Eliminating Condensation and Resulting Corrosion

In

Sulphur Tail Gas and De-Gas Lines

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Abstract

Sulphur recovery units in refineries or gas plants usually include tail gas or de-gas vapor lines. These lines are commonly heated to prevent the condensation of either sulphur 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 dew point temperature (there are two dew points involved, one for water and one for sulphur). It has been common practice to employ conventional tube tracing (or in some cases electric tracing) to heat the line. Despite these efforts, condensation and resulting corrosion is often still a problem. The cause is shown to be uneven or inadequate heating of the pipe. By conducting a detailed thermal analysis of the pipe, gas, heating elements and insulation it was shown that more uniform heating of the pipe is required. The flowing process gas is actually cooling the pipe wall while the heating elements (steam or electric) are usually not heating the pipe uniformly, resulting in cold spots where condensation occurs. By using high performance steam tracing material properly distributed around the pipe it has been shown that condensation can be prevented. The authors have been involved in such an installation at a natural gas plant sulphur degassing unit in central Alberta, Canada.

INTRODUCTION

Sulphur recovery units in refineries or gas plants usually include tail gas or de-gas vapor lines. These lines are commonly heated to prevent the condensation of either sulphur or water inside the pipe. Without proper heating, internal condensation can result causing severe corrosion, substantially reducing the life of the piping system. Exactly this has occurred at a Canadian gas plant.

Experience suggests that the critical requirements of such lines are often either over-stated, understated or misstated , having a substantial impact on cost. It is the purpose of this paper to discuss the thermal (heat transfer) phenomena occurring within the pipe and gas stream and how they affect the design of the jacketing or tracing system. Information which the Process Engineer must provide to the jacketing designer is defined.

THE PROBLEM

The purpose of a sulphur vapor line jacketing or tracing system is to prevent the condensation of sulphur, water vapors or other component on any point in the pipe under all flow conditions, including zero flow. A secondary purpose is to maintain the pipe above the melting point of sulphur in case sulphur does collect. If the primary purpose is met the secondary should not be necessary.

It is common to assume that the gas entering the line is saturated with sulphur vapor and high in water vapor content. It is also common to specify that the pipe wall must be kept "near" the temperature of the incoming gas stream. The definition of "near" is the most critical part of the specification. Should it say "above the gas temperature" or should it say "within a few degrees of the gas temperature"? The difference between those two definitions can affect the system cost by two to four times.

Tail gas entering a piping system is usually hot (say 130°C), at a pressure near atmospheric and moving at a maximum of several meters per second. Piping sizes in the range of 12" to 48" are common (The large size of these lines cause the possible use of traditional jacketed pipe(pipe-in-a-pipe)to be an economically non-viable alternative for discussion in this paper). The gas stream itself is a very good heater and will heat an untraced pipe to a temperature "near" but always below the gas temperature. If the pipe is well insulated (say 100mm of good insulation), the pipe wall temperature will be from 2°C to 20°C below the gas temperature (on a cold winter day), depending on the flow rate. That is very "near" the saturation temperature but is it good enough? If so, the job just becomes one of providing enough heat to keep the gas from cooling as it goes down the line, and of heating the pipe supports and flanges to prevent cold spots. The question is "is the gas actually saturated or near saturation"? If it is truly saturated, condensation will occur for any pipe wall temperature below that of the gas stream, even a fraction of a degree. An example to which we can all relate, an air-water vapor mixture at 75% relative humidity, 25 °C will condense water on a surface which is only about 3°C below the air temperature.

If the decision is made to prevent all possibility of condensation, the pipe wall temperature must be maintained above the sulphur "dew point" and hence above the gas temperature everywhere in the system. Doing so may be more difficult and costly to achieve. It requires that the heat applied be distributed quite evenly over the surface of the pipe. If the heaters (steam or electric) are spaced too far apart, the point between receives no heat and will operate several °C below the free stream. Every point on the pipe must receive heat by conduction along the wall of the pipe. That is the only way it can be kept above the free stream temperature.

There are other considerations as well. What happens to the pipe wall temperature if flow stops? Does the system require active control to prevent overheating of the pipe? Does some portion of the pipe become too cold under no flow conditions such that there is excessive condensation either during the shut-down or during start-up?

VISUALIZING HEAT FLOW

Figure 1 is a depiction of a large diameter pipe with multiple steam tube tracing elements. The steam containing tube gives heat to the pipe wall. The amount of heat is dependent upon the size and shape of the tube, the method of attachment and the temperature of the steam. Once heat enters the pipe wall it is conducted along the wall away from the tube. Step 1 in the figure shows that as the heat flows along the pipe it splits. Some goes out through the insulation, some is transferred into the process gas and the remainder continues along the pipe wall by conduction. At step 2 the smaller amount of heat remaining splits again as it does at step 3. By the time step 4 is reached the heat available in the pipe wall is less than is needed to make up for the heat loss through the insulation. This causes heat to be transferred from the gas to the wall to make up the difference. It is at this point that the pipe wall temperature becomes less than that of the process gas. From there on the pipe is cold compared to the gas and condensation can occur if the gas contains sufficient condensable vapor.

METHOD OF SOLUTION

The relative influence of the various parameters involved in heating/cooling of the pipe is important to understand. Controls Southeast, Inc. (CSI) has developed a proprietary finite-difference computer model to be used with its ControTrace high-performance tracing product. Its purpose is to determine detailed temperature profiles of the piping system under all operating conditions. It is designed to allow all parameters to be changed and quickly see the affect.

Most trace sizing programs simply deal with the pipe size, temperature, insulation and ambient conditions. Total heat loss from the pipe is calculated. The number of heating elements to replace that amount of heat is determined. No consideration is given to how the heat gets distributed to all parts of the pipe. Adding more heat than is being lost does not assure that all points on the pipe are above the condensation temperature.

A more correct analysis will look at how much heat is going into the pipe, how that heat is distributed by conduction along the pipe wall and through the insulation and by convection to the process itself. In doing so one must know: 1) the pipe size, 2) wall thickness and material properties, 3) insulation thickness and properties, 4) worst-case ambient temperature and 5) wind conditions. Because there is substantial heat exchange between the process gas and the pipe wall, 6) the process gas properties and 7) flow rates must also be known. Using those properties and flow conditions a convection heat transfer coefficient can be calculated.

By applying this program, the detailed temperature profiles can be determined for any combination of conditions. Number of heating elements and their spacing can be varied. Steam temperature can be varied. Insulation thickness effects can be evaluated. Flow conditions can be varied from maximum expected to zero flow. The designer can verify that the number of elements chosen and their placement will produce pipe wall temperatures which will prevent process condensation.

ANALYSIS EXAMPLE

This method of analysis was employed in designing replacement steam tracing for the degas vent system at the gas plant in Alberta, Canada. The design of the original system is discussed below.

The new tracing system was to be made using ControTrace high performance tracing as shown in Figure 2. This material is drawn from SA178 carbon steel boiler tube into a rectangular shape with one side curved to fit the outside contour of the pipe. ControTrace is nominally 25mm by 50mm and is registered in Canada with a pressure rating of 2380 kPag at 340°C. Because of the shape of the ControTrace and the use of a thin film of heat transfer mastic, heat exchange between the steam and the pipe is greatly enhanced resulting in an improved and more predictable performance, using less elements (tubes) than the traditional round tubing.

Analysis of pipe temperature profiles required that the Process Engineer provide the following table of information. This data should always be available if the performance of the tracing system is to be accurately predicted. Data shown is for the Alberta customers degas system.

INFORMATION NEEDED TO DESIGN TRACING SYSTEM	
Process Stream Vapor Composition	N2=76.9, O2=20.5, H2O=2.3, S1=0.2 (mole %)
Process Stream Flow Rate	15,000 kg/hr
Process Stream Feed Temperature	130°C
Process Stream Pressure	20 kPag
Is Condensation a Concern	Yes
Minimum Allowable Pipe Wall Temp.	130 °C
Heating Medium	Steam
Heating Medium Pressure	500 kPag
Heating Medium Temperature	159°C
Pipe Diameter	20”, 24”, 30”
Pipe Material	Carbon Steel, A106, Grade B
Pipe Wall Thickness	0.375”
Insulation Material	Mineral Wool
Insulation Thickness	100 mm
Ambient Temperature	-40°C to +30°C
Wind Velocity	15 m/sec
Pipe Support Details	See Accompanying Drawings

TABLE 1

The data in Table 1 was used to determine process gas properties and then to calculate the convection heat transfer coefficient on the inside surface of the pipe. A value of about 23 W/m2 °C was predicted for the 30” line with a value of nearly 48 W/m2 °C for the 20” line. An external (wind) coefficient was also determined. These values and the remainder of the data in the table and associated material properties were entered in the computer model. Figure 3 shows a typical temperature profile around the 30” pipe. It is symmetrical about each heating element.

The data of Figure 3A shows that 3 ControTrace elements are not thermally adequate. The pipe temperature at the coldest spot, half way between to elements, is 1°C below the gas temperature (actually 0.7 degrees according to the model). That is enough to result in condensation. The use of 4 elements was specified for installation because the temperature of all points on the pipe were above the gas feed temperature, Figure 3B. Remember that the pipe wall temperature is coupled very closely to the gas temperature, particularly at high flow rates. If the pipe is shown to be hotter than the gas at one gas temperature, changing the gas temperature will change the pipe temperature nearly an equal amount leaving it still hotter than the gas.

The program also calculates the net heat transferred to or from the gas. In the case of 4 elements there is a net gain of heat by the gas stream. The result is that the gas will increase in temperature as it proceeds along the pipe. The increase will be about 0.1 °C per meter. That increase is quite small because there is a high mass-flow of gas. Note that if only two ControTrace elements had been used there still would have been a net heat transfer to the gas, more than making up for the heat loss. The pipe wall temperatures would have been far below the gas temperature over a large portion of the pipe. Condensation would have occurred even though enough heat was supplied to make up for losses.

FLANGES AND SUPPORTS

From a heat transfer standpoint, flanges and pipe supports act like large cooling fins. They commonly cause localized cold spots, again causing condensation and the collection of corrosion causing liquids.

Because ControTrace can be rolled to fit circumferentially around either the pipe or the flange, a flange jacketing ring is easy and effective as a flange heater. Thermal modeling again shows that a single

ControTrace ring on each flange (a dual element ring on a flange pair) completely neutralizes the cooling effect of that flange. Figure 4 depicts such a flange pair jacket.

Pipe supports are somewhat more difficult to deal with. Each support design must be looked at separately. Thermal modeling is desirable and is generally done by CSI. With a little experience modeling becomes less necessary. A good rule to follow is that “overkill” never hurts when jacketing a pipe support. The designer just has to model a number of different support designs in order to develop a feel for what constitutes overkill. Running steam tubing along side the support is generally not nearly adequate. Direct heating of the pipe around the support or of the support repad is usually required. Figure 5 shows a typical method of heating a pipe support. Many variations are possible.

SAMPLE INSTALLATION

The degas vent piping at the Alberta Plant had been in place for about 6 years and had suffered serious corrosion, particularly in and around the low spots. The original steam tracing had been done with conventional 5/8” tube tracing employing 500kPag saturated steam. Vent line sizes were 20”, 24” and 30”diameter running a total of about 55 meters from the degas pit to the incinerator. They had been installed with 10 tracing tubes on the 20” and as many as 13 tubes on the 30” line. The tracing was generally located around the bottom of the pipe in horizontal runs and on a convenient side on vertical runs. The analysis model showed that 13 tubes was the very minimum that could be used if they were spaced exactly equally around the 30” pipe.

Because of the short life of the original pipe, it was determined by the plant personnel that a better yet economical way to maintain pipe temperature was needed. They had had some but limited experience with the product ControTrace but investigated other references. It was found that similar lines had been successfully jacketed with ControTrace and had been in service for over ten years.

A material cost and installation expense analysis was conducted. It was concluded that though the material cost for ControTrace was slightly higher than for tube tracing, the installed cost was expected to be significantly reduced. Because a much longer life was expected when using ControTrace, both the performance and economics criteria seemed to be met. The decision was made to use ControTrace and a contract was awarded to Controls Southeast for the necessary thermal modeling/design and fabrication of tracing system. Installation was to be done by the plant or plant contract personnel.

Installation of the ControTrace was conducted while the system was in operation. In spite of this the actual installation costs were several percent less than originally predicted. Most of the installation was done from scaffolding although some was shop mounted prior to pipe hanging. The ControTrace is supplied prefabricated into rings and headered panels. See figure 6 for typical straight run. The process of installation involves the application of non-hardening heat transfer mastic to the trace surface and bolting the individual panels and ring halves together. It was important to be sure the panels and rings were pulled snuggly against the pipe and flanges. This was not difficult because the ControTrace is very rugged and can withstand large bolting pressures. The installation crew expressed satisfaction that it was easier than tube tracing would have been. Figures 7 and 8 show installations around an elbow and at a pipe support. Although final data is not collected at this writing, overall project cost forecast is below the original projection used to justify the tracing selection.

Following the installation the system was insulated. Insulating over the ControTrace was no more difficult than insulating pipe of that size with tube tracing. Trapping of the steam system was based on plant standards and steam loads taken from the thermal modeling program. Interconnection of steam between individual components was done with hard piping in accordance with plant standards. Many installations use stainless steel flexible metal hose which would reduce the time required for this step.

Startup In July, 1999,was uneventful. Pipe wall temperatures were checked with a surface pyrometer. Temperatures quickly came to values in the expected range. As of this writing provisions had not yet been made to monitor gas temperature in the line so exact correlation with predicted values was not possible. Numerous pipe wall temperature measurements have been made with all values falling in the expected range. Systematic data collection with both flow and temperature recorded at the same time has not yet been possible. All available data through two months of operation indicates the system is performing as designed. Additional data should be available at time of paper presentation.

CONCLUSIONS

The design of sulphur vapor handling systems must include a carefully analysis for cold spots on the pipe. It is critical that the heat supplied be properly distributed around the pipe. Computer modeling can provide the tool needed for such designs but all factors must be taken into account. Making up for all the heat that is lost is not adequate.

The ControTrace product transfers far more heat to a pipe than does tube tracing. It therefore has the advantage that less heating elements are required. Actual installation costs have shown that the improved performance can be achieved for less cost than tube tracing.

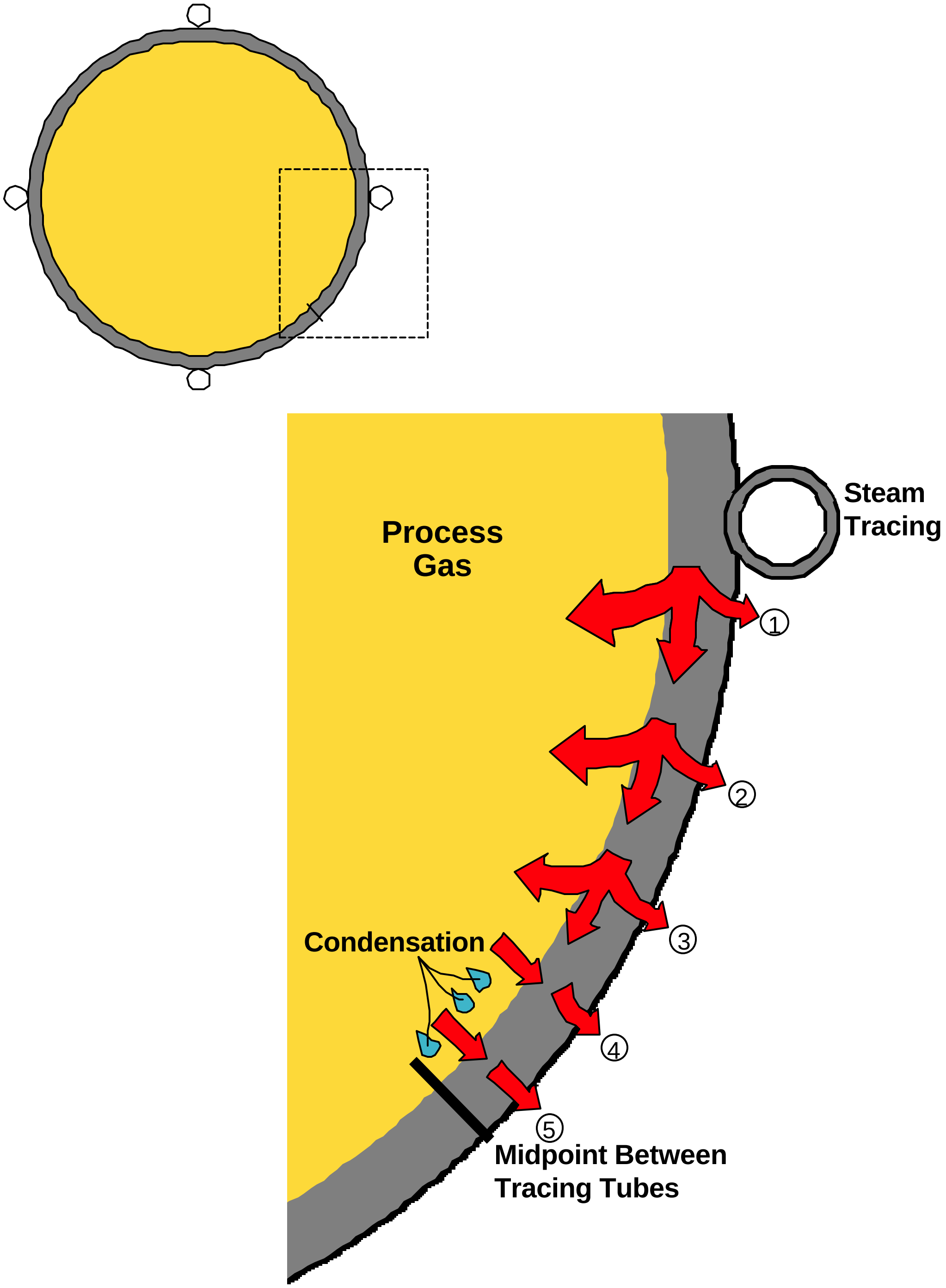

Steam
Tracing
Process
Gas
①
②
③
Condensation
④
⑤
Midpoint Between
Tracing Tubes

Figure 1

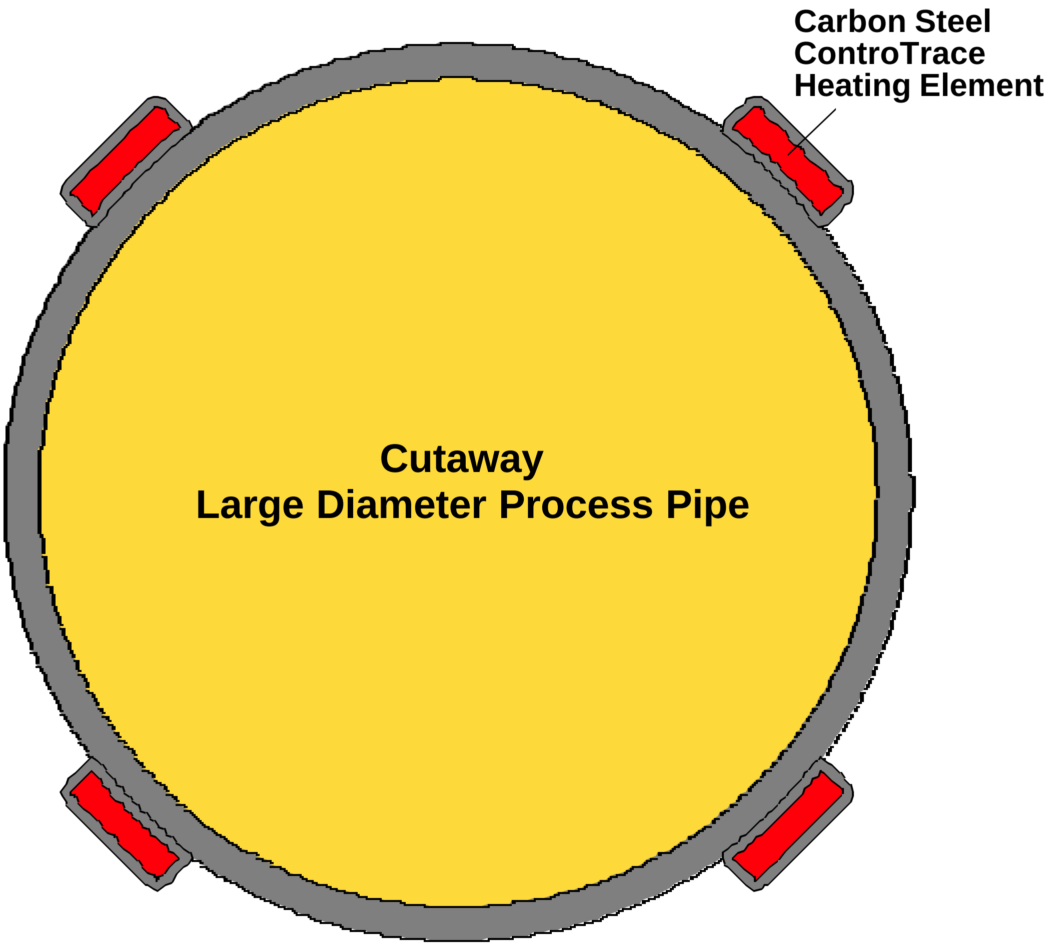

Carbon Steel
ControTrace
Heating Element
Cutaway
Large Diameter Process Pipe

Figure 2

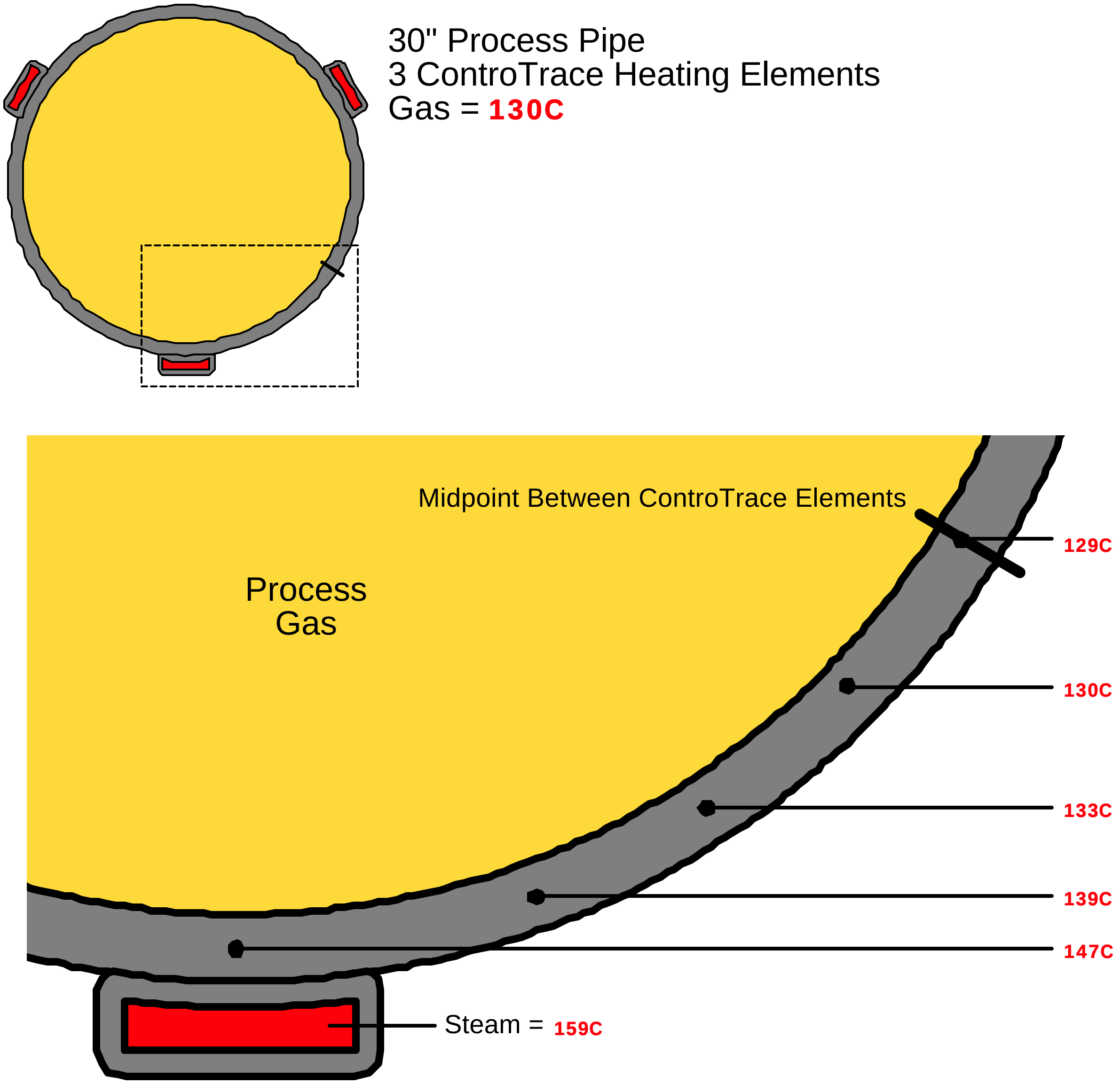

30" Process Pipe
3 ControTrace Heating Elements
Gas = 130C
Midpoint Between ControTrace Elements
Process Gas
129C
130C
133C
139C
147C
Steam = 159C

Figure 3A

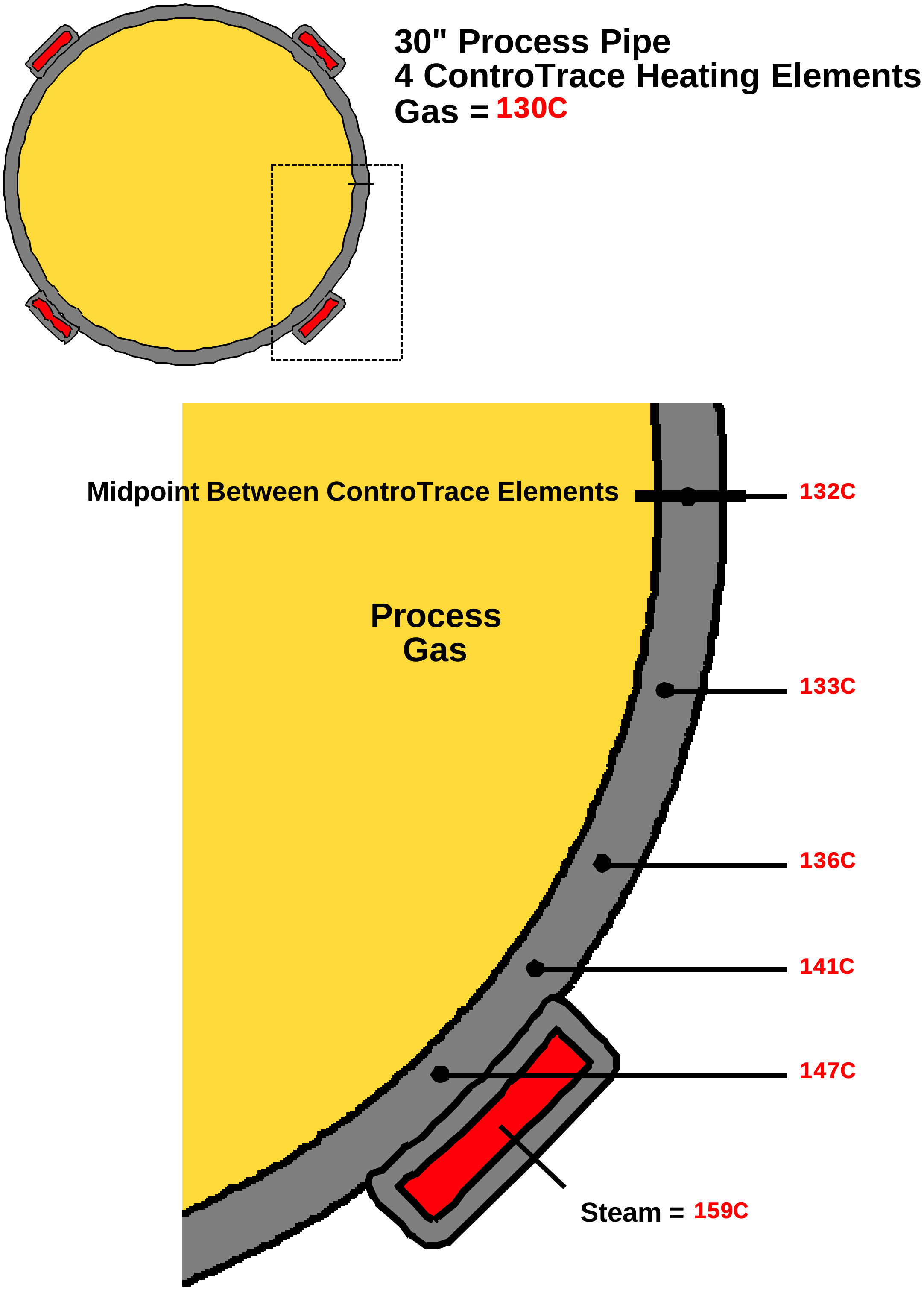
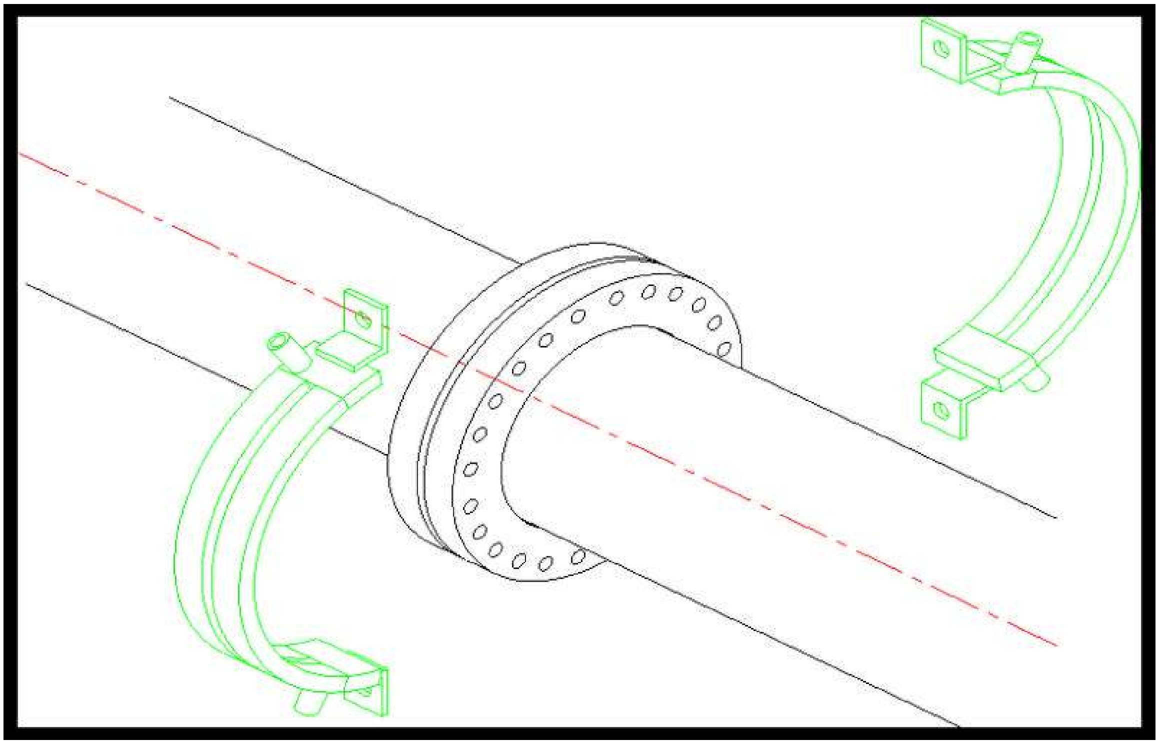
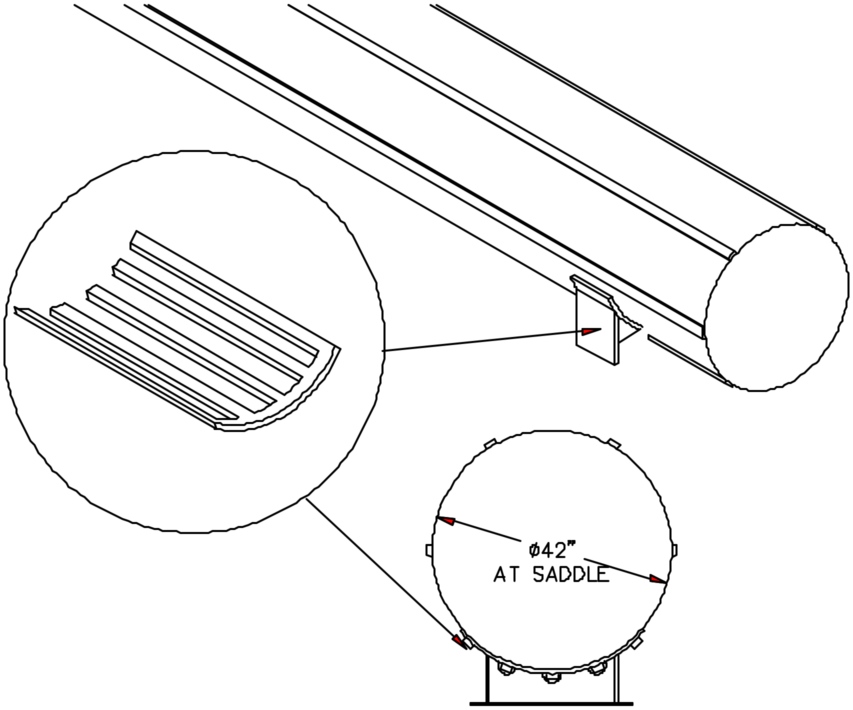

30" Process Pipe
4 ControTrace Heating Elements
Gas = 130C
Midpoint Between ControTrace Elements
132C
Process Gas
133C
136C
141C
147C
Steam = 159C

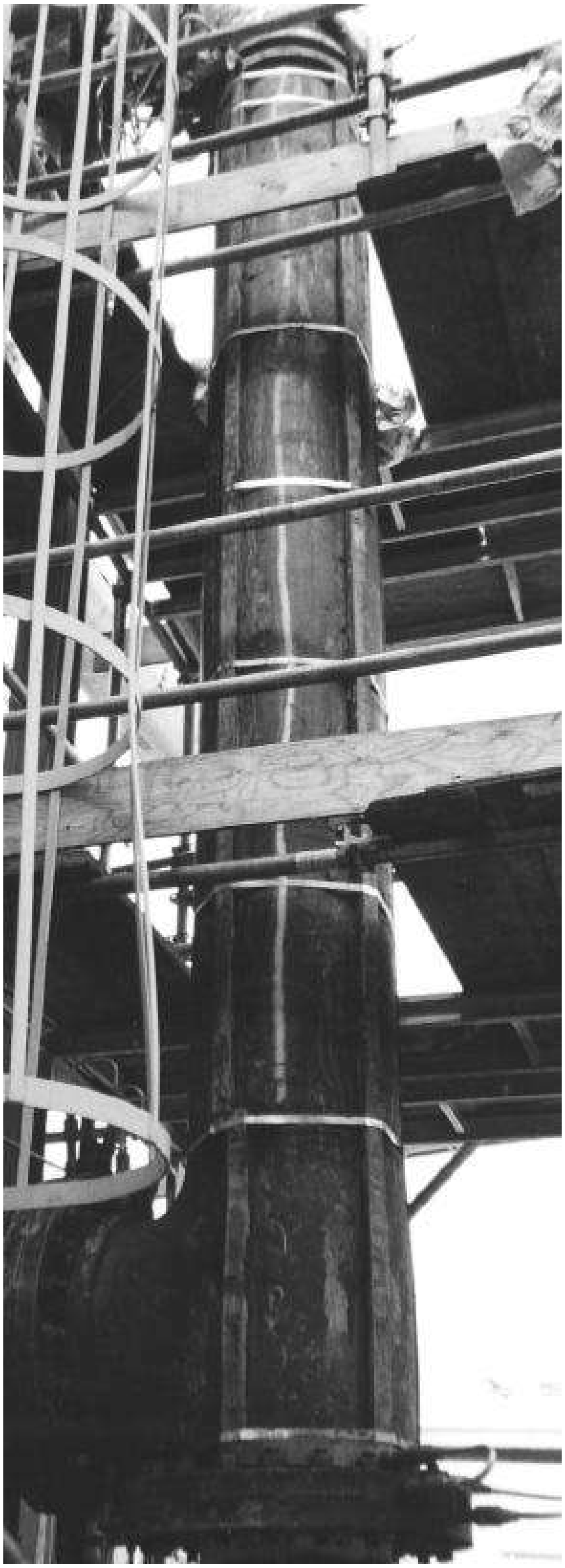
Figure 3B



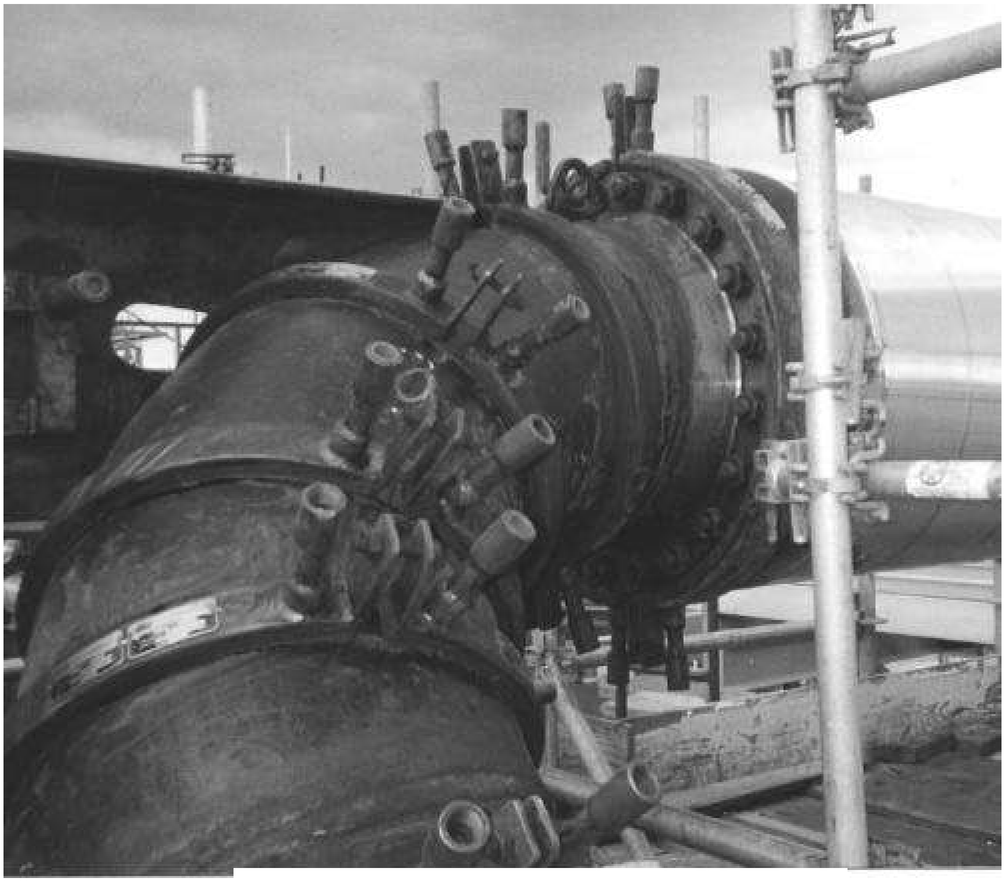
Flange Heater
Figure 4



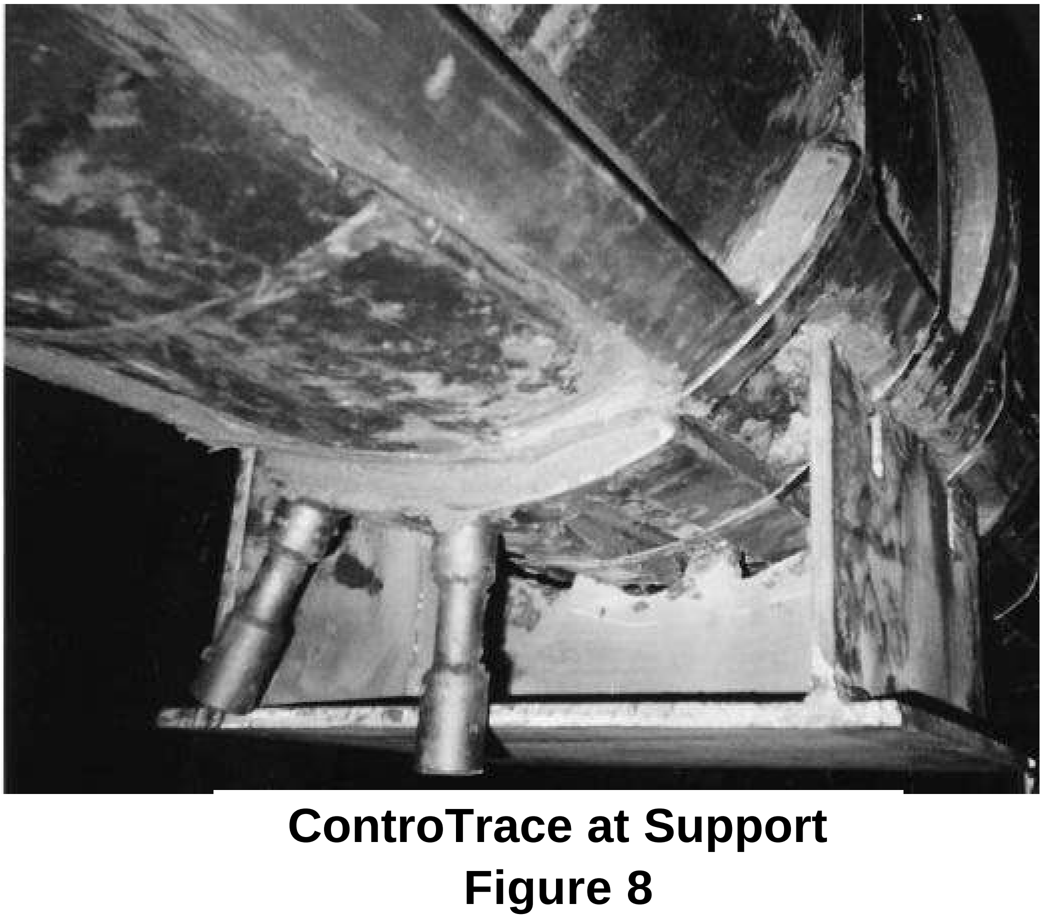
Pipe Support Heater
Figure 5



ControTrace Installation
Figure 6



ControTrace on Elbow
Figure 7



ControTrace at Support
Figure 8