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Concentrator System: The Preferred Solution for Dilute VOC/HAP Applications

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INTRODUCTION

Industries faced with choosing an air pollution control system for an application characterized by large air flow and dilute VOC or HAP concentration have several factors to contend with. They obviously need to select a technology that will meet all local, state, and federal emission regulations. In terms of regulations, the EPA has indicated that a new National Ambient Air Quality Standard (NAAQS) for ozone will be implemented. This will likely increase the number of non-attainment areas across the country and might result in minor emission sources being reclassified as major sources. Thus, additional pressure may be applied to sources that emit a relatively dilute source of VOC or HAP.

The chosen system also has to be cost-effective. This choice often involves comparing two or more systems, and evaluating the capital and operating costs of each. There are two technologies that are usually examined for such applications. These are the concentrator system and the regenerative thermal oxidizer. While both technologies can efficiently destroy the pollutants, the concentrator system is usually the cost-effective solution.

Some typical applications where these technologies would be considered are:
- Furniture Manufacturing
- Printing
- Automobile and truck spray painting
- Aircraft spray painting and coating
- Semiconductor manufacturing
- Manufacturing of fiberglass molded products such as shower enclosures, hot tubs, etc.
- Spray coating of various products

These applications are characterized by large airflow with VOC/HAP concentrations of 10-1,000 PPM.

Both of the technologies under discussion employ thermal oxidation for destruction of the organic contaminants. Thermal oxidation is the process of converting organic materials by raising the temperature of the organic above its autoignition point and holding it there for a period of time to complete the oxidation process. The byproducts of oxidation are CO_2 and H_2O, unless there are halogenated compounds in the process stream.

REGENERATIVE THERMAL OXIDIZER (RTO)

Regenerative thermal oxidation systems (see Figure 1 below) offer destruction efficiency up to 98%. This type of system consists of multiple chambers filled with a ceramic matrix, and a central combustion chamber. The thermal efficiency of the unit is determined by the amount of ceramic matrix provided in the chambers, and can be as high as 95%. The chambers are provided with dampers or valves to regulate the flow of air into or out of each chamber. In this manner, each chamber can act as either a pre-heat or a recovery device. Thus, energy efficiency is achieved by alternately storing and releasing heat in each of the chambers. For example, for a regenerative thermal oxidizer (RTO) with 95% thermal efficiency, the process air at 100°F will be preheated to approximately 1,430°F after it leaves the ceramic matrix in a chamber. Typically, the combustion zone will operate at 1,500°F, thus leaving only 70°F of heat-up. The heat associated with this 70°F temperature difference can be provided by the VOC in the process stream, by the auxiliary burners, or a combination of the two. The clean exhaust at 1,500°F will leave the RTO through a chamber in heat recovery mode and exit the unit at approximately 170°F. This mode of operation makes the RTO one of the most energy efficient devices for applications with large air flow. However, for dilute VOC/HAP concentration applications, the fuel consumption and pressure drop will be relatively high for an RTO. This will translate into relatively large operating costs for these particular applications.

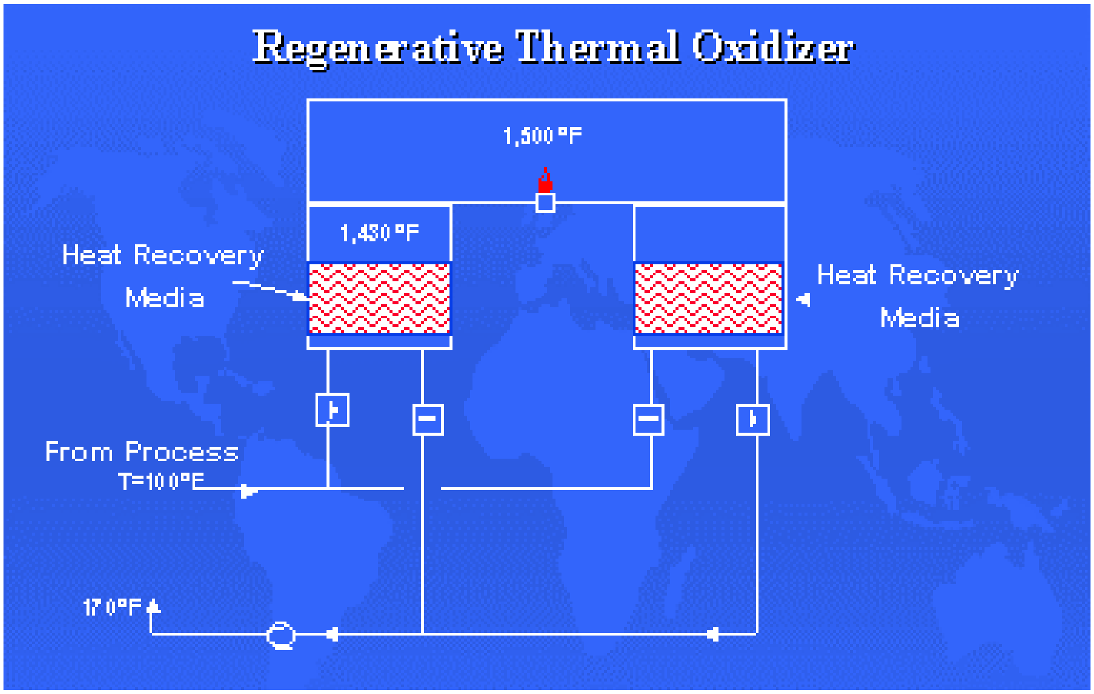

Figure 1

CONCENTRATOR SYSTEM

The concentrator system (figure 2 below) is the preferred method for controlling dilute VOC concentration applications. It is a very efficient and cost-effective alternative to thermal oxidation systems that offers far lower operating costs. The concentrator system is a hybrid system that is composed of a concentrator module and a thermal oxidizer. The concentrator module can consist of a fixed-bed adsorber, or a rotary-bed adsorber. The difference between these two types of adsorbers will be discussed later.

These systems typically utilize a catalytic or recuperative oxidizer for destruction of the pollutants. For air streams with relatively low solvent concentration, a VOC concentrator system can be used to concentrate the VOC emissions into smaller air streams that can be handled more economically than a thermal oxidizer.

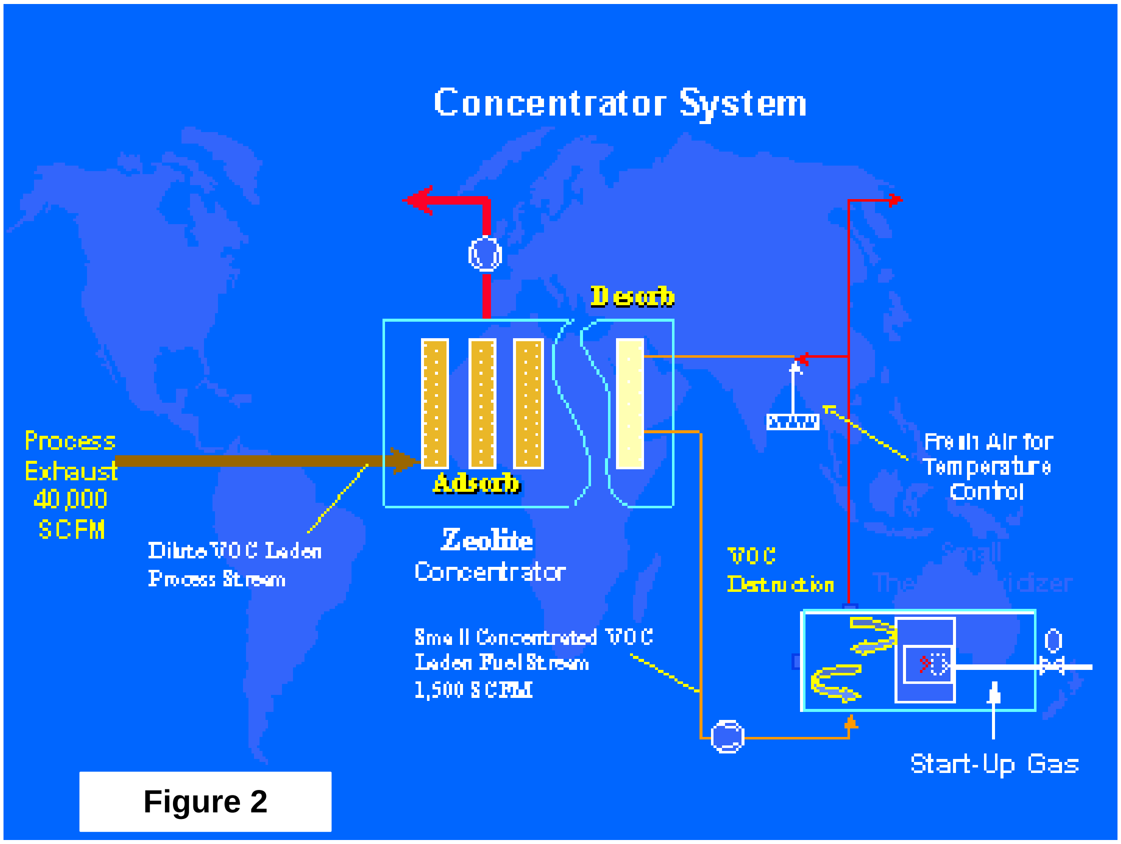

Figure 2

A catalytic oxidizer is utilized in most applications as the destruction portion of the system. This type of oxidizer makes it possible to operate at a destruction temperature of 500-600ºF rather than the 1,400ºF that is required for a recuperative thermal or regenerative oxidizer. Therefore, a catalytic oxidizer improves the already low fuel consumption that is characteristic of a concentrator system. For applications with higher inlet VOC concentration, a recuperative thermal oxidizer is the appropriate choice. The higher concentration coupled with the concentration effect will allow the recuperative thermal oxidizer to operate with little or no supplemental natural gas. The choice of oxidizer used with the system is evaluated on a case by case basis.

The concentrator system combines the technology of two different processes to achieve economical VOC removal and destruction. Exhaust from the process with a low concentration of VOC's is routed to an adsorber module. The adsorbents that are typically used are activated carbon or hydrophobic zeolite. However, this discussion will focus on the zeolite-based concentrator. The VOC-laden air is passed through the adsorbent bed where the VOC's are trapped by the process of surface adsorption. When the adsorption cycle is terminated the regeneration or desorption cycle is initiated.

The oxidizer exhaust is used to regenerate the adsorber modules. The hot oxidizer exhaust is ducted into an adsorber module, thus raising the temperature of the adsorbent, causing it to desorb and release the VOC's. This desorption air stream is usually 3-10% of the incoming process air stream. This high concentration gas is sent back to the oxidizer where it is used as a secondary fuel for the burner. The exhaust from the oxidizer is controlled to maintain the desired regeneration temperature. The oxidizer is in constant operation during the adsorption and regeneration cycles, and is constantly monitored and controlled by the system PLC. Thus, there is no need to shut down the oxidizer during normal operation, and there is no intervention required by the plant operating personnel.

The total operating cost for this system is well below that for competing technologies, since the pressure drop in the concentrator and oxidizer is relatively low, and the fuel consumption in the oxidizer is greatly reduced due to the concentration effect.

ANALYSIS

The following analysis compares the costs of a concentrator system and an RTO for a ten year life cycle, and is typical for a dilute VOC concentration application:

Table 1. Life Cycle Cost Evaluation

System sized for 30,000 SCFM	**Capital Cost + 10 Year Operating Cost**
Concentrator	$864,000
RTO	$1,776,000

Notes: (1) Operating costs are based on an operating schedule of 8,000 hr/yr and a VOC loading of 20 PPM. Utility costs were assumed to be $4.00/MBTU for natural gas, and $0.04/kWH for electricity.

CASE STUDIES

Several recent evaluations were made comparing the economics of an RTO and a zeolite fixed bed concentrator system for applications characterized by dilute VOC concentration. These evaluations showed the fixed bed concentrator system as the cost-effective choice. The following data illustrate the performance of the concentrator system as measured by actual compliance test results compiled after the system start up:

Table 2. Concentrator System Performance Data

Application	Rotogravure Printing	Semiconductor	Semiconductor	Aerospace Parts Coating
Flow, SCFM	41,500	16,100	16,100	13,500
Inlet Concentration	477	119	67	354
Avg. Destruction Efficiency	99.6	99.9	98.9	98.2

TECHNICAL CONSIDERATIONS

The concentrator system also offers significant operating flexibility, with no manual adjustments required for fluctuations in airflow or solvent loading. As with an RTO, the fan is controlled by a variable frequency drive set for a constant static pressure at the system inlet. This allows for changes in airflow at the process source with the concentrator system adjusting itself to meet these fluctuations. Fluctuations in VOC loading are easily controlled due to the large volume of zeolite in the adsorber section and the operating parameters of the regeneration cycle. The adsorber section is capable of holding large volumes of VOC's. The adsorber section is segregated for regeneration prior to saturation. Thus the concentrator system can be designed to provide for 98-99% overall control efficiency even with large inlet concentration spikes.

Unlike RTO's, the concentrator system has no warm up period, and is designed to be turned completely off at the end of a workday. The adsorber section is ready for operation as soon as the fan is started, and there is no warm up time required for the oxidizer prior to starting the system. This provides another advantage over oxidizers requiring a constant flow of natural gas to keep the system at operating temperature during equipment startup, or during periods of idle operation.

COMPARISON OF CONCENTRATOR TYPES

There are two types of adsorber modules used in concentrator systems. The fixed bed type utilizes multiple cells through which the process and regeneration air flows. This type typically uses a pelleted zeolite as the adsorbing medium. The rotary adsorber utilizes a rotating cassette or carousel that uses a substrate coated with zeolite in a powder form. The following highlights the advantages of the fixed bed over the rotary adsorber:

- The fixed-bed adsorber uses pelleted zeolite vs. the coated monolith used in a rotary adsorber. This results in more zeolite per cubic ft. of adsorbent---10-20 times more. The adsorption efficiency of a concentrator system is directly related to the amount of adsorbent present.
- The fixed-bed adsorber can effectively adsorb/destroy light compounds, i.e. methanol, ethanol to a minimum destruction efficiency of 95%.
- The fixed-bed adsorber can accommodate concentration spikes without the need for additional equipment such as a sacrificial carbon pre-filter.
- The fixed-bed adsorber design allows for more efficient sealing--destruction in excess of 98% is commonly achieved.
- The fixed-bed adsorber can be desorbed at higher temperature and can therefore handle high boiling compounds. Rotary concentrators need a sacrificial carbon pre-filter to keep these compounds from entering the adsorber.
- The fixed-bed adsorber has higher concentration ratio--up to 30:1. This results in a smaller oxidizer and lower operating costs.
- The fixed-bed adsorber uses a modular design that makes it cost-effective to expand capacity in the future.
- The fixed-bed adsorber is skid-mounted. Complete installation usually occurs within 4 days.

CONCLUSIONS

For the class of air pollution applications defined by large airflow and low VOC/HAP concentration, the concentrator system has consistently proven to be the cost-effective solution. It combines superior destruction efficiency, simplicity of operation and low operating costs.

Within this class of VOC control device, the fixed-bed concentrator system has significant advantages over the rotary concentrator system. The main benefits of the fixed-bed system are capital cost, operating flexibility and cost-effective expansion for future process air changes.