to calculate the amount of heat required:-

- 1 - Table 1a - select loss factor for pipe size and insulation thickness.
- 2 - Table 1b - multiply the selected loss factor by the 'K' value of insulation used.
- 3 - Multiply the resultant from Tables 1a and 1b by the temperature difference between lowest ambient and required temp ( $\Delta t^{\circ}\text{C}$ ).
- 4 - Multiply - by an appropriate safety factor - typically 1.2
- 5 - The resultant number x is the heating load in watts/metre of pipe

It should be noted that this *design* heating load is only needed when the ambient temperature is at its *minimum* design level. At all other times the heating load will be greater than necessary.

*The excess heating load is normally managed by the temperature control system.*

### Raising temperature of pipelines

Often, it is more economic to maintain the heating over short shutdown periods, e.g. weekends, than to make provision for heating up from cold. Where it is essential to provide sufficient heat for warming up in addition to heat loss compensation, the time allowed for warming up should be at least 12-24 hours, as shorter periods normally involve inconveniently high loadings.

Heat required for warming up can be calculated as follows:

#### Formula 1

$$W = \frac{(P \times S) + (C \times Q) \times \Delta T}{E \times H \times 3600} \text{ W/m}$$

where W = heating required in watts/metre

P = weight of pipe work in kg/m

S = specific heat of pipe work in J/kg $^{\circ}\text{C}$

C = weight of contents in kg/m

Q = specific heat of contents in J/kg $^{\circ}\text{C}$

$\Delta T$  = temperature rise  $^{\circ}\text{C}$

H = time allowed in hours

E = efficiency factor, use 0.73\* but may vary (\*typical for non-self-regulating tracers)

This figure must be added to the heat loss compensation calculated previously. It is not necessary to work on the full temperature because, during the heating-up period, the pipe temperature will be below the final temperature, therefore the following equation should be applied:

**Total Load = heating up load + 2/3 steady loss at final Temperature, but heat loss load as a minimum**



Table 1a

Pipe nominal bore	Pipe O.D	Insulation thickness							
		12 1/2	25 1	37 1 1/2	50 2	75 3	100 4	125 5	150mm 6 in
in	mm	Normalised loss factor							
1/2	21.35	8.01	5.16	4.13	3.58				
3/4	26.7	9.39	5.89	4.65	4.00	3.30			
1	33.4	11.34	6.91	5.36	4.56	3.71			
1 1/2	48.3	14.86	8.74	6.63	5.54	4.41			
2	60.3	17.88	10.28	7.69	6.36	4.98	4.26		
2 1/2	73.05	21.05	11.89	8.79	7.21	5.57	4.72		
3	88.9	25.00	13.90	10.15	8.24	6.29	5.28		
4	114.3		17.08	12.30	9.88	7.42	6.15		
6	169.3		23.82	16.82	13.30	9.74	7.93	6.83	
8	219.1		30.13	21.04	16.50	11.89	9.57	8.16	7.20
10	273		36.82	25.53	19.86	14.17	11.29	9.55	8.38
12	324		43.12	29.73	23.03	16.29	12.90	10.85	9.47
14	355		47.05	32.36	25.00	17.60	13.90	11.66	10.15
16	406		53.35	36.56	28.16	19.73	15.50	12.90	11.20
18	457		59.64	40.76	31.31	21.84	17.08	14.22	12.30
20	508		65.92	44.96	34.46	23.95	18.67	15.49	13.37
24	609		78.50	53.35	40.76	28.16	21.84	18.04	15.50
30	762		97.36	65.92	50.20	34.60	26.58	21.84	18.60

**Heat loss compensation for tanks, vessels & hoppers**

Similarly the design criteria for calculating heat loss compensating and/or raising and maintaining temperature associated with tanks, vessels, or hoppers are as follows:

**Formula 2a (for flat surfaces)**

$$\text{Loading required} = \frac{A \times K \times (T1 - T2)}{E \times t} \text{ watts}$$

**2b (for cylindrical surfaces)**

$$\text{Loading required} = \frac{2 \pi K \times L \times (T1 - T2)}{E \times \ln (D/d)} \text{ watts}$$

where A = total surface area of tank, vessel, etc. to be heated in square metres (m2)

K = thermal conductivity of the insulation in W/m°C

T1 = temperature to be maintained °C

T2 = min. ambient temperature °C

t = thermal insulation thickness in mm

L = length of surface

D = diameter across insulation

d = outside diameter of pipe

E = efficiency factor, use 0.73 but may vary

**Raising temperature of tanks, vessels and hoppers**

**Formula 3**

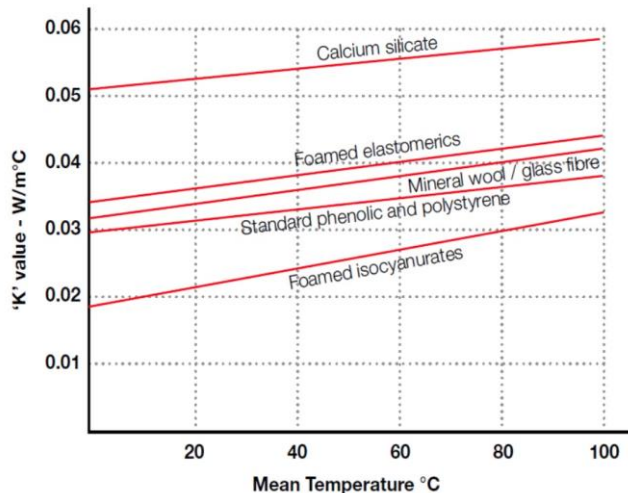
$$\text{Kilowatt loading required} = \frac{\text{mass(kg)} \times \text{sp heat (J/kg°C)} \times \text{temp rise °C}}{E(0.73) \times 1000 \times \text{hours} \times 3600} \text{ kW}$$

As for pipework, it is necessary to consider both the vessel and its contents. Therefore apply the above formula to both vessel and contents and add the respective loads together to arrive at the total kilowatt loading. After raising the tank and contents to the required level, it will be necessary to allow for heat losses as in FORMULAE 2a or 2b.

**Total Load = heating up load + 2/3 steady loss at final Temperature, but heat loss load as a minimum**

Types of thermal insulation used for pipelines and vessels together with thermal conductivity, i.e. 'K' factor, are shown in Table 1b.

**Table 1b**



### Thermal Insulation – effect on heat losses

Heat loss calculations and trace heating performance are dependent on the thermal insulation meeting its specified properties. The most common things that can adversely affect performance are:-

- a) Moisture content of the lagging material – the thermal conductivity value, particularly of mineral wool and glass fibre, may be badly affected by just a few per cent moisture ingress. Weatherproof cladding is imperative.
- b) Insulation pipe sizes must accommodate the volume taken by the heating cable. If standard insulation pipe sizes are used, the heating cable, particularly when spiralled, often creates a gap which will cause large heat losses unless filled with additional thermal insulation by the installer.
- c) A common mistake is to select the next insulation pipe size up to accommodate the heating cable. But, if this is done, heat losses should be calculated based on the larger size, rather than the actual size of pipe.
- d) Use of the wrong thermal conductivity k-value. These values are usually quoted at 20°C, but the value used for heat loss calculation should be the average value across the thickness of insulation. This occurs at its mid-point temperature.

Thermal insulation of pipework fittings such as valves, flanges, filters, pumps, etc., is particularly important – it is the author's experience that often a temperature gradient exists across fittings, the trace heating designer having allowed insufficient heating cable length to account for well insulated fittings, which in reality are poorly insulated.

## **ELECTRIC TRACE HEATING – A Safe System**

A heat tracing installation should provide the highest appropriate levels of Safety. This is mainly provided for by:-

- ensuring temperature safety
- over-current and short-circuit circuit protection
- earth-leakage protection

This document focuses on methods that provide the highest levels of safety together with practices that ensure the most commercially competitive system without compromising safety.

### **TEMPERATURE SAFETY**

Our industry standards have contributed most to the improvement in trace heating safety by their approach to ensuring temperature safety. Temperature safety is ensured by preventing the surface of the heat tracer from exceeding the limiting temperature. This limiting temperature is usually the maximum rating of the tracer itself, but could also be a process temperature limitation or, for example, the Temperature Classification if the installation is within a hazardous area.

This is achieved by means of a stabilised design, which does not rely on controls for temperature safety, or else by a temperature controlled system. Almost by definition, the latter is less safe and should only be adopted when a stabilised design is not possible. Certain applications, for example the tracing of plastic pipes, will suggest the need for a stabilised design over temperature control.

#### **Controls-dependant safety**

Where a stabilised design cannot be assured, it is then necessary to employ temperature control. Here the safety of the system is reliant on the correct functioning of the controller and the correct location and operation of the temperature sensor. *This is therefore the least safe option.* Specifiers should guard against being offered such designs unless absolutely necessary - they may have capital benefits but with attendant safety risks.

Potential problems from a controlled design are many and include:-

- Is the control temperature sensor in a representative location?
- Where over temperature control is employed, is the temperature sensor in the hottest location?
- Has it been moved during maintenance and not replaced correctly?
- Has the sensor become damaged / open circuit?
- Has the controller failed?
- Does the control system take account of all the different flow paths that are possible with a complex piping system – *usually the answer is No!*

#### **Stabilised design – by calculation**

A stabilised design should therefore be the one of choice. It may be accomplished in either one of two ways. The first way involves calculating the maximum pipe temperature that could occur under uncontrolled runaway conditions, and then, knowing the relationship between the pipe temperature and the heater surface temperature (for a given geometry, construction, and power output), determining a safe heater sheath temperature. Runaway conditions and heater/pipe temperature relationships are explained below.

Stabilised design calculations are complex and should only be undertaken by persons suitably skilled. Design software from some companies is able to automatically confirm whether a design is temperature-safe. When it is not, the designer has the choice of selecting tracers having a lower power output or opting for a less safe temperature controlled system.

The designing company must demonstrate to a notified body that they understand the pipe-heater temperature relationships. Hence, this method may still be the subject of human error though, overall, it is significantly safer than a heat traced system dependant on temperature controls.

#### **Stabilised design – by IT-S (Inherent Temperature Safety)**

The second way to provide a stabilised design is by the deployment of IT-S heating cables. This is where self-regulating semi-conductive PTC heating cables are selected that deliver substantially zero power output at a temperature below the limiting temperature of the system. Thus the heater can never generate an unsafe temperature irrespective of flow or other factors.

Clearly, IT-S Inherent Temperature Safety, when available, provides by far the safest electric trace heating system.

## Runaway Temperatures – explained

A runaway condition results from the most onerous conditions. These may typically occur:-

- On the hottest summer day
- When the heating cable is manufactured to its minimum electrical resistance tolerance, i.e. having a higher power output than the cable's nominal output
- When the supply voltage is at its maximum tolerance, further increasing the cable's power output

These conditions are opposite to those assumed in determining the heating load i.e.:-

- The coldest winter day
- When the heating cable is manufactured to its maximum electrical resistance tolerance, i.e. having a lower power output than the cable's nominal output
- When the supply voltage is at its minimum tolerance, further reducing the cable's power output.

I first focused on the potentially dramatic effect on the runaway pipe temperature when this situation was addressed in the 1970's during the development of BS6351, the first trace heating standard.

Let's consider a simple application to freeze protect a water line with a constant power heating cable in a cold climate:-

- Maintain line at 3°C
- Minimum ambient temperature – minus 30°C
- Design  $\Delta T = 33^\circ\text{K}$
- Maximum ambient temperature – +30°C
- Heating cable manufacturing resistance tolerance is +/- 10%
- Supply voltage tolerance is +/- 10%
- The calculated pipe heat loss is  $\gamma$  W/m at minimum ambient temperature
- To allow for the worst case supply voltage at -10%, and the manufacturing resistance tolerance of +10%, the design heating load is corrected to  $1.37\gamma$  W/m

Now, consider runaway temperatures from the most onerous conditions i.e. the control (if any) is failed on the hottest summer day with the heating cable at its minimum electrical resistance tolerance and the supply voltage is at its maximum tolerance:-

- Now the ambient temperature is at +30°C
- The heater power will be the design heating load of  $1.37\gamma$  corrected to allow for the worst case supply voltage at +10%, and the worst case heater resistance of -10%. As power varies to the square of the voltage, and directly with resistance, the new worst case installed load becomes  $1.82\gamma$  W/m i.e. 82% more than the calculated maximum winter heat loss.
- The design  $\Delta T$  was  $33^\circ\text{K}$ , but  $1.82\gamma$  W/m has a capability now of  $60^\circ\text{K}$
- Thus on the hottest summer day at +30°C, a pipe temperature of 90°C is possible

Further, the above only applies if a heating cable is selected having a nominal power output of  $1.37\gamma$  W/m or less, in which case it would be spiralled to the pipe to apply the calculated design heating load. Often, straight tracing is specified, causing the designer to select a tracer having a higher power output than the design heating load. In such a case the potential pipe temperature will be still higher than 90°C!

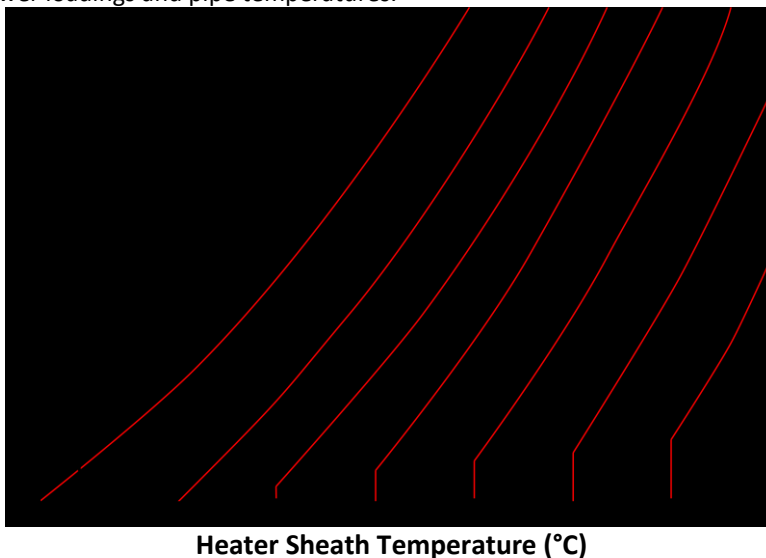
For a stabilised design, the designer must now select a heating cable having a power output that results in a heater sheath temperature below the limiting temperature. The limiting temperature may often be the maximum withstand temperature of the tracer, but could also be the temperature classification of the hazardous area, where appropriate, or a limiting process temperature.

The relationship between the pipe temperature and the tracer sheath temperature is discussed below.

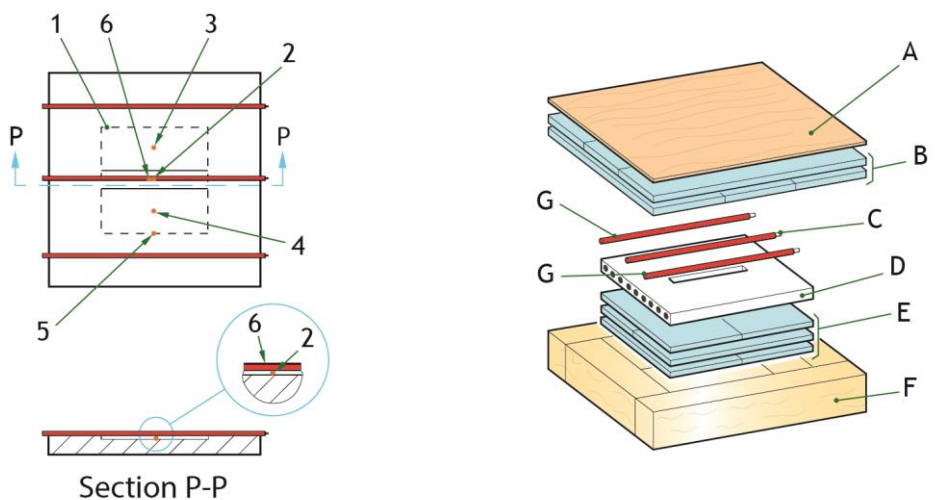
## Pipe / tracer temperature relationship – Hotplate test

Trace heating standards previously discussed identify 2 test methods whereby the designer can demonstrate his ability to predict safe tracer sheath temperatures for a given pipe temperature. For stabilised designs, this is done under the most onerous / runaway conditions discussed above.

These two methods are the so-called Pipe Sculpture test, and, alternatively, the Hotplate test, and relate to the trace heating of steel pipes. This paper focuses on the Hotplate Test, which the author believes to deliver the most reproducible results. The results from this test can be represented as per the following graph depicting the relationship between pipe and tracer sheath temperatures for various power loadings and pipe temperatures.



The following sketch shows 3 tracers representing adjacent spirals located within the hotplate, that itself represents the metal pipe. The tracers are positioned such that a 6mm air gap exists between the tracer and hotplate to reflect a real installation when a tracer is away from the pipe where, for example, it crosses a valve or pipe fitting. This is where the worst case temperature will exist.



### Key

- |   |                                      |
|---|--------------------------------------|
| 1 300mm x 300mm test area.  | A Wood board                         |
| 2 Thermocouple on bottom surface of trough.                       | B Two layers of rigid insulation     |
| 3 Plate temperature control point 75mm from centreline of trough. | C Test sample                        |
| 4 Thermocouple 75mm from centre of plate.                         | D 600mm x 600mm plate                |
| 5 Thermocouple 150mm from centre of plate.                        | E 75mm insulation below plate.       |
| 6 Thermocouple on test sample.                                    | F 150mm mineral wool sides of plate. |
|   | G Two unpowered support samples.     |

**Figure 9 – Verification of sheath temperature, hotplate test**

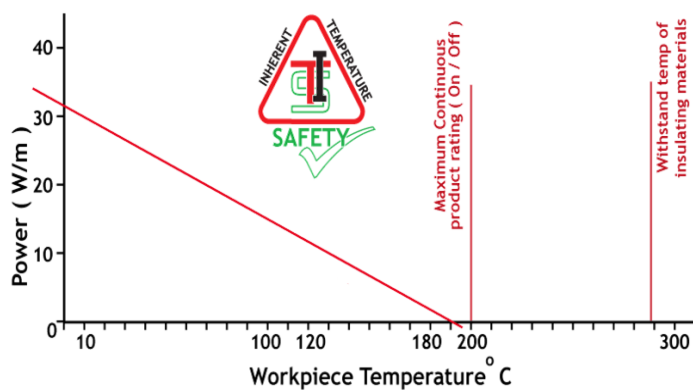
The Pipe Sculpture test is likely to produce less conservative, less reproducible, and less safe results than the Hotplate.

## IT-S INHERENT TEMPERATURE SAFETY

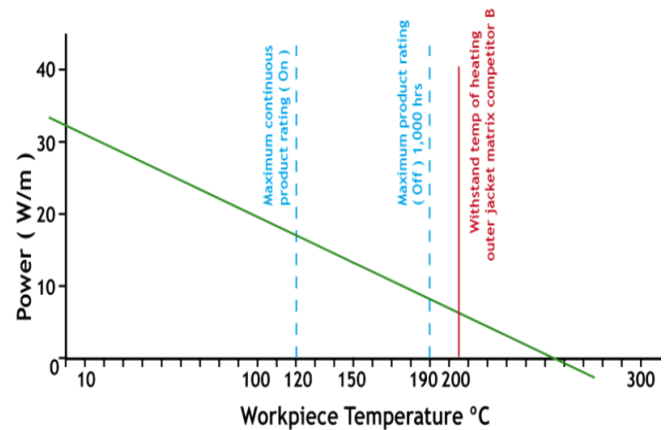
IT-S is by no means new. When self-regulating semi-conductive PTC heating cables were first introduced in the 1980's, they were initially low temperature products used mainly for winterization. They were effectively switched off at around 70°C and could be considered inherently temperature-safe since they only operated within the temperature constraints of their constructional materials.

Since that time, self-regulating heating cables having higher withstand temperatures have been developed for medium and higher process temperature maintenance. However, many of these cables are NOT inherently temperature-safe, and continue to deliver power when operating beyond their maximum continuous withstand temperatures. Such products still require temperature controls to ensure safe temperatures unless a stabilised design by calculation is possible.

**INHERENTLY TEMP. SAFE**



**NOT INHERENTLY TEMP. SAFE**



It will be appreciated that, in terms of the necessity for temperature control, non IT-S self-regulating heating cables provide no benefits over constant power or so called power-limiting cables, which also rely on controls. Indeed, non IT-S self-regulating heating cables perhaps should be referred to as power limiting rather than self-regulating.

It can be seen that there is now a need to differentiate between IT-S and non IT-S heaters. A definition is needed in IEC62395 and IEC60079-30 to address what could potentially be a safety issue. A proposal might be:-

*“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 control.”*

### Double thermal insulation trace heating

The implicit requirement for IT-S heaters is highlighted in both IEC62395 and IEC60079-30 which describe a trace heating methodology intended for tracing pipes which may have an exposure temperature above the withstand capability of the heating cables.

This method comprises the sandwiching of IT-S self-regulating semi-conductive PTC heating cables between two layers of thermal insulation whose thicknesses are determined so as to arrive at an interface temperature within the constructional limits of the heating cable. This practice was originally intended for winterization applications.

Double insulation tracing is questionable at the very least. To install a self-regulating heating cable in a substantially adiabatic environment effectively turns off the heater, creating simply a warm surface running through the centre of the insulation. This may be sufficient to prevent freezing most of the time, but is unlikely to be effective for higher temperature maintenance duties. Far better to provide a properly designed system suited to the exposure temperatures involved!

Although it is the author's opinion that this methodology should be removed from future standards editions, only IT-S inherently safe heaters can be used in this way – they will be temperature-safe, after all!

### **Intermittent Temperature ratings – beware!**

Some manufacturers quote intermittent temperature ratings that are higher than their continuous withstand temperatures. For example, a cable may be rated 121°C maximum continuous withstand, but with a “maximum intermittent un-energised exposure temperature of 215°C – 1000 hours”. Clearly, it is a safety risk to rely on such a rating – who is checking how long the cable may be exposed to such a temperature? If it is limited to an intermittent exposure or a limited time limit, it implies that the cable will deteriorate if these limits are exceeded.

Ask the maker for his maximum continuous temperature ratings, energised or not. Temperature safety is paramount!

### **Circuit Over-current Protection**

Each heating circuit should be provided with over-current protection. Maximum safety is provided by a circuit breaker having a rating close to the operating current of the circuit. Some self-regulating heat tracers exhibit a high in-rush current on start-up from cold and require the use of a highly rated circuit breaker with a delayed breaker action. This reduces the level of safety provided. To improve safety, consideration should be given to incorporating into each circuit a soft-start device, if available, that can reduce in-rush currents by up to 50%, thus allowing the use of circuit breakers having lower ratings more closely matched to the operating current.

### **Circuit Earth Leakage Ground Fault Protection**

Each heating circuit should be provided with earth leakage protection, double pole if the application is in a hazardous area. The residual current device should normally have a sensitivity of 30mA and operate within 30ms. Exceptionally, for example where long heating circuits apply, it may be necessary to decrease the sensitivity level to avoid ‘nuisance’ tripping. Similarly, multiple parallel circuits from a common contactor/mcb/rcd such as winterisation systems, may also dictate reduced sensitivity.

### **Circuit Arc Fault Protection**

To optionally provide the highest level of electrical integrity and safety, it is possible to specify circuit breakers which will disconnect the supply in the event of an arc occurring (for example a loose terminal). This is a fault condition that is unlikely to be detected by overcurrent and earth leakage (ground fault) protection.

### **Application Criticality**

Most trace heating applications are deemed non-critical, having no requirement for additional or redundant heating equipment. The requirement for redundancy and the degree of redundancy is determined by the criticality of the application. For example, trace heating within the inaccessible containment area of a nuclear reactor may dictate complete redundancy, comprising duplicate sets of heating cables, controls, and power cables, whereas a critical process may require spare heating cables with automatic changeover in the event of heater failure. Judgment lies with the process engineer.

### **Corrosion Resistance**

Heating cables selected must not be adversely affected by contact with their environment nor by contact with the pipe contents should leakage occur.

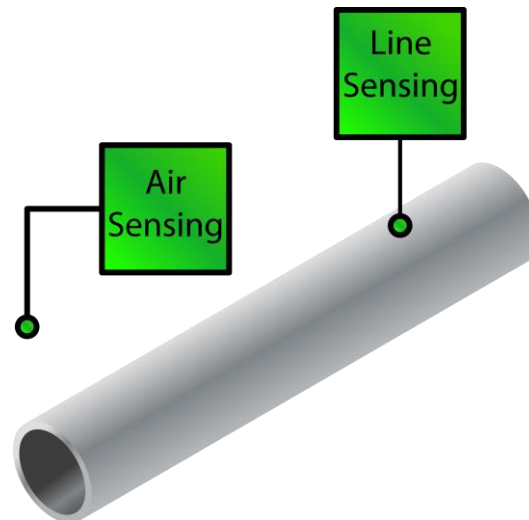
This often requires the provision of a suitable heater outer jacket of thermoplastic, fluoropolymer or elastomer.



## CONTROL & MONITORING

Even when not required for ensuring temperature safety, some form of temperature control is usually provided, if only for energy efficiency.

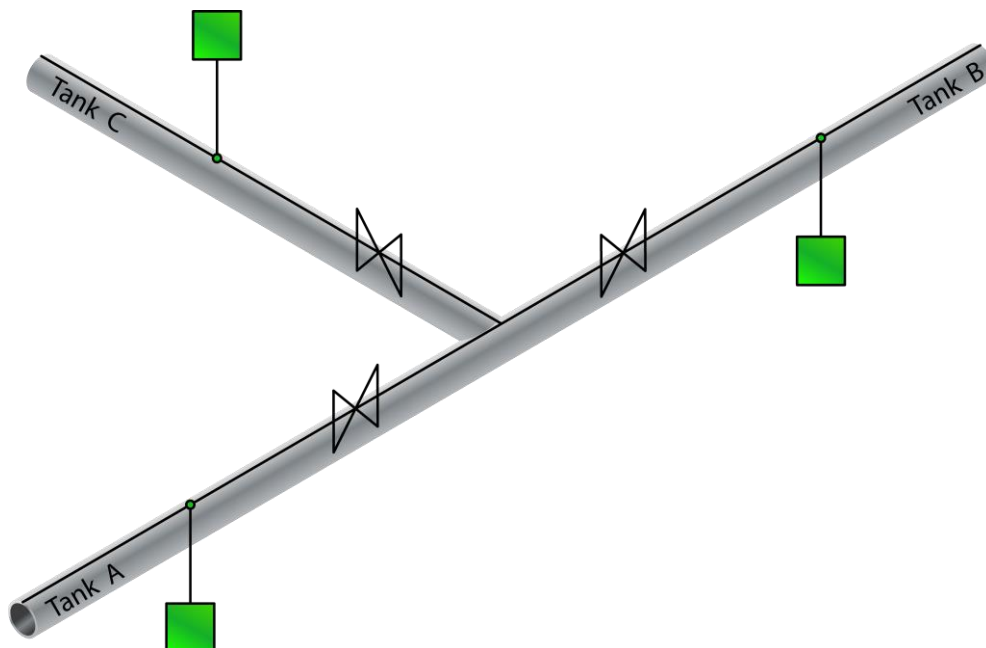
Control can either be provided by monitoring the temperature of the surface being heated and switching the heating load on or off within a dead band (called the switching differential) about the temperature to be maintained, or else, when a stabilised design is possible, by monitoring the ambient temperature and adjusting the applied load to match the heat losses as they vary with changes in ambient temperature. **Surface control must be adopted for non-stabilised designs.**



### Surface sensing control

Most commonly, surface control has been used where a temperature sensor is located on the pipe surface operating an on/off thermostat. It is important to understand the effect that flow and static conditions have on the design of the temperature control system. It will be appreciated that under no-flow conditions, heat will be lost through the thermal insulation so that trace heating is required to maintain temperature, whereas, during flow, the trace heating is probably not required.

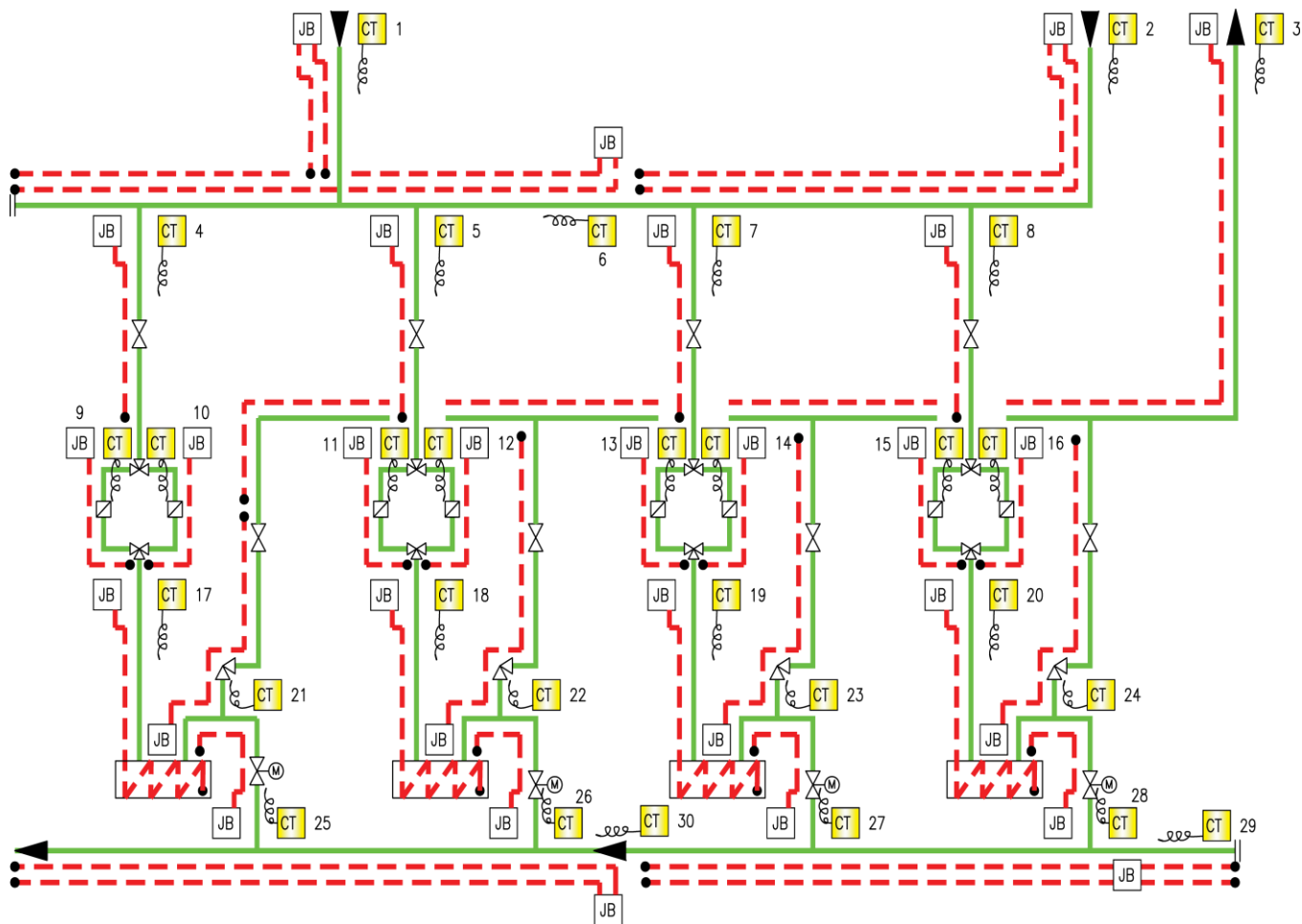
For example, consider a simple system where heavy fuel oil is held in 2 adjacent tanks A and B at 60°C. Oil can be transferred from either to another tank, C. When the lines are static, i.e. no flow, they must be maintained at 55°C. When oil flows from tank A to C, heating is not required to those 2 pipes, whilst the third pipe from tank B will cool unless traced. So, for this simple piping arrangement, there needs to be 3 heating circuits, each controlled separately.





## Surface sensing control

In-plant control is often made ever more difficult in complex valved piping systems where multiple flow paths necessitate many controllers if surface sensing devices are used. For example, around the four pump sets shown below, there are a myriad of flow/no flow permutations. To control this correctly taking account of all flow possibilities, it would be necessary to employ 30 thermostats for the correct design shown. It is the author's experience that most designers recognise that they will be uncompetitive if they have so many controls and such a large distribution board for such a small amount of pipework. They therefore cut a few corners, supplying fewer thermostats than are really needed. Safety is compromised by cost.

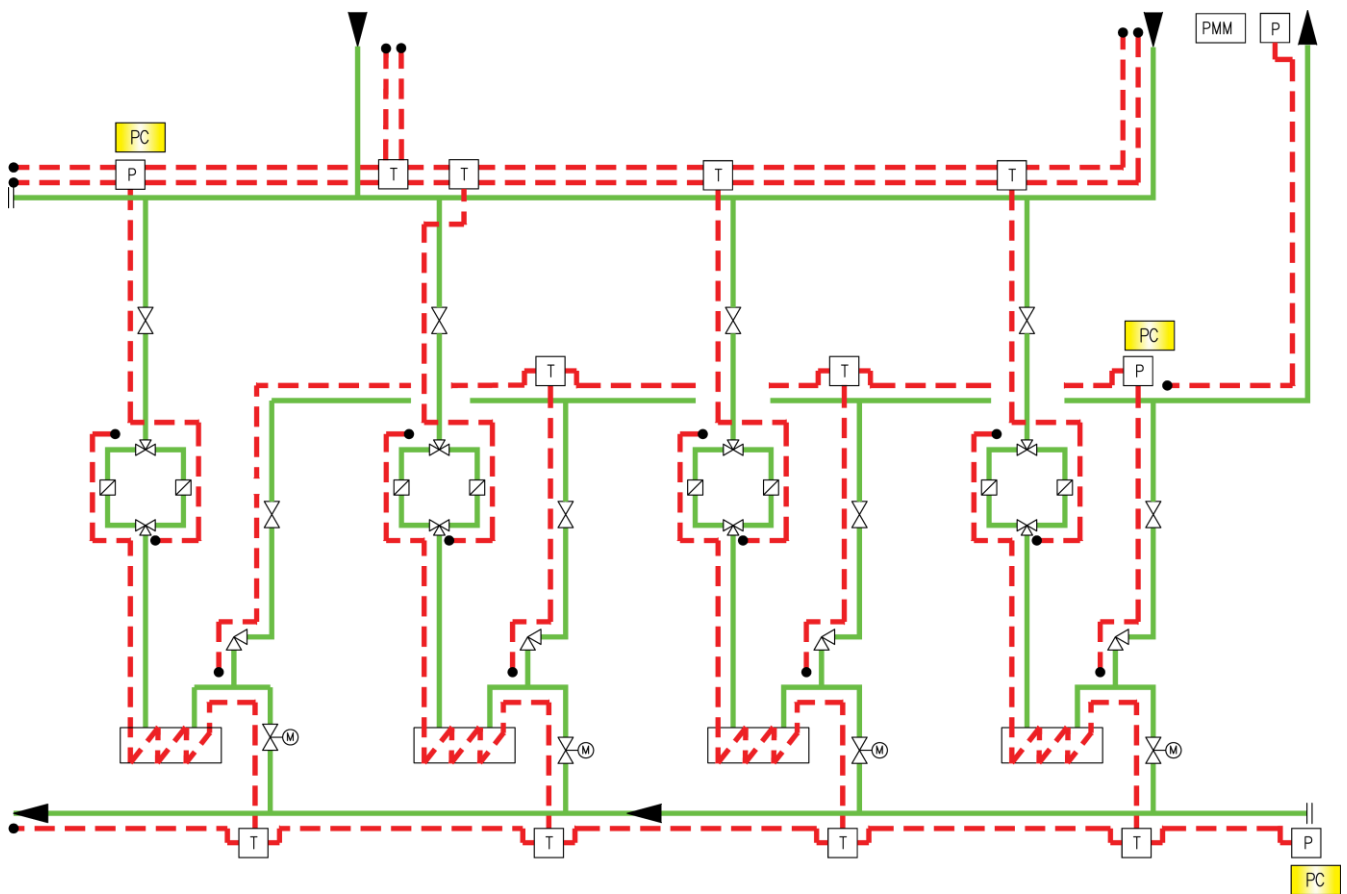


## Air sensing control

An alternative to pipeline sensing is to provide air-sensing control and ignore flow patterns. Considering again Tanks A, B, and C above (page 20), it will be appreciated that if heat is applied to all pipes when only one is static, the added heat will not be wasted as less heat will be needed to maintain the temperature in Tank C. It is therefore much simpler to employ air sensing control, but only if a stabilised design is possible, preferably with inherently temperature-safe heating cables.

In this case, a proportional controller should be employed. This monitors the ambient conditions and adjusts the amount of heat delivered to the pipes proportionally according to the air temperature and hence the heat losses.

As well as simplifying the trace heating system, far fewer heating circuits are required. For the pumping sets shown above, the 30 heating circuits can be reduced to 3 as shown here. Temperature fine tuning can be provided by having a surface sensor for each circuit located on a dead leg i.e. a heated section of pipe having no flow. *This sensor may also be utilised as a high or low temperature process alarm.*



The total capital cost of a trace heating system is often most influenced not by the cost of the heating cables but by the cost of the control and distribution panels, together with the additional power cabling to all those heating circuits.

**Thus heating circuit design is an extremely important element in the provision of both a safe and competitively priced trace heating system.**

## Heat Tracer installation – straight trace or spiral?

The choice of straight, alternatively, spiral trace should be determined according to the degree of temperature accuracy specified for the project. The IEC trace heating standards address three levels of temperature control accuracy:-

a) Maintaining above a minimum temperature

Straight tracing of tracer cables to pipework is sometimes preferred, and is acceptable for this low level of temperature control accuracy. Certainly, it is easier/quicker to install. But it does mean that pipes will be provided with more heat than the calculated minimum design load as a tracer having a higher output must be selected. This in turn means that some energy efficiency will be lost. Recognising that all designed systems include additional power (an efficiency factor) to cater for potential losses beyond the control of the designer, and that a *minimum* design ambient is used, that under normal circumstances is not sustained, there will always be an excess of power capability to regulate.

b) Maintaining within a broad temperature band e.g. 10°K

In order to meet this requirement, the author recommends that the power delivered by straight tracing is limited to no more than 15% more than the calculated design load; otherwise spiral trace should be adopted. Selecting a tracer having a lower power output than the calculated loss, means it can be spiralled to provide exactly the designed heating load.

c) Maintaining within a narrow temperature band e.g. 5°K

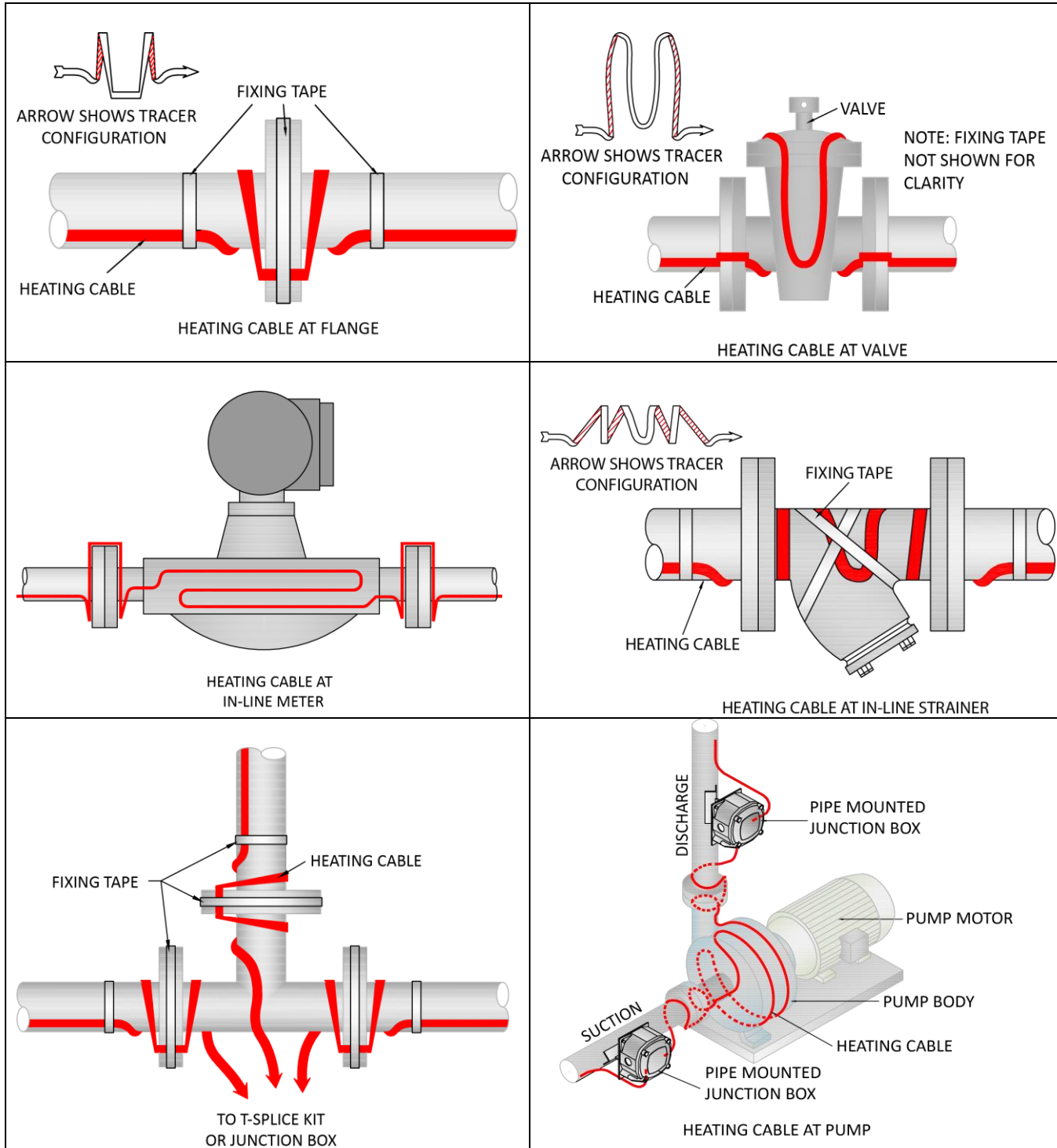
In this case, tracers must be spiralled to provide exactly the calculated design heating load.

In general, straight tracing provides a lower cost in heating cables, and a quicker installation, whereas spiralling produces a balanced heating load, more accurate temperatures across the system, and better efficiency, albeit at a higher heating cable and installation cost. It should also be mentioned that the additional cable cost from spiralling will be small when compared with the saving in control/distribution panels and power cables when inherently temperature-safe heating cables are supplying a stabilised design.

However, spiralling can be easier if installed by fixing the cable to the pipe at both ends and spiralling the 'loop'. This method also permits in-line pipe fittings to be removed for maintenance without the necessity of removing a complete heat tracing circuit.

For spiralling examples, see the following set of images on page 24:

**Examples of Spiralling Heating Cable Around In-Line Equipment and Flanges for Access and Maintenance**



## **CIRCUIT DESIGN**

Circuit design becomes a most important consideration for the trace heating designer. For all applications calling for heat loss compensation, which is the majority of all installations, then if IT-S heating cables are available, temperature control can be simplified by an ambient proportional control system. This enables the number of heating circuits to be reduced, saving capital costs. Energy efficiency is provided by a controller turning the heating system up or down according to changes in the ambient temperature and hence in concert with the variation in heat losses.

One proportional controller is required for each different temperature system. For large installations, circuit numbers are often determined according to the circuit breaker capacity. For example, often trace heating circuits are limited to 40 amps. The number of heating circuits may sometimes be further reduced when self-regulating heating cables are energised by means of a soft-start, thus effectively increasing the heating cable circuit length. The soft starting of circuits improves safety as circuit breakers are more closely aligned with operating current.

Each heating circuit can be monitored for correct operation with alarm signals for fault conditions such as loss of power, low or high temperatures, switching of protective devices, etc.

Such control and monitoring systems improve the safety and reliability of electric trace heating installations.

### **Panel Location – heat maps**

The optimal positioning of control/distribution panels can be assisted by design software which is able to provide heating load heat maps on the plot plans of the plant. This produces the most competitive location in terms of minimising the power cable distances and cost.

### **Steam cleaned lines – care in design**

It is becoming more and more common for plant pipework to be periodically steam cleaned at steam temperatures which may typically be any temperature up to 500°C. Clearly, the heating cables must be capable of withstanding the steam temperature during the cleaning process.

Where steam temperatures exceed the limitations of inherently temperature-safe self-regulating heating cables, safety can be ensured by employing a control system that switches off the entire trace heating prior to the steam cleaning process being activated, assuming, of course, that the tracers can continuously withstand the steam exposure temperature when un-energised.

## **‘CRADLE TO GRAVE’ TRACE HEATING**

Most major manufacturers of heating cables have developed design software that addresses safety as well as the design requirements of electric trace heating.

Control and monitoring systems can be provided which can monitor system health and correct operation remotely from the jobsite, in many cases in different parts of the world. Trace heating systems can be provided which include for the Design, Supply, Installation/Commissioning, and Servicing. Servicing is the area of trace heating that is most commonly neglected,

Remote monthly or quarterly reports may be supplemented with annual service visits over the design life of a project, i.e. a ‘Cradle to Grave’ electric trace heating system.

**The continuous monitoring and service elements of the contract provide, in the author’s opinion, the greatest of all improvements in the safety, efficiency and reliability of electric trace heating.**

***PART 2 - Safe Electric Trace Heating at Optimal Cost***

**SPECIFICATION**

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## 1.0 SCOPE

This Specification addresses the general requirements for the design, supply, performance, installation, inspection and testing for in-plant Electrical Heat Tracing Systems. It relates particularly to in-plant pipelines which are relatively short in length. It is intended as a 'template' specification for design engineers to adjust to their own needs and is based on the design philosophy explained in a more general way in **Part 1 – Philosophy**.

These systems are usually required for the freeze protection (winterization) or temperature maintenance of pipelines, instruments, vessels, and other pipeline equipment, in both safe and hazardous locations.

In some cases, process heating may be required to raise the pipe and/or its contents from cold to process temperature within a given time period.

Electrical Trace Heating shall be provided to maintain the minimum specified process temperature in the piping and equipment during normal operation, both under flow and no-flow conditions, in order to prevent freezing, or to maintain temperatures in the piping and equipment that may include instruments and tubing.

Where appropriate, the Electrical Trace Heating cables selected shall not be adversely affected by exposure to steam temperatures when cleaning pipework and equipment. They shall also be resistant to the environment in which they operate and also to damage from pipe leakage.

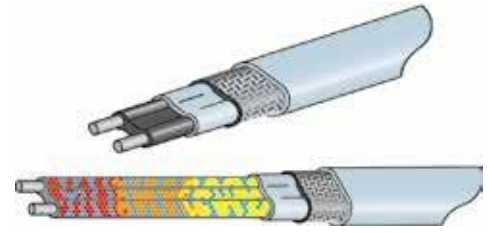
For very long (multi-kilometre) pipelines, a separate specification is to be made available.

## 2.0 DEFINITIONS

Definition of terms can be found in the relevant trace heating standards IEC62395 and IEC60079-30. However, those shown below are some which the author believes require clarity.

### 2.1 Self-regulating (or self-limiting) heating cable

A self-regulating heating cable is one whose power output varies with changes in its temperature, such that maximum power is delivered at minimum temperature and the cable has effectively no power output at the cable's maximum withstand temperature. A heater meeting this definition is deemed to be inherently temperature-safe.

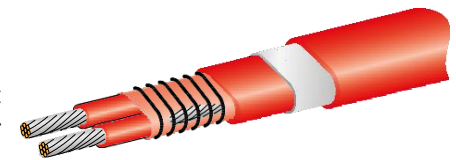


Parallel Self-regulating Output - typical construction

*Comment – many semi-conductive heating cables do not satisfy this definition. In many cases, power output varies with changes in cable temperature, but the cable continues to deliver power beyond the maximum continuous temperature limit of the cable. Such heaters may be referred to as 'self-regulating'. More correctly perhaps, such cables should be called 'power limiting', as some form of temperature control is required to ensure temperature safety. See 2.2 below.*

### 2.2 Power limiting heating cable

A power limiting heating cable is one whose power output varies with changes in its temperature such that maximum power is delivered at minimum temperature, but where the cable continues to deliver power output beyond the cable's maximum withstand temperature.



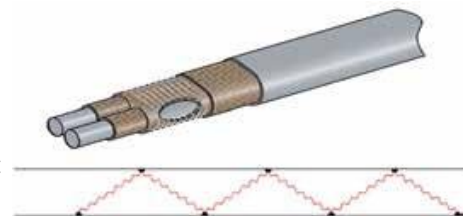
Power Limiting Output - Typical construction

### 2.3 Constant wattage (or constant power) heating cable

A constant wattage (or constant power) heating cable is one whose power output remains substantially constant across its operating temperature range.

### 2.4 Parallel resistance heating cable

A cable whose heaters are in parallel with its conductors, permitting a cut-to-length facility without affecting the cable's power output per unit length. The cable may be self-regulating, power limiting, or constant wattage



Parallel Output

### 2.5 Series resistance heating cable

A cable whose heaters are connected in series with the electrical supply. Such heaters must be specifically designed to suit length, voltage, and power requirements.



Series Output

### 2.6 Electric Trace Heating

May also be referred to as Electric Heat Tracing, or by the acronyms EHT or ETH



### 3.0 CODES AND STANDARDS

Unless otherwise specified, the design, equipment, materials, and installation of the electric heat tracing system, shall conform, to the applicable requirements of the international standards and codes listed below.

Engineering design and installation shall comply with latest edition of applicable international Codes and Standards.

The main Trace Heating IEC international standards are listed below. Equivalent national U.S., Canadian and Russian national Standards may also need to be considered, with required CSA or CU-TR conformity certification.

The information contained in this document follows and conforms to the general requirements and recommendations laid down in the following international standards and codes.

#### International Electro-technical Commission Standards and Recommendations (IEC)

<b>IEC62395-1</b>	Electrical resistance trace heating systems for industrial and commercial applications - Part 1: General and testing requirements
<b>IEC62395-2</b>	Electrical resistance trace heating systems for industrial and commercial applications - Part 2: Application guide for system design, installation and maintenance
<b>IEEE/IEC 60079-30-1</b>	Explosive atmospheres, Part 30-1: Electrical resistance trace heating – General and testing requirements.
<b>IEEE/IEC 60079-30-2</b>	Explosive atmospheres, Part 30-2: Electrical resistance trace heating – Application Guide for Design, Installation and Maintenance
<b>IEC 60702</b>	Mineral insulated cables and their termination with a rated voltage not exceeding 750V
<b>IEC60079-0</b>	Explosive atmospheres - Part 0: Equipment - General requirements
<b>IEC60079-1</b>	Explosive atmospheres - Part 1: Equipment protection by flameproof enclosures “d”
<b>IEC60079-2</b>	Explosive atmospheres - Part 2: Equipment protection by pressurized enclosures “p”
<b>IEC60079-7</b>	Explosive atmospheres - Part 7: Equipment protection by increased safety “e”



#### **4.0 DESIGN CONDITIONS**

Electrical Trace Heating shall be designed to take account of the climatic and environmental conditions at the construction site as specified in the enquiry documentation. The possibility of condensation forming, during large temperature fluctuations in humid atmospheres, shall be taken into account.

The electrical equipment shall be designed for single or 3 phase, 50Hz or 60 Hz operation as required and at the specified voltages. Voltage tolerances and transient voltages should be taken into account in the design of a system. The voltage variations shall not adversely affect equipment operation.

When installed in potentially hazardous areas, the electric heating system must be suitable for the area and temperature classifications.

It is recommended that Engineers carrying out heat tracing system design should have the ETHIC-GLOBAL eAcademy accreditation.

## 5.0 OPERATING & SAFETY REQUIREMENTS

The Trace Heating System supplier shall ensure that all equipment and components provided (including that from sub-suppliers) are safe and suitable for the specified operating conditions.

A Trace Heating installation should provide the highest appropriate levels of Safety. This is mainly provided for by:-

- ensuring temperature safety
- over-current circuit protection
- earth-leakage protection

### 5.1 Ensuring temperature safety

Temperature safety is ensured by preventing the surface of the heat tracer from exceeding the limiting temperature. This limiting temperature may be the maximum rating of the tracer itself, the maximum allowable process temperature or, for example, the Temperature Classification (T Class) if the installation is within an hazardous area.

Temperature safety may be provided in a number of ways. The choice open to a designer, in order of preference, are:-

#### 5.1.1 Stabilised Design

A stabilized design is one where, under the most onerous conditions, the heater surface remains within the limiting temperature without the necessity of temperature controls.

This may be possible:-

##### 5.1.1.1 By the use of inherently temperature-safe heat tracers.

Some self-regulating tracers are inherently temperature-safe, their power output reducing with rising temperature such that the maximum withstand temperature of the cable cannot be exceeded due to the heat produced by the tracer. It must then be ascertained that the cable's withstand temperature does not exceed a lower limiting temperature e.g. process or T-Class. *Inherently temperature-safe heat tracers therefore provide the highest level of temperature safety.*

##### 5.1.1.2 By calculation

Here, a calculation is made to ensure that, under the worst case 'runaway' conditions, a tracer always operates at below the limiting temperature, without the need for external temperature control. 'Runaway' conditions occur when the ambient temperature and the supply voltage are at their maximum, and when the electrical resistance of the heater is at its minimum manufactured tolerance. Where inherently temperature-safe heat tracers are not available, *a calculated stabilised design provides the second highest level of temperature safety.*

*Comment – IEC60079-30 describes two methods for determining maximum possible cable sheath temperature, namely via 'Hot Plate' or alternatively 'Pipe Sculpture' tests. ETHIC-Global has demonstrated that the Hot Plate provides the most reproducible/reliable results, whilst being more conservative than the pipe sculpture, and is therefore recommended from the safety standpoint. The hot plate produces the relationship between a steel pipe temperature and cable sheath temperature when an air gap is present. The designer thus calculates the maximum uncontrolled 'runaway' pipe temperature and then rates the tracer power so as to produce a cable sheath temperature below the limiting temperature.*

#### 5.1.2 Temperature control

Where a stabilised design cannot be assured, it is then necessary to employ temperature control. Here the safety of the system is reliant on the correct functioning of the controller and the correct location and operation of the temperature sensor. This is therefore the least safe option and should be used by the designer as a last resort.

## **5.2 Circuit Over-current Protection**

Each heating circuit must be provided with over-current protection. Maximum safety is provided by a circuit breaker having a rating close to the operating current of the circuit. Some self-regulating heat tracers exhibit a high in-rush current on start up from cold and may require the use of a circuit breaker having a delayed breaker action which reduces the level of safety provided. Consideration may be given to incorporating a means of soft starting into the circuit protection system allowing the use of circuit breakers having ratings more closely matched to the operating currents.

## **5.3 Circuit Earth Leakage (ground fault) Protection**

Each heating circuit should be provided with earth leakage protection. The residual current device should normally have a sensitivity of 30mA and operate within 30ms. Exceptionally, for example where long heating circuits apply, it may be necessary to reduce the sensitivity level to avoid 'nuisance' tripping.

## **5.4 Circuit Arc Fault Protection**

To optionally provide an even higher level of electrical integrity and safety, consideration should be given to the specifying of circuit breakers which will disconnect the supply in the event of an arc fault occurring that is unlikely to be detected by overcurrent and earth leakage (ground fault) protection.

## 6.0 HEATING SYSTEM REQUIREMENTS

### 6.1 General Requirements

#### 6.1.1 Ingress Protection

As a minimum, the outdoor enclosures shall have a degree of protection IP 55 and indoor enclosures a degree of protection of IP41, in accordance with IEC 60529, unless specified otherwise in the enquiry documents.

#### 6.1.2 Electromagnetic Compatibility (EMC)

Harmonic current emissions in both the power supply input and output of the system shall be controlled within acceptable limits with respect to Electromagnetic Compatibility (EMC)

Electromagnetic disturbance generated by the heater and its components must not exceed a level that would affect the correct operation of radio and telecommunications equipment.

The heat tracing system shall be unaffected by external electromagnetic disturbance.

#### 6.1.3 Temperature Considerations

Heat tracing on piping and equipment that may be subjected to periodic steam cleaning shall have a minimum continuous withstand temperature above the steam temperature with the power "OFF".

Heating cables or equipment shall be selected having a withstand temperature equal or greater than the maximum possible operating temperature plus 20°C.

The power output of the heating cables shall be such that the temperature limits of the pipe, heaters and pipe contents, are not exceeded.

#### 6.1.4 Maintenance Considerations

Heat tracing equipment which may be subject to maintenance shall be easily accessible to allow for safe and convenient performance of such requirements. This may, for example, involve designing for easy cable disconnection at valves, pumps etc. Parallel resistance heating cables that can be cut-to-length are preferred as they provide such a capability.

System components shall be standardised where possible.

### 6.2 Temperature Requirements

The Electrical Heat Tracing (EHT) system shall be categorized as "Process temperature maintenance", "Winterisation", or "Temperature raising", as required.

The extent of the EHT system shall be specified via the enquiry's Line / Equipment / Instruments / Package Lists /Area Plot Plans, P&ID's, together with pipework layout and isometric drawings.

Enquiry information with respect to temperatures of traced piping and equipment shall be provided to include:-

- Maximum and minimum ambient temperature conditions.
- Operating temperatures / Temperature to be maintained.
- Minimum / Maximum process temperatures. (High and low temperature ranges).
- Shutdown temperature conditions (e.g. for steam cleaning).
- Lines with intermittent or no flow, shall be clearly identified (e.g. spare pumps, by-passes).

### 6.2.1 Temperature Raising

In most applications, temperature raising is not required. However, it is useful, for example at start-up or after a power failure, to know how long it will take the system to reach its maintained temperature. This will depend on how much heat capacity is available. If heat up time is an important factor, additional heating capacity of the trace heating, over and above that required for temperature maintenance, shall be taken account of in the design.

Apart from temperature maintenance, there may be a need to melt out the contents of a pipeline within a certain time. This may be required for example when the product is solid under ambient conditions (e.g. heavy fuel oil). Additional heating capacity is needed in this case.

This can be achieved by increasing the temperature maintenance heating capacity or by installing additional heaters dedicated for this duty. Consideration should be given to the maximum heat density allowable under those circumstances.

### 6.2.2 Redundancy

For critical processes, it may be necessary to provide a redundant heating system. This may apply not only to the provision of additional heating cables, but also to independently separate controls and electrical supplies to ensure that process requirements are maintained even during a supply failure.



Redundant circuits on long pipeline

### 6.2.3 Start-up Conditions

The temperature at start-up often determines the start-up current and hence the start load particularly when semi-conductive self-regulating tracers are specified. This temperature in turn determines the rating of the circuit breaker. With self-regulating heaters, the lower the specified temperature at start-up, the higher the power output will be, and the protective device will need to be rated accordingly.

If the electrical protection rating is enquiry-specified, then the heating circuit length must be limited to a maximum value such that the start-up load does not exceed the circuit breaker rating and the start-up current is matched with the circuit breaker characteristic.

As mentioned in 5.2, consideration may be given to incorporating a means of soft-starting into the circuit protection system, allowing the use of circuit breakers having ratings more closely matched to the operating currents, or enabling longer heating circuits.

## 7.0 HEATING CABLE SELECTION

### 7.1 General

For in-plant trace heating, the following generic types of heating cable may be available to satisfy requirements. The most appropriate type may be selected according to safe / hazardous area installation, together with the requirements and parameters for the electrical tracing of process lines, equipment, instruments etc., as specified.

- Self-regulating (Self-limiting) parallel heaters;
- Constant wattage (or power limiting) parallel heaters;
- High temperature elastomer /polymer insulated series cables
- Mineral Insulated (M.I.) heaters

### 7.2 Self-Regulating (or Self-Limiting) Heaters

Self-regulating heaters are the most popular generic form of heating cable. This is because they are generally perceived to be inherently temperature-safe i.e. the power output of the cable reduces with increasing temperature such that the heater is effectively switched off before the limiting temperature is reached. This may sometimes be true of low temperature (<100°C) self-regulating heaters, but for medium or high temperature products, **most** manufacturer's semi-conductive heating cables are not inherently temperature-safe, and thus still need temperature controls to ensure temperature safety. In that case, they offer no advantage over constant power heating cables. Such cables ought, more correctly, to be termed 'Power limiting' rather than 'self-regulating'.

*Comment - Request a written undertaking from the manufacturer that the semi-conductive, self-regulating cables offered by them, are inherently temperature-safe, as per the definition at 2.1. Otherwise, the cables should be re-classified as power limiting,*

Self-regulating heaters, when inherently temperature-safe, are the safest option and shall be utilised wherever possible, within their restrictions of heat output, operating temperatures and steam cleaning requirements. Some manufacturers have low and high temperature product ranges that can be used for all winterising and the majority of temperature maintenance requirements.

The heating cable shall generally comprise two parallel conductors, between which is extruded a self-regulating semi- conductive heating matrix. This matrix shall be insulated by an extruded polymeric or elastomeric jacket, covered with a continuous metallic earth screen covering at least 70% of the surface and, optionally, a corrosion resisting outer jacket.

The tracer shall have a power output that varies in response to the sensed temperature at every point along its length. As the temperature increases, the heat output shall decrease automatically and vice versa. The natural reduction in heat output by increasing temperatures shall be such that the heater will not be damaged due to overheating as a result of, for example, overlapping, irrespective of the application i.e. inherently temperature-safe.

Self-regulating cable shall be capable of being overlapped on itself (although this should be avoided wherever possible) without causing hot spots, when uncontrolled.

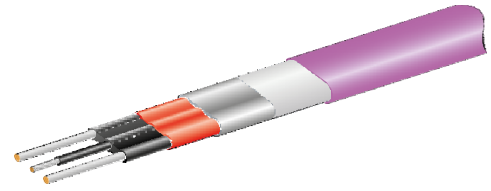
Being of a parallel resistance construction, self-regulating heating cables can be cut-to-length at site without affecting the power output per unit length. This, together with inherent temperature safety, results in self-regulating cables being the preferred generic type, where temperature and power constraints permit.

Such cables are now available from certain manufacturers suitable for use with process temperatures of 275°C, either energized or switched off.

*Comment - Life of self-regulating heating cables is usually determined by the gradual reduction in contact levels between the power conductors and the extruded semi-conductive heating matrix. Consideration should be given to the specifying of cables having an integrated bonding system that provides significantly increased life of 15 years or more.*

### 7.3 Self-Regulating (or Self-Limiting) Heaters

Where long pipes are being traced consideration may also be given to 3 phase self-regulating heating cables (where available) which enable circuit lengths of 3 times those of single phase heaters. Circuits, typically up to 1000 metres, may be possible when operated on elevated voltages.



3-Phase Self-regulating Cable

### 7.4 Constant Wattage (or Constant Power or Power Limiting) Parallel Heaters

Constant wattage (or Power Limiting) parallel heaters should be utilised (if available) when the required heat output or the operating temperature is beyond the capabilities of self-regulating heaters. A constant wattage (or Power Limiting) parallel heating cable comprises two insulated copper conductors having heating resistance wires electrically connected across and along them at certain distances, to form multiple short heating zones. The length of a heating zone is usually within the range of 0.5 to 1.5 metres, and determines the power loading of the cable. Cutting of the tracer results in a cold lead section from the cut to the first electrical connection.

The conductors and the heating elements shall be provided with one or more layers of insulating material. All insulating material shall be heat resistant, and shall be covered with a continuous metallic earth screen covering at least 70% of the surface and, optionally, a corrosion resisting outer jacket.

The tracers shall provide a substantially constant (or gradually reducing) power output regardless of the operating temperature. In the event of a hot spot, the affected short heating zone may fail leaving, however, the remaining part of the heater in operation.

Being of a parallel resistance construction, constant wattage (or Power Limiting) heating cables can be cut-to-length at site without affecting the power output per unit length. Although not inherently temperature-safe, constant wattage (or Power Limiting) heaters become the preferred generic type, if self-regulating heating cables are not available. They require temperature controls to ensure temperature safety if a calculated stabilised design cannot be assured.

Some manufacturers market 'Power Limiting Heaters'. This term is essentially marketing jargon. The cables are constructed similarly to constant wattage heaters, but the heating resistance wires, have a slight PTC (Positive Temperature Coefficient), rather than the ZTC (Zero Temperature Coefficient) characteristic of constant wattage. This results in some power reduction with increasing temperature of the resistance wires though unlike inherently temperature-safe self-regulating heaters, the power limitation provides no advantage and temperature controls are still required. The power limitation may actually be viewed as a disadvantage as the user cannot know the wire temperature and hence it's actual power output.

However, in terms of heater generic type preference, power limiting cables offer similar benefits to constant wattage heating cables, as both can be cut-to-length without affecting power per unit length, while both usually require some form of temperature control to ensure temperature safety.

Constant wattage parallel heaters are available having withstand temperatures up to 500°C, and are the heater of choice where very high process or steam cleaning temperatures, outside the range of self-regulating heaters, are encountered. Power limiting heaters usually have a lower temperature rating.



## 7.5 High Temperature Elastomer / Polymer Insulated Series Cable Heaters

Series heating cables may be used where the heating circuit length is beyond the capability of parallel heaters. This will reduce the number of power supply points and associated power cabling. Such cables may be used for example for the heating of long transfer lines between plants, which may be kilometres in length.

Medium temperature series cable heaters usually comprise one or more conductors insulated by water resisting material such as silicone rubber, or fluoropolymers, over which a continuous metallic screen having low electrical resistance and covering at least 70% of the surface is applied. Optionally a waterproof outer jacket (e.g. silicone rubber, or fluoropolymer) may then be further applied.

The heaters shall provide a substantially constant power output irrespective of the operating temperature. They may be flat or round, depending on the heat dissipation requirements and operating voltage.

The power output of series heaters shall be limited to prevent the possibility of overheating or burn-out under normal operating conditions.

It should be recognised that all series type heating cables are specifically designed to provide the appropriate power output relative to circuit length and voltage, and usually require some form of temperature control to ensure temperature safety. Thus they should only be used for long pipe runs where parallel cables are not available.

## 7.6 Mineral Insulated (MI) Heaters

If the required temperatures are beyond the limits of self-regulating and constant wattage (or Power Limiting) parallel heaters, **then** Mineral insulated series heaters may be considered.

Mineral insulated heating cable shall comprise a metal outer sheath enclosing a metallic heating conductor, insulated with magnesium oxide powder. The outer sheath may typically be stainless steel or Alloy 825. Such a construction may typically be suited to operating temperatures up to 600°C.

The cable shall have a substantially constant power output per unit length determined by the conductor electrical resistance, the length of the cable and the applied voltage.

MI cables are extremely craft sensitive - the cable shall be prefabricated into the required length and provided at ends with proper seals, cold connection leads and metal cable glands. Site fabrication and termination is not allowed. *They are particularly unsuited to the heating of instrument impulse lines which are usually site run, such that actual tube lengths are not known at the design stage. Cut-to-length tracers are necessary for such instrument lines.*

## 8.0 TEMPERATURE CONTROL AND MONITORING

### 8.1 Temperature Control - General

Each application will have its own particular temperature control requirements. These may include, for example, operational flexibility, energy efficiency, and acceptable temperature tolerance or span.

The selection of an appropriate temperature control system is dictated by its purpose or objective. The following considers two forms of control:-

- Air-sensing, where the air temperature is monitored and the heating load is either:
  - a) fully applied at a set temperature, as traditionally used for freeze protection installations, or,
  - b) varies with changes in ambient temperature, and hence heat losses (sometimes called proportional control or Power Matching).
- Pipe, or surface sensing, where the controller sensor is located directly on the pipe, or equipment surface. This method has been traditionally employed for temperature maintenance duties.

The purpose or objective of the temperature control system may be any one or more of the following:-

#### 8.1.1 Ensuring temperature safety

It has already been stated that temperature control for ensuring temperature safety is the least favoured option – inherently temperature-safe self-regulating heaters, or a calculated stabilized design provide greater safety. But where these options are not available, then for ensuring temperature safety, pipe or surface sensing is appropriate. In this case, care is required to ensure that all pipes which can experience differing flow conditions are controlled independently – this may result in a large number of heating circuits.

When ensuring temperature safety, the designer needs to understand the relationship between the pipe temperature and the heater sheath temperature such that the heater can never exceed the limiting temperature when energized with the pipe at its set-point temperature.

*Comment – the sensor needs to be located to provide a representative temperature – installers often choose the most convenient location!*

*Comment – controlling the heater sheath temperature by mounting the sensor directly onto the heating cable is strongly discouraged; a) how can it be known to be at the hottest part of the cable, and b) if the sensor is moved during maintenance and not correctly re-positioned, safety is compromised – an accident waiting to happen!*

#### 8.1.2 Energy efficiency

The highest levels of energy efficiency have usually required a pipe or surface sensing form of control system. This again often results in multiple heating circuits to accommodate the many permutations of flow conditions. In this case, sections of pipe having differing flow conditions need to be controlled independently. The degree of energy efficiency is also influenced by the accuracy of the controller – electronic devices are often more accurate than mechanical types.

#### 8.1.3 Low capital costs

The lowest EHT capital costs will usually result from a temperature control system having the fewest number of heating circuits. This is normally achieved by an air-sensing form of temperature control system.

## 8.2 Process temperature accuracy

Three levels of process temperature accuracy are defined in IEC heat tracing standards, as types I, II, and III, The approach to selecting the best control system for each type of process is described below.

### 8.2.1 Type I process control – maintaining above a minimum temperature level

A Type I control system will be extremely energy wasteful. For example, a freeze protection installation controlled by an air-sensing thermostat will be 100% energised at all times when the ambient temperature falls below the thermostat setting (typically 3°C or 4°C). However, the average heating requirement over the number of winter hours that the system is energised is likely to be less than 20%, i.e. over 80% of the delivered heat will be wasted. Most of this waste heat may be avoided by adopting a Type II process, achieved at a very modest additional cost, where energy savings recover the additional cost in a very short period of time.

### 8.2.2 Type II process control – maintaining within a broad temperature band

Type II control is sufficient for most in-plant trace heating installations and has traditionally been achieved by means of mechanical capillary thermostats, having their sensors located on the pipe surface. However, in-plant piping systems are often complex, having multiple flow permutations. To control all possible permutations, a separate thermostat is required for each section of pipe having differing flow conditions. This results in many heating circuits within an expensive distribution system.

For stabilised designs Type II process control may be achieved, whilst at the same time reducing to a minimum the number of heating circuits, and hence, distribution and control panel costs, by means of proportional temperature controllers which monitor the ambient temperature and vary the heat delivered by the tracer according to changes in ambient temperature, and hence, heat losses. By monitoring the air rather than the pipe surface temperature, only one controller (or setting) is needed for each different 'maintain' temperature. The system can be used equally for either freeze protection or process temperature maintenance.

### 8.2.3 Type III process control – maintaining within a narrow temperature band

To control all sections of a piping system within a narrow temperature band of 2-5°C, as required for temperature sensitive materials (e.g. chocolate), has traditionally required the use of numerous high accuracy electronic controllers, controlling several sections of pipe which may have differing flow conditions. This has necessarily been provided at a high capital cost.

For stabilised designs however, Type III process temperature accuracy can now be achieved with the same power matching proportional temperature controlling system described for Type II systems above, but with the addition of a fine-tuning temperature control. Again, the heating load delivered at any time is matched to losses according to the ambient conditions.

To ensure narrow band process accuracy, a further sensor is located on a short heated 'dummy' line incorporated into the piping system.

The narrow band accuracy may require the heating cables to be spiraled onto the pipes to ensure that the relative heat losses from different pipe sizes are compensated for in their correct ratios.

*Comment - it may be difficult to achieve the narrow band accuracy across pipe fittings such as valves, flanges, etc., where the designer cannot know surface areas and simply accords the fitting with an equivalent pipe length heat loss. Similarly, pipe supports are almost never detailed on the enquiry documentation, but, depending on design, may have substantial losses, unless the supports are thermally insulated from the pipe.*

## 8.2.4 SUMMARY

**Type I process control** – maintaining above a minimum temperature level

- Is very energy wasteful. Not recommended

**Type II process control** – maintaining within a broad temperature band

- can be achieved by air-sensing proportional control to provide good energy efficiency from the fewest number of heating circuits i.e. least capital cost. Only for use on stabilized designs. For controlled designs, surface sensing must be used, requiring more heating circuits.

**Type III process control** – maintaining within a narrow temperature band

- can be achieved by air-sensing proportional control plus fine-tune line control to provide good energy efficiency from the fewest number of heating circuits. Heating cables may need to be spiraled. Only for use on stabilized designs. For controlled designs, surface sensing must be used, requiring more heating circuits.

## 8.3 Other Control Considerations

For hazardous area applications, requiring a temperature control device to ensure temperature safety by limiting the maximum surface temperature, a separate over-temperature protective device shall be deployed that will de-energise the system should the maximum permissible operating temperature be reached. Reset shall only be possible manually after the specified process conditions have returned. In the event of damage to the controller or its sensor, the heating system shall be de-energised to allow the defective equipment to be replaced. The setting of the protective device shall be secured and sealed to avoid tampering.

The protective device shall operate independently from the temperature monitoring or control system, if provided.

The materials of construction of the heating cable must be able to withstand the maximum process temperature. Heaters applied to lines which may be subject to periodic steam cleaning should additionally be able to withstand exposure to the steam temperatures continuously when un-energized. Manufacturers temperatures ratings that are conditional, such as 'intermittent' or 'maximum 1000 hours cumulative' shall be disregarded and only continuous temperature rating are accepted. The control system shall ensure that, during steam cleaning, the complete EHT system is de-energised.

Plastic pipes should be heated with inherently temperature-safe self-regulating heating cables having no heat output at the maximum temperature rating of the pipe.

Temperature control of supply piping of safety showers requires careful consideration towards personnel. The water temperature should be neither too cold which could cause shock, nor too hot which could scald. However, the heating system should have the facility to periodically raise the water temperature to kill and avoid the development of bacteria. The shower should be out of use during such heating operations.

## 8.4 Circuit Monitoring

Automatic monitoring of heating circuits can provide the user with valuable information regarding system safety and performance. The monitoring of electrical properties such as current draw, voltage and electrical resistance can indicate the health of the heater, which is particularly valuable for hazardous area applications. Similarly, temperature readouts can indicate other potential problems, such as moisture ingress into the thermal insulation. Software and equipment that enable monitoring of the heating system remotely are therefore recommended, and can form a major element of the system's maintenance plan.

### 8.4.1 Large Installations

Multi-channel, computer assisted energy management, control and auditing systems may be preferred for large / critical heat tracing installations. These may be stand-alone systems, or integrated into the plant's SCADA or DCS system, providing the user with the ultimate in monitoring facilities.

SCADA type control has all the benefits of localized electronic control, complemented by remote visualisation with two-way communication between the control system and a remotely located computer.

All control parameters, collected data, system drawings, and system information can be stored and retrieved, with full visual indication available. Heating circuits are continuously monitored for correct function and temperature.

Circuit currents and supply voltage may be measured and used by the software package to calculate the individual circuit power and running costs. Alarms may be raised in the event of any non-compliance.

A data link to the main process control system may also be made available, with the option of an internet protocol module for providing communications over TCP/IP and HTTP for web pages, or emailing of alarm messages. Control and monitoring parameters may be inputted either remotely or locally as specified. System parameters are stored in the computer and in each controller. This provides ultimate reliability, as all parameters are capable of being downloaded to replacement units.

**Consideration should be given for such a system to operate as part of a service contract.**

### 8.4.2 Small Installations

Where critical to the process, circuit health monitoring of smaller heat tracing installations may typically be provided by a monitoring device located in the control and monitoring panel, which periodically energises the circuits to ensure that they are operating correctly. In the event of damage to a tracer, an alarm is raised to enable corrective action before the pipeline has time to cool to an unacceptable level.

## **9.0 POWER SUPPLY AND DISTRIBUTION**

The heat tracing Distribution Boards in the field will normally be fed from dedicated heat tracing Power Control Centres (PCCs) located in sub-stations.

The heat tracing Distribution Board of a particular area will normally be fed from a heat tracing PCC located in the relevant sub-station.

The number and positioning/location of the distribution boards require special attention as this also determines the power cabling requirements to the boards. Consideration should be given to the provision by the designer of heat maps depicting the location and density of the trace heating loads in order to optimise the panel locations and minimise the power cable requirements.

### **9.1 Distribution Boards**

The heating system shall be connected to Distribution Boards.

The number of distribution boards and the number of circuits per board should be designed so as to optimise the grouping of heating circuits considering their function and working temperatures.

Distribution Boards shall comply with the appropriate panel specification according to location that may be indoors/outdoors, and within a hazardous, or non-hazardous, area.

Each heat tracing Distribution Board shall be divided into a number of circuits, each provided with a fixed miniature circuit breaker (MCB). The circuits may be single phase, or three phase, with neutral and protective earth. In the case of single phase, the heating loads should be substantially balanced across the three phases.

The heat tracing cables will often be single phase, 3 wires, 3 pins (1Ph+N+PE). The Contactor or Solid State control voltage shall be derived from the Distribution Board itself.

It is usual to allow 20% additional fitted circuit ways to cater for future plant expansion.

### **9.2 Circuit Protection**

Miniature circuit breakers shall be double pole for single phase circuits, or four pole for three phase circuits. These should have trip characteristics corresponding thermally and electro-magnetically to the relevant standard IEC 60947 2, Category A or B.

Unless otherwise specified, the maximum rating of the circuit breakers for parallel type heaters shall be 50A, and the minimum short circuit breaking capacity shall be according to the panel design criteria with current limiting capabilities.

The size of the circuit breaker can be defined during detail engineering according to the loads of the various tracing circuits.

It shall be ensured that the protective devices will operate effectively regardless of the location of a possible fault in the heating cable. The breaker shall be suitable for the start-up or inrush current of the heating elements.

Consideration may be given to the use of soft start devices for semi-conductive heating cables, in order that the MCB trip current is more closely matched to the operating current, to improve the safety levels.

Heating circuits shall be protected against overload, short-circuit and equipped with residual current devices with an operating current up to 300mA, but normally 30mA.

### **9.3 Field Distribution**

The power cables connecting the distribution board to the heaters shall have a cross section sized according to the maximum load, and limiting the voltage drop between the distribution board and the start of the heating cable under full load to a maximum 5% of the nominal voltage. The cables shall have copper conductors and a galvanized steel tape armouring, fire retardant PVC plastic sheath, unless otherwise specified.

Cold cables (from sub-station to local EHT field distribution Panels and EHT Distribution Panels to EHT connection boxes) are normally within the Contractor's scope of supply.

Cabling and heaters shall be connected via connection boxes. Heating elements shall be connected in a radial system, in order to provide independent protection and control of each heating element.

Where appropriate, the heaters of instrument enclosures shall also be connected into a heater supply circuit.

### **9.4 Heating Circuit Distribution**

#### **9.4.1 General**

Heaters shall be arranged and grouped in such a way as to minimize the number of heating circuits, thermostats and power cabling required.

In installations where surface temperature control is employed, and where the process flow can follow different routes (for example bypasses and safety showers), each flow path shall be controlled separately and supplied via separate circuit breakers. This will necessarily result in multiple controlled circuits. Conversely, where proportional air-sensing control is possible, much fewer circuits will be possible. Of course, pipe sections seeing flow will receive some heat, but this normally creates no problem and reduces heat input requirements further downstream

Heating systems of duplicated process control instruments shall be connected to independent circuits.

Heater circuit designs shall be sized to a maximum of 80% of circuit breaker rating to allow for subsequent design changes and to accommodate minor changes in piping during construction.

The operating current rating of self-regulating and power limiting heaters shall be assessed based on the minimum operating temperature of the heaters.

To prevent overloading of the heater conductors, the maximum recommended circuit lengths of a parallel heating cable shall not be exceeded.

Unless otherwise specified, in-line and tee splices shall not be made under the pipe insulation, whereas end seals and 'cold lead' connections may be used. All other connections shall be accessible within connection boxes. The installed heating load shall take account of the effects of voltage drop towards the end of the heating conductors. Similarly, assessment of maximum heater surface temperatures shall take account of the heat produced by the tracer's power conductors at the start of a circuit, in addition to that from the heating element.

#### **9.4.2 Circuitry to allow removal/bypass**

Heat tracing circuits shall be designed to allow removal or bypass. This shall generally be achieved by arranging the circuit such that the section to be isolated can be disconnected within a junction box during a short period of circuit isolation, allowing fast re-energization of the remaining circuit.

### 9.4.3 Circuit Design for Piping and Equipment

Where *surface* control is necessary for temperature safety, heating circuits for piping and equipment shall be controlled separately to accommodate all heat requirements from flow patterns and cycles during operation, maintenance, repair, and plant shutdown. The following criteria shall be applied:

- a) Circuits for lines handling different services shall have independent controls and power feeders.
- b) Circuits for lines containing both flowing and static fluids shall not be combined under the same surface control.
- c) Circuits for lines that may be concurrently in operation and be isolated for maintenance, or repair, shall be separately controlled and fed.
- d) Where specified, the design shall facilitate removal of pumps and valves without affecting the heat tracing on associated equipment, or process lines.
- e) Consideration should be given to providing local disconnection of tracers at pumps and valves to facilitate removal without affecting operation of heat tracing on connecting process lines.

However, when inherently temperature-safe self-regulating heat tracing cables are specified, it is possible that the criteria noted in Item (b) through (e) above can be waived. Heating circuits using self-regulating cable could be economically combined provided that all possible heat requirement patterns and cycles are not adversely affected during operation, maintenance, repair, and plant shutdown.

This is usually possible when ambient sensing proportional temperature control is combined with the self-regulating heating cables, and indeed may be the preferred system design as fewer circuits are often possible

### 9.4.4 Circuits for Instrumentation

Instruments, together with their process piping, that are associated with a process line, or lines having common characteristics, may be traced using a common heat tracing circuit. Self-regulating heat tracing cable shall be used wherever possible. For other types of tracer cable, temperature control devices are usually necessary.

- a) Unless otherwise specified, a separate circuit shall be provided for each instrument and its associated process sensing line. Where multiple instruments are connected to a common branch circuit, each instrument shall be provided with a local means of disconnection.
- b) Instruments that are connected to associated process lines having a very short length may be heat traced with the same tracer cable and combined under a single power supply and temperature controller.



#### 9.4.5 Heating Cable Length

- a) Heat losses at pipe flanges, valves, supports, and other pipework fittings shall be compensated by the use of additional lengths of heat tracing.
- b) Heat tracing cable length shall be the cable spiral ratio multiplied by the pipeline length plus the extra lengths required to compensate for heat losses from the components noted in (a) above. Typical allowance for losses from fittings are:-
  - Flange – loss from 0.3m of equivalent pipe diameter
  - Ball/gate valve – loss from 1.5m of equivalent pipe diameter
  - Pipe support – loss from 1.0m of equivalent pipe diameter
  - Pump – loss from 3.0m of equivalent pipe diameter

This length shall normally be increased by an additional percentage to be agreed with the Contractor.

- a) The length of heat tracing cable runs shall not exceed the manufacturer's maximum recommendation for cold start-up ambient conditions and end-of-line voltage conditions, whichever is the more restrictive.
- b) Voltage drop should be considered when applying constant wattage, power-limiting, or self-regulating heat tracing cable in long runs, as the wattage per unit length at the end of the run will be less than at the beginning of the run. This should also be considered when determining the location of the temperature sensor.

Cable runs without splices are preferred. However, where splices are required, they shall be cold junction splices made in accessible connection boxes outside the insulation, unless sub- insulation in-line splices are allowed by the enquiry documents.

#### 9.5 Connection Boxes

Connection boxes shall be provided for:

- a) Connecting the supply cable to the heating cable.
- b) Connecting a circuit of the distribution board to sub-circuits. Only one circuit of the distribution board shall be allowed per connection box.
- c) Combinations of a) and b)
- d) Splitting a three phase circuit into three single phase circuits.

Separate terminals shall be provided for each conductor. The terminals shall be of non-loosening construction and of the wedge or cage clamp type, obviating the need for cable lugs and constructed to avoid direct contact between screw and conductor. Terminals shall be identified in accordance with the related diagram. In addition, earth terminals or an earth bar with sufficient earth connection points shall be provided to earth the metal screens of all cables and heaters.

Connection box material shall be GRP unless otherwise specified, provide IP66 minimum protection and be in compliance with hazardous area classification requirements where appropriate. The connection box shall be provided with a GRP direct entry sealed termination unit that enables all heating cables to exit the pipe thermal insulation and enter the connection box without being exposed to the potential for mechanical damage. All the accessories required for mounting the connection boxes shall be heat tracing vendor's scope of supply.

**10.1    Pre-installation**

It is essential that the heat tracing system is correctly installed, tested, commissioned, and maintained. The EHT system supplier will provide comprehensive instructions for the installation of the system equipment. However, we would recommend that the following points are taken into consideration:-

- **Personnel**

Persons involved in the installation and testing of electric heat tracing systems should be suitably trained in all special techniques required. Installation should be carried out under the supervision of a qualified electrician who has undergone supplementary training in electric heat tracing systems.

Where systems are for use in explosive gas atmospheres, additional qualifications apply, such as knowledge of system certifications.

- **Equipment verification**

Prior to installation, the design data used for the heat tracing design should be verified and the as-built piping and other equipment should be checked against the enquiry drawings. The installation of the heat tracing system should be coordinated with the piping, thermal insulation and instrument disciplines.

- **Pre-installation testing**

Pre-installation tests shall be performed and documented on a checklist similar to that opposite. This also helps verify the heat tracing design.

- a) Heat tracers shall be visually checked for damage. Continuity and insulation checks should be made and insulation resistance measured from heat tracer conductors to the metallic braid or sheath, with a minimum 500Vdc test voltage. The measured insulation resistance shall not be less than 20 MΩ.
- b) Controls shall be tested to ensure correct calibration of, for example, set points, operating temperature range and span.
- c) Control panels shall include documentation certifying that all wiring, layout and functions are correct and have been tested. A general inspection of the panels shall confirm that no damage has occurred in transit.

**Table 1 - Pre-installation checks**

Items to be checked	Remarks
<b>1</b> Is the workpiece fully erected and tested and all temporary supports removed? Is the surface to be heated free from sharp edges, weld spatter and rough surfaces?	Any welding or pressure testing after the installation of a heat tracer could damage the device
<b>2</b> Is the surface upon which the heat tracer is to be applied normal steel or non-metallic?	If the surface is of polished stainless steel, very thin-walled pipe or non-metallic of any kind, special precautions may be necessary
<b>3</b> Do the items to be heated correspond in size, position, etc. with the design?	It is sometimes difficult to be sure that the correct pipe is being heated. A suitable line numbering system may be of assistance
<b>4</b> Has it been specified that metallic foil be installed before the application of the heat tracer?	This may be used to aid heat distribution
<b>5</b> Has it been specified that metallic foil be installed after the application of the heat tracer?	This may be used to prevent insulation from surrounding the heat tracer or to aid heat distribution
<b>6</b> Can flow of product under normal or abnormal conditions reach temperatures greater than those that the heat tracer can withstand?	This would normally be covered in the design stage; however, further discussion with staff at the plant may show that incorrect or out-of-date information has been used
<b>7</b> Is the heat tracing system documentation (working drawings, designs, and instructions) available?	No change should be contemplated without reviewing the heat tracing system documentation, as careful calculations are necessary to ensure safe operation
<b>8</b> Can pipes or surfaces expand and contract so as to cause stress on any part of the heat tracing installation?	In this case precautions are necessary to avoid damage
<b>9</b> Can sensors of temperature controllers be affected by external influences?	An adjacent heating circuit could affect the sensor
<b>10</b> Is the heat tracer to be spiraled or zigzagged onto the workpiece, according to the design?	Check design loading per unit length of pipe (or surface area) to determine if spiral or zigzag application is necessary
<b>11</b> Are cold leads, when fitted, suitable for contact with the heated surface?	If the cold lead is to be buried under the insulation, it has to be able to withstand the temperature
<b>12</b> Is the pipework hung from a pipe rack?	In this case, special precautions are required to ensure the weatherproofing of the insulation at points of suspension
<b>13</b> Does pipework have its full complement of supports?	The addition of intermediate supports at a later stage could damage the heating system
<b>14</b> Are sample lines/bleed lines, etc. at the plant but not on drawings?	These could obstruct or prevent the fitting of the heat tracer, and a review of the heat tracing system documentation may be necessary
<b>15</b> Are other parameters used in the design of the equipment as specified by the design documentation?	More or less lengths of trace heater may be required than was called for in the design. This may require for redesign of the circuit.
<b>16</b> Are the heat tracers, controllers, junction boxes, switches, cable glands, etc., suitable for the environmental conditions and are they protected as necessary against corrosion and the ingress of liquids and particulate matter?	If the trace heater design does not meet the intended application, the circuit must be redesigned and the system documentation must be updated.

## 10.2 Installation of heat tracers – General

Heat tracers should be attached to clean piping and equipment in accordance with the instructions. Care should be taken at flanges and fittings to position heaters so as to avoid damage. Check that the heater assembly can accommodate movement and vibration. The installer should allow the appropriate amount of heater to compensate for additional heat losses from pipeline fittings, as allocated by the design software. A heat tracer should be kept in as intimate a contact as possible to the heated surface, but without preventing the tracer from expansion and contraction during heating / cooling cycles. Where close contact is not possible, such as on valves, a heat-conductive covering of metal foil may be used.

It is recommended that the heat tracer is not folded, twisted, or allowed to overlap, cross or touch itself. Attention should be given to the minimum bending radii. Where heat tracers cross possible sources of leaks, for example, flanges, they should be positioned to minimize contact with the potentially leaking medium.

***Only genuine manufacturer's components may be used or else the system certification will be invalidated.***

- **Straight tracing runs on pipe**

Single straight-traced runs are usually positioned at the underside of the pipe, fixed at 300mm centres, using only the correct fixing tape. Multiple straight heat tracers should be equally spaced around the circumference of the pipe. Extra lengths of heat tracer will have been provided for in the design to compensate for the additional heat losses at pipe fittings, valves etc.

- **Spiral tracing runs on pipe**

The pipe and equipment should be marked at the design spiral pitch. Then apply the heat tracer in a uniform spiral from the power supply point maintaining slight tension in the tracer as it is applied. Fix at no more than 2 metre centres using only the correct fixing tape. Spiral tracing runs should be applied in such a way that valves, etc., can be easily removed or replaced.

- **Connections and terminations**

It is essential that all heat tracers are terminated correctly with approved components to the manufacturer's instructions. Series resistance heat tracers intended for site termination should be checked to ensure that the installed lengths correspond to the design length and loading. Connection of the heat tracer to the power supply should be such as to prevent physical damage and positioned to prevent the ingress of moisture.

Heat tracing circuits are connected into junction boxes specifically designed for connection of the tracer. The boxes provide appropriate protection and certification. Junction box lids should not be left open at any time. The metallic braid or sheath of the heat tracer must be bonded to the earthing system to provide for an effective ground path. Tracer end seals must be securely fitted to the manufacturer's instructions and protected to avoid mechanical damage and ingress of moisture.

If during the installation stage heating cables are installed but await termination into a junction box, the ends shall be temporarily sealed against water ingress until such time as they are properly terminated.

- **Marking and tagging**

After installation, all the circuits must be properly marked / tagged, as follows:-

- a) Branch circuit breaker
- b) Monitor and alarm apparatus
- c) Heat tracer power connection
- d) Circuit number and set point for each temperature controller

Marking shall be carried out for each heat tracing circuit, on the respective junction box.

- **Post installation testing**

The pre-installation insulation resistance test described above shall be repeated on all heat tracer circuits after installation, using a minimum 500Vdc megger. This shall take place prior to applying thermal insulation and shall be witnessed by the customer's representative. Continuity and resistance checks and circuit lengths shall be recorded.

The measured insulation resistance shall not be less than 20M $\Omega$ . Continuity and resistance checks shall be made for each circuit and the installed tracer load confirmed with the design load. The type, length and electrical data of each heat tracer shall be noted for inclusion in the final documentation. The connection points shall be recorded for entry in the piping and instrumentation diagrams.

### 10.3 Installation of control and monitoring equipment

- **General**

The installer is usually responsible for fixing the control and monitoring and distribution panels. These will, as a minimum, provide over-current and earth-leakage protection as well as means of isolation. Some form of temperature control or limitation is usually provided to ensure safe temperatures or for energy efficiency purposes.

- **Verification of equipment suitability**

The supplied controllers, thermostats, sensors, and related devices shall be checked to match those specified in the design with regard to the service temperature, the IP rating, and, for hazardous areas, certification.

The certification of heat tracing systems may prescribe the use of specific components. In these cases it is mandatory to use only parts specified by the ESH system supplier.

- **Temperature controller and monitoring devices**

The sensors of the temperature controllers may be air sensing or applied directly to the pipe. The sensors are usually resistance temperature detectors, or capillary tube thermostats. Water and corrosive vapour intrusion can cause failure of temperature controllers. The cover or lid of a controller housing should always be closed after installation, except when required for access.

- **General sensor installation**

The sensor for surface temperature control is installed onto the surface of the pipe or equipment in accordance with the designer's instructions in a position that will provide a temperature representative of the overall circuit.

The sensor should be positioned so as not to be unduly influenced by the temperature of the heat tracer, or other factors such as heat sinks and solar gain.

Ambient temperature-sensing controllers should be sited in the most exposed position for the installation. Line sensors should be strapped in good thermal contact with the pipe or equipment and protected so that thermal insulation cannot be trapped between the sensor and the heated surface. Care should be taken not to damage the capillary tube, or RTD leads, or to distort the sensor and thereby cause calibration error. Care should be taken to ensure that the capillary tube, or RTD leads, emerge from the thermal insulation in a manner that will not allow the ingress of moisture.

- **Sensor installation for temperature limiting device**

When a system has to employ a temperature controller in order to ensure temperature safety, then clearly the positioning of the sensor is critical to the safety of the plant. The sensor for the temperature limiting controller is installed onto the surface of the pipe or equipment in a position that will provide a temperature representative of the overall circuit. In order to assure that the safety temperature controller can accurately react to the maximum heat tracer surface temperature, particular attention must be paid to the location, method of attachment and set point.

This method of sensor installation is based on the known relationship between the equipment temperature and the heater sheath temperature at a given power output.

It is important that the controller is set such that the heater sheath temperature does not exceed the limiting temperature under worst-case conditions (e.g. voltage +10%, tracer at upper limit of manufacturing power tolerance, heater out of contact with the pipe/equipment, high ambient, no external convection).

#### **Warning**

*Some heat tracing companies offer low cost series resistance heaters of minimal mechanical strength that are designed for use with voltage regulating devices. These require the sensor of the over-temperature controller to be fitted to the surface of the heater itself. However, this is a practice that is not recommended because:-*

- *It will rarely be known to be sensing the hottest point of the heater (which is likely to be where the heater is out of contact with the equipment) and*
- *When the sensor is removed, for example during maintenance work, it cannot be guaranteed to be returned to the hottest part of the heater. The practice of fitting a temperature sensor to the heater to ensure temperature safety is dangerous!*

#### **10.4 Installation of thermal insulation system**

Precautions must be taken to protect tracers from mechanical damage and moisture intrusion after they have been installed and prior to the application of thermal insulation. The installation supervisor shall coordinate with the thermal insulation contractor, so that the thermal insulation is applied as soon as possible after the installation and testing of heat tracers. It should be confirmed that the thermal insulation to be installed is of the size, specification and thickness used for the design of the heat tracing system.

The thermal insulation installation crew should be experienced / trained in fitting insulation over tracers, particularly with a view to avoiding mechanical damage, which is most likely when cutting and forming sheet metal cladding around flanges and other line equipment. Warning labels must be fixed to the cladding at 6m intervals advising that electric tracers are installed beneath the thermal insulation and fitted to the cladding over each valve or item of equipment that may require periodic maintenance.

- **Field circuit insulation resistance test**

The test procedure described above shall be conducted on all heat tracer circuits after lagging, with the requirement that the measured insulation resistance shall not be less than 5MΩ.

- **Visual inspection**

Carry out a visual inspection of the thermally insulated system to ensure that:

1. moisture cannot penetrate the insulation
2. screws or other fasteners securing cladding are short enough to preclude any possibility of damage to tracers or temperature sensors.
3. entry cut-outs in the cladding for heat tracers, temperature sensors, etc., are dimensioned so as to render contact impossible
4. cladding joints and thermal insulation entries are properly sealed with an elastic, non-hardening sealant resistant to chemical attack.

- **Documentation**

The thermal insulation material and its thickness shall be documented.

#### **10.5 Installation of electrical power**

The branch circuit wiring of each heat tracing circuit requires an over-current protective device.

The size and type of distribution wiring, and the ratings of the branch circuit protective devices is based on heater start-up currents and their duration at the minimum temperature that the heat tracing device may experience. An earth fault protective device RCD shall also be provided. Check that protective devices are sized correctly to the rated current and, where applicable, have appropriate certificates.

## 11 COMMISSIONING AND DOCUMENTATION

### 11.1 Functional check

The heat tracing system(s) shall be commissioned after the thermal insulation has been installed and the electrical distribution is completed. The heat tracer commissioning record given in Table 2 shall be completed and retained.

- a) Close all branch circuits and verify proper current. A temporary bypass may be required for the temperature control device.
- b) Verify that monitor or alarm circuits are operable. A bypass may be required at field contacts.
- c) Fill out the heat tracer commissioning record (Table 2) for each circuit. This shall clearly document all testing and commissioning data.
- d) Record the electrical insulation resistance values for each measurement taken.
- e) Record the applied voltage and resulting current after five minutes of energisation, and pipe temperature if required.
- f) Verify that the alarm and monitor components operate as intended.
- g) Verify that the calibration check at the temperature controller set-point has been completed and the controller has been set at this value.

### 11.2 Final documentation

Adequate and uniform documentation of the electric heat tracing circuits is an essential precondition for economical maintenance of this equipment. This is especially important to facilitate rapid troubleshooting in the event of circuit problems. It also provides the basis for simpler, faster and less costly handling of any desired modifications and expansions by a specialist for electric heat tracing systems. The documentation of each heating circuit of a heat tracing system shall include the following elements:

#### 11.3 Design and testing documentation:

- a) Table of contents
  - b) Piping diagram showing the heat tracing circuits and the location of power points, connections, splices, tees, end terminations, and temperature sensors for control and limitation
  - c) For vessels: layout of the heat tracing
  - d) Pipe and insulation list
  - e) Individual circuit length of heat tracers
  - f) Calculation and dimensioning data
  - g) Material list
  - h) Heat tracer installation instructions
  - i) Heater cabling plan
  - j) Description of and installation instructions for temperature sensors
  - k) Heater commissioning record (Table 2)
  - l) Temperature profile measurement
  - m) Installation certificate
- **Circuit diagrams:**
    - a) Wiring and circuit diagram
    - b) Terminal connection diagrams, switchgear with parts list
    - c) Switchgear with parts list
    - d) Installation instructions
  - **Other:**
    - a) Technical descriptions and instruction manuals for the individual pieces of equipment
    - b) Functional diagram as agreed to with the design engineer
    - c) Certificates or declarations of conformity from a certification agency for explosive gas atmosphere equipment, as required.

**Table 2 – Heat tracer commissioning record**

Location		System		Project number		Reference drawing(s)	
Line number		Heat Tracer number		Area classification		Temperature classification	
Panel number		Location		Circuit number		Circuit amp/voltage	
Heat Tracer manufacturer		Heat Tracer model		Heat Tracer wattage unit length/voltage rating			
Verify certification marking:							
<b>HEAT TRACER INFORMATION:</b>							
Heat Tracer total design length				Heat Tracer total installed length			
Thermal insulation type				Thermal insulation thickness			
Workpiece maintain temperature				Maximum workpiece temperature			
<b>HEAT TRACER TESTING: (data from heat tracer installation record)</b>							
Electrical resistance (continuity) test, in ohms							
Electrical insulation resistance test, in Megohms							
Test ambient temperature							
PERFORMANCE DATA:		Volts a.c.		Current in amperes			
	Panel	Field	Single-phase	Three-phase			
			Line	A phase	B phase	C phase	Neutral
Start-up							
After 5 min							
After 4 h							
Ambient temperature at time of test							
Pipe temperature at beginning of test				After 4 h			
Calculated watts per unit length (V x A/m)				After 4 h			
TEMPERATURE CONTROL: type							
<b>Heat Tracer controller</b>		<b>Ambient sensing</b>		<b>Workpiece sensing</b>		<b>Temperature setpoint</b>	
<b>High limit controller</b>		<b>Type</b>		<b>Location</b>		<b>Temperature setpoint</b>	
Heating controls calibrated							
Heating controls operation verified							
ALARMS/MONITORING: type							
Temperature		High setting		Low setting		Operation verified	
Heat Tracer current		High setting		Low setting		Operation verified	
Residual current				Setting		Operation verified	
Loss of voltage						Operation verified	
Other						Operation verified	
<b>RCD PROTECTION: type</b>							
Setting		Measured current		Tested in operation			
Performed by:				Company		Date	
Witnessed by:				Company		Date	
Accepted by:				Company		Date	
Approved by:				Company		Date	



## **12 MAINTENANCE**

### **12.1 General**

It is recommended that the maintenance schedule in Table 3 is undertaken each year. All maintenance activities should be recorded in the maintenance log (such as that shown in Table 3) and retained as part of the system documentation.

Due consideration shall be given for easy accessibility to all the items for maintenance and operational requirements when designing the layout of the equipment. Access shall be provided to all equipment and any area requiring maintenance. The equipment shall be designed such that all maintenance can be carried out with the minimum of special facilities/tools. System components shall be standardised as much as possible.

### **12.2 Fault location**

Specialised methods of fault location may be necessary to find faults in electric heat tracing systems covered by thermal insulation and metallic cladding, and advice should be sought from the electric heat tracing system designer. Most commonly, faults are caused by mechanical damage, corrosion, overheating or ingress of moisture.

### **12.3 Fault rectification**

When the fault has been located, the defective component should be replaced or repaired. Those parts of the installation that have been disturbed should be checked in accordance with Table 2 and recorded in accordance with Table 3.

### **12.4 Service Contract**

Consideration should be given to the placing of a Service Contract with the system supplier, where available.

**Table 3 – Maintenance schedule and log record**

Location system		System		Reference drawing(s)	
<b>CIRCUIT INFORMATION</b>					
Heat tracer number		Circuit length		Breaker panel no.	
Power connection		Design voltage		Breaker pole(s) no.	
Tee connection		Residual current protection (type)			
Splice connection		Residual current trip setting			
Process control type I, II or III		Heating controller type			
Circuit Monitoring	YES / NO				
<b>VISUAL</b>					
Panel no.		Circuit no.			
		Date			
		Initial			
Thermal insulation					
Damaged insulation/ lagging					
Water seal acceptable					
Insulation/lagging missing					
Presence of moisture					
Heating system components					
Enclosures, boxes sealed					
Presence of moisture					
Signs of corrosion					
Heat tracer lead discolouration					
Heating and/or high limit controller					
Operating properly					
Controller set point					
<b>ELECTRICAL</b>					
Insulation resistance testing (bypass controller if necessary)					
Test voltage					
Megger value, M.Ohms					
Heat tracer supply voltage					
Value at power source					
Value at field connection					
<b>Heat tracer circuit current reading</b>					
Amps reading at 2 to 5 min					
Amps reading after 15 min					
Ground-fault current					
Comments and actions					
Performed by:		Company		Date	
Approved by:		Company		Date	

# SAFE ELECTRIC TRACE HEATING AT OPTIMAL COST

## Notes Page

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