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RTO or RCO For VOC Control: How To Decide

Introduction

Regenerative thermal oxidizers (RTOs) are widely accepted for the control of volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions. Years of experience with this technology have shown that RTOs can operate very reliably and do an excellent job of destroying VOCs; efficiencies of up to 99% are not uncommon.

However, even though RTOs are up to 95% efficient in energy consumption, the cost of fuel in today's marketplace is a big concern. For example, even at 95% thermal efficiency the temperature rise of the emission stream as it passes through the RTO is approximately 75º F. With present natural gas price levels at $7 per MM BTU, a source with 50,000 scfm could cost as much as $250,000 a year to supply with auxiliary fuel.

One way of reducing this energy burden is by using catalyst in the regenerative oxidation process. Catalysts work by allowing chemical reactions to proceed at lower temperatures. Thus, the regenerative oxidizer can operate at a much lower temperature with attendant fuel savings.

The big question is how do you decide if catalytic operation is appropriate for your emission control application? When does catalytic operation make sense and what pitfalls should be avoided? This paper will outline the important factors to be considered when assessing this economically attractive option.

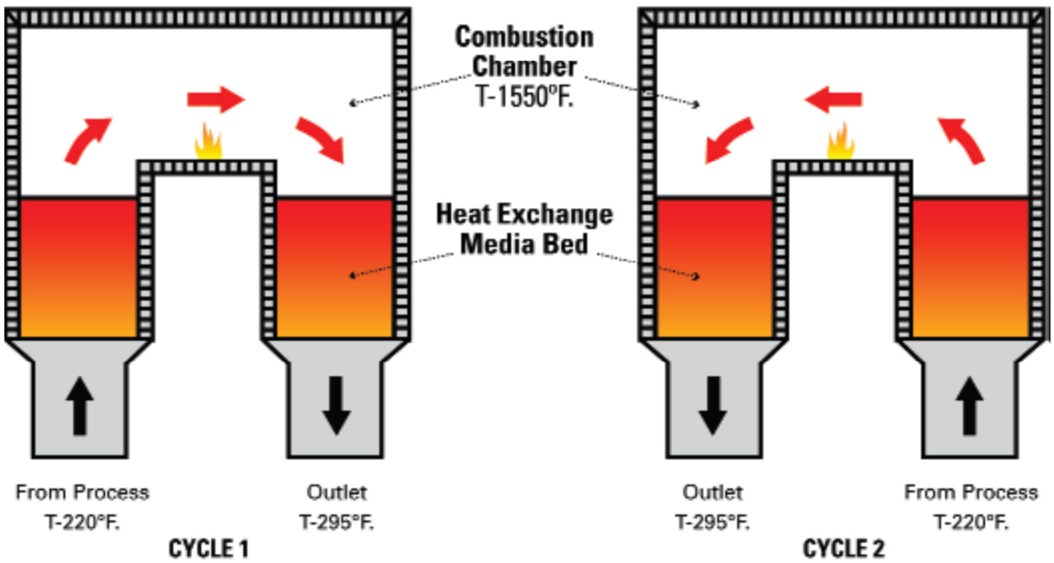
RTO Basics

Regenerative thermal oxidation technology is a simple way of preserving the temperature needed to oxidize VOCs. It works like this.

As shown in the diagram below, VOC-laden gas is routed into a heat recovery chamber that is filled with ceramic media. By passing through the inlet heat recovery chamber, the emission stream is preheated to a temperature very near the combustion chamber temperature. In the combustion chamber, a gas burner maintains the temperature to approximately 1,500°F (the temperature required for complete thermal oxidation).

Upon exiting the combustion chamber, the emission stream enters the outlet heat recovery chamber. The gas stream passes through the outlet heat transfer media bed where the heat energy gained from the inlet heat recovery chambers and combustion chamber is transferred to the ceramic heat exchange media (heat sink). This is the final step in the regenerative process. By operating in this way the discharge temperature of the gas stream can be kept to only 75°F above the inlet temperature.

After a prescribed period of time (2 to 6 minutes) the gas stream is reversed. This back-and-forth, regenerative, operation allows the RTO to recover up to 95% of the heat generated in the combustion chamber to greatly minimize fuel costs.



RCO CYCLE

HOW A CATALYTIC UNIT WORKS

By definition, a catalyst is a substance that allows a chemical reaction to proceed at lower activation energies than are necessary without the catalyst. Also, while it plays a major role in the chemical reaction it does not change as the reaction occurs. Thus, the catalyst is not consumed in the reaction. What this means is, with the right catalyst, oxidation of an undesirable organic compound can happen at lower temperatures than are normally needed. This effect happens at the surface of the catalyst. Hence, whereas 1500°F may be necessary to oxidize an organic compound in normal circumstances, the same oxidizing reaction can proceed with a catalyst at less than 800°F because of the role the surface of the catalyst plays in lowering the necessary reaction activation energy.

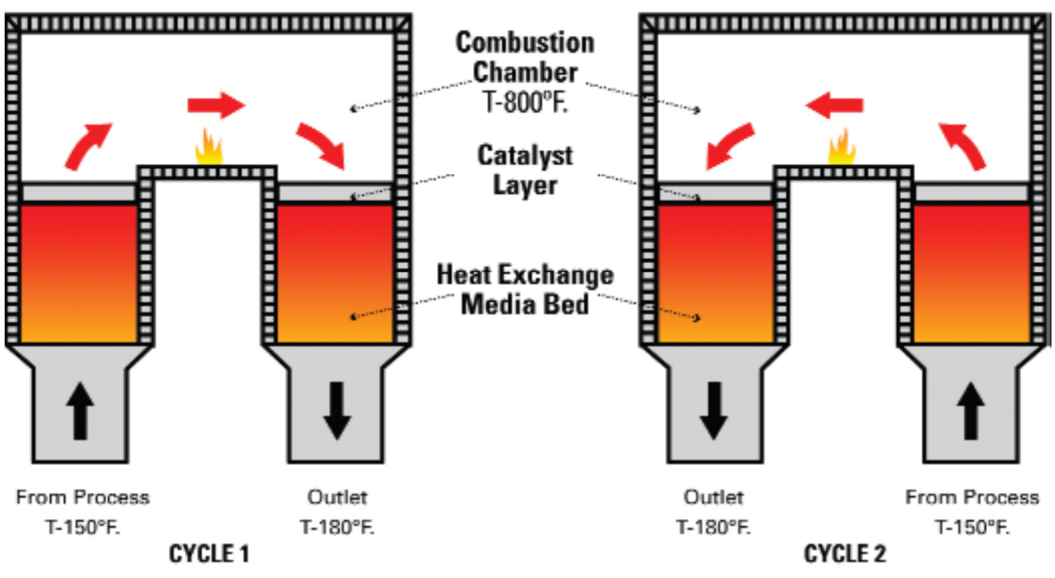
There are two major classes of VOC control catalysts: noble metals and base metals. Platinum and palladium are the most widely used noble metals. Oxidation reactions on platinum or palladium occur very fast; this is why commercial noble-metal catalysts only require a very small amount of noble metal on the surface of the substrate shape. A photograph showing noble-metal coated ceramic saddles is shown below.

Ceramic Saddles Coated with Noble Metal Catalyst

The base metal catalysts are actually oxides of transition elements of the Periodic Table, such as copper, chromium, manganese, nickel, etc. Base metal catalysts are typically less active than noble metals; therefore, larger quantities are needed. However, the much lower price for the base metal results in lower overall cost of the entire catalyst charge. Also, in contrast to surface-coated noble metal catalysts, base metal catalysts are fabricated as porous monolithic shape thus allowing for more active surface area. This also helps offset the lower activity. Photographs of typical base metal catalysts that are used in thermal oxidizers are shown on the next page.

FORMS OF BASE METAL CATALYSTS USED IN RTOS

Employing a catalyst in a regenerative thermal oxidizer is a relatively simple affair. It only requires that a bed of catalyst be added to the top of the heat recovery beds and reducing the temperature of operation from 1500°F to 800°F. This modified RTO is normally referred to as a regenerative catalytic oxidizer or RCO. A diagram is shown below.



RCO Cycle

The energy savings of this conversion are obvious. Note that the temperature rise of the emission stream as it passes through the RCO is only 30°F as opposed to 75°F in the RTO example on the previous page.

RTO or RCO

Deciding whether or not to employ a catalyst is an important decision. Properly designed, a catalytic unit can result in tremendous savings over the life of the oxidizer. However, catalysts add to the initial cost of an RTO so the decision should balance the operating cost savings against the first cost.

Before performing an economic analysis, the technical feasibility of catalytic operation should be determined. There are several factors to consider. These are:

Poisons

Certain compounds may poison a catalyst by reacting with the active sites on the catalyst to render it inactive. Typical elements that need to be considered are sulfur, phosphorus, silicon and heavy metals. Even very small concentrations of these elements can render a catalyst ineffective. The gas stream must be carefully characterized to make sure that poisons do not exist.

Particulate

Particles may or may not be important to the operation of an RCO. Particulate matter can mask or even poison a catalyst to render it ineffective. However, size and physical state must be carefully considered. For example, if the particles are coarse they will be caught in the media bed and will not reach the catalyst layer on top. Also, if the particles are condensible, the particles will re-volatilize by the time they reach the catalyst. Neither case would prevent catalyst operation. However, if the particulate is very fine it may reach and deposit on the catalyst layer. The message here is to make sure you evaluate the type and concentration of the particulate going into the RCO. You may be surprised. Particles in the gas stream do not necessarily mean that RCO cannot be used.

VOC Concentration

Perhaps this is the most important factor. If the VOC concentration is too high there is no point in considering catalytic; i.e., at a typical 95% thermal efficiency the VOC concentration may provide enough energy to operate as an RTO with little or no external fuel required. Also, temporary excursions of high VOC concentrations must be considered. Excursions can cause the RCO to overheat and threaten the catalyst.

EXAMPLE ANALYSIS

It's all about money. If you have an application where you are confident that 1) there are no poisons 2) the particulate matter is of very low concentration or not a threat and 3) the VOC concentration is in the correct range, the economic advantage of catalytic operation should be evaluated. Here is an example of how you can do the analysis.

	RTO SYSTEM	RCO SYSTEM
Oxidation Temperature	1,500° F	800° F
Oxidizer Outlet Temperature (To)	170° F	135° F
Heat Required [scfm x 1.08 x (To-Ti)	3,780,000 BTU/hr	1,890,000 BTU/hr
Oxidizer Housing Losses	305,000 BTU/hr	230,000 BTU/hr
Combustion Air Requirement	61,000 BTU/hr	11,000 BTU/hr
Total Energy Required for Process Air	4,146,000 BTU/hr	2,131,000 BTU/hr
VOC Heat (100 lb/hr) x (13,500 BTU/lb)	(1,350,000 BTU/hr)	(1,350,000 BTU/hr)
Net Energy Requirements	2,796,000 BTU/hr	781,000 BTU/hr
Annual Fuel Cost	$156,576	$43,736
Catalyst required (50,000 scfm) x (60 min/hr)/(6000/hr)	N/A	500 cubic feet
Catalyst Cost	N/A	$150,000
Payback	N/A	1.3 years

BASIS

Gas flow rate – 50,000 scfm
Process exhaust temperature - 100°F
VOC concentration – 300 ppm as propane (~100 lb/hr)
VOC heating value – 13,500 BTU/lb
RTO thermal efficiency – 95%
Necessary catalyst space velocity – 6000/hr
Catalyst cost - $300/cubic foot (installed)
Natural gas cost - $7.00/MM BTU
Duty – 8000 hours/year

(Note: The above analysis is based on a forced draft supply fan for the oxidizer equipment. The pressure drop for both systems has been assumed equal. If the design is induced draft the RCO system will provide additional power savings due to the lower operating temperature at the fan.)

As important as the economic analysis is, perhaps more important are the future trends for energy and capital costs. While electric costs continue to rise slowly at least they are somewhat predictable. Natural gas is much more volatile. Recently, the price for natural was over 13 per MM BTU in many locales and most people expect the long-term trend to be up. Similarly, the cost of capital and the availability of capital must also be considered because catalytic systems have a higher first cost.

Finally, the duty cycle is very important. RCOs cost more than RTOs and the economic advantage can be lost as annual operating hours are reduced. If the process duty cycle is prone to change make sure this is considered.

Conclusion

Catalytic operation of regenerative thermal oxidizers can greatly enhance the economic attractiveness RTO technology. If you do your homework and pay careful attention to the technical questions and economics you may be able to improve your operation’s bottom line.