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"HEAT TRACING" - SELF-LIMITING ELECTRIC  
TRACING AND STEAM TRACING

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INTRODUCTION

Heat Tracing has not been widely used in most industries in India: Manufacturing units like Textile mills, Glass factories, Steel plants, Foundries, Thermal Power station etc. do not have the need to do Heat Tracing because the ambient temperatures are high ( $30^{\circ}\text{C}$ ); even the process does not involve any heat tracing applications.

In 1974, energy balance changed throughout the world with the high crude oil prices. Fuel oil prices which were then at Rs.200/- to Rs.250/- per tonne is now at four times its price of four years ago. From that time onwards many things happened all over the world: oil exploration and production plans were speeded up; fuel oil conservation plans were drafted; refinery processes were modified to extract more distillates from crude oil leaving heavy residual oil for industrial use. In India maximum use of indigenous crude from Ankleshwar oil fields was made and the oil exploration and production platforms at Bombay High were expedited. The result of which, we have today our new and unique indigenous oil from waxy crude, known as Low Sulphur Heavy Stock (LSHS). This LSHS oil has a pour point of  $57^{\circ}\text{C}$ , which makes Heat Tracing a common subject to all industries using and depending at the moment on fuel oil and light diesel oil.

All products like LSHS oil, have to be maintained at a temperature above their pour point during storage and handling. Since maintenance temperatures are higher than ambient temperatures, heat losses will occur from insulated surfaces of tanks and pipes. These losses can be minimized by: selecting proper quality and thickness of thermal insulation and by maintaining low temperature differentials. This helps to prevent 85% of losses. Balance 15% of heat losses will still continue to take place and therefore some heat is needed to

be replenished. Replenishing this heat loss is known as HEAT TRACING.

Steam Tracing has been pre-dominantly used, because steam was considered to be the cheapest form of energy for Heat Tracing. This is no longer true. It is true that steam is cheaper on K.Cal (or Btu) basis as compared to electrical energy. But, due to efficient and close control of electrical energy, steam tracing becomes expensive on Heat Tracing applications. Moreover, increase in oil prices has made steam tracing still more expensive.

Since 1930, there have been many electrical Heat Tracing systems on the market. They saw limited use because: they have to be custom designed and custom fabricated to obtain the desired voltage heat output; burnout problem is common when more intimate thermal contact with the pipe is not achieved or the supply voltage increases. In such systems, a constant wattage is applied across a relatively constant resistor to produce an almost constant voltage. Their thermal model is a constant Energy Source and is independent of ambient temperatures.

In 1963, a parallel circuit tracing system was introduced, which overcame most of these problems. It could be cut to length without affecting thermal output per unit length. This was possible by inserting thin multilayer construction of a patented graphitic compound between two electrical bus bars and sealed with thin asbestos sheets and electrically insulated in a sealed laminated sheath of polyster or teflon.

In 1971, the parallel circuit heat tracing system was improved with the addition Self Limiting, Self regulating conductive compound, with carbon loaded irradiated web between two parallel conductors. Any increase in temperature of the tapes, increases the resistivity per circuit length, resulting in reduced heat generation. Thus it is able to regulate the energy supply into a system, when and where needed. By change in product temperature or the variation in ambient temperature-, the energy will be accordingly regulated. They offered reliability and economy in operating and installation costs.

### Self-Limiting Parallel-Circuit Electric Tracing

A brief explanation of the technology involved in resistive conductive compound will help you to understand and appreciate all the features of "Auto-Trace" self limiting electric heat tracer.

Thermoplastic materials used in the core are normally long chain molecules arranged in random order. When any thermoplastic material is heated, it melts and begins to flow. When applied heat source is removed, the heated thermoplastic now forms a different shape upon cooling.

If a thermoplastic material is given high energy atomic radiation, a permanent cross-linking will occur. These cross-links are additional permanent bonds formed in the crystalline area. They are not affected when heated. Therefore cross-linking does not allow the thermoplastic material to flow when heat is applied. Thermoplastic material has now become elastomeric in nature i.e. it will regain original form on cooling. A diagrammatic discription of cross-linking is given in Fig. 1.

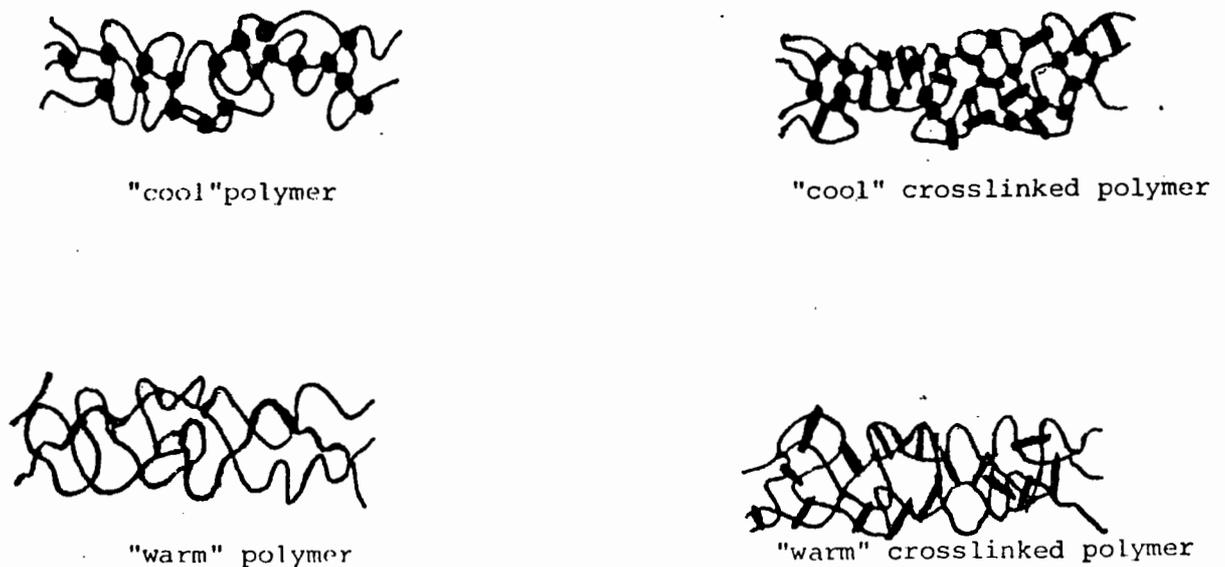


Fig.1

In self-limiting parallel-circuit heaters the core material is a mixture of polymers, graphite and stabilisers. This core is cross-linked and therefore ensures fixation of graphite molecules in position, making it impossible for them to migrate, even at elevated temperatures. The graphite molecules are now so arranged that it forms a semi-conductive web.

In operation, electric heating current flows from one conductor to another through the graphitic path, with wires functioning as busses. The resistance in electrical path causes heating to take place. The heat so generated or the heat from the process pipes or tank surfaces, causes expansion of molecular path to take place. But, the polymers in which graphitic molecules are fixed, are blended in such a manner so as to cause non-linear thermal expansion. This increases the resistance of the molecular region by orders of magnitude (60 ohms to 600,000 ohms). The current accordingly reduces proportionately till it reaches to zero. Upon cooling, the electrical paths proportionately return to original configuration, and allows heating to take place. This is diagrammatically explained in Fig.2.

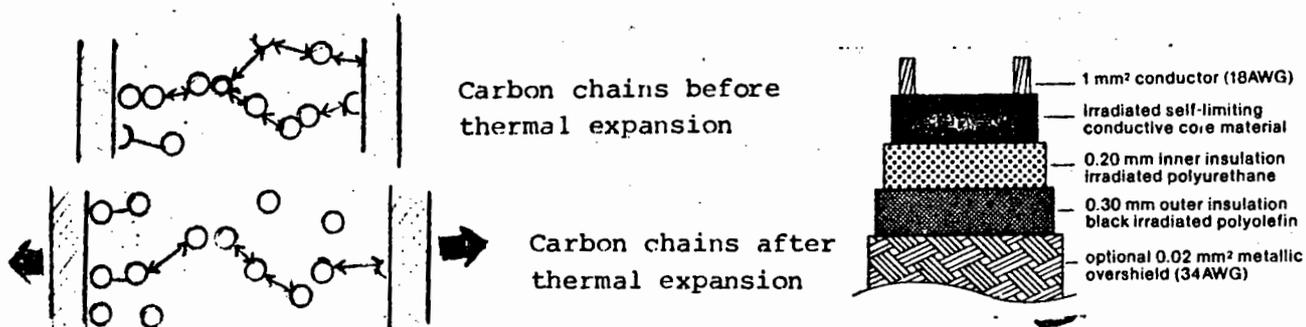


Fig. 2

It will now be understood that the cross-linking of the polymers is a key to successful operation of the heating element. The process of cross-linking is sometimes called "beaming" and is also known as "irradiation" process.

The outer jacket of self-limiting heater is made from electrically insulated, irradiated material. Where applications demand, there are additional jackets provided such as metal braids and chemical resistant cross-linked jackets.

Having understood the basic structure of self-limiting electric heat tracers, one can now appreciate its characteristics and functions and thereby its use.

In self-limiting element, there is no fixed energy input into the system since resistance is a function of core temperature. Thus a thermal model for the self-limiting element is a Temperature Source (unlike other systems having Energy Source). With increase or decrease in the temperature differential, a lower or higher power output takes place. Accordingly it will provide more required energy in areas which are cold but, less required energy in adjacent areas which are hot.

The totally new concept of a temperature source is a bit difficult to appreciate at first encounter, but the benefits are very much appreciated when safety, reliability and efficiency are considered. In a temperature source element, no over-temperature can occur at any place, no "hot spots" and most important of all, no burnouts. The basic heating element is also a control system, bringing heat where needed and denying it where not needed.

Features and characteristics of self-limiting heater like "Auto-Trace" offers: a simple system to design and install; a clean system to work with and maintain; reliable and easy way to heat trace pumps, valves, flanges, instruments; saves time and money on installation, operation and maintenance; completely safe even in hazardous and chemically hostile environments.

## OBJECTIVE

The objective in selecting a heat tracing system is to find out Economics, Safety and Reliability of the system that is going to be used.

Economics of selection should depend on original installation costs, operating costs, and maintenance costs, the latter including down time and reduced product yield due to tracing failures.

Let us examine the two heat tracing systems: self-limiting "Auto-Trace" and conventional Steam system.

## Installation Costs

The installation cost will be determined by: the general plan layout of the system to be heat traced, source of energy available and its location in the general plan layout; heat tracing standards and specification to which the work is to be carried out. These costs will therefore vary from industry to industry and from user to user. This is being explained in detail in this article.

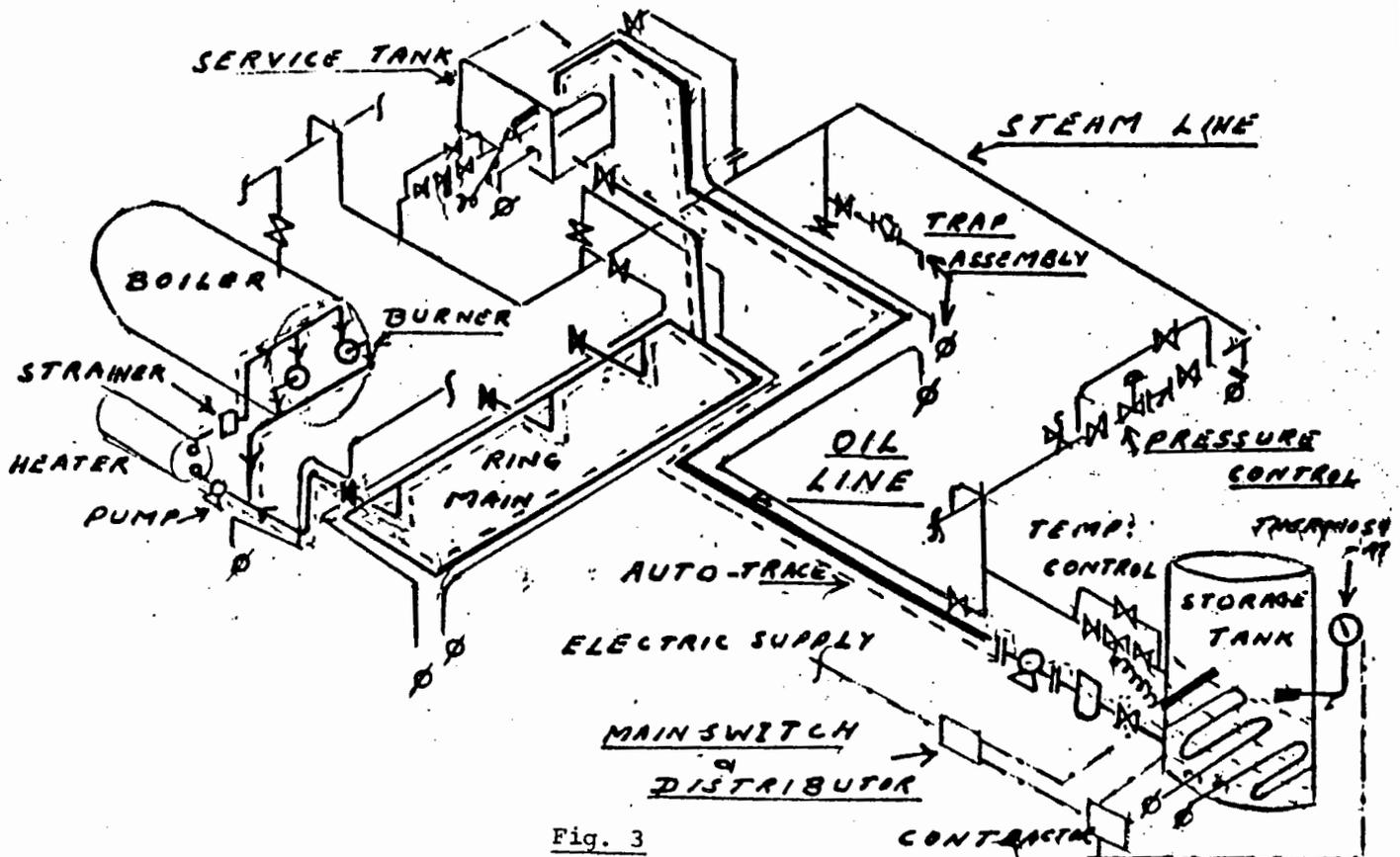


Fig. 3

Fig. 3 shows a typical system of oil handling and also explains certain practices of heat tracing. Let us first consider a steam system:

- Main storage tanks are located at a distance away from the main plant, where the steam supply is generally not available. Greater the distance between the steam supply source and storage tank, more will be its costs to steam tracing system.
- Pressure and Temperature control stations and steam temperature assemblies should be provided with isolation and by-pass arrangements for maintenance ease and reduced down time. They should be complete in all respect with strainers, safety valves etc. This also adds to the cost of steam system.
- Steam supply to tracer lines must always be given from topmost section allowing condensate to flow by gravity to bottom most point. Therefore for such piping arrangements, steam branch lines should be laid accordingly and accounted for.  
For similar reasons, steam coils in storage tanks should be given necessary supporting work for necessary slopes.
- To heat trace valves, pumps and filters either copper/s.s. coils should be used or steam jacketing to the equipment should be provided. Each such piece should be individually drained with steam trap assembly. These are efficient steam utilisation aspects, but, raises the installed cost.

Looking into all the factors, the installed cost ratio for a compact textile mill layout ranges from 1.26 to 1.85 for steam and 1 for self-limiting heater; for a steam forge shop it was 1.6 for steam and 1 for self-limiting electric tracer; for a medium size steel plant where steam is not used for process, it was 1.4 for steam and 1 for self-limiting heaters; and for glass factory 2.76 for steam and 1 for self-limiting heaters. These figures are based on actual studies conducted.

There have been instances where total installed cost ratio has been in favour of steam system, yet, the final choice was for self-limiting heater because of compactness, operating costs, maintenance and other features of "Auto-Trace".

It can therefore be said that a detailed study of both alternative systems is necessary to evaluate total installed cost. This is best done by preparing preliminary designs of both systems.

Self-limiting electric heat tracing element requires no special considerations other than the normal electrical codes followed in factories. The total power consumption on self-limiting electrical heaters is in the order of 20 to 50 KWH, spread out over the installation layout of 4000 to 10,000 feet. There is no special necessity to lay power supply cables. For this reason the cost towards energy supply system is much lower in electrical systems when compared to steam system.

When hazardous classified areas are considered, it is vital to include cost of special enclosures and switches which are certified for use in the rated hazardous locations. This will increase the cost of a system as compared to ordinary area classified system.

#### OPERATING COSTS

The annual operating costs of a system will greatly depend upon the basic price of available energy. In India, for small and medium size units, cost of steam can be considered at Rs.50/- per million Btu (Approximately Rs.100/- per tonne steam), and for electricity the cost at Rs.100/- per million Btu (Rs.0.30 per KWH). For large size plants it can be as high as Rs.80/- per million Btu for steam and as low as Rs.80/- per million Btu for electricity. A lot will depend upon the overheads of an organisation and the efficiency at which the plants are operating. Energy, in whatever form, needs careful and efficient utilisation. Heat tracing systems are no exception. Matter of fact, no system has any exceptions, where efficient energy utilisation is thought of as practiced.

Refer Fig. 3 again, and understand the various factors for operating energy requirement for a steam system:

- Steam supply lines for tracing requirements will have certain losses due to condensation of steam. Sometimes these losses can be high as compared to the actual heat tracing requirements. A 3" n.b. insulated line will form condensation at the rate of 10 pounds steam per hour per 100 r.ft. at a pressure of 50 psig. A 300 ft. of this 3" n.b. line will accordingly consume annually 98 tonnes of steam without doing any useful work.
- Radiation losses from unlagged steam traps, stop valves, control valves which are used for steam tracing should also be considered. There are published figures to this effect from the tests carried out by Electrical Power and Heat Laboratory of the Technical University of Munich, in Germany. At 176 psig steam pressure and the ambient of 32°C, energy radiated on no load conditions for a 1/2" size trap is: 671 Btu/hour for thermodynamic trap; 1357 Btu/hour for Inverted Bucket trap; 2183 Btu/hour for float trap. Accordingly annual steam consumption can be from 1 tonne to 3 tonnes of steam for each trap, depending upon the size of the steam trap used.
- Leakage is another source of steam wastage which occurs in a steam system inspite of the best maintenance efforts. If there are eight leaks in the entire system, of average size of 1/64", annual steam loss will be 81 tonnes of steam at a pressure of 50 psig. These leaks can be from places like valve glands, trap orifice, screwed joints. Many times the leakages go unnoticed and steam losses are very high.
- Heat Transfer from a steam tracer to the product line accounts for the major operating costs. This is because steam energy cannot be effectively controlled, particularly when maintenance temperatures are below 100°C. It is increasingly difficult to control the energy input when the product to be heat traced is continuously flowing.

Heat loss from insulated product line is in the region of 15 to 20 Btu/hour/foot of pipe for line sizes upto 4". However, the heat energy given out by a steam tracer will vary from 25 to 50 pounds steam/hour/100 feet of steam tracer at 50 psig, depending upon the flow condition

and maintenance temperatures. This is based on steam tracing standards such as; number of tracers to be used for a product line size and suggested spacing between steam-trap stations.

Recent articles on steam-tracing designs suggests that the set standards have over design factors, making steam tracing expensive. New designs formulas have been derived and they are based on design factor which work out to 10 lbs steam/hour/100 feet of tracer.

Consider any standards and you will find that for low maintenance temperatures, steam tracer will give away more than ten times the energy than the required work to be done. This makes it uneconomical.

- Finally, an estimated 25% of sensible heat energy is lost at the trap. Economic trade-offs have to be considered for installing flash steam and condensate recovery system.

*Based on studies carried out for heat tracing tanks and pipes the operating energy costs ratio were; for textile mills it was 5 for steam and 1 for self-limiting heaters; for Forge Shop, 10 for steam and 1 for self-limiting electric tracing; for Steel rolling mill, 5.7 for steam and 1 for self-limiting electric tracing. For glass factory 8.3 for steam and 1 for self-limiting electric tracing; for a Chemical factory 3.8 for steam and 1 for self-limiting electric tracing.*

Operating costs for self-limiting electric heat tracers are low because it replenishes only the required heat loss. In electric distribution system, there is no significant heat loss to account for.

#### Maintenance Costs

The frequency of maintenance for electrical tracing systems is far lower than that for steam systems. Generally, mechanical maintenance staff has to give priority to machinery breakdowns and repairs, thus neglecting steam line maintenance and steam leak repairs.

Reliability of heat tracing systems also determines the maintenance costs. Frequent failures and break downs in tracing system can even affect the production output of a plant.

Self-limiting electric tracing system offers total reliability. Any mechanical damage can be easily rectified.

#### Safety in Hazardous areas

All electrical equipment used in hazardous areas should conform to standard requirements set forth in article 500 of the National Electric Code. Electrical heat tracing is no exception. It is not inherently more dangerous than other electrical equipment, even though its function is heating. In fact, self-limiting heat tracing products have a fail-safe feature that limits their surface temperature even under unexpected or abnormal conditions.

With electrical heat tracing, there are two sources of fire and explosion:

- (a) areas in switching equipment (thermostats, contactors)
- (b) excessive surface temperature on the tracer.

The first source can be eliminated by housing all switching equipment in a NEMA 7 or other explosion proof enclosures.

The second source can be remedied by selecting a tracing suitable for a given application. According to the NEC, Article 500-2, "the temperatures shall not exceed 80% of the auto ignition temperature of the specific gas, vapor, or dust to be encountered.

Steam and self-limiting heaters share a common feature. Both have a maximum sheath temperature for a wide range of atmospheric conditions.

The self-limiting tracing systems limit the maximum sheath temperature in instances of poor heat transfer, over-voltage excursions in the power supply and control thermostat malfunction.

CONCLUSION

Both steam and self-limiting electric tracing system can be used for heat tracing applications in ordinary and hazardous area. Both are reliable and safe alternatives. The dominance of steam tracing is likely to be eroded by electrical tracing due to the energy conservation gained by self-limiting elements and the maintenance benefits.

Whilst selecting a heat tracing system, considerations should be given in comparing a total system rather than comparing only the isolated features. Besides reliability, economics and safety, other factors to be considered are: Installation time; Heat-up time; energy availability; applications and its complexity of the system to be heat traced.

*Finally, don't forget the basic Rules of Heat Tracing:*

- Prevent heat losses by
  - (a) selecting right quality of thermal insulation.
  - (b) Economical insulation thickness
  - (c) Lower temperature differentials by maintaining the required minimum maintenance temperatures.

*Higher temperature maintenance can mean increased heat losses by 30% and even more.*

- Prevent excess heat input by
  - (a) selecting light sheath temperatures of tracers.
  - (b) avoid over designing
  - (c) Efficient temperature control.

*Excess heat input can result in higher temperature causing increased heat loss, product spoilage, pump cavitation, lowering pump capacity etc.*

Careful consideration of heat tracing applications, stagnant conditions or flow conditions, maintenance temperature put together for reliability, economy and safety will find self-limiting electrical systems an ideal candidate for heat tracing in hazardous and ordinary areas.

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