



Bolt-On Thermal Maintenance System in new SRU challenges old design rules

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Abstract In a Sulphur Recovery Unit (SRU) there are several areas where reliable thermal maintenance of the process is vital: sulphur rundown lines, tail gas lines, and sulphur collection vessels are prime examples. Rundown lines can freeze up, especially at low rates; tail gas lines and collection vessels can corrode away, caused by acidic vapor condensation. Any of these thermal maintenance failures can shut down refinery production.

With the new, world-scale SRU at Scotford, reliable performance at a reduced cost was the primary goal—a goal that forced the project to revisit and re-evaluate many traditional caveats about the design of the SRU's thermal maintenance system.

Weld-on steam jacketing has been the proven industry standard for SRU thermal maintenance systems for many years. Deviating from this industry standard required detailed evaluations of technical feasibility, cost, and risk. This paper discusses the results of our evaluations, which, after several design iterations, led to a bolt-on thermal maintenance system for the critical areas of the SRU.

The technical validation of the bolt-on system pivoted on the evolving technology of thermal predictability. Through computer modeling, we viewed temperature distributions in numerous pipe sizes under varying conditions of process constituents and throughputs, ambient temperatures, insulation thickness, and steam pressures.

Our risk evaluations examined such areas as trap failures, insulation deficiencies, and internal steam leaks (cross contamination) in jacketed systems.

Once an acceptable design for the bolt-on system was established, we made a detailed cost analysis of a piping system thermally maintained by the two competing methods: bolt-on jacketing versus weld-on jacketing.

In the end, these evaluations resulted in a favorable assessment and subsequent choice of the bolt-on thermal maintenance system. This choice has been supported by over a year and a half of SRU operation, including three scheduled startups and two shutdowns. During this period there were no thermal incidents in SRU processes maintained with the bolt-on system.

Introduction

In the winter of 1999, detailed engineering work commenced on the Athabasca Oil Sands Downstream Project (AOSDP). The AOSDP was a joint venture to construct a grass roots bitumen upgrader adjacent to the existing Shell Scotford Refinery.

The feedstock was to be 155,000 bpd of bitumen, piped down as a diluent mix, from a new oil-sands mine and extraction plant in Fort McMurray. Products from the Upgrader would be synthetic crude oil blends used in the Scotford Refinery and sold to third parties. Sulphur removal from the bitumen was required to meet the product specifications. To support this requirement a Sulphur Recovery Complex (SRC) became a key component of the new Upgrader facility. The SRC consisted of two amine regeneration units, a sour water stripping unit and a sulphur recovery unit (SRU) capable of processing 1200 tonnes/day of sulphur. The Upgrader SRC is depicted in Figure 1, which is a rendering extracted from solid-modeling software used to design the entire plant.



FIGURE 1 DIGITAL RENDERING OF SCOTFOR UPGRADER SRC FACILITY

The task of the SRC detailed design team was to create a unit capable of achieving a 99.5% on-stream factor at the lowest possible capital cost. To achieve this task, the design team identified and explored many alternatives to traditional design methods.

One of the areas addressed by the SRC detailed design team was the thermal maintenance system for the SRU.

Steam jacketing is the traditional design method for maintaining thermal stability in piping systems that contain liquid sulphur and sulphurous components.

The piping systems that carry sulphur components are subject to two main failure mechanisms. In liquid sulphur piping the most frequent failure is line blockage due to solidification at temperatures below 118 to 122 deg C.

In vapour lines the most frequent failure results from corrosion; holes develop in the piping due to acidic attack. Acid forms when condensing water combines with sulphur, forming sulphuric acid. Water vapour condenses in the vapour lines when pipe wall temperatures drop below the dew point of the water vapour in the process stream. A uniformly-maintained pipe-wall temperature above the dew point is the design key that avoids water condensation and subsequent corrosion failure.

Over the years, steam jacketing has been viewed as the most reliable method of maintaining sulphur piping temperatures.

Bolt-on thermal maintenance technology, an alternative to steam jacketing, had been successfully implemented in a smaller scale at other Shell facilities. Based on this usage, a detailed evaluation was conducted to determine if benefits could be achieved by using it in a larger scale at the Upgrader SRU.

SRU CONFIGURATION

The primary units of the Scotford Upgrader SRU are two parallel, 2-stage traditional Claus trains with direct-fired re-heaters, as illustrated in Figure 2. The two parallel Claus trains each have a main reaction furnace, a waste heat boiler and a condenser, followed by 2 stages of re-heaters, Claus converters, and condensers.

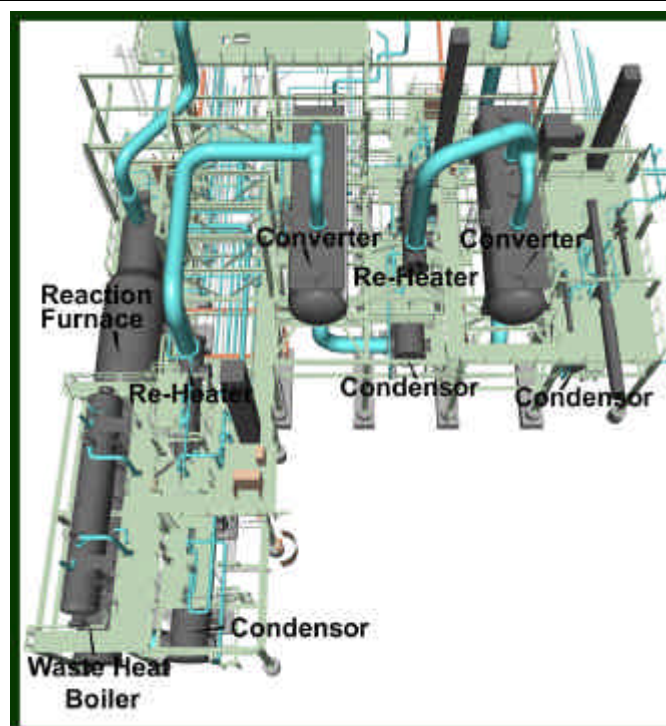


FIGURE 2 ONE OF TWO TRADITIONAL CLAUS TRAINS AT UPGRADER SRU

To achieve the licensed sulphur-recovery efficiency of 98.8%, a common third-stage Claus unit, and SuperClaus tail-gas recovery unit were incorporated into the design.

To maximize on-stream time, several bypass lines were added to allow for equipment maintenance without impacting plant throughput. Each of the two-stage Claus trains can bypass both the third and SuperClaus stages, and feed directly to the incinerator. Both trains can also be bypassed around the common third stage and go to the SuperClaus stage. The SuperClaus stage has two bypass lines: one around the converter, and the other around both the converter and condenser.

A significant portion of the piping in the SRU, including the bypass and liquid sulphur rundown piping, was originally specified to be steam jacketed, to minimize corrosion and pluggage risks. The specific areas are illustrated in Figure 3, a block diagram of the Upgrader SRU with the thermally critical piping highlighted. Figure 4 illustrates the 145 meters of 24-inch and 36-inch bypass piping, and 25 meters of 64-inch tail gas piping. Figure 5 shows the 320 meters of liquid sulphur run-down piping, ranging in sizes of 3-inch to 8-inch.

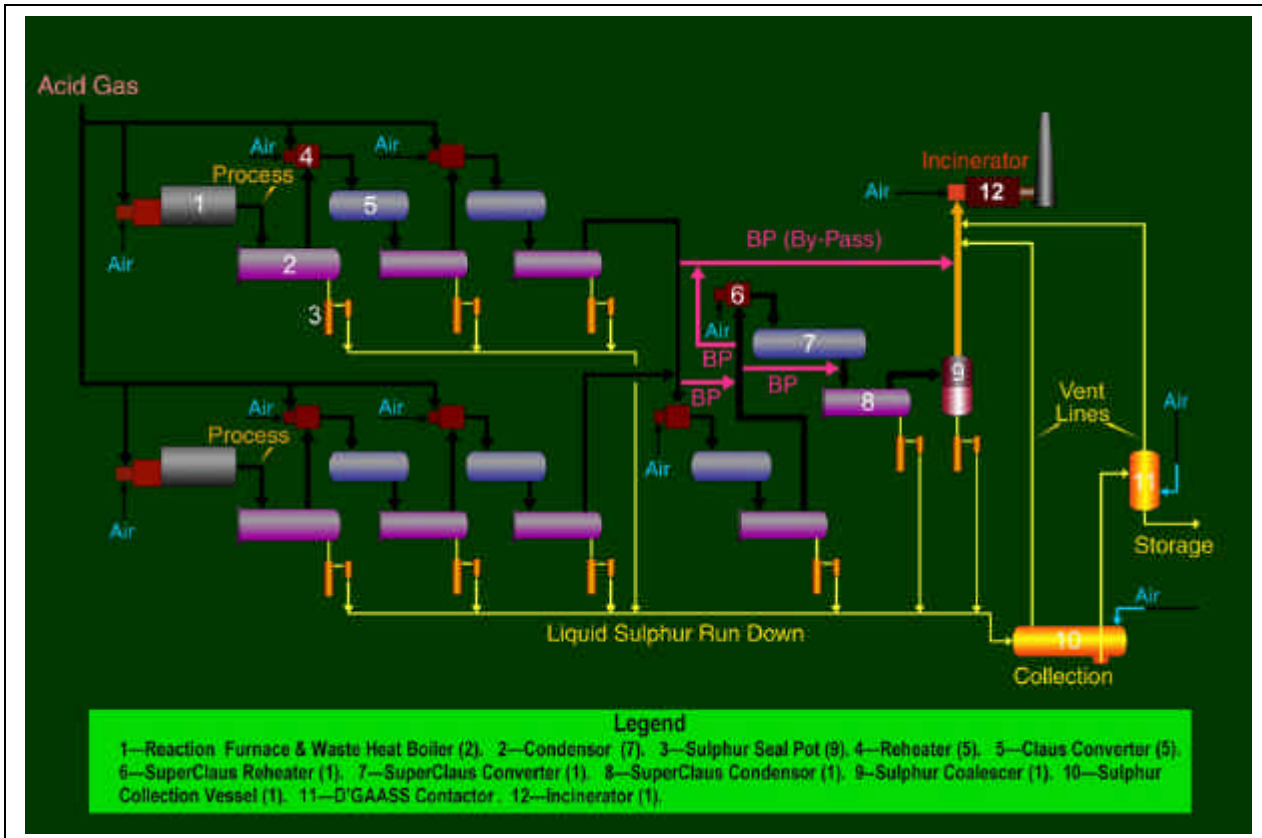


FIGURE 3 THERMALLY MAINTAINED PIPING IN UPGRADER SRU

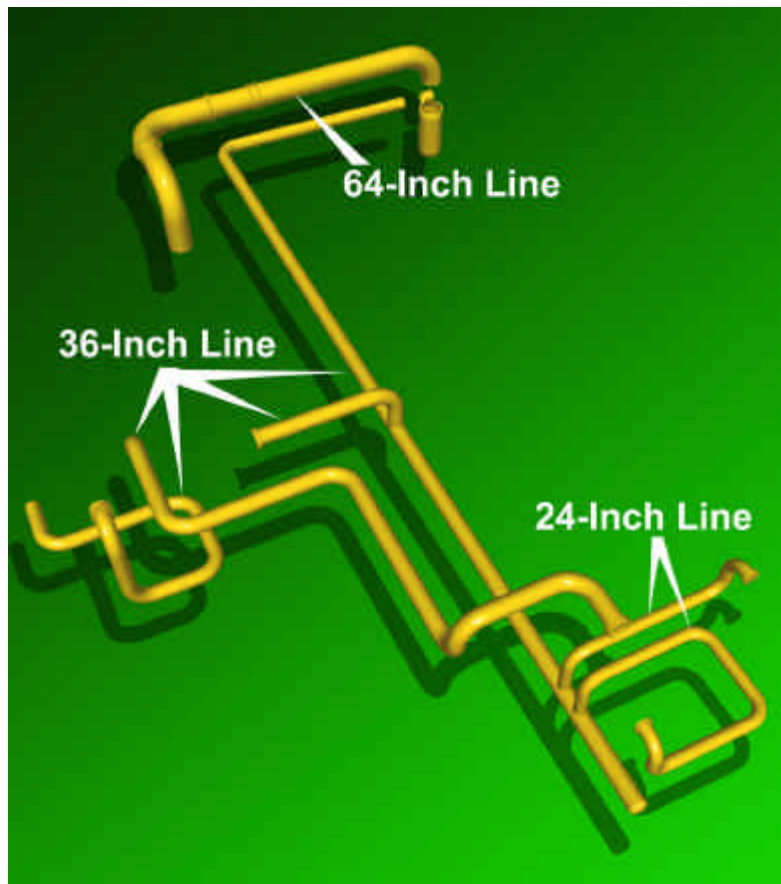


FIGURE 4 BYPASS PIPING AT UPGRADER SRU

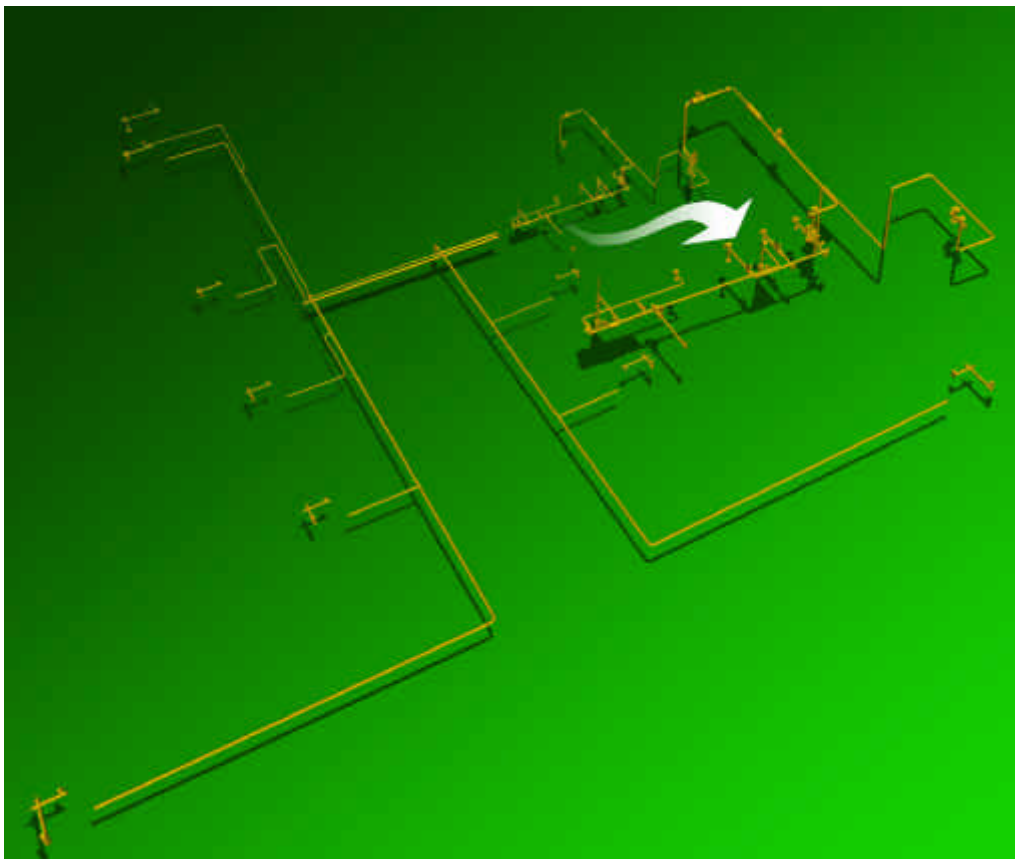


FIGURE 5 SULFUR RUN-DOWN PIPING AT UPGRADER SRU

The majority of the piping addressed in the evaluation were by-pass lines and liquid sulphur rundown lines, but there were also a number of miscellaneous piping systems and some vessels to be considered. The total amount of piping relative to size is shown, roughly, in the following table:

Pipe Size	Quantity (meters)
2"	25
3"	30
4"	250
6"	115
8"	150
24"	25
36"	120
64"	25

All of this piping and various components must be heated in some manner. The task was to choose the best thermal-maintenance path to support the 99.5% on-stream factor and cost minimization targets

METHODS TO HEAT PIPE

Several different technologies are used for thermal maintenance of piping systems including tube tracing, electric tracing, ControTrace and steam jacketing. Given the high reliability requirement for the Upgrader SRU, only steam jacketing and ControTrace were considered for the final system.

Jacketed Pipe

This product is a pipe within a pipe. The core pipe transports the process which is heated by a fluid, typically steam, flowing in the annulus between the core pipe and the jacket pipe. Figure 6 shows the construction of typical jacketed pipe used for sulphur run-down lines. While there are a variety of jacketed-pipe constructions, the pipe depicted is the design most commonly used, because it assures uniform pipe-wall temperatures. The flanged design requires that all piping be built in sections up to a maximum length of 6 meters. All flanged connections are required to be "oversized." That is, the flange size must match the size of the jacket pipe while accommodating the core pipe.

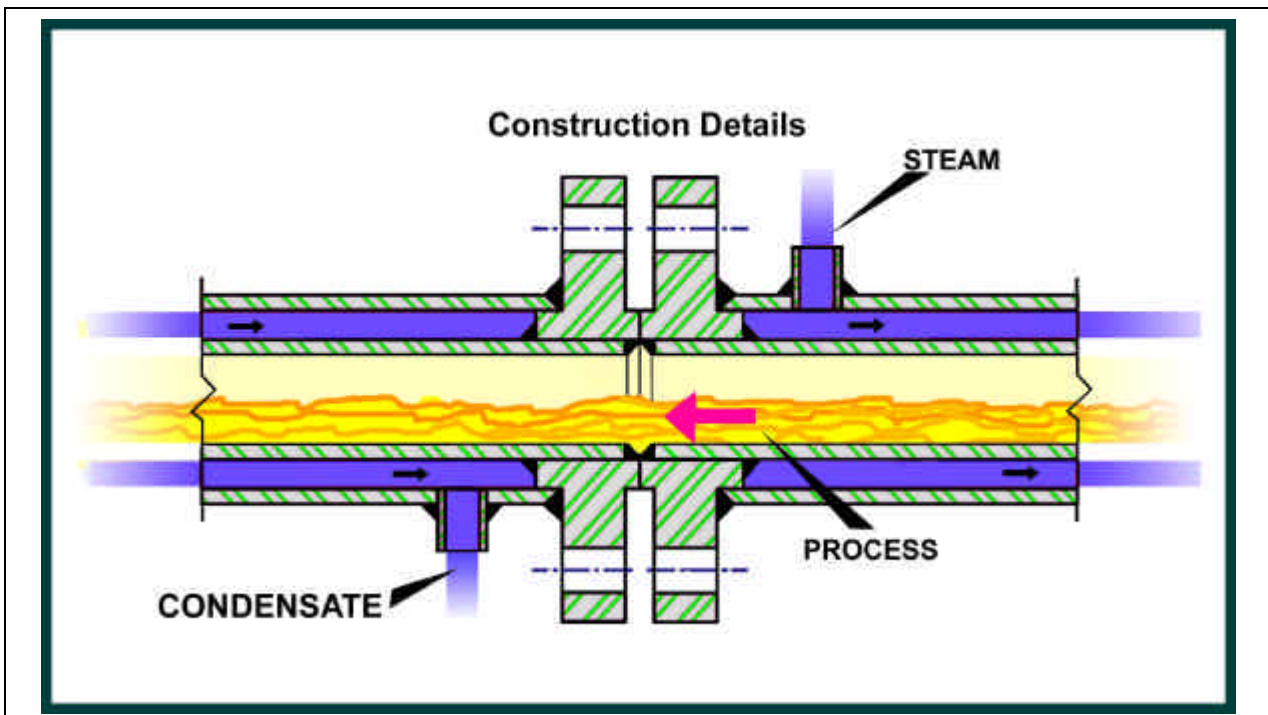


FIGURE 6 TYPICAL JACKETED PIPE FOR SULPHUR RUN-DOWN.

ControTrace (CT)

is a bolt-on thermal maintenance system used for heating piping. The CT element is a rectangular tube with one surface curved to match the outside diameter of the pipe to be heated. It is strapped onto the outside of the pipe with a layer of heat transfer cement in between it and the pipe. Heating fluid, typically steam, runs through the tube heating the pipe. The number of elements used on a pipe are adjusted to match the thermal requirements. The CT product is illustrated in Figure 7.

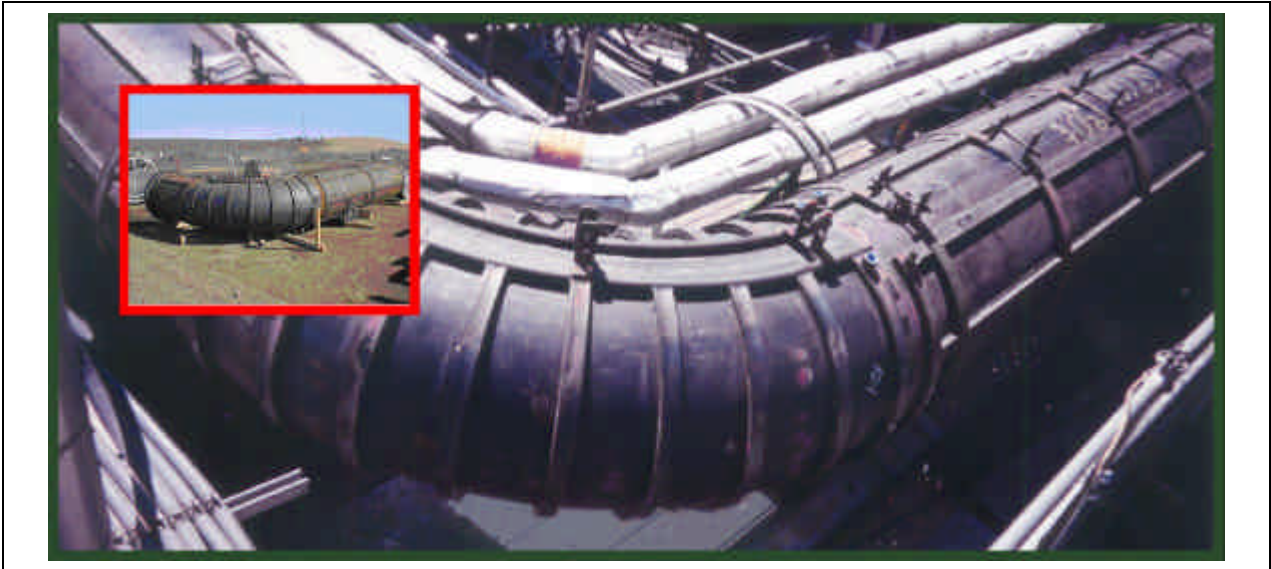


FIGURE 7 ONTROTRACE THERMAL MAINTENANCE ELEMENTS

COMPARATIVE EVALUATIONS

The evaluation of the bolt-on technology versus steam jacketed piping was made in three phases. The first phase was to define, without consideration of costs, the risks and benefits associated with each system. Considering these risks and benefits, a system design was selected for both systems, and a detailed cost analysis was performed to obtain the relative costs. The last phase was to compare the results of the analyses for the two systems and determine the optimum thermal maintenance method.

Risk/Benefit Analysis.

Steam Jacketed Piping has a compelling attribute: it maintains very uniform temperatures on the process pipe wall. Even if insulation is removed or damaged, it can still work. In the event of a system outage, jacketed piping, on start-up, becomes an effective heat exchanger for quick melt-out. As the proven industry standard for many years, it also has the advantage of operator familiarity and trust.

On the negative side, cross contamination (steam entering the sulphur) caused by weld failure can occur and go undetected for long periods of time. This contamination can lead to longer term corrosion issues in downstream vessels and tankage. Figure 8 shows cross contamination resulting from weld failure in a typical run-down line.

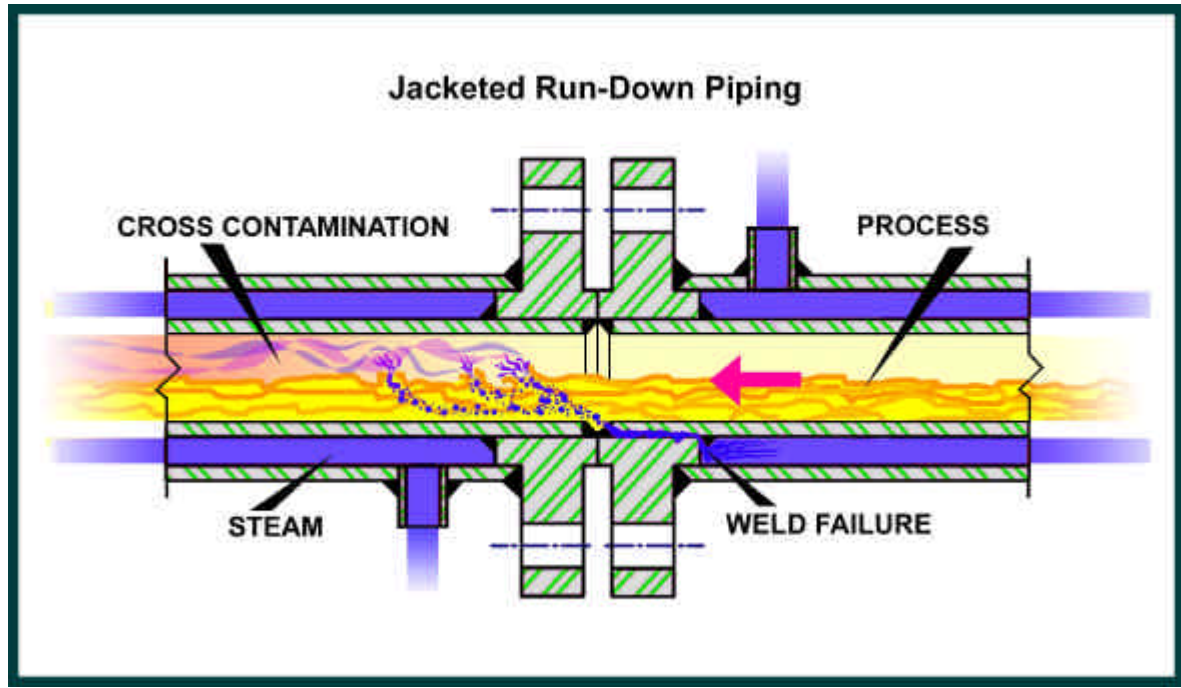


FIGURE 8 CROSS-CONTAMINATION IN SULPHUR RUN-DOWN LINE CREATES ACIDIC VAPORS

From a design perspective the “rigidity” of the jacketed piping requires thorough stress analysis, even on short runs. This rigidity coupled with the requirement for a large number of flanges in a system increases the potential for flange leaks.

One of the most frequently occurring problems in steam jacketed systems is steam trap failure. If the jacketed pipe is not constructed to adequate cleanliness standards, and not properly commissioned, contaminants in the jacket annulus can quickly cause steam trap pluggage and failure on start-up.

ControTrace (CT) Heating Elements are bolted to the outside of the pipe. A steam leak, if it occurs, vents to the atmosphere, not into the process. This eliminates the potential for cross contamination of the process.

However, unlike jacketed pipe with the heating fluid in direct contact with the process pipe, the thermal path for the CT element is longer and slower. Adjusting the number of elements on the pipe can modify the heat transferred to the pipe. In order to set the system design for number of elements, a process design basis had to be established. Because it does not completely cover the pipe, the CT system is sensitive to ambient conditions and insulation quality. Sulphur run-down piping typically is close to grade. It is often stepped on and its insulation crushed. To set the CT-system design at a level that minimized risk, a design basis, shown in the following table, was established.

Parameter	Specification
Ambient Temperature:	-43 deg C
Insulation:	Crushed to half design thickness
Process Flow:	None (worst case)
Wind:	25 mph
Steam pressure :	320 kPa saturated (worst case)
Minimum pipe wall temperature:	130 deg C

A detailed thermal analysis was performed by CSI to determine the number of elements required for each pipe size to meet the process design conditions. Figure 9, for example, shows the temperature profile of the 64-inch tail gas line from the coalescer in the SuperClaus stage to the incinerator.

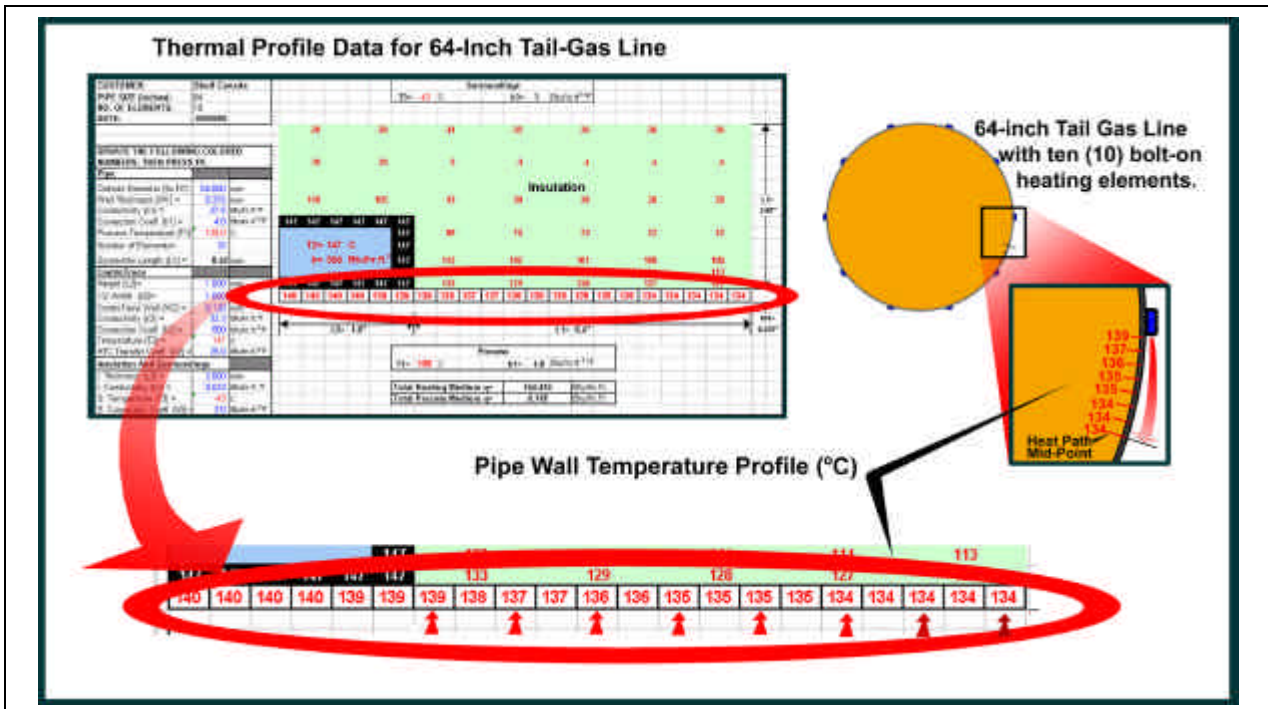


FIGURE 9 THERMAL MODELING DATA WITH PIPING TEMPERATURE PROFILE

The nature of the CT system containing multiple elements created the opportunity to mitigate the risk of steam trap failure in run-down piping by providing fully redundant heating systems on each piping section. That is, each piping section would have a minimum of two heating assemblies of one or more CT elements on each pipe. Each assembly would have separate steam supplies and condensate returns.

Based on the thermal analysis and on providing redundancy, the required number of elements for each pipe size were selected, as shown in the following table.

Pipe Size	No. of Elements
3"	2*
4"	2*
6"	2
8"	2
24"	4*
36"	6
64"	10

* extra element added to provide redundant assemblies

Cost Analysis.

Once the design was established, a cost analysis was performed. Given the fundamentally different natures of these two systems, it was important to perform a full, total-installed cost analysis, ensuring that there were no hidden “extras” in either system. Areas often overlooked include steam supply and return lines, inspection costs, field welding, bolt-up and insulation labour. Some of the key components of the comparative estimate are shown in the following table

Materials	Labour
Pipe and fittings	Pipe spooling
Bolts and gaskets	Shop CT assembly
Valves	Field welds/bolt-ups
Jumpovers	Inspection
Steam traps	Hydrotest
ControTrace Elements	Vendor documentation/engineering
Heat Transfer cement	Installation supervision
Pipe supports	Steam supply/return installation
Insulation	Jumpover installation
Banding	Insulation installation

The liquid sulphur rundown system was chosen as the sample system to perform the comparative cost analysis. Preliminary isometrics for the system were used as the basis for the cost estimators to provide costs for both a steam jacketed and a CT heated piping system.

The final results showed a 22% total installed cost savings to the CT system over steam jacketing.

Combined Analysis:

In order to select the best system to meet our reliability and cost targets, the results of the risk, benefit and cost analyses had to reviewed as a whole. The primary components affecting the decision are depicted in Figure 10.

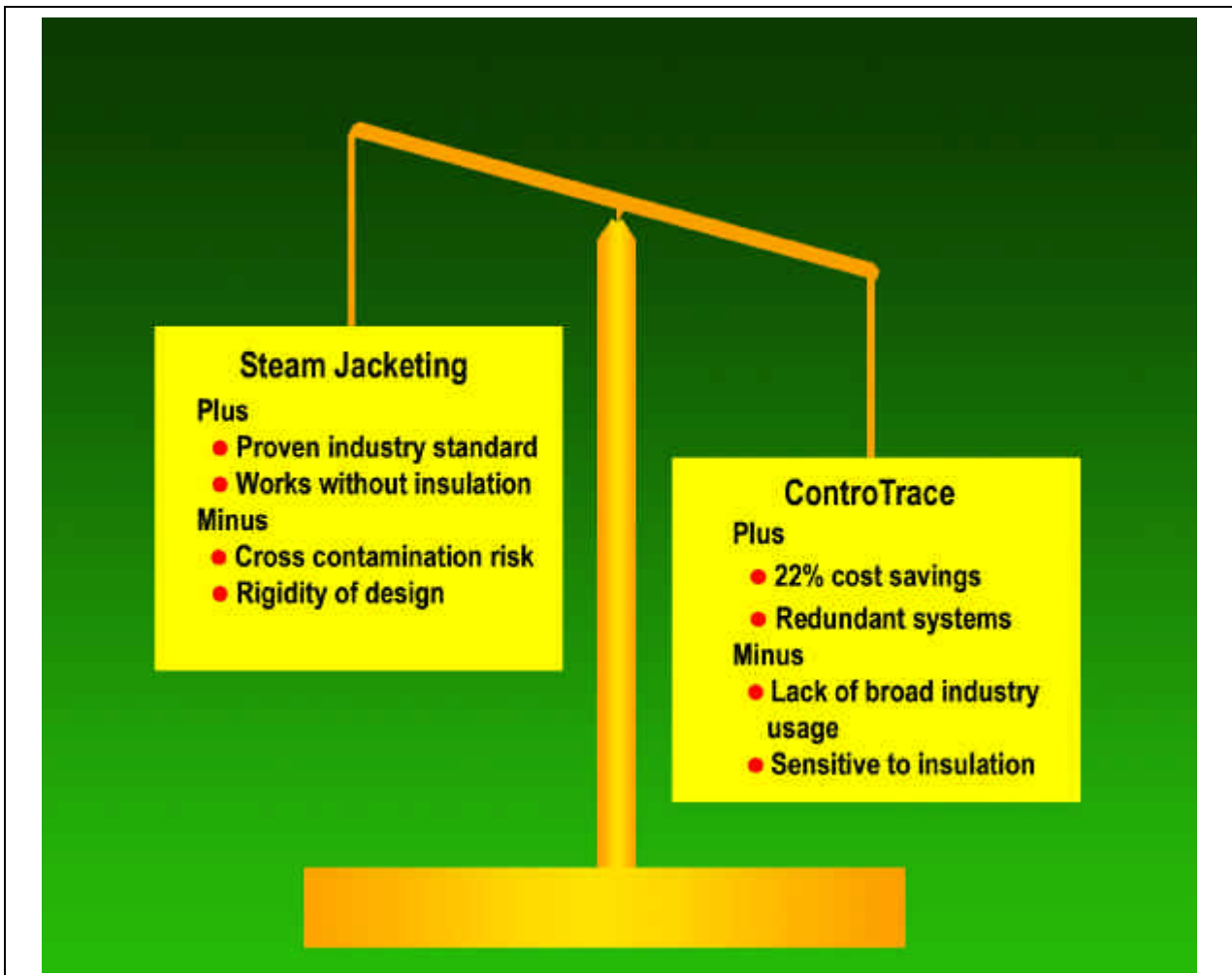


FIGURE 10 COMBINED ANALYSIS DECISION MEASUREMENTS

The final decision was made to proceed with ControTrace, based primarily on the cost savings that existed despite the rigorous parameters of the process design basis and added expense of components for redundancy.

CONCLUSION

The Upgrader SRU completed construction and was turned over to Operations May 31, 2002. A short performance test was conducted in February, 2003 to verify functionality of the sulphur systems prior to the start-up of the entire Upgrader in April.

Following the first start-up and operational test, there was a period when the piping system was heated and the process was turned off. This no-flow period provided an opportunity to verify pipe wall temperatures without a thermal boost from the process. Small diameter thermocouples were installed under the insulation on several run-down lines at numerous, strategic locations. A computer thermal model run for the specific conditions of operation on the day of testing (ambient temperature about -3 C) was also performed. The temperatures measurements agreed with the thermal predictions generally within 2 C at all points. All of the measured temperatures averaged about 8 C above the minimum pipe wall requirement.

Since that initial check-out, the SRU has undergone two start-ups and a one shutdown. Throughout this period no thermal maintenance issues have arisen with any of the CT-heated piping systems.

Although the long term effectiveness of the CT system has yet to be proven, information to date has shown it to be both cost effective and operationally reliable. This performance justifies the significant effort expended to perform the detailed risk, benefit and cost analyses required to deviate from proven industry standards.