ELECTRIC GUT TRACING - AN INNOVATIVE APPROACH TO PIPELINE HEATING

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Abstract - Applying electrical heat tracing to pipelines can dramatically increase the reliability and efficiency of such pipelines. As a matter of fact over the years, electrical heat tracing has played an important role in the enhancement of flow assurance of oil pipelines. In most cases, the application of heat is on the outer surface of the pipeline, taking advantage of the efficient conductivity characteristics of metallic pipe. While the method of adding thermal energy to the product inside through "conduction" is an efficient method, it introduces a few complexities as well. Examples of these complexities include; the necessity for good contact of the heating cable with the pipe surface and the possibility for higher heat losses requiring the use of oversized insulation. More uniform heating can be achieved by installing the heating cable inside the pipe where it is in direct contact with the heated fluid or what is normally known in the industry as "gut" tracing.

This paper will evaluate the advantages and disadvantages of using a gut tracing approach to heating pipelines as compared to more conventional outer surface heat tracing methods. We will look at the Finite Element Thermal analysis (FEA) of these conventional systems as well as the gut tracing systems. This paper will address the limitations and reliability of both approaches as well cost-benefit analysis and other relevant comparisons. Finally, this paper will identify the ideal applications for a gut tracing approach.

Index Terms — Finite element analysis, gut tracing, pigging, pipeline electrical heating.

I. INTRODUCTION

Heating of pipelines is necessary due to a variety of reasons, such as simple freeze-protection, process temperature maintenance, heat-up/remelt requirements, viscosity control, and condensation and hydrate formation prevention. Alternate technologies such as steam tracing and chemical injection have been used in lieu of electrical heat tracing but they are not considered as cost effective and often pose an environmental hazard. More economical and reliable electrical heating technologies have been developed since the late 1960's. In most cases, however, these technologies have the heating element(s) installed on the outer surface of the pipe and with a thermal insulation envelope. Heat transfer is accomplished mainly through conduction by attaching the heating element to the outer pipe wall. Heat transfer aids have been used to enhance the heat transfer from the heating element to the pipe. For most pipeline applications this surface heating methodology seems to offer a good solution. However, there are special heating applications that require an alternate approach. This paper presents the various aspects of electric gut tracing (or internal pipe tracing) that can be more practical and beneficial for some special pipeline heating applications.

Different heat tracing technologies have been used over the years to reliably maintain products flowing in pipelines. In the case of gut tracing, both steam and electrical tracing have been used on a limited basis, mostly on water freeze protection and asphalt and sulphur process maintenance applications. However, so far, the use of gut tracing has been limited to very few and special applications. It is the intent of this paper to enlighten heat tracing designers in the use of gut tracing and seek opportunities for this technology which, if properly applied, can deliver reliable, practical and economical solutions for some of the difficult heating applications for pipelines.

II. ELECTRIC HEAT TRACING FOR PIPELINES

Electrical heat tracing has been popular for almost 50 years and the design and application of the heat tracing on the pipeline has been simplified. However, pipeline heating designers face some special design challenges when dealing with submerged pipelines, pipeline river crossings, underground road and rail-track crossings, long underground or buried pipelines, pipes with existing insulation or plastic pipes. Frequently, these challenging applications are dealt with by careful selection of conventional electric heat tracing cables and special installation techniques. In the event the pipeline is inaccessible after installation, designers normally call for the installation of the heating cable inside a channel or conduit to allow future removal and replacement in case of failure. Skin-effect tracing systems have been successfully used in this type of application because the heating element is made up of a heat tube and a wire that can be pulled out and replaced if required. However, depending on system lengths, pulling the heating cables out of a long small channel or conduit can become impractical. In addition, except for the skin-effect tracing system, the heat transfer coefficient of a heating cable that is "laying" inside a channel or conduit and attached to the carrier pipe is relatively low. In addition, constant-wattage heating cables in such applications will have higher sheath temperatures due to the lower heat transfer and this may pose a problem for systems installed in classified hazardous areas and also will result in reduced service life.

Fig. 1 shows components of a commonly used electrical heating system:

- a power supply (transformer and breaker panel)
- a control system (electronic controllers or thermostats)
- power distribution and control cabling
- heating cables and connection kits
- a thermal insulation system

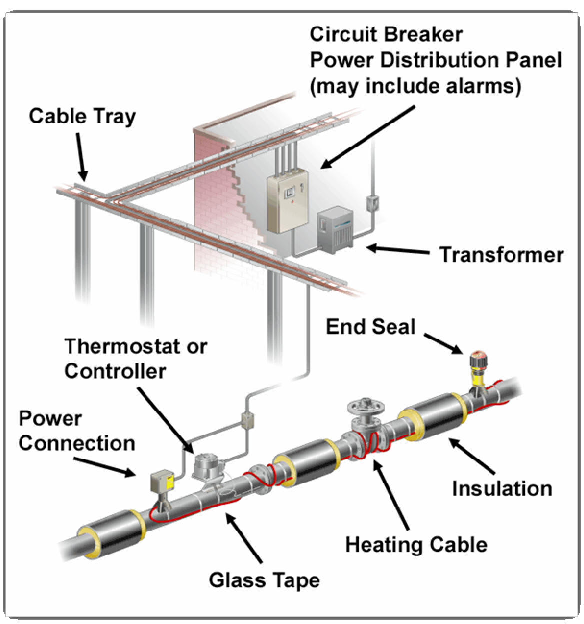

Fig. 1. Typical Electric Heat Tracing System

As explained later in section IV, and depending on the application, a wide variety of heating technologies are used for electric heat tracing including mineral insulated, self-regulating, variable power density, flexible series-resistance cables and skin-effect heating systems. For the most part, however, these technologies are used on surface heating applications with the heating cable attached to the outside pipe wall. See IEEE Std 515™-2004 [1] for design and installation considerations for mineral insulated, self-regulating, variable power density and flexible series-resistance cables. Refer to IEEE Std 844-2000 [2] for full details on skin-effect heating system design and installation.

III. ELECTRIC GUT TRACING - GENERAL OVERVIEW

Gut tracing is defined as a heating method that uses a heating element installed inside the carrier pipe to provide the heat required for the application. The heating element can be either a hot circulating fluid, normally steam, or an electric heater.

Steam tracing and other hot circulating fluids have been used for gut tracing. For instance, a steam tracer can be run inside a sulphur carrier pipe to internally heat the molten sulphur. However, this gut tracing is not a preferred method as it will be difficult to locate and repair a leak in the steam tracer located inside the carrier pipe.[3] Cross-contamination is also a problem; depending on which fluid (sulphur or steam) has the highest pressure, a rupture on the steam tracer will result on either water in the sulphur carrier pipe (product degradation) or sulphur inside the steam tracer (plugged steam traps eventually cooling and plugging the molten sulphur).[4] The introduction of electrical heating elements for gut tracing has effectively replaced the use of steam and hot fluid in gut tracing applications. Various types of electrical heating elements, depending on applications and customer preference have been increasingly popular in many applications.

This paper will primarily focus on the technology advantages and use of electric gut tracing.

A typical electric gut tracing system is illustrated in Fig. 2. Power supply and control systems are not shown as they are similar to what is used on a conventional surface heating system (see Fig. 1 in section II).

Means of entry (and sometimes exit) of the gut tracer into (and out of) the carrier pipeline are provided through a mechanical port. The gut tracer can be either in direct contact with the heated product or can be run in a sealed metallic envelope that is installed inside the carrier pipe. Factory terminated heaters or heaters that are installed inside a sealed tube may only require one entry port at the power end.

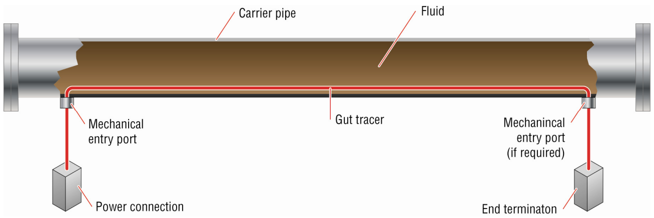

Fig. 2. Gut Tracing System

IV. HEATING TECHNOLOGIES FOR ELECTRIC GUT TRACING

The following electric heat tracing technologies have been successfully used for electric gut tracing applications:

A. *Heating Cables with Constant Power Output*

1) *Mineral Insulated Cables (MI):* MI cables are made of one or more conductors embedded in a mineral powder electrical insulant, normally magnesium oxide, surrounded by a continuous metal sheath. Depending on temperature and chemical exposure requirements, sheath material can be copper, stainless steel or high nickel alloys.[5] Nickel-alloy MI cables can maintain temperatures up to 550℃ (1022℉) and be exposed to 670℃ (1238℉). They can operate up to 600Vac in a single- or three-phase configuration. MI cables are series-resistance type heaters that are usually factory-terminated and supplied in fixed lengths. Reverse glands and pulling-eyes are cable construction options that are normally required for electric gut tracing applications.

2) *Flexible Series-Resistance Cables (FSC):* FSC cables, also known as flexible series constant wattage cables, are made of one to three alloys or copper conductors with multiple dielectric fluoropolymer jackets. FSC cables can maintain temperatures over 100℃ (212℉) and be exposed to 250℃ (482℉). Similar to MI cable, FSC cables can operate up to 600 Vac in a single- or three-phase configuration. FSC cables are series-resistance type heaters. Although FSC cables can be cut and terminated in the field, their installed length must be as per design as length will affect the effective power output.

B. *Heating Cables with Positive Temperature Coefficient*

1) *Self-Regulating Cables (SR):* As their name indicates, SR cables, also known as self-limiting cables, provide a power output that decreases with increasing temperature (self-regulating principle). They are comprised of a conductive heating element between two copper bus wires and dielectric jackets with a grounding braid. SR cables can maintain temperatures up to 149℃ (300℉) and can be exposed to over 204℃ (400℉). They can operate up to 277 Vac. SR cables are parallel-type heaters that are “cut-to-length” and terminated in the field. Approved termination components are available from most manufacturers. Heat shrinkable end terminations are available and commonly used in gut tracing.

2) *Variable Power Density Cables (VPD):* VPD cables, also known as power limiting cables, have a positive temperature coefficient (PTC) which reduces the power output as the temperature around them increases. They are comprised of a coiled resistor alloy heating element wrapped around two copper bus wires and dielectric fluoropolymer jackets with a grounding braid. VPD cables can maintain temperatures over 204℃ (400℉) and be exposed to 260℃ (500℉). VPD cables can operate up to 480 Vac. Similarly to SR cables, VPD cables are parallel-type heaters that are “cut-to-length” and terminated in the field. Approved termination components are available from most manufacturers.

C. Skin-effect Heating Systems

A skin-effect heating system (SEHS) is a form of impedance heating where a single electrically insulated copper conductor is installed inside a ferromagnetic envelope (carbon steel heat tube). The conductor is connected to the heat tube at the far end and an ac power source is connected between the conductor and the heat tube at the supply end.[2] This method of heating is called skin-effect heating because the return path of the circuit current is pulled to the inner surface (approximately 0.7 mm) of the heat tube by both the skin effect and the proximity effect between the heat tube and the conductor.

SEHS heaters can maintain temperatures up to 200℃ (392℉) and be exposed to 250℃ (482℉). They are series-resistance type heaters than can operate at voltages as high as 5000Vac. When using coiled-tubing technology, SEHS heaters are well positioned to be utilized in electric gut tracing applications due to their construction and design flexibility.

V. SAFETY AND RELIABILITY CONSIDERATIONS

Electric gut tracing can provide a safe and reliable heating system. The heater is mechanically protected by the carrier pipe from physical damage. In addition, since the gut tracer is in direct contact with the fluid, it runs much cooler than conventional pipeline surface heaters; as a result, the gut tracer systems can have a longer service life. Ground-fault protection, as required by the National Electrical Code [6], is also required on all electric gut tracing technologies with the exception of skin-effect heating systems.

As detailed in the next section, electric gut tracing design must guarantee that the right heating technology is selected for the application. Heating cable external jacket materials shall be compatible with the fluid being heated. In many instances, the gut tracer may have to be contained in a tube or conduit to isolate the heating element from a corrosive or chemically incompatible fluid. Special attention needs to be placed when designing gut tracer entry into the carrier pipeline to insure that the pipeline is sealed.

VI. GUT TRACING DESIGN CONSIDERATIONS

A. *Heat Loss and Thermal Insulation*

Heat loss calculations for electric gut tracing are not different from what is used for conventional surface heat tracing. Required design parameters are minimum ambient, maintain, operating and maximum exposure temperatures, thermal insulation material and thickness, insulation cladding material, environmental conditions, wind speed, heat loss safety factor, tracing operating voltage and electrical area classification. Actual heat loss calculations can be implemented using IEEE Std 515™-2004 equations.

Most of the commonly available heat tracing software programs are mainly used for above-grade heating applications. In the case of buried pipes, which may be a good application for gut tracing, designers tend to use the same equations and/or softwares and often estimate what the minimum underground ambient temperature is. If the soil thermal conductivity is known, a better approach would be to use the following equation to calculate the underground heat loss rate of an insulated pipeline:

$$Q = \frac{2\pi(Tp - Ta)}{\frac{\ln(4H/D2)}{k1} + \frac{\ln(D2/D1)}{k2}}$$

where

Q heat loss rate (W/m)
H depth from the surface of the soil to the centerline of the pipe (m)
$D2$ outer diameter of insulation (m)
$D1$ pipe outer diameter (m)
Tp pipe maintain temperature (°C)
Ta ambient air temperature (°C)
$k1$ thermal conductivity of the soil (W/m.°C)
k2 thermal conductivity of the insulation (W/m.°C)

One significant difference in calculating heat loss for a gut tracing system is the need to oversize the thermal insulation to accommodate the heating cable installed on the pipe required on surface heating applications is not a requirement for electric gut tracing. The oversized insulation adds to the total heat loss and results in additional heat input. Another advantage is the saving in space requirements due to the decreased overall diameter of the insulated pipe section.

B. *Technology Selection*

Selecting the right electric gut tracing technology for the application is critical for both reliability and system safety. In most cases, gut electric tracer selection criteria is similar to what is used for conventional surface heating. The optimal technology for a gut tracing application is one that:

- Meets the temperature requirements of the application, not only with respect to the temperature to be maintained but also in regards with the maximum operating and exposure temperatures
- Meets the electrical requirements of the application (voltage, area classification, etc.)
- Provides chemical compatibility between the fluid and the gut tracer
- Can be safely installed and replaced

Flexible heaters such as SR, VPD and FSC cables are or can be used in freeze protection or process maintain applications with relatively low operating temperatures. They can either be in direct contact with a fluid that is compatible with their jacket material, or they can be installed inside a tube or conduit that isolates them from a non-compatible fluid.

MI cables are preferred in high temperature applications such as asphalt and bitumen lines. Depending on the sheath material, they can also be in contact with the heated fluid or away from it through their installation in a tube or conduit. Fig. 3 illustrates the installation of three MI cables in steel tubes inside an encased asphalt pipeline that runs across a bridge above a rail-road crossing. Note the use of reverse glands and pulling eyes on this MI cable application.

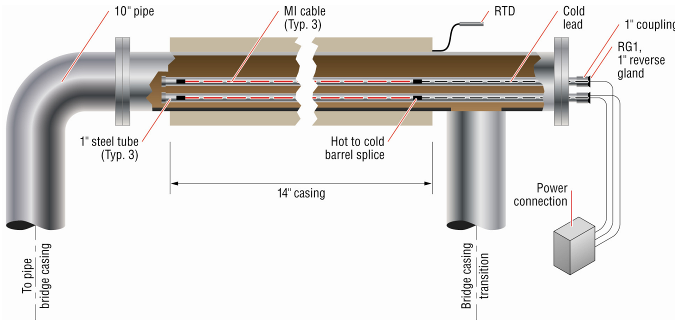

Fig. 3. MI Cable Gut Tracing of Asphalt Line

SEHS heaters are especially suitable for gut tracing in an underground application, particularly for critical installations such as underground road or rail-track crossings. In contrast to standard SEHS heating for surface heating which have to be weld-coupled every 6 or 12 meters, gut SEHS heaters are made of coiled tubing, a proven technology widely used in the off-shore and submerged pipeline industry. While the pulling of conventional heaters through long underground piping runs with multiple bends is quite difficult to achieve, the installation of coiled-tube gut SEHS heaters for this type of application is much easier as the tube can be "pulled" as the pipeline is laid out underground.

C. *Limiting Factors*

1) *Vibration:* Special attention is required during the gut tracing design to the effect of fluid flow on the gut electric tracer. High velocity flows could cause the heater to vibrate or flex to the point of failure.

2) *Pigging:* Pigging, the moving of a device inside a pipe in order to clean, dimension, or inspect that pipe, is sometimes required in pipeline work. For obvious reasons, gut tracing is not recommended for these types of applications.

3) *Coking and Effect of Fluid Types:* Some fluids may be prone to coking or build up on the heater sheath. One typical example is asphalt which can "coke" around 340°C (644°F). Once a gut tracer design is completed and heater power output and sheath temperature are known, a finite element analysis (FEA) can be carried out to determine if coking or build-up temperatures will be reached. Heater redesign may be required in order to prevent coking.

Fluids with high content of sand or other debris could cause heater abrasion or other problems. Gut tracer encasement in steel tube or conduit may be required.

4) *Heat Sinks and Complex Piping:* Pipe supports are a source of heat dissipation. Conventional surface heating design accounts for pipe support heat loss through the use of "adders", additional heating cable that is installed around the support. As this is not possible with gut tracing, the designer should include an additional safety factor when running heat loss calculations.

Electric gut tracing is not recommended for complex piping, that is, piping with valves, inline instruments, and/or multiple piping bends.

5) *Electrical Area Classification:* Under normal operating conditions when the pipeline is full, the sheath temperature of the gut tracer is much lower than what it would be if the heater was installed outside the pipe as the heat transfer coefficient is much higher for a tracer that is in direct contact with the heated fluid. However, there may be instances where the pipeline, or sections of it, could be empty and the gut tracer could still be energized. As a result, it is a recommended practice to calculate the sheath temperature of the gut tracer using the stabilized design method as defined by IEEE Std 515™-2004.

VII. THERMAL MODELING FOR GUT TRACING – CASE STUDIES

A traced and insulated pipeline can be modeled using a Finite Element Analysis (FEA) tool. The FEA creates a system of elements on the piping geometry that is being analyzed. Each element has a finite set of equations that describe that portion of the geometry and the finite element has a finite number of unknowns. By making logical assumptions about the system a modeler may accurately predict the response of the system.

FEA case studies were run to compare electric gut tracing to conventional surface heating for two fluids, water and phenol. Case studies were based on a -29°C (-20°F) ambient air with 11.2 m/s (25 mph) wind. Carbon steel pipe, 8 inch in diameter, was used for both cases. Additional data required to run the FEA cases is summarized in Table I.

TABLE I.
ADDITIONAL DATA FOR FEA CASE STUDIES

Fluid	Cable Output	Insulation	Maintain Temperature
Water	22.5 W/m (6.8 W/ft)	1.5" Polyiso-cyanurate	5°C (41°F)
Phenol	52.0 W/m (15.8 W/ft)	2.5" Mineral Wool	57°C (135°F)

Three cases were analyzed for each fluid:

Case 1. Heating cable installed on upper outside pipe wall at 45 degrees from vertical axis.
Case 2. Gut tracer centered in pipe.
Case 3. Gut tracer on inside bottom of pipe.

Figs. 4 through 6 illustrate the thermal profiles for each of the three cases listed above for water. Temperature values are in °C. Thermal profile of the insulation and cladding has intentionally been omitted in order to emphasize the temperature distribution on the fluid, the pipe and the heating cable.

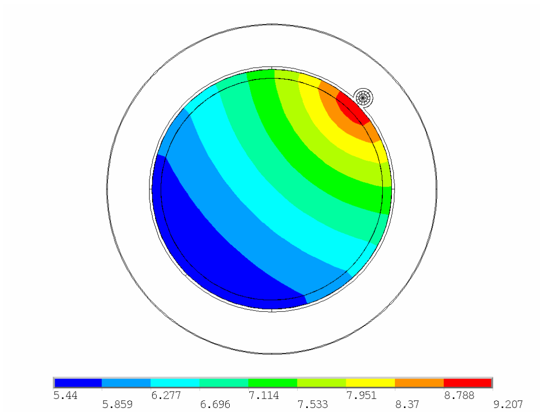

Fig. 4. Thermal Profile of Water – Case 1

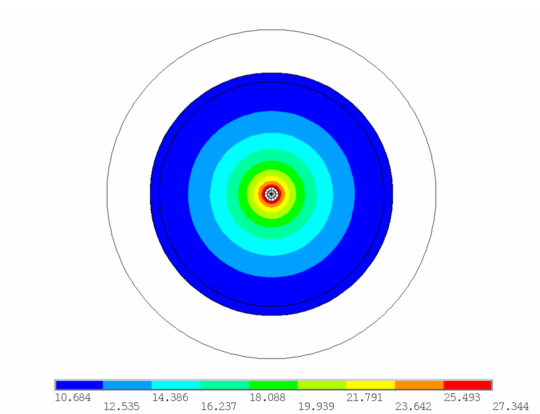

Fig. 5. Thermal Profile of Water – Case 2

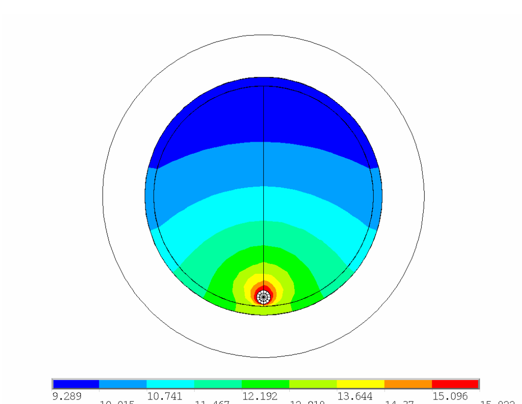

Fig. 6. Thermal Profile of Water – Case 3

Had plastic pipe been used for water instead of carbon steel pipe, the gut tracer heat transfer efficiency would have been even greater when compared to surface heating due to the poor heat transfer coefficient of plastic materials.

Figs. 7 through 9 illustrate the thermal profiles for each of the three cases listed above for phenol.

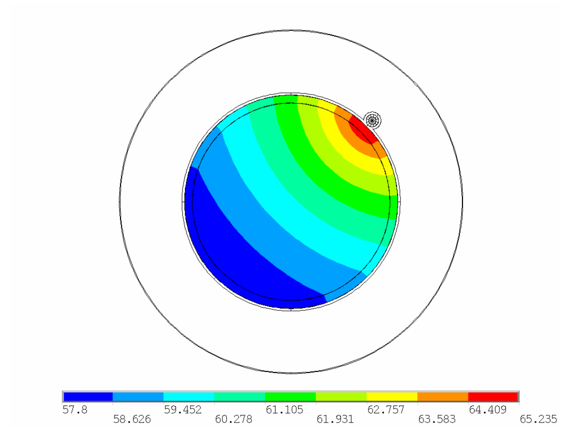

Fig. 7. Thermal Profile of Phenol – Case 1

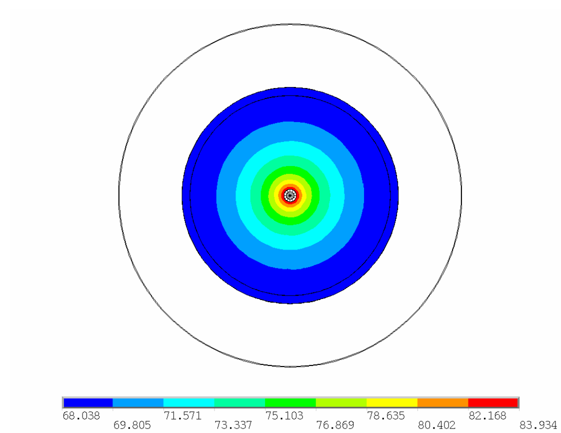

Fig. 8. Thermal Profile of Phenol – Case 2

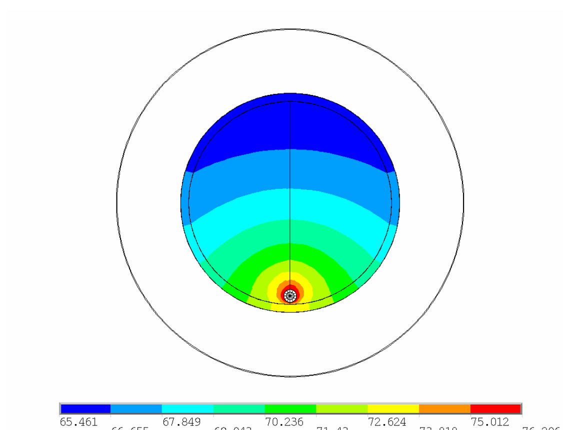

Fig. 9. Thermal Profile of Phenol – Case 3

Comparing the thermal profiles of cases 1 and 3 for each fluid shows that electric gut tracing transfers heat more efficiently than surface heating. This is illustrated by the higher fluid temperatures achieved by the gut tracer. Case 2 provides the most efficient heating of the three cases but case 3 must be used in the comparison as the gut tracer is normally just laid down without regard for specific heater location inside the pipe.

As mentioned earlier, FEA can also be employed to determine if coking or product build-up will take place around a gut tracer. An FEA was run to resemble the MI cable rail-road crossing gut tracing installation depicted in Fig. 3. After calculating a sheath temperature of 301°C (573°F) for the MI cable in contact with the steel tubes, a thermal load equal to this temperature was applied to the model. As shown in Fig. 10, the asphalt temperature is kept above the desired set point of 149°C (300°F) and no coking of the fluid takes place at the steel tube as the temperature outside the tube is below 340°C (644°F), the coking temperature of asphalt.

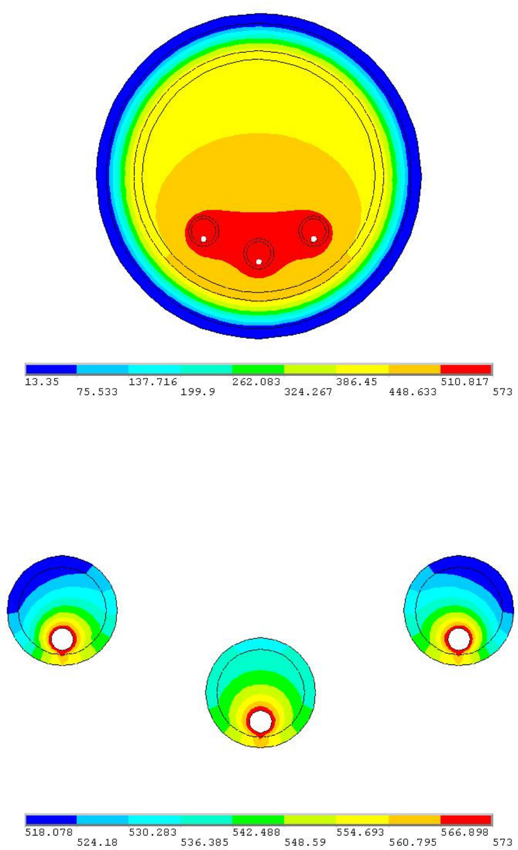

Fig. 10. Thermal Profile of Asphalt Gut Tracing

VIII. CONTROL AND MONITORING

Control and monitoring for electric gut tracing applications is similar to what is used for conventional surface heating applications. Depending on the control methodology, a temperature sensor either senses the ambient air or is attached to the outside wall of the pipe. If mechanical thermostats are used, the gut tracer can either be switched on and off directly through the thermostat or through a mechanical contactor (if thermostat current rating is exceeded). If resistance temperature detectors (RTD) are used, electronic controllers with either mechanical contactors or solid-state relays can be used to energize and de-energize the gut tracer.

Control modes can be one of the following:

1) Standard Ambient-Sense Control. In this method, one or two temperature devices (thermostats or RTDs) sense the coldest ambient air and turn the gut tracing on when the air temperature drops below the desired set point, normally 5°C or 10°C (41°F or 50°F). The system is energized independently of the fluid temperature as long as the ambient air stays below the controller set point.

2) Proportional Ambient-Sense Control. In this method, one or two temperature RTD's sense the coldest ambient air and the heat tracing controller adjusts the duty-cycle of the gut tracer proportional to the ambient temperature. The closer the ambient temperature is to the designed minimum ambient temperature, the longer the gut tracer stays on. As the ambient temperature approaches the set point, the controller decreases the amount of time the tracer is on. As with the standard ambient-sense control mode, the gut tracing is energized independent of the fluid temperature. However, energy is saved with proportional ambient-sense control as the controller "follows" the ambient air to energize and de-energizes the heater. Note that proportional ambient-sense control is not only used in freeze-protection applications but can also be used in process maintain applications where tight temperature control is not required.

3) Line-Sense Control. In this control method, one or multiple temperature sensors (thermostats or RTDs) are installed on the outside wall of the pipe and their signals are used to energize the gut tracing once the temperature drops below the controller set point. Mechanical contactors or solid-state relays are used to switch the tracing on and off. More sophisticated temperature control methods, if required, can be implemented through dedicated heat tracing controllers or standard process temperature controllers (DCS or PLC). However, on/off control is usually sufficient most due to the thermal inertia of heated pipelines.

IX. GUT TRACING APPLICATIONS FOR PIPELINES AND NON-STANDARD PIPELINE SYSTEMS

Non-standard or otherwise unusual pipeline systems have forced the electrical heat trace industry to consider alternate methods of providing heat to their process piping. Typically, these systems are either hard to access, as in below grade piping, or access is restricted as in the case of pipelines maintained over rail lines. Providing conventional heat tracing for these pipelines is often the most expensive option and/or seriously lengthens the project's duration due to the need to provide access to the pipe or to obtain the necessary permits in order to work on the piping in a restricted space. Gut tracing therefore has become a viable alternative to accommodate these unusual situations.

Although the use of electric gut tracing to-date has been limited to mostly above grade applications, there is no reason that this methodology cannot be applied to a variety of piping scenarios. Examples of such pipeline applications are:

A. Submerged Pipelines
B. River and Rail Line Crossings
C. Below Grade Road Crossings
D. Combined Above Ground and Below Grade Pipelines
E. Plastic Piping.

They key factor in the decision to use gut tracing is that at least one end of the pipeline system remain accessible to allow for the internal gut tracer to be inserted into the product pipe. In the case of the aforementioned rail line crossing, it was necessary to utilize gut tracing because the project's schedule would not accommodate the lengthy process to obtain permits to access the portions of the pipeline which traversed over rail line property. The ends of the pipeline however were readily accessible and were located on the pipeline owner's property. As such, three internal gut trace tubes made of steel were welded to the end flange of the rail crossing pipe and one MI cable was inserted into each gut trace tube to allow direct internal heating of the process fluid (see Fig. 3).

As seen in the previous example, electric gut tracing can offer unique solutions to difficult pipeline systems. Submerged pipelines also offer great hindrances to standard electrical heat trace systems. Skin-effect gut tracing systems using coiled tubing technology are well suited for submerged applications.

Most below grade pipelines that are required to maintain a set process temperature are contained within a casing pipe. Being that it is nearly impossible to completely seal these casings against moisture penetration, it is inevitable that water becomes a factor in the heating process.

Combined grade pipeline systems are often unique because their transition points are usually quite creative. These points typically combine a number of elbowed, flanged and valved fittings. As such, it may prove difficult to pick one particular method of heat tracing. To accommodate these hybrid pipelines, multiple heat tracing technologies are often used. It is not unusual that a standard surface type heating system is employed with a skin effect system. Gut tracing offers a consistency that might otherwise not exist.

Finally, the heat tracing of plastic piping is an ideal application for electric gut tracing. Although it has yet to be explored, gut tracing may offer the best method to uniformly provide heat to plastic piping. Typically, plastic or polymeric composite piping is a poor conductor of heat. When standard surface heating methods are used to heat trace carbon steel piping, heat is transferred to the process fluid by conduction. Thus the pipe itself becomes the medium of heat transfer. In the case of plastic piping, this transfer of heat is seriously degraded. In order to provide more heat to the pipe, aluminum foil is usually applied to the pipe and wrapped around the heating cable. This foil reflects the heat from the outer service of the cable back into the surface wall of the pipe to maximize the heat transfer effect. Without this foil, the efficiency of the heating system is seriously degraded. Electric gut tracing of plastic piping not only negates the need to wrap the pipe in foil, but it also channels the heat directly to the process fluid and allows for the conduction of heat transfer to occur much more efficiently. It is also important to note that plastic piping has a low degradation temperature. In many cases, the skin temperatures of standard heating cables excessively exceed these degradation temperatures making it even more difficult to engineer a quality heating system.

X. CONCLUSIONS

Even though the concept of gut tracing to add heat to the contents of a pipeline has been an accepted technology, the problems associated with the fluid based gut tracing system has limited its use in the industrial plants. This is changing and the use of electric gut tracing is emerging as an effective alternate to the fluid based system. The absence of any cross contamination or difficult and costly repair process has given electric heat tracing designers an attractive alternate. In submerged and sub-sea pipeline applications, electric gut tracing offers appreciable advantages in pipeline installation techniques. This is also the case for some river and rail line crossings, below grade road crossings, combined above ground and below grade pipelines and plastic piping applications.

Since the heating element is in direct contact with the product inside, electric gut tracing offers a homogenous thermal profile for these products and can provide faster remelt capability.

XI. References

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XII. VITA

Franco Chakkalakal received a BS degree in EE from Kerala University, India, a MS degree in EE from St. Louis University, St. Louis, MO and an MBA from DePaul University, Chicago, IL.

Franco joined Chicago Bridge and Iron Company in 1972. Prior to joining Tyco Thermal Controls in 2001 as Global Product Manager for Skin effect heating technologies, he held several management positions in heat tracing industry, including the position of Chairman and Managing Director of a large heat-tracing operation in India, and Vice President of Engineering for another heat-tracing manufacturer based in the United States, responsible for Project, Product and System Engineering involving multinational projects. Franco was a member of IEEE 844 working group that developed the industry standards for skin effect systems. He is a member of IEEE and ISA.

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