

Operational and Safety Considerations for SRU Shutdowns Due to Tail Gas Thermal Oxidizer Trips: A Case Study from Motiva Port Arthur Refinery

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Tail gas Thermal Oxidizer (TO) trips remain a significant operational challenge for Sulfur Recovery Units (SRUs), often resulting in full unit shutdowns and substantial impacts on refinery and gas plant throughput, emissions compliance, and overall operational continuity. This paper explores both the consequences of TO trips and the different operating philosophies employed in the industry. At many facilities, a TO trip mandates an immediate SRU shutdown to prevent the potential release of untreated gases. In contrast, other operators allow waste gas to continue flowing through the TO for a defined period while attempting to relight the burner.

A key focus of the paper is safety, specifically the evaluation of NFPA 86 guidelines regarding purge requirements and how these guidelines can be applied to oxidizer restarts. Additionally, the paper considers methods for determining the Lower Flammability Limit (LFL) of waste gas streams and compares their application and implications in real-world operating scenarios.

A case study from Motiva's Port Arthur, TX refinery is presented, outlining the site's current trip philosophy and quantifying the time lost due to TO-related SRU shutdowns. The study underscores the value of optimized restart procedures when aligned with safety standards. The paper concludes with a review of LFL compliance evaluation and discusses the feasibility of alternative restart strategies to improve operational resilience at Motiva's Port Arthur refinery.

1. INTRODUCTION

Tail gas Thermal Oxidizers (TOs) play a critical role in sulfur recovery units (SRUs), ensuring the safe and compliant treatment of residual sulfur compounds before atmospheric release. In refinery operations, TO trip events—triggered by flame instability, stack draft failure, or instrumentation faults—can lead to automatic shutdowns of upstream SRUs. While these shutdowns are designed to protect personnel, equipment, and the environment, they also introduce significant operational challenges, including lost production, increased maintenance demands, and reduced overall efficiency.

Motiva's Port Arthur Refinery is one of the largest refineries in the world processing a total of 720+ MBPD of feedstocks. The refinery provides a unique opportunity to evaluate TO trip management in a real-world setting. The facility operates two sulfur blocks—SBU1 and SBU2—with distinct design philosophies and trip response protocols. SBU1 utilizes natural draft thermal oxidizers and does not require automatic SRU shutdowns upon TO trips, offering greater operational flexibility. In contrast, SBU2 employs forced draft thermal oxidizers with integrated Waste Heat Boilers (WHBs) and mandates immediate SRU shutdowns in the event of a TO trip, prioritizing safety and emissions control.

This dual-block configuration enables a comparative analysis of trip management strategies and their impact on refinery performance. Historical data from SBU2 reveals substantial downtime associated with TO-related SRU shutdowns, affecting throughput and environmental emissions.



Fig. 1: Photo of Motiva Port Arthur, TX SBU2

In response, a joint study between Motiva and Zeeco was initiated to quantify these impacts and explore optimized restart procedures aligned with NFPA 86 standards and Lower Flammability Limit (LFL) compliance. Since SBU2 commenced operations in 2012, there have been five notable incidents where Incinerator TO trips led to associated SRU trips. Among these, two events triggered cascading SRU shutdowns, immediately removing 1,710 LTPD of sulfur processing capacity from service. One such event, which occurred in May 2014 during the start-up of HCU2, resulted in acid gas flaring due to a significant amine system swing that ultimately caused both TO and SRU trips (Fig. 2). The most recent incident took place during Winter Storm Uri in February 2021; however, this did not result in acid gas flaring (Fig. 3). These trends show the SO₂ emissions in ppm from the SRU5 (blue), SRU6 (green), and SRU7 (red) TGTU's.



Fig. 2: Amine System Upset – 2014

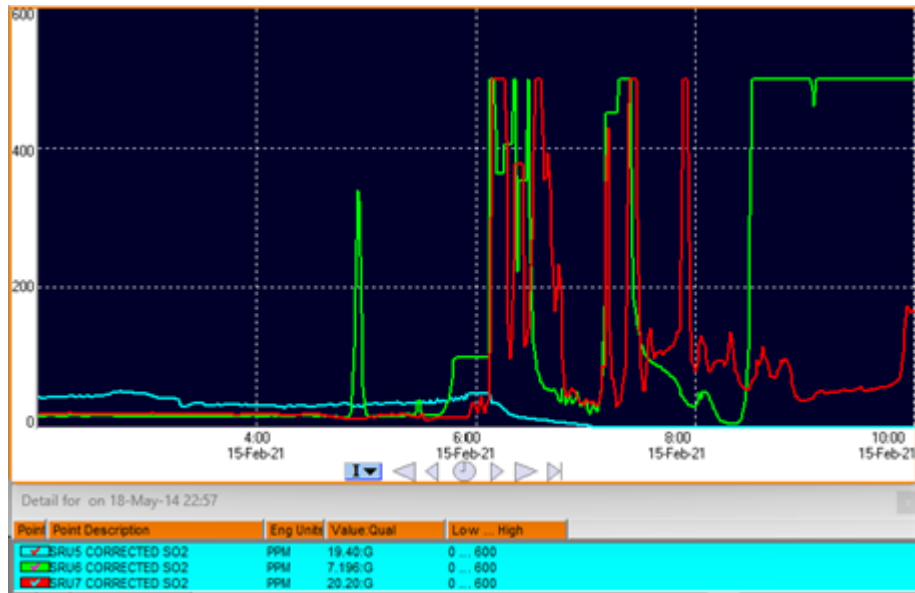


Fig. 3: Winter Storm Uri – Feb 2021

The purpose of this paper is to examine the operational and safety considerations surrounding TO trip events, evaluate the effectiveness of current shutdown protocols, and propose data-driven strategies for improving restart logic. By leveraging design-specific insights and industry standards, the study aims to enhance reliability, reduce downtime, and maintain environmental integrity in sulfur recovery operations.

2. MOTIVA SBU2 THERMAL OXIDIZER

2.1. Thermal Oxidizer Design

The SBU2 thermal oxidizer at the Motiva Port Arthur Refinery has separate injectors for fuel gas, and for waste gases. In this case, the waste gases are the SRU SCOT absorber off gas or SCOT bypass gas, merox vent gas, and pit sweep gas (Fig. 4).

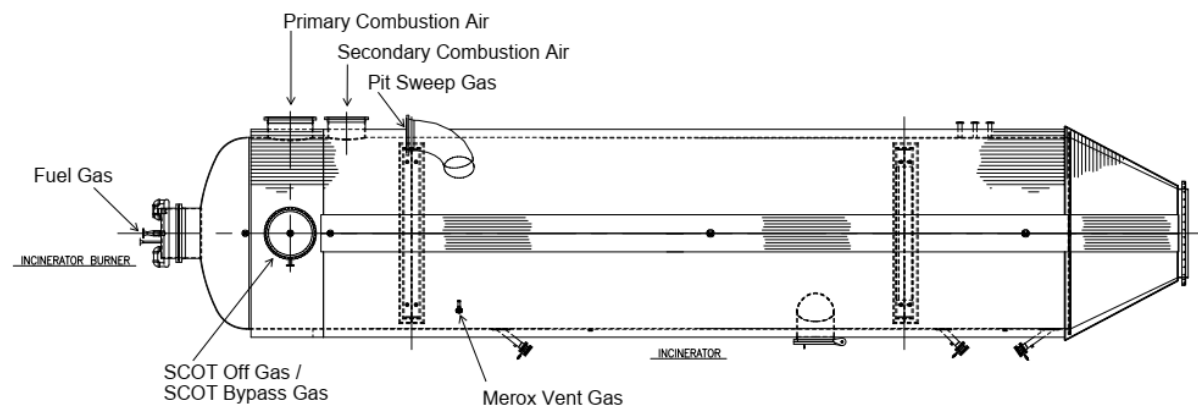


Fig. 4: SBU2 Thermal Oxidizer (Plan view)

The fuel gas and waste gases contain combustible components that can contribute to the flammability of gases in the combustion chamber of the thermal oxidizer, albeit to varying degrees. Primary combustion air provides air for the fuel gas, with suitable excess, and the secondary air provides combustion air for the SCOT off gas / SCOT bypass gas, and sufficient excess air for at least 3 vol% (wet basis) oxygen in the flue gas. The fuel gas, waste gases, and combustion air are not mixed prior to injection in the combustion chamber. The injection points for each gas are arranged in a way to

promote stable combustion, and to ensure that all waste gas streams are heated to sufficient temperature, and mixed with sufficient oxygen, in order to provide complete combustion of all streams.

This combination of combustibles and air, while required for proper operation, requires the proper isolation of any sources that can lead to the accumulation of a flammable mixture in the combustion chamber prior to ignition of the burner. In order to achieve this proper isolation and safe introduction of each combustible stream to the furnace, a prescribed startup sequence and emergency shutdown protocol must be followed for any thermal oxidizer.

2.2. NFPA 86 standard

The National Fire Protection Association (NFPA) establishes fire safety standards, including standards for the safe operation of processes. NFPA 86, the Standard for Ovens and Furnaces [1], addresses the safe operation of Class A, Class B, Class C and Class D ovens, dryers, furnaces, **thermal oxidizers** and any other heated enclosure used for processing of material and related equipment.

- NFPA 86 is the only code to specifically state that it covers thermal oxidizers and fume incinerators.
- NFPA 86 2023 section 3.3.28 defines Fume Incinerator as any separate or independent combustion equipment or device that entrains the process exhaust for the purpose of direct thermal or catalytic destruction, which can include heat recovery.
- NFPA 86 2023 section 3.3.52.4 defines Thermal Oxidizer as an independently controlled, enclosed oxidizer system whose purpose is to destroy VOC, HC gases or vapors, or both, using elevated temperature, residence time, mixing, and excess oxygen without catalysts.

Zeeco's policy is to design all burner management systems for combustion equipment to follow NFPA 86 as a minimum standard. The philosophy of NFPA 86 requires that the media for the pre-purge before burner ignition be "inert", or verifiably and indisputably non-flammable.

2.3. Thermal Oxidizer Startup

Prior to the start and throughout the lightoff and operation of any combustion equipment, a safe operating condition must be ensured. As applied to a process waste gas thermal oxidizer, this generally requires a sequence of actions:

- Verify that all alarm conditions are healthy.
- Verify that all sources of combustibles are isolated from the furnace.
- Pre-purge of combustion furnaces with fresh air or inert gas to ensure no accumulation of combustibles in the furnace.
- Light the pilot and/or burner as prescribed by the manufacturer.
- Continuously verify stable flame for the pilot and/or burner.
- Continuously verify all other alarm conditions.
- Heat the furnace to the prescribed operating temperature and condition per the manufacturer's recommendations.
- Introduce any waste gases / liquids to the thermal oxidizer.

Proper control of the startup ignition sequence, and alarm monitoring and shutdown control is the purpose of the burner management system (BMS).

2.4. BMS Best Practices

The typical approach to BMS design for a thermal oxidizer is to isolate all sources of combustibles before burner startup, and to purge the thermal oxidizer combustion chamber with fresh air before ignition of the burner. For most applications, the waste gas is considered to have an unknown and uncontrolled composition, because upset or off-spec cases can

occur, especially for a waste gas stream. Therefore, for most thermal oxidizer applications, the waste gases are not considered to be an inert media, even if the design waste gas compositions in all operating cases would indicate that is the case.

Instead, the waste gases are introduced after the burner is established and the thermal oxidizer has been heated to its normal operating temperature. This method is consistent with standards such as NFPA 86, which requires at least four system volumes of “fresh air or inert gas” to be introduced to the furnace during the purge prior to startup.

However, SRU plants are often not designed to have any SRU tail gas or TGTU off gas outlet other than the thermal oxidizer. Therefore, isolating the SRU tail gas / TGTU off gas and purging only with fresh air may not be possible unless the entire SRU is shut down on any thermal oxidizer trip. ***The question then is whether we can consider the SRU tail gas / TGTU off gas to be “inert gas”.*** The composition of these waste gases typically varies based on the operating condition of the SRU, and can also deviate from the design compositions, flow rates, etc. as originally considered in the design. Per NFPA 86, verifying the waste gases are inert gases requires us to show that the gases are not flammable at any temperature, and contain less than 1% oxygen. For a thermal oxidizer in a working plant, verifying this to a level sufficient for safety design may be a difficult or nearly impossible task.

2.5. Flammability Analysis for Thermal Oxidizer Waste Gases

Flammability of mixtures of inert and flammable gases in air is discussed in US Bureau of Mines Bulletin 503 *Limits of Flammability of Gases and Vapors* [2]. This includes laboratory flammability data for a wide range of hydrocarbons and other flammable gases, and a manual calculation method for determining flammability of mixtures based on these data. US Bureau of Mines 627 *Flammability Characteristics of Combustible Gases and Vapors* [3] includes an equation for predicting lower flammability limits of hydrocarbons at elevated temperatures for individual flammable gases.

A method for determining the flammability of a mixture of flammable gases and inert gases that can be readily adapted to a spreadsheet is described in Section 4.3 of *Gas cylinders – Gases and gas mixtures – Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets*, EN ISO 10156:2017 [4]. This method considers the ability of various inert gases to reduce the flammability of the gas mixture relative to that of nitrogen. Although the calculations and methods in ISO 10156 don't apply only to gas cylinders, the target application is considered to be at ambient temperature, and it does not account for the effect of elevated temperatures on the flammability envelope.

Chapter 10 of NFPA 86 specifically addresses the safe operation of thermal oxidizer systems. Note that the SRU thermal oxidizer falls under the definition of a thermal oxidizer in this standard, and in the industry the terms “thermal oxidizer” and “incinerator” are used nearly interchangeably. As mentioned above, Chapter 10 does not explicitly require any flammability analysis of pre-startup purge gas, only that the purge media be combustion air or inert gas. However, it does clarify that a thermal oxidizer shall comply with the requirements for a Class A Oven, which is defined as “an oven or furnace that has heat utilization equipment wherein there is a potential explosion or fire hazard that could be occasioned by the presence of flammable volatiles or combustible materials processed or heated in the furnace”. The NFPA 86 method allows a source air mixture or vent gas to be purged into an operating furnace (Section 8.4.1.4) or thermal oxidizer (Section 10.6.2.(1)) if it can be demonstrated that the flammable vapor concentration is no more than 50% of the LFL of that gas. However, the context of these statements would indicate this is relevant to preventing flashback during operation, not to a pre-purge scenario.

Section 6.5.2(2) of NFPA 86 and the corresponding section of the appendix give a sample calculation to determine the dilution of radiant tube-type heating systems (not thermal oxidizers) to a noncombustible state. The appendix refers to the temperature correlation shown in USBM 627 and shows the dilution to less than 100% of the LFL at temperature as sufficient for this purpose.

Chapter 11 of NFPA 86 shows that a Class A Oven, safety ventilation shall not be required “unless flammable constituents evolve in the process of heating”, i.e., evaporation of volatiles from a process media. However, when it is required for

solvent vapor ventilation, then there should be a means to prevent the vapor concentration in the oven exhaust from exceeding 25% of the LFL and presents the equation from USBM 627 showing the temperature dependence of the LFL for hydrocarbons.

Chapter 10 can be applied to direct-fired waste gas thermal oxidizers in the industry by using an “inert gas” as the purge media, or, more simply, by using combustion air as the pre-purge gas. In the case that an inert gas is used, then it is defined as a nonflammable gas containing less than 1% oxygen, where a “nonflammable gas” is one that is known to be nonflammable at any temperature. Process thermal oxidizers typically operate at nominal furnace temperatures ranging from 1,200°F to 2,300°F, depending on the application. The nominal operating temperature is typically measured at the outlet of the furnace in order to ensure adequate temperature for destruction of the waste gases, but higher temperatures can and do occur at or near the burner. Since, as shown in Figure 21 from USBM 627 (Fig. 5), the LFL is strongly dependent on temperature, it is difficult to argue that a waste gas having any hydrocarbon is truly inert at temperatures it may encounter, at least in a localized region, in a thermal oxidizer when trying to restart it soon after operation at normal temperatures. Add to that any uncertainty there may be regarding the waste gas composition, especially during upset conditions, and it is difficult to apply NFPA 86 to a thermal oxidizer unless the purge gas is fresh air or an inert gas like nitrogen.

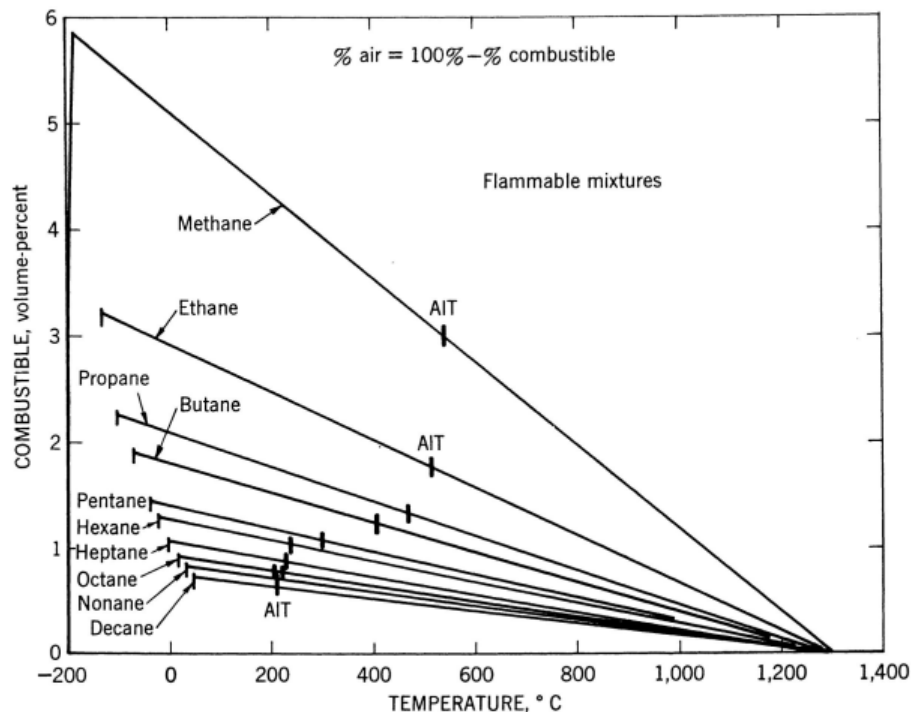


FIGURE 21.—Effect of Temperature on Lower Limits of Flammability of 10 Paraffin Hydrocarbons in Air at Atmospheric Pressure.

Fig. 5: Fig 21 from USBM Bulletin 627

2.6. The Role of Flammability Analysis in BMS Design

In this report we apply the calculation basis of ISO 10156 to the SRU thermal oxidizer at Motiva's Port Arthur Refinery, and, as an illustrative counterexample, to another gas processing SRU thermal oxidizer (not at a Motiva site). By using the ambient-temperature method presented in ISO 10156, we can show that if a waste gas is shown to be flammable, and with the available air in the system a potentially explosive mixture can be formed, then a gas is known to be unsafe for use as a pre-purge gas.

However, caution should be used when trying to assert that a waste gas is known to be safe to use as a purge gas. This is because of several factors:

- The dependence of the LFL on temperature.
- Variations in temperature in the furnace occur because the injection points are separated, and the fuel gas burner must be separated from any typically inert waste gas that may quench the burner flame.
- Because of heat storage in the furnace refractory, elevated temperatures remain for long periods of time in the thermal oxidizer after it has been tripped.
- Waste gases, combustion air, and fuel gases are not perfectly mixed in the thermal oxidizer furnace and are typically not mixed at all prior to injection into the furnace, so significant local variations in mixture composition occur.
- Waste gas compositions can vary from the design compositions during operation. Typical flammable components of SRU waste gases may include H_2 , H_2S , and CO , and concentrations of each of these may be increased for several reasons based on the condition of the SRU and TGTU.
- Many SRUs have safety system logic that shifts the pit sweep gas from the SRU main burner to the thermal oxidizer when the SRU trips.

Each of these factors has the potential to have a significant impact on the flammability potential of a thermal oxidizer in the field. For example, seemingly small increases in concentrations of H_2 and H_2S can have a big impact on the flammability of the waste gas. If hydrogen is injected in the tail gas upstream of the hydrogenation unit, then an upset in this system may trip the thermal oxidizer on high temperature. If this is the root cause of an thermal oxidizer trip, it's even more reason not to trust it as a purge gas. Any other upset condition in the SRU or TGTU that could result in high concentrations of H_2S , CO , or other flammable components could also increase the flammability of the waste gases.

Although pit sweep gas rarely has significant concentrations of flammable species, it often contains oxygen. The pit sweep gas flow rate is usually small relative to the combustion air blower capacity and SRU tail gas / TGTU off gas rates, if the blower combustion air is isolated after a thermal oxidizer trip and any flammable waste gas is not isolated, then any oxygen in the pit vent could contribute to a potentially explosive mixture in the TO, so the analysis method needs to account for all the potential flammable or oxidizing gases that could be present in the system.

3. FLAMMABILITY ANALYSIS METHODS

3.1. Flammable Gases

The lower flammability limit (LFL) of a flammable gas is the lowest concentration of the gas in air that can be ignited at ambient temperature. Similarly, the limiting oxygen concentration (LOC) is the lowest concentration of oxygen (with nitrogen as the inert media) that will support ignition of a flammable gas. The LFL and LOC of various single-component combustible gases can be determined empirically using laboratory-scale equipment, and results can readily be found in the literature.

A method for determining the flammability of a mixture of flammable gases and inert gases as described in Section 4.3 of EN ISO 10156:2017 is provided below. This method considers the ability of various inert gases to reduce the flammability of the gas mixture relative to that of nitrogen.

For a gas mixture with n flammable gases $\{1, \dots, i, \dots, n\}$, and p inert gases $\{1, \dots, k, \dots, p\}$, let

A_i = concentration of flammable gas i

B_k = concentration of inert gas k

K_k = equivalency coefficient (relative to nitrogen) for inert gas k

T_{ci} = Maximum content of flammable gas i which, in a mixture with nitrogen, is not flammable in air

Then it can be shown that a mixture of these n flammable gases and p inert gases is not flammable in air when:

$$\sum_{i=1}^n A_i \left(\frac{100}{T_{ci}} - 1 \right) \leq \sum_{k=1}^p B_k K_k$$

To evaluate the lower flammability limit of a gas mixture with n flammable gases $\{1, \dots, i, \dots, n\}$, and p inert gases $\{1, \dots, k, \dots, p\}$, let

L_i = Lower flammability limit of pure gas i

L'_i = Lower flammability limit of gas i in the gas mixture

L'_M = Lower flammability limit of the flammable gases in the mixture

L_M = Lower flammability limit of the total gas mixture

Then for a mixture of flammable gases of concentration A_i , with only nitrogen as the inert component, the flammability in air can be closely approximated by taking the sum of the n flammable components over their concentrations in the mixture (leaving out the nitrogen):

$$L_M = \frac{100}{\sum_{i=1}^n \frac{A_i}{L_i}}$$

However, to consider inert components other than nitrogen, we have to weight them in a manner similar to that used when considering the flammability criterion T_c :

$$L_M = \frac{100}{\sum_{i=1}^n \frac{A_i}{L'_i}}$$

where

$$L'_i = \frac{\left(100 - L'_M - (1 - K) \frac{\sum_{p=1}^k B_k}{\sum_{i=1}^n A_i} \times L'_M \right)}{(100 - L'_M)} \times L_i$$

and L'_M is the LFL of a mixture containing only the flammable components, and K is the average of K_k , weighted according to the composition.

A mixture containing both flammable and oxidizing gases is flammable if it meets both conditions

$$\sum A_i > L'_M$$

and

$$\sum A_i > T_{CF}$$

where

$$T_{CF} = T_{CM} (1 - x_o / 21\%)$$

and T_{CM} is the maximum concentration of flammable gas in a mixture of flammable gas with nitrogen that is not flammable in air.

3.2. Flammability Charts

These results can be summarized in a flammability chart with oxygen on the vertical axis and flammables concentration on the horizontal axis:

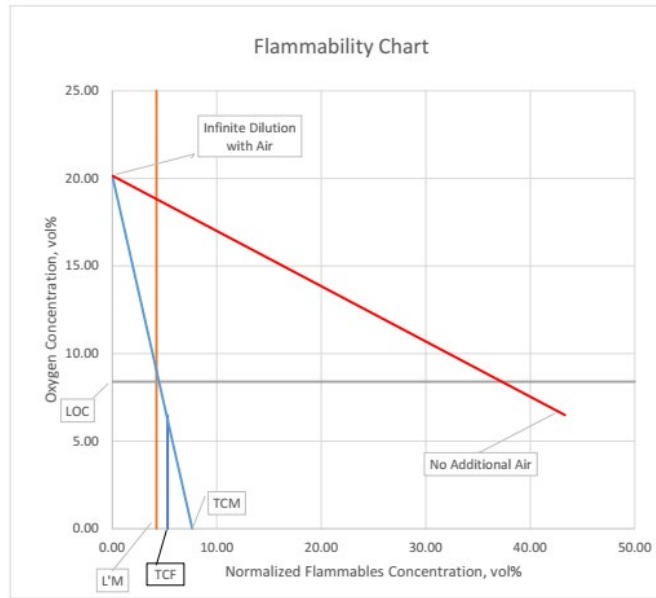


Fig. 6: Flammability Chart

The line from T_{CM} to 20% oxygen, 0% flammables represents the blending of the limiting mixture T_{CM} with air. If the gas mixture contains oxidants (O_2 in this case), the maximum concentration that is not flammable is reduced up to the oxidizing potential of the gas. The regions of the flammability chart are shown in Figure 7 below:

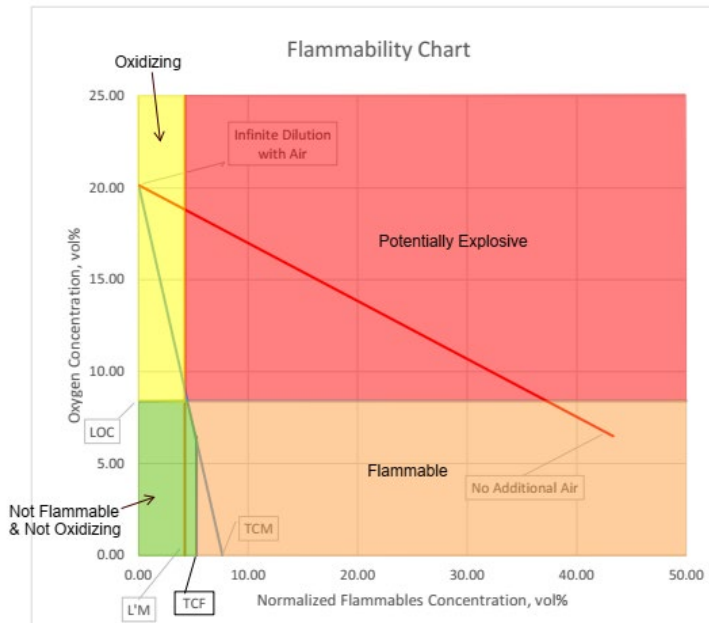


Fig. 7: Regions of the Flammability Chart

For this study, we consider the waste gases for the SBU2 thermal oxidizer at the Motiva Port Arthur Refinery, with compositions shown in Table 1.

	SCOT Absorber Off Gas	Merox Gas	TGTU Bypass	Pit Sweep
Mass Flow Rate, lb/hr	69,687	132	114,117	9,654
Composition, vol%				
Hydrogen	3.079%	8.486%	2.236%	0.000%
Water	5.823%	0.000%	47.610%	67.041%
Carbon Monoxide	0.002%	0.000%	0.352%	0.000%
Nitrogen	89.574%	49.584%	46.962%	25.937%
Oxygen	0.000%	6.489%	0.000%	6.895%
Carbon Dioxide	1.510%	0.499%	0.518%	0.000%
Hydrogen Sulfide	0.010%	0.000%	1.710%	0.045%
Sulfur Dioxide	0.000%	0.000%	0.427%	0.004%
Carbonyl Sulfide	0.000%	0.000%	0.114%	0.000%
Methane	0.000%	33.943%	0.000%	0.000%
Ethane	0.000%	0.832%	0.000%	0.000%
Propane	0.000%	0.166%	0.000%	0.000%
n-Butane	0.000%	0.000%	0.000%	0.000%
MDEA	0.001%	0.000%	0.000%	0.000%
S6	0.000%	0.000%	0.002%	0.000%
S8	0.000%	0.000%	0.007%	0.000%
Sulfur Liquid, S1	0.000%	0.000%	0.062%	0.078%
Total	100.000%	100.000%	100.000%	100.000%

Table 1: Waste gas compositions for the SBU2 thermal oxidizer

For example, the flammability chart for the merox vent shows that it has an oxidizing potential and is flammable:

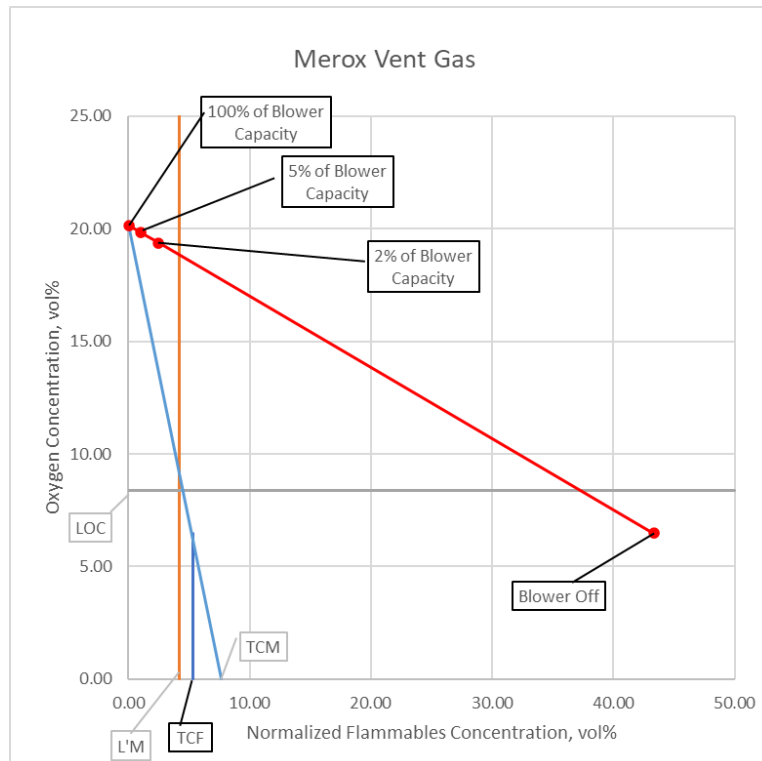


Fig. 8: Flammability Chart for the SBU2 Merox Vent Gas

The operating curve for a system containing only merox vent gas and combustion air is represented by the red line. The merox vent contains 43.4% combustibles and 6.49% oxygen, which is shown as the “blower off” point on the red line. The oxidizing potential of the merox vent is 6.07% (the oxidation potential is lower than the oxygen concentration because of the inerts in the gas). As in the remaining examples, the total flammables concentration on the X axis is normalized to account for the relative inerting capability of the inert species relative to that of nitrogen, although in this case the inert gases are nearly entirely nitrogen. As air is added to the system, the flammable concentration decreases and the oxygen concentration increases. In so doing, the operating curve passes through the potentially explosive region of the flammability chart (O_2 concentration $>$ LOC and $\Sigma A_i > L'_M$). Because of the small rate of merox vent relative to the combustion air capacity, the merox vent is rapidly diluted below the flammability limit by the combustion air, such that when the air rate is above 0.5% of the blower capacity, the merox vent gas cannot be ignited.

3.3. Flammability for Trip Conditions of the Motiva SBU2 Thermal Oxidizer

The flammability chart for the Motiva SBU2 Thermal oxidizer when only the SCOT off gas is flowing to the thermal oxidizer is shown below:



Fig. 9: Flammability Chart for the SCOT Off Gas

The flammables concentration (normalized to account for the relative inerting power of CO_2 and H_2O compared to N_2) for the SCOT off gas is 3.0%. Since the oxygen concentration of the SCOT off gas is zero, the operating point with only SCOT off gas in the system is at the point marked “Blower Off”. As combustion air is added to the system, the flammables concentration decreases and oxygen concentration increases, until we reach the blower capacity as shown above. Since we start below the flammability limit, and at no point does the mixture enter the potentially explosive region, we can say that the mixture is not flammable and not potentially explosive, given the assumptions of this method.

However, a variation in SCOT off gas composition (say, an increase in hydrogen) from the expected or design composition can have significant consequences to the flammability analysis. If we double the SCOT off gas hydrogen concentration from 3.0% to 6.0%, then Figure 10 shows that the operating curve is shifted to the right of the TCM line, putting the SCOT off gas into the flammable region, and to the potentially explosive region at certain air rates. Increased hydrogen is a plausible upset condition, because Motiva uses direct injection of hydrogen in lieu of a reducing-gas generator (RGG) to generate hydrogen in their TGTU process. However, if there is an RGG that may potentially generate both CO and H₂, then flammability of the CO would also be taken into account by the analysis.

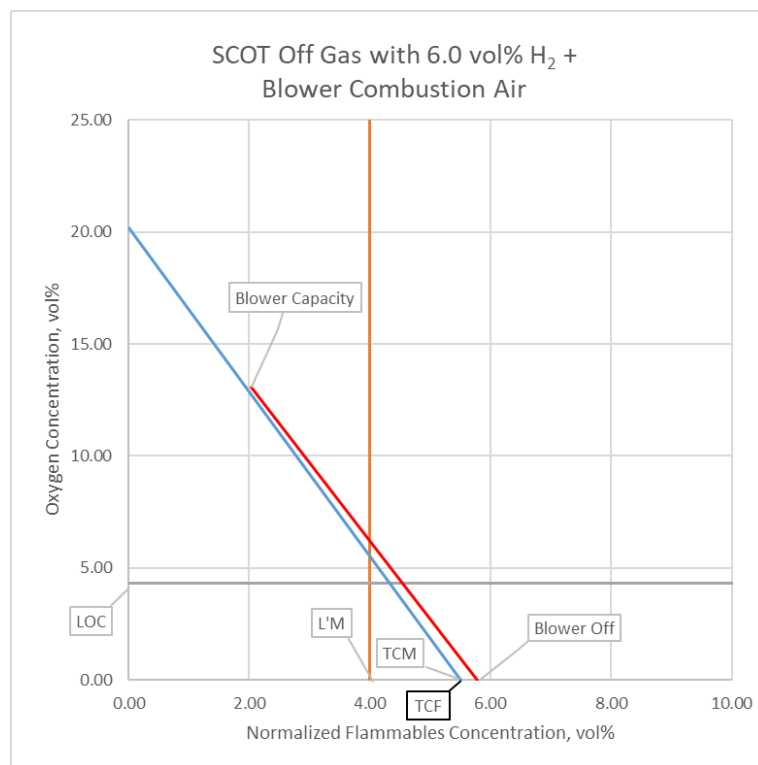


Fig. 10: Flammability Chart for the SCOT Off Gas with 6.0 vol% H₂

In the TGTU bypass case with mercox vent and pit sweep vent gases, the total waste gas mixture now has an appreciable oxidizing potential, as shown in Figure 11:

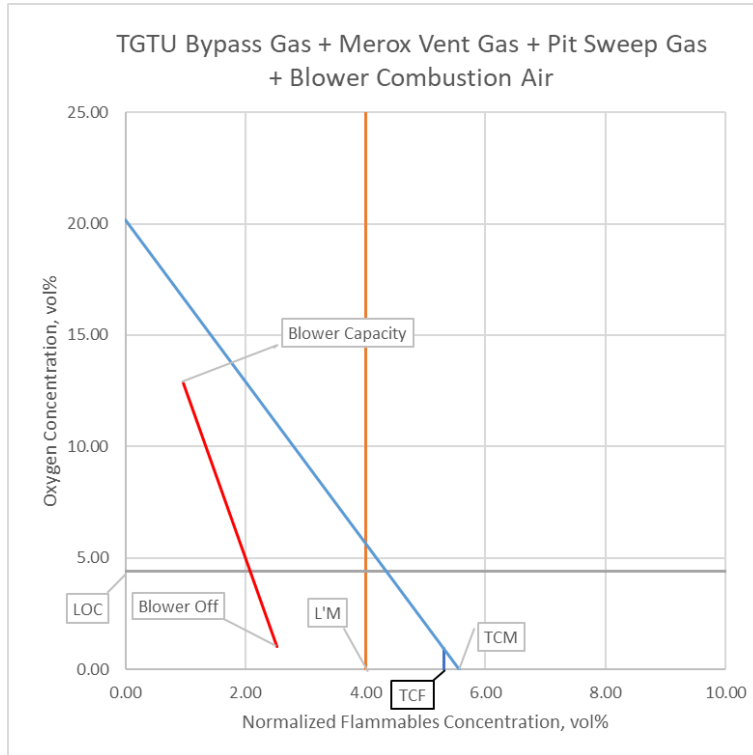


Fig. 11: Flammability Chart for the TGTU Bypass Gas, Mercox Vent, and Pit Sweep Vent

However, the oxygen available in the pit sweep gas (and mercox vent gas) does not have a significant effect on the overall flammability analysis. Although the mercox vent gas is quite flammable on its own, it has a negligible effect on the overall combustibles content of the waste gas mixture.

4. FLAMMABILITY FOR A TRIP CONDITION OF AN SRU AT ANOTHER SITE (NOT MOTIVA)

The flammability chart for one of the trip conditions of an SRU thermal oxidizer as originally conceived (at a different jobsite owned by another company) is shown in Figure 12 below:

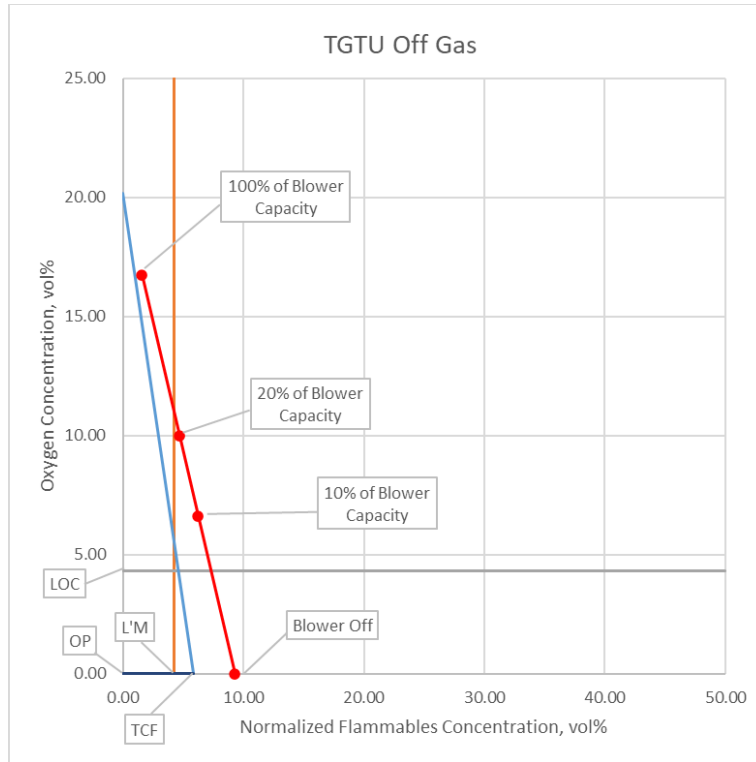


Fig. 12: Flammability Chart for TGTU Off Gas at Another Site

In this case, the TGTU off gas has a significant concentration of hydrogen:

TGTU Off Gas Composition	Vol %
Hydrogen	11.57%
Water Vapor	8.17%
Carbon Monoxide	1.82%
Nitrogen	14.80%
Carbon Dioxide	64.20%
Carbonyl Sulfide	0.013%
Argon	0.16%
Total	100.00%

Table 2: TGTU Off Gas Composition for Another Site

The combustibles concentration of the TGTU off gas is 12.7%. The normalized flammables concentration of 9.3% is clearly above the flammability limit of the gas mixture. As blower combustion air is added to the system, it enters a region where the mixture is to the right of the TCM-air line, to the right of the flammability limit, and above the LOC, making it a potentially explosive mixture.

Note that in this case, the TGTU off gas composition listed above represents an expected operating condition, as originally conceived in the design, and does not have any additional margin on the concentration of any combustibles in the waste gas that may arise from an upset condition. In this case, the operator will avoid restarting the thermal oxidizer with waste gas in this condition.

5. CONCLUSIONS

Thermal oxidizer burner management systems typically require the isolation of all sources of combustibles before burner startup, and to purge the thermal oxidizer combustion chamber with fresh air before ignition of the burner. For most applications, the waste gas is considered to have an unknown and uncontrolled composition, because upset or off-spec cases can occur, especially for a waste gas stream. Therefore, for most thermal oxidizer applications, the waste gases are not considered to be an inert media, even if the design waste gas composition indicates that is the case.

However, a special case occurs for some SRU applications, where there is an operational desire to avoid isolating the SRU tail gas / TGTU off gas from the thermal oxidizer following a thermal oxidizer trip. In this case, the tail gas / off gas effectively becomes the purge gas after a thermal oxidizer trip, unless the entire SRU is shut down. If the tail gas / off gas is truly inert, this is not an issue, however, if we cannot be assured the tail gas / off gas is effectively inert, then the burner management system is in a quandary.

If the SRU is not tripped after a thermal oxidizer shutdown, a philosophy that keeps the SRU in operation with tail gas / TGTU off gas flowing through the thermal oxidizer while the thermal oxidizer is being restarted is assuming, implicitly or explicitly, that the tail gas / TGTU off gas is inert. This paper shows that this may not be a valid assumption in all cases. For example, if the TGTU off gas has a high hydrogen concentration because of the RGG and/or hydrogenation unit operating conditions, especially if the SRU is operating with high level of oxygen enrichment (i.e. with less N₂ diluent), then the risk of restarting the thermal oxidizer without shutting down the SRU should be further evaluated.

It is important to note that this analysis assumes complete and uniform mixing of all gases. In practice, each gas stream is introduced at different points within the thermal oxidizer, which can lead to localized concentrations with varying flammability characteristics. Additionally, during actual operation, blower air may be unavailable or significantly limited, and the mixing of potentially flammable waste gases with combustion air may be incomplete. This analysis does not account for furnace temperature; however, elevated internal temperatures are likely during restart conditions following a recent trip.

Applying a temperature correction to the method to account for the residual heat stored in the thermal oxidizer raises more issues. First, what temperature is to be applied? Nominal flue gas temperatures at the SRU thermal oxidizer outlet typically range from 1,200°F to 1,800°F, but temperatures near the burner can range up to 2,400°F or higher, especially if a high-intensity burner or multistage reducing-oxidizing design is used to reduce NO_x emissions. Second, although temperature corrections for flammability are available in USBM 627 and other sources[5], the complex geometry of thermal oxidizer systems means that the assumption of perfect mixing of gases from different sources may not be appropriate in all thermal oxidizer applications. It is possible that computational fluid dynamics modeling of a thermal oxidizer system in purging scenarios could resolve uncertainties in the evaluation of waste gases for purging operations, although it may impose a heavy computational burden.

While a more detailed analysis accounting for these factors could be explored in future work, this paper demonstrates that caution is warranted when a sulfur recovery unit (SRU) thermal oxidizer burner management system (BMS) permits a restart while tail gas or TGTU off-gas is still flowing. In light of these considerations, Zeeco recommends following NFPA 86 as a general guideline.

6. REFERENCES

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