SULPHUR PLANT TAIL GAS INCINERATORS IN ALBERTA

A SURVEY OF CURRENT OPERATING PRACTICE AND OPPORTUNITIES TO REDUCE FUEL GAS CONSUMPTION

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Attention : **Dennis Gaudet**
Reference : **Sulphur Plant Tail Gas Incinerators in Alberta - A Survey of Current Operating Practice and Review of Opportunities to Reduce Fuel Gas Consumption**

Sulphur Experts has conducted a detailed review of the current operating practices of the numerous Thermal Incinerators which are used to treat the tail gas waste gas from Sulphur Recovery Units in the province. The complete results of this study contained in this report. If you have any questions about the information contained in this report, please contact us by phone at 403-215-8400, by fax at 403-215-8419 or by email at *help@sulphurexperts.com*.

Yours truly,
Sulphur Experts Inc.
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1.0 Introduction

All sulphur recovery units (SRUs) in the Province of Alberta employ thermal incinerators to treat the tail gas effluent from the SRUs prior to emitting the waste gas to the atmosphere. The purpose of the thermal incinerator is to facilitate the oxidation of all of the common reduced sulphur compounds (H_2S, COS, CS_2 and sulphur vapour) to SO_2 prior to release to the atmosphere. Currently in the province there is a informal guideline which requires that the maximum Total Reduced Sulphur (TRS) content of the stack effluent be maintained at 300 ppmv or less.

The thermal incinerator also provides significant thermal energy to the SRU tail gas in order to raise the waste gas temperature sufficiently to ensure that the stack plume rises in the atmosphere. This facilitates the effective dispersion of the plume and ensures that the ground level concentration of the SO_2 from the plume does not exceed the Alberta Environment guidelines for this pollutant (450 $\mu g/m^3$).

Due to the very large volumes of SRU tail gas that are treated in these thermal incinerators and the process temperatures required for successful operation, there is a significant amount of plant "fuel gas" consumed in these incinerators.

In previous work it was determined that there was/is a significant opportunity to reduce the consumption of fuel gas in these systems by optimizing the operation of the incinerators. This "Incinerator Optimization" program has been implemented at many plants in the province and significant fuel gas savings have been realized as a result.

However, in the current climate of high energy costs and increasing concern over CO_2 emissions from natural gas fired systems, it appears that there are significant, *incremental* opportunities to further optimize these systems.

In order to assess this opportunity, PTAC has contracted Sulphur Experts to investigate these opportunities. This report provides detailed background information on the current operating practices for thermal incinerators in the industry and identifies potential methods for further optimizing these systems.

1.1 Thermal Incinerator Optimization Overview

Based on the best available data from Alberta Environment (AE) and the Alberta Energy and Utilities Board (EUB), there are approximately 45 plants in the province which operate thermal incinerators on their SRUs. These plants vary in size from a few tonnes to 5000+ tonnes per day of sulphur production. In order to characterize these plants, records from AE and EUB were used to determine the conditions indicated in their operating licences.

In general, the original designs for these thermal incinerators and stacks were determined by the requirement for efficient oxidation of the TRS compounds and successful dispersion of the incinerator effluent. In fact, virtually every incinerator/stack in the province had been originally designed to be of sufficient height so that with a stack exit temperature of 1000°F (ca. 538°C) all of the TRS oxidation and SO_2 plume dispersion requirements of the plant operating licences were being consistently met. This particular stack exit temperature became the "de-facto" standard for the entire industry.

This survey has revealed that 30 of these plants are operating with a licenced stack exit temperature of less than 538°C. This indicates that these plants have successful implemented a stack top temperature reduction (STTR) program some time in the past. Of the balance, 14 plants have not implemented a STTR program and the licence conditions for 1 plant are not known.

For this study, data for all of these 45 plants was collected. However, due to inaccurate records or lack of available current operating data, only *35 of these plants were used for a more detailed review*. These 35 plants represent approximately 94 percent of the total sulphur processing capacity (based on licenced EUB sulphur inlet values) in the province.

<u>Historical Perspective</u>

In the late 1970's, a detailed study of these incinerators systems was conducted by Western Research and Development in order to identify opportunities for reducing fuel gas consumption while meeting the required TRS and SO_2 plume dispersion guidelines. As a result of this work and subsequent operating studies of specific incinerators, the licenced operating conditions (stack exit temperature) have been modified in many existing plants. This has resulted in a significant reduction in fuel gas consumption in these systems over the past 25+ years.

Based on this survey, 24 of the 35 plants for which data is available, are operating at a temperature less than 538°C which indicates that they have successfully implemented a stack top temperature reduction (STTR) program some time in the past. The balance (11 plants) have a licenced minimum stack exit temperature of 538°C.

Based on current operating data for these 35 plants (plant throughput, incinerator operating conditions), these plants would be consuming approximately 978,000 m^3/d of fuel gas if they were required to operate with the original minimum stack exit temperature of 538°C. Since 24 of the plants have optimized to some level, the current actual fuel gas consumption of these plants is approximately 705,000 m^3/d. This represents a fuel gas savings of 273,000 m^3/d, a benefit which is being realized every day that these plants stay in operation.

Limitations for Future Optimization

The operating conditions for these thermal incinerators is determined by the requirement to efficiently oxidize the TRS compounds to SO_2 and to ensure adequate plume dispersion of the SO_2 in the stack effluent. Therefore, as an incinerator system is put through a rigorous optimization program, the ability to reduce the stack exit temperature is ultimately limited by one of these two parameters (or both).

Based on the data from the 45 total plants, 14 plants currently have an operating licence which requires a minimum stack exit temperature of 538°C. Of these, 3 plants have attempted to implement a STTR program but were limited by ground level SO_2 and plume dispersion issues. Therefore, without some change in the criterion for the SO_2 dispersion there is no opportunity to optimize these plants.

The other 11 plants have either not completed a STTR review at all or have not implemented a completed review for unknown reasons. *It is recommended that the status of these plants be reviewed to determine if any STTR program opportunities exist*.

The licence data for one plant is not available and the remaining 30 plants have a minimum stack exit temperature less than 538°C which indicates that they have successfully implemented at STTR program. Of these 30 plants, the available data from these seven (7) plants is insufficient to determine which factor is limiting the system.

Twelve (12) of these "optimized" plants are limited by the SO_2 dispersion component of the system and eleven (11) are apparently limited by the TRS content in the stack effluent.

For the eleven TRS limited plants, there exists the opportunity for further optimization of the incinerators and stacks if the TRS in the process systems can be reduced. Details on these opportunities are discussed in detail in the following sections.

For the twelve plants which are SO_2 limited, a change to stack licence parameters would be required. Details on these opportunities are also discussed in more detail in the following sections.

For the seven undetermined plants, further investigation will be required in order to determine the limiting factor.

2.0 Future Opportunities

Given the significant continued consumption of fuel gas in these systems, PTAC has contracted Sulphur Experts to investigate whether additional incremental saving could be realized by further assessing and optimizing these thermal incinerator systems. The areas which were investigated as a screening tool for assessing future opportunities are discussed below.

2.1 Optimize the current operating conditions within the existing licence requirements

The most significant parameter which can be continuously optimized is the amount of excess oxygen which is used in the incinerator. Previous studies have indicated that the typical “optimized” excess oxygen concentration is in the 2 to 4% range (as measured in the stack effluent) in order to ensure adequate oxidation of the TRS compounds.

However, many operating plants do not operate at these optimum conditions as a result of normal day to day operating issues including:

- over-sized incinerator systems and air blowers;
- inadequate air flow control systems;
- lack of continuous excess oxygen measurement to guide operations;
- over-sized incinerator stacks which require high flow rates to ensure the accuracy of the stack flow measurements.

This survey revealed the following results with respect to managing the optimum excess oxygen in the 35 operating plants:

- 20 plants were operating with excess oxygen contents in line with optimum conditions;
- 15 plants were operating with excess oxygen significantly higher than the optimum conditions.

Simulations of these incinerators with respect to excess oxygen content revealed the following:

- Current fuel gas demand is 705,000 m^3/d at current operating conditions;
- Optimizing the 15 plants to an average excess oxygen content of 3% in the stack would decrease this demand to 611,000 m^3/d;
- The *resulting fuel gas savings would be 94,000 m^3/d* (a 13% reduction) with current plant acid gas loads.

Based on these results it is clear that all plants should review their incinerator and stack hardware arrangements in order to fully optimize the operation for excess oxygen.

2.2 Investigate a full STTR program for the "Un-optimized" plants.

Currently, 11 plants are operating a the original 538°C stack exit temperature. There is no evidence to suggest that these plants could not benefit from a full STTR review.

The simulations conducted for this study indicate that if the remaining 11 "un-optimized" plants were to improve their TRS conditions in the SRU tail gas and proceed with a relatively modest STTR program, significant fuel gas savings could be realized. Currently these 11 plants are consuming approximately 144,000 m^3/d of fuel gas. If these incinerators were to optimize to a conservative 450°C stack exit temperature (which is still higher than the average of those plants which have already been optimized), the fuel gas consumption would be reduced by approximately 10,000 m^3/d. *Therefore, it is recommended that these plants be investigated in more detail in oreder to better define this opportunity.*

2.3 Optimize SRU Operations to Minimize TRS in the waste gas.

The amount of TRS compounds in the SRU tail gas are a direct result of the operation of the upstream SRU plants with respect to plant configuration, acid gas feed composition and operating conditions.

H_2S Content in the SRU Tail Gas

The H_2S content in the tail gas is affected directly by the composition of the acid gas and the overall recovery efficiency in the plant. Generally plant's with higher overall recovery efficiencies have lower H_2S in the tail gas. However, the dilution effect of high CO_2 in the acid gas can also affect the *concentration* of H_2S in the tail gas and the stack gas effluent. Within the constraints of a typical plant operating licence, the H_2S content in the tail gas can not be drastically reduced without significant increases in overall recovery efficiency. There this is not seen to be a significant opportunity for improvement.

COS and CS_2 Formation In The SRU

The COS and CS_2 content in the tail gas is also affected directly by the composition of the acid gas and the overall recovery efficiency in the plant as well as the operation of specific units in the SRU.

The amount of COS and CS_2 formation in the plant is affected most strongly by the acid gas composition. In general, the COS formation rate in the reaction furnace is most strongly influenced by the CO_2 content in the acid gas. Therefore, it would be possible to decrease the COS in the SRU by reducing the CO_2 content in the acid gas. There is available technology for reducing the CO_2 content in the acid gas by using a selective amine in the upstream amine treating unit. However, there is no evidence yet to suggest that changing to a selective amine can be justified by the improvement in COS in the SRU tail gas alone. *However, this line of opportunity should be investigated in more detail.*

The CS_2 formation rate in the reaction furnace is strongly influenced by the hydrocarbon content in the acid gas feed. The CS_2 formation rates tend to increase with increasing hydrocarbon content in the acid gas. In a well optimized upstream amine treating unit, the hydrocarbon content in the acid gas can be reasonably minimized. However, some plants suffer from high hydrocarbon content due to unstable upstream operations or amine plants that are not fully optimized. The anecdotal evidence suggests that the opportunity to *significantly* reduce the hydrocarbon content in acid gas streams by optimizing amine plant operations is not high. Also, the relative overall benefits of this approach to minimizing TRS in the SRU have not been established. *However, this line of opportunity could be investigated in more detail*.

<u>COS and CS_2 Conversion In the SRU</u>

In a typical SRU, a significant portion of the COS and CS_2 is (or can be) converted back to H_2S prior to exiting in the SRU tail gas. However, the amount of COS and CS_2 remaining in the tail can vary dramatically from plant to plant depending on the configuration and operation of the SRU. It should also be noted that the levels of COS and CS_2 in the tail gas are not necessarily reflected in the overall recovery efficiency in the plant although, as a rule, plants with higher overall required recovery efficiencies are likely to have relatively lower COS and CS_2 content in the tail gas.

The results from this survey indicated the following with respect to COS and CS_2 in the tail gas:

- the total COS + CS_2 in the tail gases varied from less than 50 to more than 5000 ppm;
- the median plant of those surveyed had a COS + CS_2 content of 370 ppm in the tail gas;
- 14 plants had SRU tail gas streams with more than 500 ppm COS + CS_2.

Since the TRS residual left in the stack effluent is directly related to the TRS in the tail gas, any reduction in the TRS content in the tail gas *could* result in further opportunity to optimize the incinerator/stack. The most obvious route to achieve this would be to increase the conversion rate of COS and CS_2 in the Claus reactor(s).

The COS and CS_2 conversion occurs in the Claus reactors and is influenced primarily by the type of catalyst used, the condition of the catalyst and the operating temperature of the reactor.

Traditionally, most plant operators utilize <u>activated alumina catalyst</u> and attempt to improve the COS and CS_2 conversion by operating the first Claus reactor at somewhat elevated temperatures (ca. 340°C). It is possible to improve the COS and CS_2 conversion by increasing the Claus reactor temperatures. However, there is a practical limit to this approach because too high of reactor temperatures can detract from the conversion of H_2S and SO_2. There is, in effect, a proper balance to the maintained. In practice however, it is *recommended that all operators should attempt to optimize the balance between the two issues and could possibly reduce the overall COS and CS_2 in the tail gas to the benefit of the incinerator by optimizing the Converter 1 operating conditions*.

It is also possible to improve the COS and CS_2 conversion in the SRU by utilizing a different catalyst, <u>titania dioxide</u>. This catalyst is being used in some plants in order to increase the overall recovery efficiency. However, this comes at a significant cost due to the extremely high price (10x conventional catalyst) of this catalyst. Therefore it is only used where justified as compared to other methods for improving the overall recovery efficiency.

However, based on the results of this survey, there may be opportunity to use this catalyst to reduce the tail gas TRS content and thereby save plant fuel gas by further optimizing the incinerator operation. To date the economic benefits of this approach have not been studied in any significant detail. *Therefore, it is recommended that for those specific plants which have high COS and CS_2 in the tail gas and are TRS limited in the incinerator, that a more detailed assessment of this opportunity be completed.*

COS and CS_2 Oxidation Efficiency in the Incinerator

As detailed in previous studies, the oxidation efficiency of TRS compounds in the incinerator and stack are influenced primarily by the traditional kinetic factors of residence time, mixing efficiency and reaction temperature.

Traditionally, most existing SRUs are equipped with relatively simple burner/incinerator systems with only modest mixing capabilities and rely strongly on long residence times and adequate reaction temperatures. Of course, higher reaction temperatures require higher fuel consumption and therefore this approach for improving TRS oxidation efficiency comes at a considerable cost. Also, higher residence times require larger incinerator vessels and the attending higher capital costs. Larger incinerator vessels also have a tendency to have higher heat losses to the atmosphere which is counter-productive to the energy savings exercise.

Therefore, the most obvious opportunity for incremental improvements in incineration efficiency are by improving the mixing characteristics in the incinerator burner and mixing chamber. The mixing efficiency in these systems is typically characterized by the “kinetic mixing factor” (K factor) in the burner/incinerator. Previous work by Paskall et al. in the 1970's indicated that all conventional tail gas incinerators in the province have a K factor in the range of 1 - 8 (relative scale). The results from many STTR programs already complete indicate that most incinerators have K factors in the range of 2 to 6.

Therefore, it appears that many existing incinerators could improve the TRS oxidation efficiency by improving the K factors in their incinerators towards the higher end of this scale. *For the 11 plants in the province that are limited by TRS in the stack it is recommended that they investigate upgrades to their current technology to allow for operating the incinerators at lower temperatures while improving the relative TRS oxidation efficiency.*

It should also be noted that there have not been significant improvements in the incinerator burner/incinerator hardware used in these systems since most of these systems were commissioned. With recent improvements in combustion technology generally available to industry, it appears that there could be significant opportunity to incorporate this technology to the benefit of these incinerators.

While detailed research in this area has not been conducted to date, anecdotal evidence presented by combustion technology companies suggests that K factors in the range of 15 or better may be possible for these systems. This would significantly improve the TRS oxidation efficiency in the SRU incinerators. *It is recommended that for specific existing plants which are utilizing “old” combustion technology and are limited by TRS in the stack, a more detailed investigation in this area be completed.*

2.4 Minimize Stack Heat Losses

Most of the existing incinerators are refractory lined vessels with no insulation. Insulation is typically not used on these vessels to ensure that the metal shells of these vessels do not over-heat and corrode. Similarly, the stacks are typically refractor lined metal or concrete vessels which are also not insulated.

As a result, the heat losses (and subsequent increase in fuel demand to meet a specified exit temperature) can be significant. Currently, there is no standard practice for specifying the recommended heat losses from these systems. However, by survey, the typical heat losses in a well designed and operated system are in the range of 50 degrees C from the bottom incinerator temperature to stack exit temperature. Any temperature loss in significant excess of this amount is resulting in unnecessary fuel gas consumption.

The survey results indicated that nine of the incinerator/stack systems had temperature losses in excess of 100 degrees C and three systems had heat losses in excess of 200 degrees C. This represents extraordinarily high heat losses. In fairness to these operations, this condition occurs inevitably when a plant is operating under severe turn down conditions as is the case with all of these systems. In essence theses incinerator/stack systems are grossly over-sized for the current through out of the plant.

By way of example, a recent detailed incinerator study indicated that the fuel gas consumption in the incinerator could be decreased by approximately 20 percent by reducing the heat losses from 120 to 50 degrees C. For most of the existing incinerators which suffer from significant heat losses, the existing system would need to be modified drastically or a new, properly sized incinerator installed. While these types of changes would have significant capital costs, it is possible that the economics of these changes could be justified in fuel gas savings. *Therefore, for the nine plants which are currently demonstrating excessive heat losses from the incinerator/stack systems it is recommended that modifications or replacement of the incinerator/stack system be investigated in more detail*.

2.5 Adapt Existing Operating Licences for Variable SO_2 Emissions

All SRU incinerators are regulated with respect to the maximum allowable SO_2 emissions. These are typically related to the maximum allowable inlet sulphur load stipulated by the EUB and the minimum overall recovery efficiency required of the plant.

Historically, the SO_2 plume dispersion assessment of a given plant is determined by these *maximum* allowable SO_2 emissions regardless of the *normal* range of SO_2 emissions from the stack. This approach ensures that the stack SO_2 plume dispersion requirements are being met for *any* possible emissions conditions. However, this approach is extremely conservative for many plants which do not (and have not for some time) actually had SO_2 emissions near the maximum allowable values.

In some specific cases, it has been demonstrated when the plant SO_2 emissions are persistently lower than the licensed *maximum* emissions rates there is significant opportunity to reduce the stack exit temperature while still ensuring compliance with the ground level SO_2 emissions. In these cases, the plant licences allow for operation at a lower stack exit temperature at times when the stack sulphur inlet and or SO_2 emissions are significantly and persistently below the licenced maximum allowed. This has been demonstrated to be very large benefit in several plants where the actual plant though-put and SO_2 emissions are significantly lower than the licenced values due to significant declines in the production of the associated sour gas fields.

These variable style licences are commonly known as "tiered" licences to reflect the "production and emission tiers" that are incorporated into the regulated conditions. Currently there are at least 5 plants which are operating with this style of licence for normal day to day operations and have reduced their incinerator fuel gas consumption significantly.

By way of example, *one plant which uses a tiered licence has reduced the fuel gas consumption in the incinerator by more than 20 percent*. A similar approach at any of the other plants could be expected to realize similar benefits.

Therefore, any of the plants (12 or more) which are currently limited by SO_2 dispersion could possible benefit from this approach. *It is recommended that these plants be reviewed in more detail to determine the opportunity for implementing a tiered SO_2 emissions component in their operating licences.*

3.0 Conclusions

While a large number of the provinces existing plants have completed successful incinerator optimization studies, the results of this study indicated there is significant *incremental* opportunity available to reduce fuel gas consumption in these incinerators.

The incinerator optimization studies that have been implemented to date are resulting in on-going fuel gas saving on the order of 273,000 m^3/d. However, significant incremental opportunities have been identified by investigating the current limiting factors in many of the existing incinerator systems in the province.

The first opportunity in this renewed incinerator optimization program would be to simply optimize the operating conditions of all of the existing incinerators within the constraints of their existing licences. The results from this study suggest that an incremental savings of approximately 95,000 m^3/d could be realized by optimizing the excess oxygen content in the incinerator of these 15 plants.

The second opportunity would be to conduct detailed STTR studies on the plants which have never completed such work. Currently 11 plants have never investigated a proper STTR study and conservative estimates indicate that a fuel gas savings of approximately 10,000 m^3/d could be realized.

The third opportunity is to optimize the operations of existing SRUs to ensure that the TRS concentrations in the SRU waste gas are reasonably minimized. This survey suggests that there are 14 plants with significant COS and CS_2 content in the SRU tail gas which could be reduced by improving the COS and CS_2 conversion efficiency in the Claus plant through optimized operating conditions and the possible use of specialized catalyst systems. The absolute impact on fuel gas saving in these cases could not be determined without more detailed study.

The fourth opportunity is to investigate methods for reducing heat losses in the existing incinerator/stack systems. This study revealed that there are at least 9 plants which have temperatures losses in excess of 100 degrees C from the incinerator breach to the stack exit. While the exact benefit of reducing these heat losses could not be quantified for all of these plants, past experience in specific incinerators suggests that fuel gas savings on the order of 20% could be realized. In order to realize this benefit it would be necessary to modify our replace the offending systems which will have a significant cost which has not been defined by this work. The economics of this approach would need to be studied in more detail.

The final opportunity is related to the use of "tiered" plant SO_2 licences for plants which would normally be "SO_2 limited". In cases where the normal and persistent stack SO_2 emissions are significantly below the maximum licenced values, there exists an opportunity to allow the plant to operate with a lower stack exit temperature while still meeting all of the SO_2 plume dispersion requirements. Currently at least 5 plants are implementing this style of licence and these plants are saving on the order of 20% of their fuel consumption as a result. Currently at least 12 plants are limited by licenced SO_2 emissions and may benefit from this approach.