

# HEATED TUBING: PREFABRICATED OR FIELD TRACE & INSULATE?

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**Abstract** - Heated instrument tubing is common throughout industry and is most often used for winterization. It is also common for tubing to be maintained at high temperatures for viscous processes or to keep gas samples above dew point and prevent condensation. In many cases the tubing is field routed, electrical heat tracing is then installed, followed by the insulation and weather barrier. Alternatively, pre-insulated and heat traced “tube bundles” are designed to expedite installation, minimize total installed cost, and ensure predictable and reliable operation. This paper addresses the advantages and limitations of both approaches.

**Index Terms** - Tube Bundles, Electrical Heat Tracing (EHT), trace heating, self-regulating, power-limiting, CEMS (Continuous Emissions Monitoring Systems), winterization, heated umbilical, sample transport bundle, electropolished, and chemical passivation.

## I. INTRODUCTION

This paper will address several different aspects of applying electrical heat tracing to instrument tubing<sup>1</sup>. It considers all types of electrical resistance heat tracing, including self-regulating, power-limiting, parallel constant wattage and series resistance heat tracing. (Series heat tracing includes mineral insulated (MI) heaters – For additional information see Appendix A). All of these types of electrical heat tracing are available within pre-insulated and heat traced “tube bundles”, but parallel resistance heaters are more practical because of their cut-to-length characteristics. Examples are shown in Fig. 1.

## II. APPLICATIONS

The primary application for heat tracing is freeze protection or winterization, but also includes elevated temperature maintenance to reduce viscosity or keep vapor streams above a predetermined dew-point. Adding some complexity there are applications requiring the ability to withstand elevated temperature excursions. (Winterization of high temperature steam lines is an example of this.)

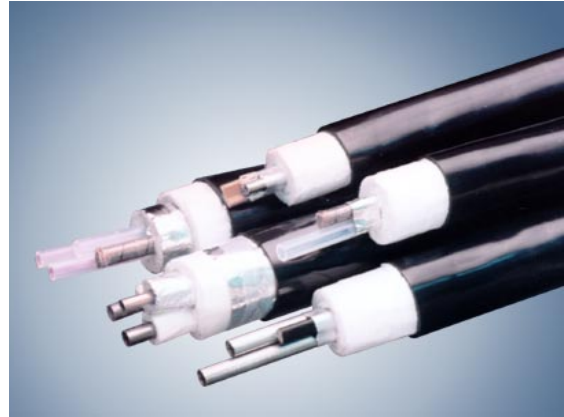


Fig 1: Typical Pre-insulated “Tube Bundles”

There are two basic types of instrument tubing to be addressed: process (flow, level, and pressure) and analytical (liquid or gas). In some cases there is no concern for wide temperature swings on the instrument tubing, while in others it is a requirement that the temperature be accurately maintained.

There is no one “best” method of heat tracing instrument tubing, and there are generally advantages and limitations of field tracing and insulating vs. prefabricated tube bundles in each specific application. Often it is preferences and misconceptions that drive decisions of one method or the other, without regard to specific applications or installation conditions. The focus should be the net installed costs and reliability of each type of installation, but occasionally it’s how quickly an installation can be completed.

Similarly, there is no single “best” type of electrical heat tracing for every instrument tube heating application. Few companies offer both bulk electrical heat tracing as well as pre-insulated and heat traced instrument tubing. So, inherent biases could exist in recommendations given from various manufacturers and vendors. Whether cut-to-length simplicity or higher temperature ratings ultimately dictate the heat tracing method, the application should be reviewed before committing to any specific package or method.

<sup>1</sup> Electrically heated hoses that include series heating wires embedded in the hose and steam heated instrument tubing are not the focus of this paper.

### III. MATERIALS AND CONSTRUCTION

#### A. Tubing

Coiled tubing is available in most any size, shape, and wall thickness. The basis of tubing material selection<sup>2</sup> is beyond the scope of this paper. It should be noted that virtually any commercially available tubing<sup>3</sup> can be specified for use in a tube bundle, but there are some size limitations as well as the number of tubes that can be pre-insulated.

For process applications, the most common tubing material is some grade of stainless steel, either seamless or welded. Exotic alloys<sup>4</sup> (Titanium, Monel, Inconel, etc.) can all be fabricated within a tube bundle, and are not uncommon in their use.

For sensitive analytical applications “electropolished” tubing and/or chemical passivation and/or an amorphous silica coating such as Silcosteel<sup>5</sup> may be preferred or required. These are issues that the chemist/analyzer specialist should address, but generally don’t impact the design of the heat tracing or a prefabricated bundle selection; only the raw tubing specification.

Many applications may call for non-metallic tubing such as fluoropolymers, which include PFA, FEP, and PTFE. Temperature ratings of different grades of various polymers as well as possible gas permeation issues need to be given consideration, but do not restrict non-metallic tubing from being used in tube bundles.

Linear expansion of the tubing in the bundle over the range of temperatures expected needs to be addressed. Depending on the material, the construction, and the length of the installation, linear expansion can become quite significant. Surprising to some, plastic tubing expands more than metal.

In bundles with multiple tubes, the tubing can be “cabled” or run parallel within the bundle. Cabling involves slightly twisting the tubing together to insure closer contact and provide better heat transfer. (See Fig. 2)

Cabling of multiple tubes can increase the minimum bend radius of a bundle. However, it reduces or eliminates concerns for differential expansion between multiple metal tubes. In extreme cases this can result in tubing splitting out of the bundle during steam blow-downs of only one tube.

The routing and installation of a prefabricated tubing bundle may be more complicated than installing bare tubing. Obtain the bundle manufacturer’s recommended minimum bend radius and note any space limitations prior to specifying prefabricated instrument tubing for an application.



Fig 2: Example of “cabled tubing” with EHT

In long runs, the weight of the bundle may also become a factor. Depending on the requirements for the installation, special supports may be required to adequately secure the bundle without crushing the pre-insulated bundle(s).

Thought also needs to be given to tubing and pipe connections at the process line or instrument and/or manifold. Pulp and paper mill standards may dictate what specific type of fitting(s) can be selected.

#### B. Electrical Heat Tracing<sup>6</sup>

Parallel resistance self-regulating electrical heat tracing is the most commonly used in prefabricated tube bundles because of its cut-to-length characteristic. However, power-limiting and parallel constant wattage heat tracing offer this same advantage and are also commonly used.

Mineral Insulated (MI) heat tracing, a series resistance heater, is also available in pre-insulated and heat traced “Tubing Bundles”. Series heaters are not cut-to-length, and MI heaters are very difficult to successfully fabricate in the field. However, where temperature ratings and/or watt densities beyond parallel heat tracing are required, MI heat tracing is often selected.

Most prefabricated tubing bundles have the electrical heat tracing applied directly to the tubing to be heated. It is typically wrapped with a foil or Mylar tape to ensure intimate contact and optimal heat transfer.

#### C. Thermal Insulation

Thermal insulation reduces heat loss, but cannot stop it. Most bundle manufacturers use the same types of non-hygroscopic fiberglass cloth insulation in the fabrication of their bundles. Other materials are beginning to make their way into the tubing bundle markets, but helically wrapped fiberglass cloth is by far the most common.

As with pipe tracing, the heat tracing requirements are simply to offset the heat lost through the thermal insulation at equilibrium during the minimum ambient conditions. Increasing insulation thickness will reduce energy requirements, but not necessarily eliminate the need for heat tracing.

<sup>2</sup> See Reference [2] for additional information on this subject.

<sup>3</sup> While small diameter pipe (<3/4” NPS) and thick-walled tubing (> 1” O.D.) may be more common in random “stick” lengths of ~20’, these can be fabricated in a pre-insulated bundle. However, the frequency of splices, (fluid connectors and electrical splices), makes this a labor intensive installation that would generally favor field installation of all components.

<sup>4</sup> Monel and Inconel are trade names of Special Metals Corp.

<sup>5</sup> Silcosteel is a trade name of Restek Corporation.

<sup>6</sup> Advantages and limitations of popular electrical resistance heat tracing are addressed in Appendix A of this paper.

Various grades of fiberglass are available for the insulation of field installed bare tubing. Alternative insulation materials<sup>7</sup> can be used for field routed tubing, including low temperature flexible foam insulation and higher temperature mineral wool insulation materials.

#### D. Weather-proof Jackets

Thermoplastic jackets are extruded over the pre-insulated and heat traced tubing to complete the manufacturing process. Various materials are available from different manufacturers, but all are primarily intended for the same purpose: protecting the integrity of the bundle and keeping moisture away from the thermal insulation.

Selecting a jacket material isn't generally a major task. Arctic installations need materials that will not crack if flexed or struck during sub-zero temperatures. Installations in the Middle East require high levels of UV resistance as well as assurance that the integrity of the jacket won't be compromised after years of service in extremely high ambient-temperature conditions.

There are occasional concerns for stress corrosion of stainless tubing when installed in bundles with PVC jackets. Keeping the insulation dry is a basic concern for all heat tracing systems, and the lack of an electrolyte (water) in the system can reduce or eliminate stress corrosion concerns. Other types of jacket materials for pre-insulated bundles are also available.

Field traced and insulated tubing will have conventional metal "lagging" or other weather barriers applied to protect the insulation. In the case of flexible open-celled foam insulation, the installer often applies an adhesive tape. However, the continuous extruded polymer jackets on tube bundles are more reliable in keeping the insulation material dry.

Paying attention to terminations and transitions are extremely important as these are the most likely areas where water can enter. Sealing the ends of the bundle where the process connections are made and then supporting them adequately to maintain that seal helps ensure a successful installation. Bundle manufacturers offer seal kits and various accessories but not all provide sufficient long term protection. As an example, heat-shrink tubing or adhesive tapes can seal those terminations, but many have limitations on prolonged high temperature exposure.

Often one end of heated tubing is brought into an instrument enclosure. The independent mounting of the heated enclosure and the instrument tubing can create stress on this transition/connection. Kits are generally available from both the bundle and heated enclosure manufacturer(s) to provide protection and ensure long-term reliability. If this seal is compromised it will not only let heat out of the bundle and enclosure it could freeze the instrument as well.

#### E. High Temperature Considerations

In recent years high jacket temperatures have become a concern. At issue is personnel safety if the jackets are allowed to exceed 140°F (60°C), possibly resulting in a burn hazard if touched by a worker. This is particularly true where superheated steam sampling systems have insulated lines with exposure temperatures of over 1000°F.

Such high temperature lines rely on heat tracing for freeze protection where steam is allowed to cool, condense, and become susceptible to freezing problems. Depending on the temperature rating of the electrical heat tracing, it may require isolation from direct contact with the high temperature tubing. See Figure 3.

There are cut-to-length electrically heat traced bundles for freeze protecting super-heated steam lines, most of which are pre-engineered specifically for the application. But even MI heat tracing designs with the heat trace applied directly to the high temperature tubing, the insulation and jacketing requires consideration of maximum surface temperatures that can represent burn risks to unsuspecting personnel working in the area.

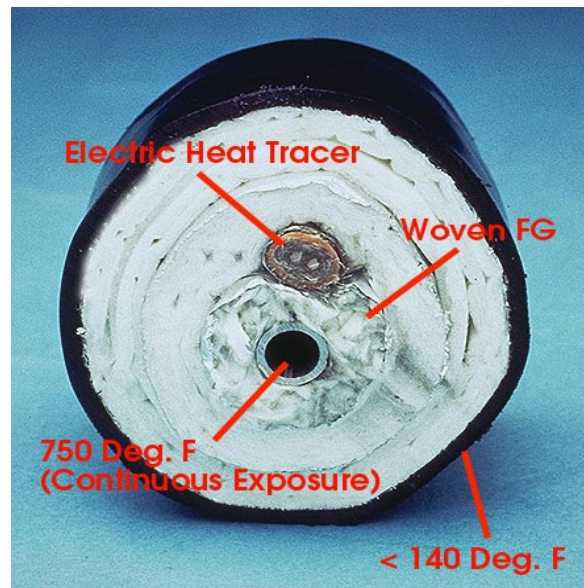


Fig. 3: Example of freeze protection bundle with EHT isolated from direct contact with the high temp tube.

#### IV. INSTALLATION CONSIDERATIONS

The lure of relatively low cost components and bulk materials, along with an incomplete estimate of installation requirements, can be misleading. The initial material cost often appears attractive but multiple trades (fitters, electricians, and insulators) can lead to a higher installed cost for heated instrument tubing. (See Appendix B for an example of such a comparison).

In many cases field routing electrical heat tracing is the most cost effective heated tubing installation. One case in point is for relatively short runs of tubing tied into larger diameter piping that is also heat traced.

Depending on the application, heat tracing can be routed off of the pipe onto the tubing and then back to the piping without a separate power circuit or even an electrical splice. Any concern for two passes of the pipe's heat tracing on the small diameter tubing should be addressed in advance to avoid any problems or delays in the field.

It's the longer runs of tubing to be heated where the benefits of installing prefabricated bundles can be realized.

<sup>7</sup> See Reference [4] for additional information on this subject.

This is particularly true when there is limited access to the work to be done.

Prefabricated tubing bundles can be easily routed and simply secured to structural steel or grouped in cable tray. So, on longer tubing runs, installation is much faster than field routing bare tubing, installing heat tracing and then insulating and jacketing the work. A comparison of a typical installation is shown in Appendix B.

#### A. Field Routing Tubing

Depending on the accessibility of the work it may be a more cost effective installation to field route bare tubing, heat trace and insulate it in the field. One of the biggest concerns with field traced and insulated tubing is heat sinks. As field routed tubing is apt to be secured to metal supports, additional care is required to address these heat sinks. In many cases it's also necessary to provide increased electrical heat tracing allowances to offset the resulting unplanned heat losses.

Heat tracing field routed tubing is a common installation, but consideration must be given to how the tubing and/or bundles are supported. The tubing itself should not be used as the support mechanism.

Slotted channel has typically been used to support tubing and also works quite well for tubing bundles. But experience has shown that continuous tray is a superior method of support. The tray is stronger, fully supports bundles longitudinally and offers more alternatives for clamping.

An alternative to field tracing an individual instrument's tube(s) is to use a tray to support bare tubing, applying heat trace under the tubes in the tray and installing insulation over the whole system. This can provide a simple, sturdy and easily constructed system, and insulation thickness can be increased for colder climates. (See Appendix C for additional information on this approach.)

This is also applicable to multiple runs of bare tubing grouped in a common cable tray, then traced and insulated together. Depending on the type of electrical heat tracing and number of branch lines that leave the common route along the way, additional splices and insulation required can amplify the installation requirements.

#### B. Installing Tube Bundles

Tube bundles don't require the same attention to the heat sinks that supports represent, but do require care so as not to be crushed by over-zealous installation contractors. Crushing the insulation not only results in poor performance, but it can also damage the jacket and allow water to enter and ruin the insulation.

It's also important that the tube bundles are not stacked or packed tightly together when routed in groups. This is particularly true in high temperature service applications as the heat retained if too close together can result in melted jackets and water ingress and ultimately system failure.

#### C. Heater Termination and Sealing the Thermal Insulation

Properly terminating each heating circuit and sealing exposed thermal insulation is critical to all electrical heat tracing systems, including prefabricated tube bundles. Wet insulation is the number one problem in electrical heat tracing system performance, so attention to weather protection is essential for a successful installation.

An example of a power connection assembly on a tube bundle is shown below in Fig. 4. Note that in this case power is fed to a mid-point and routed in two directions to increase the length of tubing heated from a common power supply point. (As with any heat tracing system, it is important to minimize power distribution to optimize the net installed cost of the system.)



Fig. 4: Power Connection Assembly with a molded case for a pre-insulated & heat traced tubing bundle. Note "step-downs" to match specific bundle diameter.

It is important that the power supply to the bundle/thermostat be isolated from other loads, preferably by a dedicated circuit breaker. In most cases, the heat tracing distribution panel (which may feed piping and tank heaters as well) may have a separate and dedicated transformer.

Typically when instrument impulse lines are heat traced the instrument itself will require freeze protection. Heated enclosures are most often used as they provide the most convenient and reliable method. It is usually advantageous to supply power to the bundle heat trace from the power supplied to the enclosure heater, and they can usually share the same thermostat. This also simplifies circuit monitoring, which is important in maintaining the heat trace system.

#### D. Performance Issues

Performing periodic tests on bulk heat tracing and fabricated circuits throughout installation can prevent problems during commissioning. It is important to keep records of the installed length of each circuit or heated tubing.

In general, prefabricated tubing bundles offer more predictable results over the life of any given installation. This is primarily due to the product being fabricated in a controlled environment with designs that have been tested in laboratory "cold chambers" and other harsh conditions.

Even if care is taken in the design, product selection, installation of the heat tracing and ultimately the insulation, attention to the "Life Maintenance" of the overall system cannot be overemphasized.

## V. CONTROL AND MONITORING

Accurate temperatures that are required on heated tubing will require separate and independent control(s). No matter

how good the installation, wide ambient temperature swings will impact the temperature maintained.

Prefabricated tubing bundles are available with factory installed temperature sensors (RTD, thermocouples, etc.) for use with a separate electronic temperature controller. Of course, mechanical thermostats can also be installed and mounted in the field.

Many electronic controllers also include some temperature and circuit monitoring functions. In fact, some can also satisfy code requirements for ground leakage equipment protection without the use of a special circuit breaker.

Monitoring of the heat trace system for process instrumentation is critical if it impacts the operation of a process value. Tubing systems, because they're inherently small, have no heat storage capacity so these tend to freeze quickly. When speed of response is critical, continuous monitoring of status to a monitored location is required. Digital monitoring of the heat trace circuit or tube temperature is easily accomplished, but at an additional cost.

## VI. CONCLUSION

There is much information comparing prefabricated bundles with field traced and insulated tubing. However, there continues to be personal preferences for both methods that don't necessarily consider the specifics of the application or installation in question.

In order to ensure that requirements are well suited for either method of heat tracing instrument tubing, carefully consider the application before committing to either method.

## VII. REFERENCES

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## VIII. VITA

Rory Johnson is Director of Design Engineering for Weyerhaeuser Co. Engineering Services. He has been involved with implementation of capital projects in the Pulp & Paper Industry for 32 years, much of that experience in controls and instrumentation applications.

Peter Baen is a Product Manager for Thermon in San Marcos, Texas. He participates in various working groups to advance the standards and practices surrounding the field of heat tracing.

## Appendix A

### Electrical Heat Trace Advantages & Limitations

Electrical Heat Trace Type	Application	Advantages	Limitations
Self-regulating (self-limiting)	Winterization/Freeze Protection Process Temperature Maintenance (Maintain to 300F/149C)	Easy to design, Flexible, Cut-to-length, Easy to terminate, Unconditional "T-Rating"	Sensitive to high temp exposure, (Generally <420F/215C), High start-up currents.
Power-Limiting	Winterization/Freeze Protection Process Temperature Maintenance (Maintain to 400F/204C)	Easy to design, Flexible, Cut-to-length, Built-in Cold Lead, High-temp exposure to 500F/260C	Higher run-away temperatures, T-rating determined by application. More care during circuit fabrication & installation.
Parallel (Zone) Constant Watt	Winterization/Freeze Protection Process Temperature Maintenance (Maintain to 400F/204C)	Easy to design, Flexible, Cut-to-length, Built-in Cold Lead, High-temp exposure to 500F/260C	Higher temperatures require control, T-rating determined by application. More care during circuit fabrication.
Flexible Series (Constant Watt)	Winterization/Freeze Protection Process Temperature Maintenance (Maintain to 400F/204C)	Flexible, Easy to Monitor Current, Can be Field Fabricated, High-temp exposure to 500F/260C	Difficult to Design, Circuit Length Affects Power Output, (Shorter Lengths may require Transformer), T-rating determined by application. More care during circuit fabrication.
Mineral Insulated (MI) Series Heaters	Winterization/Freeze Protection Process Temperature Maintenance (Maintain to 932F/500C)	Durable and Rugged Sheath, Easy to Monitor Current, Custom Fabricated Heaters, Highest-temp ratings to 1,100F/593C	Difficult to Design, MgO Dielectric Susceptible to Moisture, Field Measurements Required for Factory Fabrication (Long Lead Times) (Shorter Lengths may require Transformer), T-rating determined by application.

## Appendix B

### Cost Comparison of Prefabricated Tubing Vs. Field Fabrication\*

#### Specifics and Design Conditions

Instrument Tubing Requirements: (2) 1/2" X 0.040" Seamless Type 316 Tubing  
 Tubing Length: 35' from Orifice Tap to d/p transmitter  
 Maintain Temperature: 50 deg F (+10 deg C) Freeze Protection  
 Minimum Ambient Temperature: minus 20 deg F (-4 deg C)  
 Maximum Exposure Temperature: 366 deg F (171 deg C) (150 psig steam purge)  
 Available Power: 120 Vac  
 Area Classification: Class I Division 2

	<b>Labor:</b>	<b>Rate:</b>
<b>Field Fabricated Heat Traced Tubing: Material:</b>	<b>Hours:</b>	<b>\$38</b>
60 ft of 1/2" 0.049" seamless tubing	\$297.00	24
40 ft of high temp electrical heat trace	\$332.00	7.2
Heat trace termination and power connection	\$63.00	\$0
1" thick Foamglass with jacket for 2" NPS	\$84.28	8.68
1" thick Foamglass elbows for 2" NPS	\$14.20	\$0
<b>Subtotals:</b>	\$790.48	\$1,553
<b>Total field traced and insulated costs: \$2,343.92</b>		

	<b>Labor:</b>	<b>Rate:</b>
<b>Pre-Fabricated Tubing Bundle: Material:</b>	<b>Hours:</b>	<b>\$38</b>
35 ft of 2-tube pre-traced bundle to meet specs.	\$1,076.25	12
Bundle end seal and heat shrink boot:	\$48.00	\$0
Heat trace termination and power connection	\$103.00	\$0
<b>Subtotals:</b>	\$1,227.25	\$494
<b>Total field traced and insulated costs: \$1,721.25</b>		

**Savings with Prefabricated bundle: \$622.67**

\* Based on data from O'Brien Corporation, St. Louis, Missouri

## Appendix C

### Notes:

- A. Electrical heat trace is shown applied to the back-side of the tubing support tray with foil tape.
- B. 1" thick X 2" NPS thermal insulation (2-3/8" actual I.D.) is applied around the tubing, and heat traced tray. Insulation and electrical heat trace must be rated for the temperatures expected and must also be protected from the weather to keep the insulation dry along its entire length, including all penetrations for support and tubing entry/exit.
- C. Items 1 – 5 address one means of support for the instrument tubing between a typical transmitter and instrument taps.

