Thermal Oxidizer Experiences at a Treatment, Storage, and Disposal Facility

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ABSTRACT

Two thermal oxidizer systems were selected and installed to dispose of volatile organic emissions generated by a waste disposal operation. This paper provides a description of each case study.

A Regenerative Thermal Oxidizer (RTO) system was selected to treat contaminated air from a drum processing operation. Previous treatment was by adsorption on activated carbon. High carbon costs drove the change to combustion, after water scrubbing and other approaches were rejected. Combustible dust entrainment and occasional solvent fume spikes in the air stream resulted in detonations inside the RTO and damage to the heat exchange packing on two separate occasions. Installation of a dust filter and two flammability range analyzers, plus automatic diversion dampers has proven effective in eliminating the problems.

A Direct Fired Thermal Oxidizer (DFTO) was selected to treat contaminated air from tank truck and railcar cleaning operations, after an RTO or a flare were judged to be impractical. DFTO operation was successful, but occasional spikes in hydrocarbon load drove the stack out of oxygen[MEG1], resulting in smoke and flame above the stack and flashbacks to the waste gas detonation arrestors on more than one occasion. Installation of waste gas analyzers allowed temporary DFTO bypass during spikes. Improved process gas monitoring enabled quicker response times.

INTRODUCTION

Systech Environmental Corporation is a fully permitted TSD (Treatment, Storage, and Disposal) facility which operates a waste processing plant adjacent to the Lafarge North America cement plant in Fredonia, Kansas. Hazardous and non-hazardous waste materials are shipped to Systech in rail cars, tank trucks and drums, where they are tested, moved to tankage, blended and provided to Lafarge to supplement the purchased fuel used to operate the cement kiln.

During waste material handling, solvent fumes are produced. The adjacent Lafarge cement kilns are utilized as the control device(s) for the fumes from Systech's storage tank farm. Fume contaminated air from Systech's drum handling operation was being cleaned using activated carbon adsorption. Fume contaminated air from Vacuum Trucks at the tank truck and rail car cleaning operations were being vented to atmosphere. Systech wanted to treat all emissions.

Activated carbon treatment was successful, but carbon costs were substantial, and drove Systech to consider alternate means of treatment for the drum handling fumes. Based on previous testing of the fumes, a Regenerative Thermal Oxidizer (RTO) was selected to treat these fumes.

The contaminated air from the Vacuum Trucks used for tank truck and rail car cleaning was judged to be too rich for use of an RTO. The operation is intermittent, and flaring was considered, but fuel costs would have been prohibitive. A Direct Fired Thermal Oxidizer (DFTO) was selected to treat these two streams.

Initial operation of the RTO was successful, but dust entrained in the contaminated air during drum handling, eventually plugged the detonation arrestor at the inlet to the waste gas blower, requiring frequent cleaning. It appears that dust also collected in the structured packing used for heat transfer within the RTO. After a month of operation, unusually volatile waste solvents temporarily brought the contaminated air into the flammable range, resulting in a deflagration that damaged part of the RTO. This and a second incident a few weeks later forced reevaluation of the RTO control system. Addition of a dust filter and two Lower

Flammability Limit analyzers, combined with automatic diversion of the air stream to the activated carbon system, have resulted in good performance with much reduced carbon costs and very low fuel gas usage.

Initial operation of the DFTO was also successful, once startup bugs were fixed. A few weeks later, flames and smoke were seen exiting the DFTO stack, apparently due to periods of high fume load in the contaminated air stream. On two occasions, flashbacks occurred on the tank truck cleaning side of the system. The detonation arrestor situated at the DFTO battery limit worked as planned. Further evaluation led to the installation of process gas flammability monitors and additional programming and safety controls.

THE PROCESS AT SYSTECH

Description of the Container Processing Building Operation before Upgrade

After initial testing, drums of waste materials are placed on a conveyor and moved to one of two drain stations, where the contents are removed and further mixed with solvent material. The liquids are pumped to one of several storage tanks. Fumes are released during draining, so a ventilation hood covers each station. The hoods are networked together and connected to a transfer blower located on the roof of the building. In this way, fume exposure in the operating area is limited. Originally, the transfer blower discharge was sent to a nearby Carbon Adsorber where the hydrocarbons were captured and clean air was vented. A granular coal-based activated carbon (Tigg 5C from Tigg Corporation – see reference 1 below) was being used. Periodic testing of the clean air was used to determine when to replace the carbon. Costs for the replacement carbon were averaging about $7,000 per week.

Fig. 1. Systech Container Processing Building vent system – transfer fan on roof feeds activated carbon adsorber at left (grey box with double doors)

Description of the Vacuum Truck operation before upgrade:

Systech accepts bulk shipments of waste liquids in tank trucks, roll-off boxes, and rail cars. Each type of container has its own unloading area, where the contents are tested and then pumped to one of several storage tanks. Once the container is emptied, any "heel", including solids and residual liquids, is removed using a Vacuum Truck. In the vacuum truck tank, a diluent is added and the resulting mixture is pumped to the tank farm. Air leaving the vacuum trucks is contaminated with hydrocarbon fumes. It is forced through a water contact tower for cooling and then into a 300-gallon water drop-out tank via flexible hoses. Before the upgrade, the treated air was released to atmosphere.

Fig. 2. Tank Truck Unloading and Tank Farm

Description of the Tank Farm operation (no upgrade was needed):

Systech transfers the waste liquids into various holding tanks, where mixers assure uniform composition. Based on lab testing, the contents of the holding tanks are blended into secondary tanks to prepare a liquid with properties suitable for firing in the cement kiln burner. Each tank is equipped with a mechanical mixer and a vacuum relief valve. Tank vapors pushed from a tank due to liquid filling or simple breathing are ducted through a flame arrestor into a vapor gathering system and sent (via detonation arrestors), to the cement kiln for destruction. This system works well and was not modified.

INITIAL EVALUATION – CONTAINER PROCESSING

The Container Processing Building exhaust air stream was evaluated first, due to the on going cost for activated carbon. Considerable information from routine lab testing was available. To supplement this, carbon samples from the adsorber bed were sent to a contract laboratory for analysis. From this, a list of hydrocarbons and their approximate rate of occurrence was compiled for use in evaluating the treatment options. The most prevalent compound was methanol, followed by toluene and hexane.

Periodic testing with hand-held monitors suggested that the hydrocarbon loading in air from the Container Processing Building could range from 25 ppmv up to 2000 ppmv with a total airflow rate of 1.27 nm^3/sec (2700 SCFM).

Table I. Hydrocarbons handled by Systech (from lab testing)

Compound	Estimated Average Weight %
Methanol	63.64
Acetone	2.39
Benzene	0.43
Ethylbenzene	0.69
4 Methyl 2 Pentamine	2.81
Tetrachloroethene	1.11
1,1,1 Trichloroethane	0.21
Trichloroethene	0.24
Toluene	11.14
Xylene	0.90
Ethyl Acetate	0.95
Hexane	9.02
n Butyl Acetate	2.55
3 Methyl Hexane	0.64
Cyclohexane	0.17
Isobutyl Acetate	1.86
Methyl Cyclohexane	0.74
Pentane, 2-methyl	0.52

Several treatment processes were considered. The evaluation included these aspects:

1. Safety
2. Hydrocarbon removal efficiency (DRE at least 95%).
3. Capital cost.
4. Operating cost.
5. Maintenance cost.

The goal was to select a process at least as effective at removal as the existing carbon adsorber, but with substantial reduction in operating and maintenance costs. The carbon adsorber was judged very safe. Treatment by combustion had not been used at the plant. Several of the processes to be considered involved combustion, but strict adherence to NFPA guidelines (Reference 2) plus input from the system suppliers were judged sufficient to satisfy safety concerns.

The processes considered were these:

1. Water scrubber.
2. Activated carbon adsorption with on-site regeneration.
3. Catalytic Oxidizer.
4. Flaring (either elevated or enclosed).
5. Direct fired thermal oxidation (DFTO)
6. DFTO preceded by a hydrocarbon concentrator system.
7. Regenerative Thermal Oxidizer (RTO)

Water scrubbing was quickly rejected. Although methanol was the most common hydrocarbon found during testing, many of the other compounds were relatively insoluble in water. Inserting a water scrubber ahead of the existing carbon bed would reduce carbon costs by about 50%, which made this option attractive. However, the high vapor pressure of methanol meant that the scrubber exhaust would quickly become methanol rich without a substantial scrubber blowdown. No ready means of disposing of the scrubber blowdown was available, so this option was set aside.

Use of activated carbon had proven effective at the Container Processing Building, but replacement costs were high. Substituting a system with provisions for thermal or vacuum regeneration was considered. The fact that several of the hydrocarbons would be difficult to fully remove from the carbon without radical thermal regeneration meant that this approach was impractical – costs were judged to be about as high with on-site regeneration as with the existing replacement strategy.

Catalytic oxidation was rejected due to the variability of the solvent types involved. Small amounts of chlorinated solvents such as Tetrachloroethene were known to be present, so concern about catalyst replacement costs led to rejection of this option.

Flaring got a more careful look. An elevated flare was rejected because the flame would be visible to the neighbors. Plus, while capital cost for an elevated flare would be relatively low, fuel costs were expected to be high (40 CFR 60.18 requires fuel addition if needed to assure a flare gas heat content of 7.45 MJ/sm^3 (200 btu/scf) – a value well above what was expected, on average.)

An enclosed flare, instrumented and controlled to operate like a DFTO, would not require a minimum heat content, but maintaining the stack temperature high enough to achieve 95% DRE with the typically low hydrocarbon content from the Container Processing Building would still require excessive fuel gas usage. A flare here would be a bad choice.

Fig. 3. Elevated Flare supported by an adjacent stack.

Fig. 4. Typical Enclosed Flare (Courtesy TCE – Ref. 3)

A DFTO was considered for use at the Container Processing Building. Fuel usage would be high, even with a recuperative heat exchanger in place. Plus, using a heat exchanger presented its own problems – weld integrity problems due to frequent on/off operation each week meant high maintenance costs were likely.

Using a concentrator ahead of a DFTO would have reduced the size of the DFTO, as well as its fuel demand, since most of the oxygen and nitrogen in the contaminated air would be rejected straight to atmosphere before entering the furnace. Concentration using a hydrophobic zeolite rotor (Munters Zeol) was investigated, but that type system is poor at picking up methanol, one of the main compounds present.

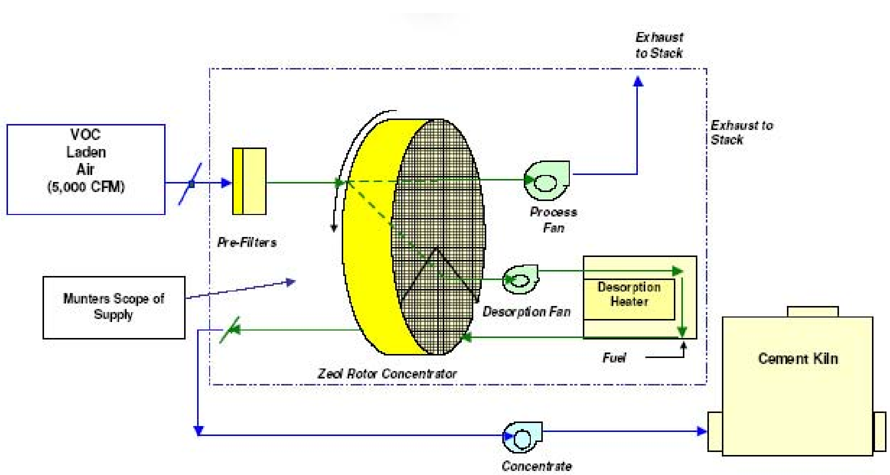

Fig. 5. Diagram shows Munters (Ref. 4) concentrator proposal for Systech vent gas disposal (kiln rather than DFTO)

Using an RTO for the Container Processing Building vent seemed reasonable – the beds of ceramic heat exchange packing would keep fuel usage low and various bypass arrangements were available to reduce heat recovery when higher solvent concentrations were present in the waste air.

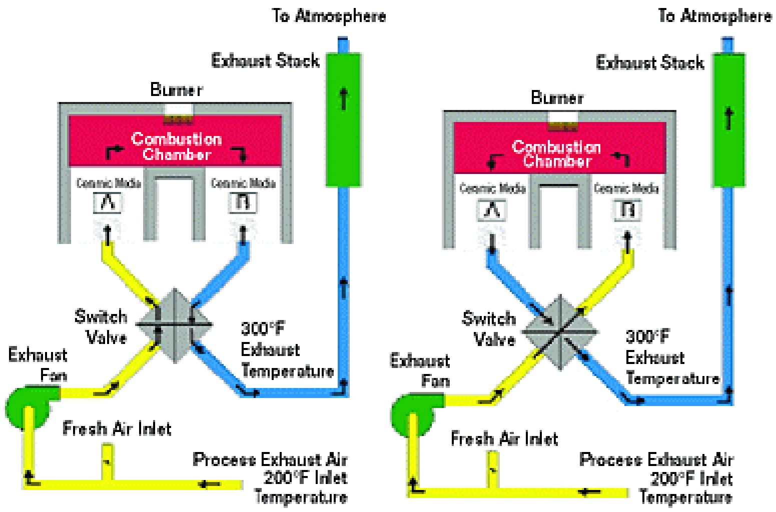

Fig. 6. Typical RTO Operating Diagram (courtesy of MEGTEC Systems – Ref. 5)

TREATMENT HARDWARE SELECTIONS

Based on the initial study, an RTO with "hot side bypass" from CMM Group (Ref. 6) was selected for treatment of the Container Processing Building vent.

RTO Operating Problems and Solutions

Installation and startup of the RTO were uneventful. The duct from the collection hood ID fan to the carbon adsorber was replaced with one from the ID fan to the RTO waste gas blower inlet. An Enardo detonation arrestor was positioned a few feet upstream of the RTO waste gas blower. Between the DA and the Container Processing Building was added an automatic isolation damper and an automatic fresh air damper (for RTO operation without the process air stream).

Fig. 7 Systech RTO with waste gas duct from Container Processing Building at left.

The photo above shows the RTO shortly after startup. The waste gas duct enters from the left. The waste gas passes through a motor actuated block damper (just above a motor actuated fresh air entry damper – both actuators blue) and then through a detonation arrestor and into the RTO waste gas fan. The clean gas outlet stack is just to the right of center. The heat exchange packing is located in each of tall rectangular boxes, the waste gas inlet and flue gas plena run across the base of the unit, and the combustion chamber runs across the top of the unit. The primary path for the cooled, treated gas is from the lower plenum to the stack base (covered with aluminum lagging). An alternate path direct from the combustion chamber to the stack (gray painted steel with internal refractory lining) is provided as a "hot gas bypass" when waste gas hydrocarbon content is high. The bypass reduces heat transfer to the packing, resulting in less waste gas preheat and a cooler combustion chamber – useful for avoiding an over-temperature situation when the waste gas is rich.

The RTO seemed to work well for several weeks aside from periodic fouling of the DA with dust from the drum emptying operation. Differential pressure across the DA was used to monitor fouling. Cleaning involved disassembling the DA and removing the dust with a pressure washer.

Finally, the operators noted a series of loud noises from the RTO, culminating in an explosion that damaged the flexible boots on the waste gas blower and the waste gas inlet plenum on the RTO. The RTO combustion chamber temperature was approaching the high temperature shutdown level, and the control logic was set to restart the system automatically following any shutdown. During this incident incandescent sparks were observed flying out of one of the vent capture hoods in the Container Processing Building. What caused this effect is still not understood. There were no injuries or damage to other Systech equipment.

Fig. 8. RTO end view.

The RTO was shut down and opened for damage inspection and to determine the cause of the flashbacks. Aside from damage to the waste gas inlet plenum at the bottom of the vessel, only a few of the soft ceramic fiber refractory modules lining the furnace were damaged, but the structured ceramic heat transfer packing was severely damaged. The packing damage looked like melting, but the melted areas were irregular and included sections with "worm hole" melting extending at angles across and through the body of many of the ceramic blocks (see photo). Ultimately, the packing damage was associated with the dust-fouling problem. Elevated temperature in the packed bed must have caused the melting, but the melting was not uniform. Nonuniform dust deposition through the small gas passages in the packing, accompanied by burning of the dust, possibly under a localized reducing atmosphere, is the most likely cause of the damage pattern.

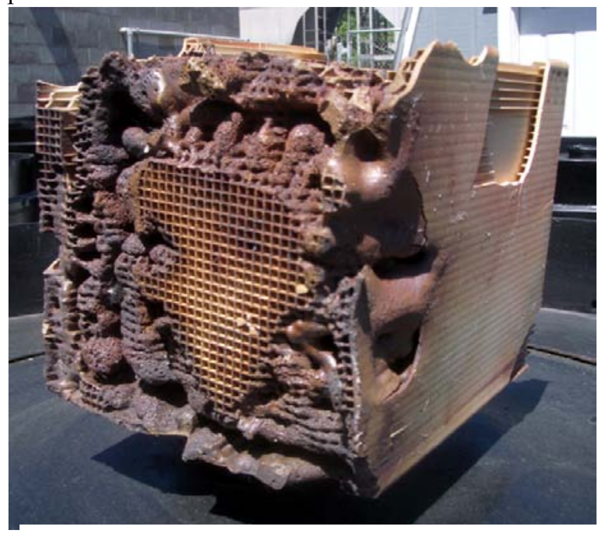

Fig. 9. Damaged RTO packing.

The damage to the RTO shell was caused by pressurization from a deflagration or detonation in the waste gas plenum. The RTO combustion chamber was not damaged. RTOs are designed to operate with waste gas well below the Lower Flammable Limit (LFL). The damage seen in this unit must have been caused by the waste gas entering the flammable range, contrary to expectations. This was probably due to processing of one or more drums of unusually volatile solvent in the Container Processing Building.

Systech made several changes to prevent further problems. These included eliminating the dust problem and automatically diverting the waste gas away from the RTO when it approaches the LFL. These were the specific changes that were made:

1. Add a dust filter to the waste gas duct between the point source pickup and the blower at the Container Processing Building. The filter is designed to permit easy filter cleaning and replacement.
2. Add two LFL analyzers with alarms on the waste gas duct. One monitor was used to divert process gas to carbon and the second monitor controls the automatic unit shutdown.
3. Reconnect the activated carbon treatment system – the waste gas normally flows to the RTO but can be diverted to the carbon unit so that solvent emissions are always controlled. An actuated damper was added to isolate the carbon unit during normal operation.
4. Replace the stock RTO isolation damper actuator with a fast acting actuator to minimize the flow of waste gas to the RTO when the LFL signal was received.

With these changes, the system has worked well for over a year. Occasional LFL diversions have occurred, but replacement carbon costs are now very low. Due to the high thermal efficiency of the RTO, fuel gas costs have also been very low.

INITIAL EVALUATION – VACUUM TRUCK OPERATIONS

The same criteria were used for the evaluation of a control device for the vacuum truck operations. Testing of the Vacuum Truck operation showed a hydrocarbon range of 10 ppmv to 17,750 ppmv and a total flow of 10,200 sm^3/hr (6,000 SCFM) from two sites. Since the Vacuum Truck vents could be much richer, and, even with bypassing, too much heat would be available, an RTO would not be practical in that application. Water scrubbing, activated carbon, and catalytic oxidizer were impractical due to reasons mentioned before.

The waste air from the vacuum truck operation was known to contain more hydrocarbons, so an enclosed flare was retained as a viable option. A DFTO (without a preheat exchanger) was also judged viable for the richer Vacuum Truck situation, so this was kept in consideration.

A flare was not chosen due to variability in the composition of the waste stream requiring excessive gas usage and increased operating costs.

Therefore, based on vendor recommendation, waste gas variability, and intermittent operation, a DFTO from Advanced Environmental Systems (now Air-Clear LLC – Ref. 7) was selected for disposal of the Vacuum Truck vents.

DFTO Operating Problems and Solutions

The two vacuum truck discharge vents were ducted separately to the DFTO for treatment. Line A transfers waste air from the tank truck cleaning operation and Line B (shown in photo) transfers waste air from the rail car cleaning operation. The ducts are galvanized steel mounted about 3.7 m (12 ft.) off the ground and sloped away from the DFTO for drainage of any water entrained by the simple scrubber at each vacuum truck. A barometric damper is located between the scrubber and the DFTO, so that if the vacuum truck operator needs to stop operation, air still flows through the duct to the DFTO. A filter box removes any particulate matter before the waste air flows to the DFTO system. The waste air blowers at the DFTO have Variable Frequency Drives. The VFD speed is automatically adjusted to maintain a constant waste air flow based on in-line flow meter readings. Operation is interrupted before the flow is low enough to allow a flashback into the duct.

Fig. 10 Vent line "A"

Waste air flows across redundant flow meters, past a pneumatically actuated isolation damper, past a modulating pneumatically actuated fresh air inlet (startup) damper, through a Detonation Arrestor, and into a centrifugal Process Blower. Thermocouples located between the detonation arrestor and process blower provide operational data. Each blower can put up about 6.9 kPa (1 psig) at a flow of 5,100 sm^3/hr (3000 SCFM). Each stream then enters the DFTO burner. The two streams enter the burner through identical circular openings located side-by-side at the face of the burner. A duct-type burner with interrupted natural gas pilot is used to bring the DFTO up to temperature and then to assure a minimum stack temperature at 815^oC (1500^oF) regardless of vent gas hydrocarbon content. The burner fires into a horizontal rectangular carbon steel furnace lined with ceramic fiber modules. Just past the burner, a third blower injects additional air if needed to keep the furnace temperature below 1038^oC (1900^oF). The flue gas is then sent to atmosphere via a 6.1 m (20 ft.) stack constructed similar to the furnace.

Fig. 11. The DFTO system in operation. Waste air enters the Detonation Arrestors from the top and is transferred to the DFTO burner via the red Process Blowers.

The DFTO system also operated well for several weeks, once some initial startup problems were resolved.

During normal vacuum truck operation, the target furnace temperature is maintained automatically, but on several occasions smoke and even flames have been observed at the stack tip. The operator shuts down the DFTO under this condition.

On two occasions, there has been a flashback in Line A. The DA in that line seems to have functioned well, but a pressure surge in the duct blew the lightweight cover off of the particle filter enclosure, startling the operator. The flashbacks generated enough pressure to deform the Process Blower casing. No other damage and no injuries occurred.

Upon review of the incident, it appears that the hydrocarbon content of the waste air became high enough to over power the cooling air blower. With smoke and fire at the stack tip, it is likely that the furnace was operating under starved-air conditions. No easy explanation for the two flashbacks was discovered. The DFTO was designed to operate with the waste air in the flammable range, but the waste air velocity entering the burner should have been enough to prevent a flame from reaching the Process Blower or DA.

Following the flashback events, the DFTO system was operated cold to investigate any potential intermittent problems, such as dampers switching to the wrong positions, loss of blower speed, etc. Nothing unusual was discovered.

Systech made several changes to prevent further problems with DFTO operation. These included monitoring the hydrocarbon content of the waste air streams, monitoring the DFTO stack oxygen content and adding rupture disks in the waste air transfer lines.

These were the specific changes:

1. An LFL monitor was installed on each waste air duct. These are used to signal any abrupt rise in hydrocarbon content of the stream and serve as an early warning of potential problems to the operator, as well as process control for the DFTO. LFL monitors were selected rather than calorimeters due to the trouble-free operation of the LFL monitors at the Container Processing Building, as well as the slow response time for the calorimeters investigated.
2. A rupture disk with an elevated discharge "snorkel" was installed between the Process Blower and the DA on each waste air duct. This is intended to minimize any pressure surge in the waste air duct, should a flashback occur again.

High readings from the LFL monitor result in closure of the waste air block damper and opening of the fresh air damper to allow the DFTO to continue operation in idle mode. Once the waste air LFL signal returns to an acceptable level, the control system resumes flow of waste air to the DFTO.

A COMMENT

The complexities and variability of these types of operations can pose significant technical challenges. Therefore, proper management of change is critical to the safe and effective operation of these units.

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