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SULPHUR

Sulphur 2010 Conference – Prague

Sulphur from oil sands

The Sulphur Doctor

Acid production with lower emissions

Improved Claus catalyst

Stop quenching those sulphur vapour lines

In sulphur recovery units the treated tail gas, tail gas bypass and sweep air lines are normally routed to the incinerator. **T.C. Willingham** of Controls Southeast, Inc. explores several of the common pipe routings that result in corrosive conditions that can lead to line failures. Specific problems associated with these common pipe routings, as reported from the field, are examined. Several recommendations and industry best practices for preventing or minimising similar line failures are provided.

In refineries and natural gas plants, the sulphur recovery unit (SRU) and the tail gas treating unit (TGTU) are essential to the processing of oil and gas. The SRU removes much of the hydrogen sulphide in the sour gas stream to produce a tail gas that is routed to the TGTU for further processing. The TGTU removes the balance of the hydrogen sulphide and other sulphur compounds to produce a "treated tail gas" that is routed to the incinerator. For TGTUs featuring SCOT technology, temperatures of the treated tail gas range from 40-55°C. While the treated tail gas temperature is well below the freezing point of sulphur (120°C), there is ordinarily no danger of sulphur plugging or corrosion in the line since the sulphur compounds have been removed from the gas stream.

In addition to treated tail gas, the tail gas bypass and sweep air lines are also routed to the incinerator. The tail gas bypass line allows tail gas to be routed directly to the incinerator in the event of a TGTU upset. This line is normally not flowing due to a diverter valve which routes tail gas to the TGTU instead of directly to the incinerator through the bypass line. The sweep air line continuously removes sulphur vapours from the vapour space of sulphur pits and tanks and, therefore, must be kept above 120°C to prevent plugging and corrosion.

In an effort to avoid the additional cost associated with running multiple lines to the incinerator, the sweep air and tail gas bypass lines are often combined into the treated tail gas line upstream of the incinerator. This results in the mixing of process streams with very different temperature requirements. The higher volume of low-temperature treated tail gas has the effect of quenching the lower-volume sulphur vapour. Upon quenching, the sulphur solidifies and tends to plate out on the inside of the treated tail gas line. Furthermore, due to the low temperature of the quenched stream and the presence of water vapour in the stream, conditions are set for an aggressive corrosion condition. Such conditions can quickly lead to line failures such as those shown in Figs 1 and 2.

Common pipe routings

Refineries and natural gas plants typically route treated tail gas, tail gas bypass, and

Fig 1: **Tail gas line failure due to plugged diverter valve**

Fig 2: **Tail gas line failure due to extreme corrosion**

Fig 3: **Routing 1 – treated tail gas, tail gas bypass and sweep air lines routed separately**

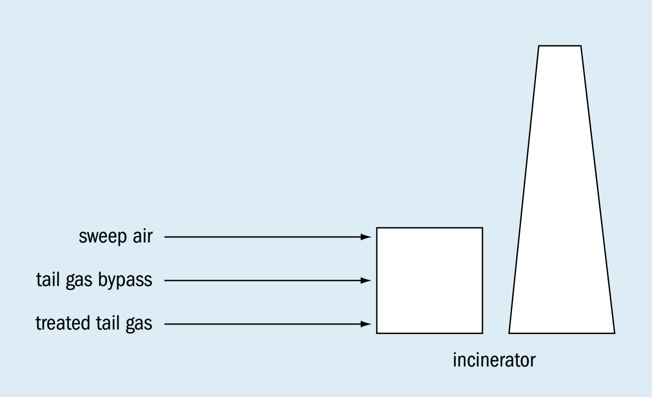


Fig 4: **Routing 2 – combined treated tail gas and tail gas bypass, and independent sweep air line**

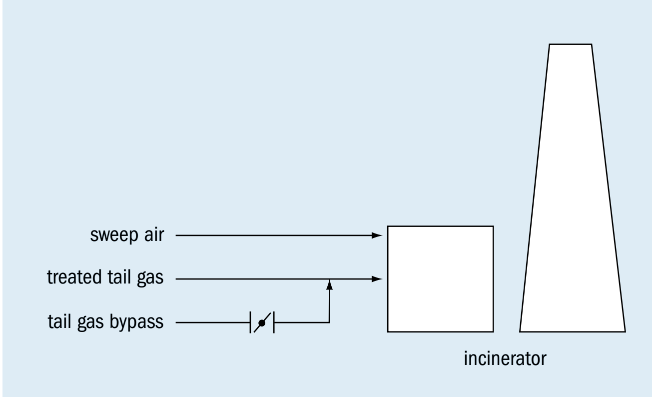


Fig 5: **Routing 3 – treated tail gas, tail gas bypass and sweep air lines combined pre-incinerator**

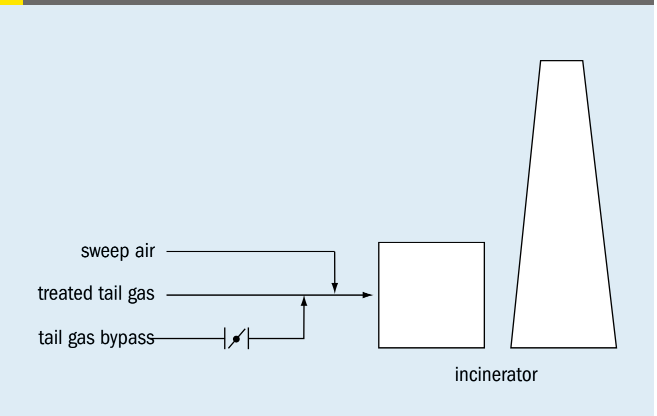
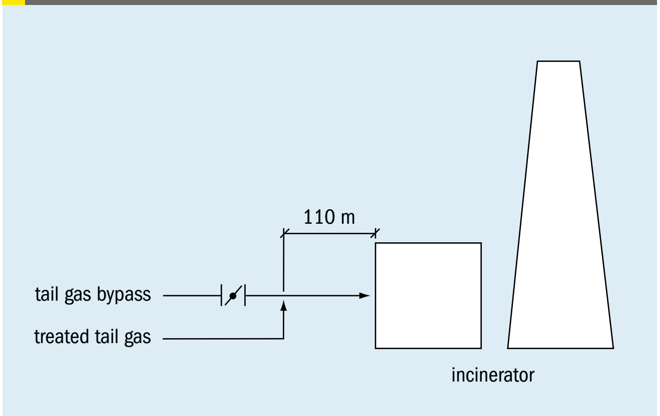


Fig 6: **Routing 2 – example with reported corrosion of 0.75 mm/month**



sweep air lines to the incinerator in one of three configurations. In the first common pipe configuration, the treated tail gas line, the tail gas bypass line, and the sweep air line are run separately to the incinerator via three independent lines. These three lines enter the incinerator through independent nozzles. This configuration is depicted in Fig. 3.

A second common pipe configuration merges the treated tail gas and tail gas bypass lines into a single line upstream of the incinerator, while the sweep air line is piped directly to the incinerator. The two lines enter the incinerator through two independent nozzles, as shown in Fig. 4.

In the third pipe routing, which appears to be growing in popularity as a design practice, all three lines are joined into a single line at some point upstream of the incinerator. The actual manner in which these three lines are combined varies from one plant to another, as does the distance between the tie-in point(s) and the incinerator. An example of this third common routing is shown in Fig. 5.

Reported problems

The author knows of no reported plugging or corrosion with Routing-1, in which the treated tail gas line, the tail gas bypass line, and the sweep air line are run separately to the incinerator. On the other hand, plugging and significant corrosion rates have been reported from multiple sites with Routings 2 and 3. For example, in late 2008, a refinery with a Routing-2 configuration reported a corrosion rate of 0.75 mm/month at the point where treated tail gas tied into the tail gas bypass line. Figure 6 shows the actual configuration for this refinery.

Theoretically, process should be flowing through either the tail gas bypass line or the treated tail gas line, but not through both lines simultaneously. A butterfly-style diverter valve is typically used to route flow through one of the lines and piping specifications commonly call for the use of diverter valves with high sealing integrity. However, in practice it appears that leaking diverter valves are common. It is widely reported that obtaining a good seal with these diverter valves is difficult; these reports seem reasonable considering the large sealing surface in typical diverter valves. For example, a 36-inch butterfly valve has almost three metres of circumference to seal, and any foreign matter along this circumference can hamper good sealing.

Once leaking does occur, the line will contain two processes with entirely different thermal requirements. The tail gas bypass must be maintained above a temperature of 130-160°C to prevent dew-point condensation. However, the treated tail gas flows to the incinerator at a temperature of 40-55°C. Any tail gas bypass that leaks into the treated tail gas line will quickly be quenched to a temperature well below the dew-point, resulting in condensation. When the mixture temperature is below the freezing point of sulphur, elemental sulphur in the mixed stream will deposit, resulting in an accumulation of solid sulphur inside the pipe. Over time, the solid sulphur can build up and obstruct the free flow of process through the pipe. When the mixture temperature is also

Fig 7: **Routing 3 – example with reported plugging downstream of tie-in**

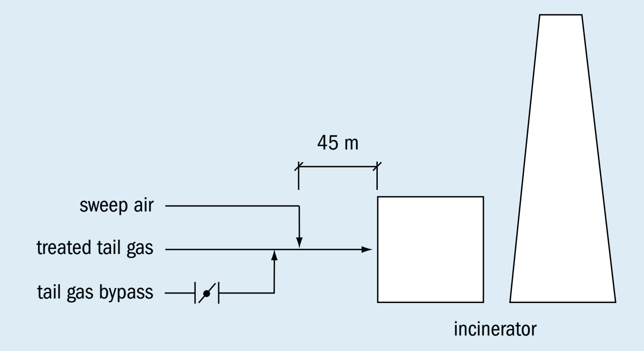
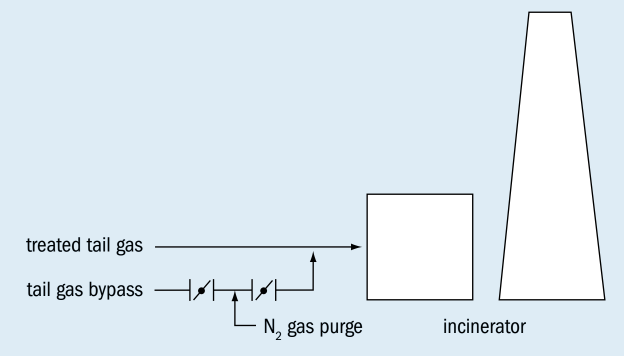


Fig 8: **Double-block gas diverter valve with nitrogen purge**



below the boiling point of water, water vapour in the stream (tail gas is saturated with water) can condense, permeate through the solid sulphur, and reach the sulphur/carbon-steel interface. This sets up a very aggressive iron/sulphur contact corrosion mechanism that has been known to produce rapid corrosion rates similar to the 0.75 mm/month reported for the scenario in Fig. 6. In some cases, depending upon the particular chemistry of the processes, condensation of acidic species (such as SO_2) can also occur and lead to corrosion.

The potential for quenching is even more pronounced in Routing-3. This is because in addition to the potential for leaking high-temperature, sulphur-containing tail gas into the lower-temperature treated tail gas line, sulphur vapours are continually entering the treated tail gas line via sweep air. As an example of this, in early 2010, a refinery with a Routing-3 configuration reported plugging downstream of the sweep air tie-in point. Figure 7 shows the actual configuration for this refinery.

Once vapour quenching has occurred, the only effective response is to prevent the accumulation of condensation and solid sulphur on the interior pipe wall. To do this, the pipe wall must be maintained at a temperature above the incoming vapour temperatures to re-vaporise any condensed process. Heating options include fully jacketed piping and ControTrace bolt-on jacketing. Jacketed piping is effective but generally considered cost-prohibitive for larger lines. ControTrace can maintain the pipe wall temperature; the number of heating elements and required steam pressure will depend upon the actual process conditions.

Recommendations

To prevent plugging and corrosion in sulphur vapour lines that is caused by temperature quenching, the author recommends the following strategies:

- Since pipe routing is at the root of sulphur quenching and subsequent plugging and corrosion, the best solution is to avoid a pipe routing that creates quenching, rather than having to implement coping mechanisms to remedy the problem. Therefore, the most effective strategy for preventing quenching is to run separate treated tail gas, tail gas bypass, and sweep air lines to the incinerator.
- If running three separate lines to the incinerator results in a cost-prohibitive piping and/or incinerator design, the recommended approach would be to delay the tie-in of the high-temperature and low-temperature streams to within three pipe diameters of the incinerator inlet nozzle. The tie in should occur in the last straight run to the incinerator. By combining the streams relatively close to the incinerator, the interior pipe wall temperature can be maintained by radiant heat emanating from the incinerator. This will help offset the quenching effect that the low-temperature stream will have on the sulphur vapours.
- If it is not possible to tie-in within three pipe diameters of the incinerator, then the recommendation is to sufficiently heat the line at and downstream of the tie-in, using either fully jacketed piping or ControTrace bolt-on jacketing. Actual heating requirements depend upon specific flow temperatures and flow rates.
- One final recommendation is important to consider in cases where the tail gas bypass line ties into the treated tail gas line upstream of the incinerator. With this pipe routing, it is beneficial to employ a double-block diverter valve configuration with a nitrogen purge as shown in Fig. 8. This strategy prevents tail gas bypass from leaking through the diverter valve into the treated tail gas line. Most plants have nitrogen readily available as a purge gas.

Summary

In conclusion, refineries and natural gas plants should be aware of the likelihood of quenching in sulphur vapour lines and the subsequent impact to their operations. It is imperative for the technology providers and plant designers that serve these facilities to consider the inherent plugging and corrosion issues caused by common pipe routings.

Experience has shown that the most effective solution is to run separate lines to the incinerator.

If this best-case solution is cost-prohibitive, then it is critical to consider the following preventative measures:

- minimise the distance from the tie-in point to the incinerator, and leverage the radiant heating from the incinerator;
- implement fully-jacketed piping or heavy ControTrace coverage with higher-pressure steam;
- implement a double-block tail gas diverter valve with nitrogen purge to prevent tail gas from leaking from bypass during normal operation.