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Environmental Products for Industrial Solutions

Technology Selection Criteria for VOC Control

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Introduction

The term VOC (volatile organic compound) represents a very broad classification of emissions. Organic gases as diverse as formaldehyde, benzene and chloroform are measured, classified and regulated as VOC.

Such a general definition presents a problem to engineers concerned with developing technologies to reduce VOC emissions. This paper presents an overview of the criteria that designers should consider when selecting a "tail-pipe" technology for abating VOC emissions.

Technology Options

While there are dozens of theoretically feasible approaches to controlling VOCs, practically speaking there are currently only three approaches. Within each approach there are several options.

- Thermal oxidation
- Adsorption and recovery
- Biofiltration

A brief description of each follows:

Thermal Oxidation – Here VOC vapors are incinerated at temperatures sufficient to cause complete oxidation. Typically, thermal oxidizers operate at 1500 ° Fahrenheit. The important consideration is energy consumption. The simplest technique would be to heat the gas in an ***afterburner*** to >1500 ° F and not recover any heat. Unless the gas stream is very rich in VOC, this would be cost prohibitive.

Thus, most thermal oxidizers are configured with some form of energy recovery. There are two basic energy recovery techniques. The first is the ***recuperative*** thermal oxidizer, which uses an air-to-air heat exchanger to recover some of the energy from the 1500 degree oxidation process. An alternative to this is the ***catalytic*** recuperative thermal oxidizer, which only operates at 800 ° and uses a catalyst bed to effect complete oxidation.

The third type is the ***regenerative*** thermal oxidizer (RTO). This design utilizes multiple heat recovery media beds (normally made of a ceramic material) which store the thermal energy from the combustion and return it to the incoming gas stream during alternating cycles in which the gas reverses flow.

Adsorption/Recovery

Adsorbtion/Recovery systems utilize a bed of sorbent materials such as activated carbon or zeolites. These materials physically adsorb the VOC to separate it from the gas stream. After the sorbent bed is saturated the VOC it is desorbed as a concentrated vapor using hot gas or steam. The concentrated VOC may then be recovered by condensing as a liquid. (The desorbed VOC may also be oxidized; because it is in a concentrated form. Energy recovery is not an issue.)

Biofiltration

Biofiltration works by passing the VOC laden gas stream slowly through a bed of material which contains a culture of living microorganisms (fungi, bacteria, algae, etc.). These microorganisms are cultured to absorb and metabolize the specific VOCs in the gas stream.

Economic Considerations

As is normally the case capital costs for these systems are in direct conflict with operating costs. For example, an afterburner system is quite very simple and as a consequence is very low in first cost. Lacking any provision for heat recovery however, the cost of natural gas to operate an afterburner system is normally prohibitive.

On other side of the spectrum is the adsorbtion/recovery technology. These are sophisticated system with high capital investment requirements. However, in recovering the VOC rather than destroying it they frequently provide a definable payback.

Exhibits 1 and 2 show a general view of the relative capital and operating costs for the technologies described above.

Technical Considerations

In addition to the economics discussed above, there are numerous technical factors that affect the choice of VOC control technology.

The most important of these are the regulatory requirements. More than any other factor, the demands of local, state or Federal regulations and/or enforcement actions will set the basic tone for the technology required to control VOC emissions. Typically, regulatory requirements fall into three categories of VOC reduction requirements. These are,

- High efficiency (> 99%)
- Moderate efficiency (95 to 99%)
- Low efficiency (< 95%)

While there are exceptions to every rule, in general, only afterburner oxidizers can be reliably designed to exceed 99% efficiency. Recuperative, catalytic recuperative and regenerative oxidizers meet the demands of the moderate efficiency category and adsorbtion/recovery systems and biofilters can not be expected to do much better than 95% under most real world situations.

The second factor is the amount of VOC in the gas stream. If the VOC levels are high enough, low energy efficiency afterburners might be favored because the energy available from the VOC may reduce or replace the energy provided by an auxiliary fuel such as natural gas. Some rough guidelines for thermal oxidizer choices at different VOC concentrations are shown below:

VOC Concentration (% LEL)	Technology Choice	Thermal Efficiency
0 to 10%	Regenerative Thermal Oxidizer	80 to 95%
10 to 40%	Recuperative Thermal Oxidizer	50 to 80%
40 to 100%	Afterburner Thermal Oxidizer	0%

Notes:
1) LEL is the lower explosive limit. This is the concentration of the VOC at a given temperature which combustion (explosion) will occur without any auxiliary fuel.
2) Thermal Efficiency is the percentage of the oxidation temperature that is recovered.

In addition, biofiltration is only applicable on gas streams where the VOC concentration is below 1000 parts per million and the temperature is less than 105ºF. This is because it is very difficult to develop a stable biological culture at very high, and potentially toxic, VOC concentration.

Finally, with respect to adsorbtion/recovery systems, the amount of VOC is best considered in terms of the economic value when recovered. A low concentration of a valuable solvent might justify the investment expense required for such a system. Conversely, if the VOC stream is comprised of many different species then an adsorbtion/recovery system would not be feasible even if the VOC concentration were relatively high.

The last major factor to consider is the gas stream condition. Specifically, what is the flow rate, the temperature, the moisture content and the particulate concentration, if any. Each of these factors can make or break a technical option which would be economically attractive. Comments on each of these gas stream parameters follow.

Flow rate – In applications involving very low flow rates (i.e. < 1000 cfm) it is sometimes most practical to select a simple afterburner or a recuperative thermal oxidizer even if the operating costs are relatively high. The significantly higher capital cost of RTOs, absorbtion/recovery systems or biofilters are normally not offset by energy savings at such low flow rates.

In the case of very large flow rates energy expense can be very significant and the extra complexity and first cost of more sophisticated systems is often worth the investment.

Temperature – High gas temperature will quickly eliminate the biofiltration option. If the wet bulb temperature of the gas stream is over about 105 º Fahrenheit then keeping a biofilter "alive" is much too difficult for real world operation.

High temperatures also made adsorbtion/recovery system unfeasible.

Thermal oxidation, on the other hand, would be favored under high gas temperature situations because of the reduced energy required to raise the gas stream to the proper oxidation temperature.

Moisture – The water vapor content has a major influence on the decision to consider adsorbtion/recovery system. Too much water vapor will interfere with the affinity of the sorbent to adsorb the VOC.

With respect to oxidizers, the very high heat capacity of water vapor may have a significant effect on the sizing of the system. An oxidizer treating a gas stream with 30% water vapor will require much larger burners than one treating a gas stream with 5% water vapor.

Particulate – Perhaps the trickiest challenge is understanding the effect of particulate matter on the choice of VOC control technologies. Particulate matter is a broad and frequently misunderstood subject.

In general, if the gas stream has heavy particulate loadings (greater than 0.02 grains/scfd) it would be wise to avoid any of the technologies that involve passing the gas through a bed of material; RTOs, biofilters and absorbtion/recovery systems.

However, if the particulate matter is actually a condensable material such as an oil, then the option of an RTO may be acceptable. This is because the heat recovery beds of an RTO are always hotter than the incoming gas stream so that condensable particulate may re-evaporate once it enters the heat recovery bed.

A matrix showing the suitability of each of the technologies with respect to the factors discussed is shown in Exhibit 3.

Case Studies

To illustrate some of the factors discussed above, below are four case study summaries.

Case 1 – Manufacturer of Specialty Medical Products

Required VOC removal	-	99%
Gas Flow Rate	-	1500 scfm
Gas Temperature	-	100º Fahrenheit
VOC loading	-	10 lb/hr
VOC	-	Xylene with small amount of silane
Technology choice	-	Recuperative thermal oxidizer @ 65% thermal efficiency
Capital cost	-	$145,000 (equipment only)
Operating costs	-	$ 3/hr (natural gas)

Factors affecting technology choice:
The small size and high efficiency requirements make this an obvious application for a simple recuperative oxidizer. The silanes, when oxidized will form SiO2 which could plug an RTO or a catalytic oxidizer. Biofiltration is unproven on this gas stream and there is not enough xylene to be worth recovering in an adsorbtion/recovery system.

Case 2 – Tire Cord Coating and Impregnating Operation

Required VOC removal	-	90%
Required Opacity at outlet	-	0%
Gas Flow Rate	-	25,000 scfm
Gas Temperature	-	450º Fahrenheit
VOC loading	-	10 lb/hr
VOC	-	Phenol, formaldehyde & 1,3 butadiene
Particulate	-	Organic condensables such as rescorsinol and latex
Technology choice	-	Regenerative thermal oxidizer @ 92% thermal efficiency
Capital cost	-	$450,000 (equipment only)
Operating costs	-	$ 6/hr (natural gas)
		$ 5/hr (electricity)

Factors affecting technology choice:
With very low VOC loadings and a relatively high gas flow rate, energy efficiency was of prime importance in the choice of an RTO for this application. The only major concern was the presence of high loading of condensable particulate matter. These condensables, however, were known to revaporize in the RTO heat recovery chambers so that build up is not a problem.

Case 3 – Gravure Printing

Required VOC reduction	-	95%
Gas Flow Rate	-	600,000 scfm
Gas Temperature	-	100º Fahrenheit
VOC loading	-	8500 lb/hr
VOC	-	Toluene
Particulate	-	none
Technology choice	-	Adsorbtion/Recovery system efficiency
Operating savings	-	Capital investment returned in less than three years

Factors affecting technology choice:
A very high gas flow rate, high VOC emission potential, homogeneous VOC mix and high economic value of the VOC make this application well suited for the use of an adsorbtion/recovery system such as the one restored. In addition, there were no problems such as high temperature, excessive particulate or the requirement for very high VOC removal.

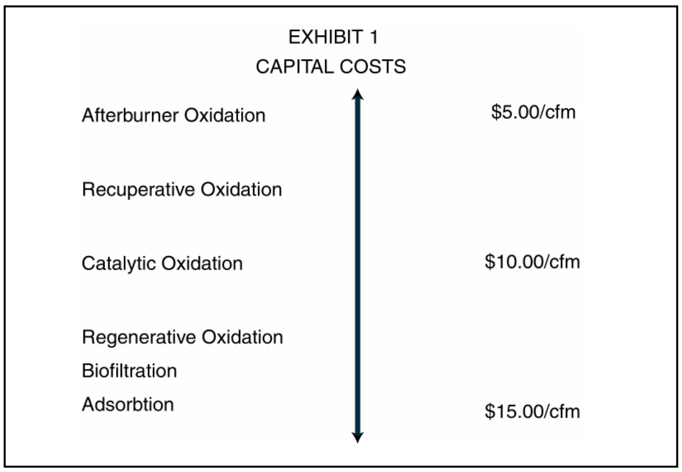
Case 4 – Particleboard Press Vent

Required VOC reduction	-	90%
Gas Flow Rate	-	100,000 scfm
Gas Temperature	-	100º Fahrenheit
VOC loading	-	100 lb/hr
VOC	-	Formadehyde, phenol and terpenes
Particulate	-	< 0.01 gr/scfd
Technology choice	-	Biofiltration
Operating cost	-	$ 12/hr (electric)

Factors affecting technology choice:
The high gas flow rate, low VOC emission potential, low efficiency required and low particulate concentration make this application a candidate for biofiltration. Previous pilot testing had shown that culturing a biomass to treat this particular mix of VOCs would be possible. The low energy consumption of a biofiltration system was also very attractive.

Conclusion

When selecting a control system to reduce VOC emissions it is important to carefully consider all aspects of the process and the emission stream. There is a control technique for any VOC problem. Making the right choice will depend on a good understanding of the problem.



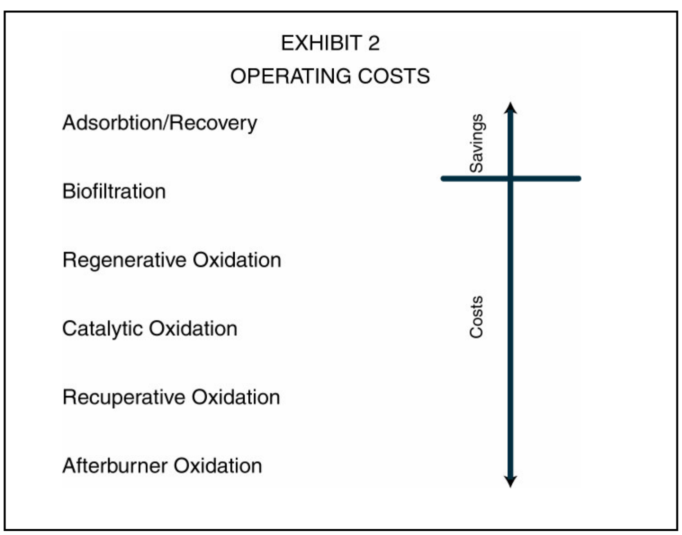


EXHIBIT 3

TECHNOLOGY CHOICE

	PROJECT DEMAND	**Afterburner**	**Recuperative Oxidizer**	**Regenerative Oxidizer**	**Catalytic Oxidizer**	**Adsorbtion**	**Biofilter**
Regulation Required	High Destruction Efficiency Required	X					
	Moderate Destruction Efficiency Required		X	X	X	X	
	Low Destruction Efficiency Required			X	X	X	X
VOC Emissions	Very High VOC Loading	X	X			X	
	Moderate VOC Loading			X	X	X	
	Low VOC Loading			X			X
Gas Stream Conditions	High Flow Rate			X		X	
	Moderate Flow Rate			X			
	Low Flow Rate	X	X		X		X
	High Temperature	X	X	X	X		
	Low Temperature					X	X
	High Particulate Concentration	X	X				
	Low Particulate Concentration	X	X	X	X	X	X