- Peristaltic Pumps Move Out of the Lab
- How Much Does Filtration Really Cost?
- Controlling Corrosion in Severe Applications

November 2000

Chemical Processing

www.chemicalprocessing.com

SPEED

The Chemical Industry's Ultimate Requirement for Survival

The Chemical Industry's Ultimate Requirement for Survival

Ensuring Uniform Heat Distribution in High-Temperature Process Piping

Thermal analysis and modern heating elements offer potential solution

By David R. Hornbaker

Piping for some hot process applications requires thermal maintenance devices to keep stream-end piping temperatures within specific limits. In such cases, conventional pipe jacketing has been regarded as a sufficient, but often very expensive, option.

One alternative to pipe jacketing, tube tracing, does not effectively prevent problems caused by temperature variations along the process pipe wall. Frequently, tube tracing is used as an economical way to compensate for heat loss.

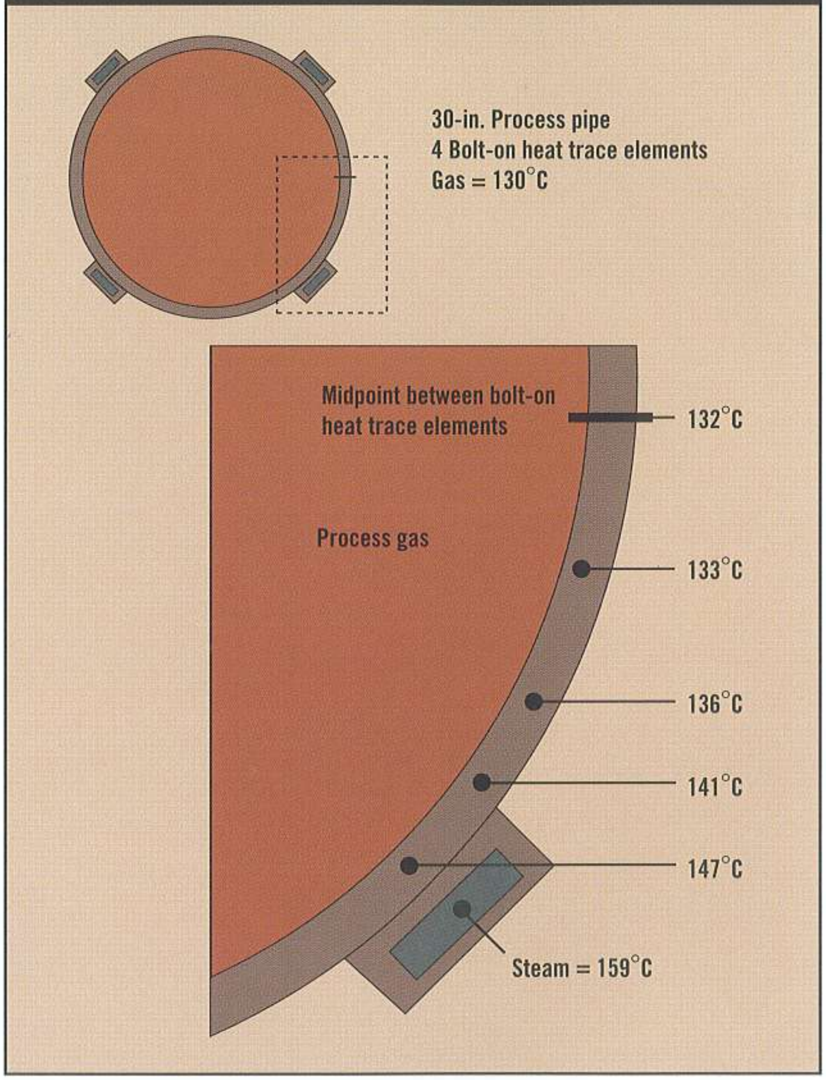
In low-temperature applications with broad temperature envelopes, steam tracing can be effective. However, in these types of applications, the position of the tracers and the temperature distribution in the pipe material are not considered important.

A new system for process temperature maintenance and uniform pipe wall temperatures consists of contoured bolt-on trace elements. Comparable in price to tube tracing, these elements are positioned strategically after heat dynamics in the operating piping system are modeled.

To prevent problems caused by unwanted heat variation, frequently the key is ensuring uniform pipe wall temperature. To accomplish this, it is necessary to manage the heat distribution in the pipe wall.

Proper heat distribution management depends on the number and placement of heating elements. This placement, in turn, depends on accurate modeling of process thermodynamics. Therefore, the heating element vendor should employ accurate process thermal analysis software for this purpose.

PROCESS THERMODYNAMIC MODELING EXAMPLE



The pipe's wall temperature decreases as the distance from the heat element increases, until a minimum of 132°C is reached.

The figure provides an example of process thermodynamics modeling.[1] Heat from steam at 159°C is applied from a contoured heating element to a pipe wall at defined intervals. Directly under the element, the wall temperature is 147°C. Note the decrease in wall temperature as the distance from the element increases, until a minimum of 132°C is reached.

At this point, heat conducted through the pipe wall from another heating element causes the wall's temperature to rise again. The wall temperature varies within a defined range, and the warmest and coolest points also can be identified readily.

Solving plant problems

The application of contoured pipe tracing after detailed thermal analysis has prevented problems caused by mixed vapors in sulfur processing at one plant, and addressed concerns associated with a common anhydrous vapor process in another facility. In the first case, the system prevented condensation and associated pipe corrosion. In the second, it prevented pipe blockage from precipitated material.

A sulfur recovery success story

Sulfur recovery units in refineries or natural gas plants usually include tail gas or degas vapor lines. These lines commonly are heated to prevent condensation of either sulfur or water.

In most cases, the gas in the line is at an elevated temperature and can be assumed to be at or above the dewpoint temperatures for water and sulfur. It has been common practice to employ conventional tube tracing — or in some cases, electric tracing — to heat the line. Despite this practice, condensation and resulting corrosion remain a problem. The cause is uneven or inadequate pipe heating.

A natural gas plant sulfur-degassing unit in central Alberta, Canada, wanted to achieve more uniform pipe heating. To do this, the plant first needed to conduct a detailed thermal analysis of the pipe, gas, heating elements and insulation. Thermal analysis revealed that the flowing process gas potentially was cooling the pipe wall. Conventional steam or electric tracing usually does not heat piping uniformly, resulting in cold spots where condensation occurs.

The Alberta plant's sulfur degassing unit's vent piping had been in place for approximately six years and had suffered serious corrosion, particularly in and around the low spots. The original steam tracing had been installed with conventional $^5/_8$-inch (in.) tube tracing employing 500-kilopascals gage (kPag) saturated steam. Vent line sizes were 20-in., 24-in. and 30-in. diameters, running approximately 55 meters from the degas pit to the incinerator. The lines had been installed with 10 tracing tubes on the 20-in. line and with as many as 13 tubes on the 30-in. line. The tracing generally was located around the bottom of the pipe in horizontal runs and on a convenient-to-access side in vertical runs.

The analysis model showed that at least 13 tubes should be used, spaced at equal intervals around the 30-in. pipe.

Because they considered the six-year lifetime of the original pipe to be economically unsound, plant management sought to find a better way to maintain pipe temperature. They reviewed the experience of similar plants equipped with bolt-on heat tracing elements. In some instances, these systems had been effective in comparable service for more than 10 years.

Using a proprietary finite-difference computer model,[1] the gas plant operator analyzed the various parameters involved in heating and cooling the pipe. A model was created for gas flow through the pipe, generating temperature profiles of the piping system under various operating conditions.

The new comprehensive analytical tool showed the plant how much heat was entering the pipe. It also measured how that heat was distributed by conduction along the pipe wall, through the insulation, and by convection, to the process itself. The analysis used the following data sets:

- Pipe size.
- Wall thickness and material properties.
- Insulation thickness and properties.
- Worst-case ambient temperature.
- Wind conditions.
- Process gas properties.
- Flowrates.

Using the data sets, the model calculated a heat-transfer coefficient specific to the Alberta plant.

By applying the model, plant management and the model provider were able to get detailed temperature profiles for various conditions. Variables included heating elements and their spacing, steam temperature, insulation thickness and flow conditions (from the maximum expected to zero flow). Using the data, they determined the optimum number of elements and their placement to ensure pipe wall temperatures would prevent process condensation.

Plant management then conducted a plant-specific material cost and installation expense analysis. It revealed that even though the material cost of the new bolt-on heat trace elements was higher than that of tube tracing, the installed cost was expected to be significantly less. In addition, because plant management expected a longer pipe lifetime with the new system, both the performance and economic criteria theoretically were met.

The sulfur pipeline at an Alberta, Canada, natural gas plant has been operational for one and a half years since installation of new bolt-on heat trace elements.

After evaluating thermal modeling, cost and expected performance analysis results, the manufacturer designed and fabricated the new bolt-on heat tracing system. Installation was performed by the plant and its contract personnel.

The heating elements used at the Alberta plant were drawn from SA 178 carbon steel into a rectangular shape. One side is curved to fit the outside contour of the pipe.

The elements used on the sulfur pipeline are nominally 25 millimeters (mm) by 50 mm. They are registered in Canada with a pressure rating of 2,380 kPag at 340°C. Heat exchange between the steam and the pipe is enhanced greatly through use of a thin film of heat-transfer mastic. This results in improved and more predictable performance. Not only does the new system use fewer elements (tubes) than traditional round tubing, it is more mechanically stable.

The sulfur pipeline continued to operate during the installation of the new system. In spite of this, the actual installation cost was less than originally predicted. Most of the installation was accomplished from scaffolding, although some of the bolt-on tracing was shop-mounted before pipe hanging. The bolt-on heat tracing system was supplied prefabricated into rings and headered panels.

Following installation, the system was insulated. Steam-system trapping was based on plant standards and steam loads taken from the thermal modeling program. Interconnection of steam between individual components was performed with hard piping in accordance with plant standards.

At startup, pipe wall temperatures were checked with a surface pyrometer. Temperatures quickly came to values within the expected range. Since then, the plant has taken pipe wall temperature readings periodically, and all values have fallen within the expected range.

Dealing with plating buildup

A major producer of a common anhydrous material — used as feedstock for production of a commodity plastic material — faced a potential blockage problem. Switch condensers had been installed to capture the process material entrained in a gas stream. Inside the condensers, vapor entered the solid phase, causing an accumulation of heat. The heat melted the solid flake particles, causing the material to flow into a holding tank.

The condensers were not completely effective, however, allowing some of the anhydrous material to enter the main waste gas header, where the gas temperature was under 200°F. There, the material precipitated, or plated, causing a buildup inside the header. The plated material conducted heat poorly, which caused the surface to become even colder, resulting in even more buildup.

To prevent plating in the waste gas header, the header's wall temperature needed to be maintained uniformly at a 280°F minimum. Precipitation would occur at 268°F, so the specified performance left a margin of only 12°F.

To help prevent plating in the waste gas header, a producer of a common anhydrous material installed new bolt-on heat trace elements to keep the header's wall at a uniform temperature.

Conventional solutions were not sufficient for maintaining the wall temperature of the waste header within this limit. Tube tracing at the required density would be difficult to fabricate and expensive to install. Also, because the performance demands were great, there was no certainty tube tracing would work.

Jacketing the entire gas header was not feasible for two reasons. First, the header's size (72-in. maximum diameter) made jacketing the most costly alternative. Second, jacketing left the potential for cross-contamination between the thermal medium and the process material in the event of leakage.

The solution was installation of bolt-on heating elements drawn into shape from A-106 carbon steel pipe and rated for service at 600 psig at 600°F.[2] Coverage requirements were determined using the same proprietary thermal management and modeling software applied at the Alberta plant.[1] The elements were attached as needed to pipe sections of various diameters and to elbows comprising the header. Coverage requirements were:

- 30-inch sections — 51 percent coverage.
- 48-inch sections — 69 percent coverage.
- 60-inch sections — 68 percent coverage.
- 72-inch sections — 67 percent coverage.

Similarly, all of the 4-in. and 6-in. process transfer lines, which interconnect the condensers and transfer the molten process to a large storage area, specified the use of the single- and dual-element bolt-on heat trace elements. Hundreds of valves and other process equipment in the piping system are heated with a similar bolt-on heating technology.

Conclusions

Uniform temperature distribution in pipeline walls can be achieved through application of new bolt-on heating elements strategically positioned using accurate thermodynamic process modeling software.[1,2] A well-designed system protects the process from interruptions caused by corrosion or blockage of the pipeline. Bolt-on tracing should be considered whenever it is necessary to prevent temperature variations outside defined limits.

References

1. The thermal analysis tool used at the facilities discussed in this article was designed and applied by Controls Southeast Inc.

2. The bolt-on heat trace elements installed at the facilities discussed in this article are ControTrace elements, designed and manufactured by Controls Southeast Inc.

Mr. Hornbaker is manager of applications engineering for Controls Southeast Inc. (CSI), Charlotte, N.C. He can be reached via e-mail at hornbaker@csiheat.com.

CONTROLS SOUTHEAST INC

PO Box 7500
Charlotte, NC 28241
704.588.3030
704.588.3031
www.csiheat.com