**Electric Heat Tracing**
**Design, Selection and Economic Evaluation of Auto-Trace and 'Constant-Wattage' Tracer, for a Stabilized Heat Tracing Systems Design.**

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## *1.0.0 Introduction*

**Stabilized design as defined by BS:6351:Part 1: 1983. para 2.29**
"A design of a heating system such that it will stabilize, under all conditions that may be reasonably foreseen including empty pipe and no-flow conditions, at a temperature below both the maximum withstand temperature of the ESH device and the hazardous area temperature classification, if any."

The various steps considered in Design, Selection and Economic Evaluation of a Stabilized design Electric Heat Tracing System are:

a.) Determine rate of Heat Loss for a minimum power (P) required at the lowest ambient.
b.) Adjust the required Heat Load ($P_A$) to take into account power reductions resulting from declared tolerances on Voltage (usually 10%) and heating conductor resistance (usually 6%) i.e. that is the lower limit of Voltage ($V_{min}$) and upper limit of Resistance ($R_{max}$).
c.) Calculate the maximum Installed Load ($P_{max}$), which occurs at maximum Voltage ($V_{max}$) tolerance and minimum Resistance ($R_{min}$) tolerance. This is essential whilst determining stabilized design, to ensure that the maximum temperature of the surface to be heated is not exceeded when the maximum installed load is applied, with the highest ambient temperature, and maximum temperature of work piece content.
d.) For the stabilized condition, determine the maximum Surface Temperature of Pipe ($T_{pipe}$) / Tank at maximum installed load ($P_{max}$).
e.) Determine maximum Tracer Sheath Temperature at maximum installed load ($P_{max}$), for various Power-Output of tracer.
f.) Select the Tracer with maximum / optimum Power-Output (W/m) having its Sheath Temperature within its electrical insulation withstand property, under condition (e) above.
g.) Calculate the Operating Energy load for each system i.e., for 'Auto-Trace' and 'Constant-Wattage' system.
h.) Calculate the Installation Cost & Maintenance Cost of each system.
i.) Carry out Economic Evaluation of each system, and compare them for suitable selection and use.

# *2.0.0 PIPE*

## 2.1.0 Heat Loss

**2.1.1 The equation for determining the rate of Heat Loss at lowest ambient is:**

$$\text{Rate of heat loss } (P) = \frac{2 \times \pi \times k \times \Delta T}{\log_n (d_2 / d_1)}$$

where,

| | |
|---|---|
| 'k' | - is the thermal conductivity of thermal insulation, in W/m.°C |
| '$\Delta T$' | - is the differential temperature, in °C.(i.e. maintain temperature minus lowest ambient) |
| '$\log_n$' | - is the natural log. |
| '$d_2$' | - is the outer diameter over insulation, in meter. |
| '$d_1$' | - is the inner diameter of insulation, in meter. |
| 'P' | - is the rate of heat loss, in W/m. |

## 2.2.0 Calculate the Adjusted Power ($P_A$) for minimum. Voltage ($V_{min}$) & max. Resistance ($R_{max}$).

2.2.1 For the purpose of design, the minimum Voltage ($V_{min}$) recorded at a location should be considered, generally at 10% of nominal voltage; and, the rise in Resistance generally at 6% of nominal resistance. The correction in Power-Load adjustment over the calculated rate of Heat Loss (P) is given by the formulae:

$$P_{ADJUSTED} = \frac{P \times (R_{max} / R_{nominal})}{(V_{min} / V_{nominal})^2}$$

(NOTE: For Auto-Trace, Self-Regulating and Self-Limiting tracer, the tracer output at minimum operating voltage ($V_{min}$) is to be considered from the product data graphs. This is because the Auto-Trace output does not vary by the square of the voltage variation.)

**2.3.0 Calculate the maximum Installed Load ($P_{max}$) at maximum Voltage ($V_{max}$) & minimum Resistance ($R_{min}$).**

The Installed Power ($P_A$), under goes a change for ($V_{max}$) & ($R_{min}$), and its adjustment is determined by the formulae:

$$W_{max} = \frac{(P_{adjusted}) \times (V_{max} / V_{nominal})^2}{(R_{min} / R_{nominal})}$$

**2.4.0 Determine the maximum Pipe surface temperature for Stabilized condition at max. ambient.**

This can be determined by method described in BS:6351: Part 2:1983, appendix C, para C.6, by calculating the maximum temperature rise ($\Delta T_{max}$) across the thickness of thermal insulation; as per example shown in appendix A, para A 1.3 in BS:6351:part 2.

For consideration of Safety, the max. Pipe Stabilized Temperature has to be determined under condition of max. Voltage, max. Ambient for a maximum installed power ($P_{max}$) with consideration to all controls in disconnect or failure mode. This is also determined by formulae in IEEE:std 515:1989, para 6.4.1 , equation 3. (over here the symbol ($P_{max}$) is replaced by ($W_{max}$). Therefore,

$$T_{pipe} = W_{max} \times \frac{\log_n (d_2 / d_1)}{2 k \pi} + T_{ambient}$$

**2.5.0 Determine the maximum Sheath Temperature of Tracer at max. ambient**

The *Sheath Temperature*, $T_{sheath}$ of depends on: (a) *Maximum Installed Load* of Tracer, $W_{max}$ (b) Circumference of Tracer, C, (c) Heat Transfer Coefficient of Tracer, U, and (d) Max. Pipe Temperature under Stabilized condition, $T_{pipe}$. This is determined by the formulae:

$$T_{sheath} = \frac{(W_{max})}{(U \times C)} + Tpipe$$

The Higher the Power Loading (W/m) of tracer, higher will be the Sheath Temperature of the Tracer. In order to limit the Sheath Temperature of Tracer, select the lower output tracer and design the stabilized system with Spiral factor for tracer. Thus, the overall circumference of tracer, C, may be considered as the multiple of geometric Circumference of tracer into the Spiral factor, R. Thus ($T_{sheath}$) is directly proportional to the Installed Load and inversely proportional to heat transfer coefficient (U) and tracer circumference (C).

### *4.0.0 Operating Energy.*

The Installed Load is generally the operating load, particularly for Tanks and pipe size 50 n.b. and above. This is because the temperature rise of Five degree centigrade above maintenance temperature will take Several Hours. For Constant-Wattage system the operating load is about 40% higher than Auto-Trace, because the installed load is high by this amount to take care of ($V_{min}$) and ($V_{max}$) tolerances. This is a significant factor for Economic Evaluation study.

In the case of Constant Wattage parallel zone tracer the temperature variation between Powering end and the terminating end can be very high 30 °C. This is due to the ($I^2$ R) heating effect in the tracer bus wires at powering end, and ($V^2$) power drop effect at the terminating end.

### **5.0.0 Maintenance Cost**

The Stabilized Design, explained above is as per BS : 6351 : part 2 requirements. This design reduces the occurrence of heater 'burn-out', however the 'burn-out' will occur at points of poor contact of heater particularly at flange joints, Control Valves, Pumps and loading arms, under extreme conditions. These are the most likely places where leakage do occur, and tracer damage takes place during maintenance work. The tracer is exposed to explosive vapors at these points where heater is not usually in perfect or adequate contact with the surface being heated. This aspect needs to noted by HAZOP and Safety managers.

The maintenance cost for Constant-Wattage system can be considered at 20% to 10% of installed cost, after considering future replacement cost. For Auto-Trace, the maintenance cost can be considered at 2% to 3% of the installed cost.

### *6.0.0 Economic Evaluation*

After considering Interest Cost, Inflation Rate, the Net Present Value (NPV) Savings becomes a significant decision factor. What may appear to be low investment cost of today may not be the Economic choice for future, if NPV Savings are determined. This aspect needs to be considered by the Project Manager and evaluated by the Purchase and Finance managers.

### *7.0.0 Conclusion*

Stabilized Heat Tracing Design is the prime consideration for operating Safety of Electric Tracing, as per BS : 6351 : part 2, particularly applicable for Constant-Wattage tracers. In the case of Auto-Trace, it has a built in Stabilized design by its property of: (a) Self Regulation having high Self Regulating Index (SRI), (b) Self-Limiting property offering Unconditional T-rating, and, Burn-out proof features.