Hybrid VOC Control Technology Offers Best of Both Worlds

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In the not too distant past most metal-finishing operations that sought to control emissions of volatile organic compounds (VOCs) were forced to choose between several diverse technologies. Was it going to be thermal oxidation? Perhaps catalytic oxidation? Maybe solvent recovery or disposal? This was a tough call for metal finishers because none of the available technologies was a perfect fit for the industry's high-volume, low-concentration (HVLC) process streams. Still, at some point, the decision had to be made to select one technology over the others and live with it—the pros and the cons.

But a new mix-and-match philosophy has overtaken the VOC control industry resulting in hybrid systems that merge the best features of once-separate technologies. One of the more interesting technology melds to appear in recent years is the combination of advanced fluidized bed carbon adsorption with thermal oxidation. The fluidized bed adsorption component of the system made its mark in semiconductor manufacturing, an industry known for its aversion to downtime. Operating all day, every day, the equipment drew notice for its ability to concentrate dilute process streams reliably and significantly—the very roadblock metal finishers face in their efforts to control airborne emissions.

AN IDEAL MARRIAGE

Though carbon adsorption and thermal oxidation are both long-proved technologies for VOC control neither provided problem-free emission control for metal finishers. Here's why:

1. Carbon adsorption systems left the user with a quantity of spent solvents that came under the classification of hazardous waste. If it was not practical to reuse the material (the norm in surface-finishing operations) disposal sometimes turned into an expensive headache. Furthermore, earlier types of carbon adsorption material had to be frequently regenerated with the use of steam, creating a wastewater problem.

2. Thermal oxidizers worked best with higher VOC concentrations. Oxidizing a large volume of air to destroy a small concentration of VOCs could be prohibitively expensive owing to higher operating cost for auxiliary fuel.

So, why weren't these two seemingly perfect partners brought together sooner? They were. But fixed-bed adsorption systems were only able to concentrate the emissions by a ratio of about 10:1 and still required relatively expensive recuperative or regenerative thermal oxidizers to complete the purification process. The breakthrough came with the introduction of fluidized-bed technology using advanced, synthetic adsorption materials. Such a system (see Fig. 1) can routinely deliver reduction ratios of between 200:1 and 1,000:1 and, in certain circumstances, as high as 10,000:1. The remaining airstream is so small its VOCs can be easily and cheaply destroyed with simple afterburners.

THE POWER OF CONCENTRATION

The hybrid system can be used on process streams ranging from 5,000 to 500,000 scfm containing VOC concentrations from 1 to 1,000 ppmv. It consists of the following components:

Adsorber: A vessel shell with a series of perforated trays inside that the carbonaceous adsorption material flows across.

Airlift Blower: A fan/pipe assembly that sends saturated adsorbent from the bottom of the adsorber vessel to the top of the desorber and sends regenerated adsorbent from the bottom of the desorber to the top of the adsorber.

Desorber: Another vessel shell, typically smaller but similar in design to
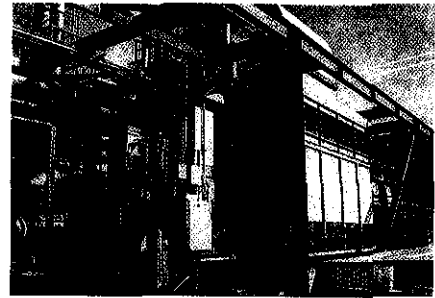

Figure 1. Fluid-bed adsorption system.

the adsorber, where the adsorbent releases the VOCs into a carrier gas stream and is regenerated for reuse.

Oxidizer: A simple afterburner with no heat recovery, where final treatment of the emissions is achieved through thermal oxidation. The thermal oxidation process is typically self-sustaining on the heat value from the concentrated stream of VOCs being burned, so except for start-up, the consumption of fuel is nil.

Heat exchanger: Captures heat from the oxidizer exhaust and uses it to activate desorption.

HOW THE SYSTEM WORKS

The first section of the system, pictured in Figure 2, contains a series of perforated plate adsorption trays. Contaminated process exhaust enters from
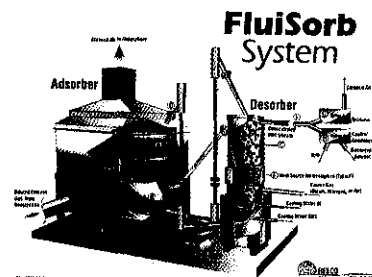

Figure 2. System schematic. (A) Perforated plate adsorption trays; (B) adsorber vessel (C) spent adsorbent; (D) regenerated adsorbent; (E) desorber heater; (F) concentrat. stream; (G) oxidizer; (H) cooler/condenser.

Table III. Effect of Cathode Current Density on the Volume Percent and Cathode Efficiency

Current Density, A/dm²	Volume in Deposit, %	Cathode Efficiency, %
2.0	20.8	87.5
3.0	17.7	88.7
4.0	16.6	85.3

Particle concentration 2.6 g/L.

properties, natural diamond powder is preferred by the industry. Hence, standardization was done only with the natural variety.

The finer the particles, the more difficult it was to make them settle on the cathode surface, which necessitates thorough mixing of the powder with the electrolyte in the presence of the wetting agent. Settling became relatively easier as the particle size was increased. The mass of the deposit obtained, which is related to the current efficiency, decreased with increasing volume percent of the particles in the deposit (Table II).

A decreasing trend in volume percent incorporation and current efficiency was observed with increasing cathode current density. At high current densities, because the metal deposition occurs at a faster rate, the volume percent decreased. Also, the deposits obtained at high current densities were very rough (Table III).

Increase in operating current density decreased the volume percent and increased the metal deposition rate. Because, in this case, the metal deposition rate need not be high, as this results in lower particle incorporation, 30°C was chosen as the optimum (Table IV).

Table V presents the effect of electrolyte pH on the volume percent and cathode efficiency of composite deposition. With increasing pH, the metal deposition rate increased, reducing the volume percent of incorporation. Deposits obtained at low pH values were bright in appearance.

Surface examination of the composites was carried out to assess the distribution of the particles in the metal matrix.

With an inclusion density of 21% by volume and a particle size of 0–2 μm, microscopic examination revealed the presence of about 200,000 particles per square millimeter. With 2–6 μm size, there were about 60,000. With 6–12 μm size, there were about 15,000. The composites were produced on 21-cm–diameter mild steel and high-carbon steel disks to a thickness of 12–15 μm and were field tested in the gem-polishing machines for more than 2 months. The adhesion and cutting ability and the life of the coatings were found to be good.

CONCLUSION

Diamond powder–incorporated nickel composites were produced successfully with particles of different sizes and on various substrates.

Table IV. Effect of Solution Temperature on the Volume Percent and Cathode Efficiency

Temperature, °C	Volume in Deposit, %	Cathode Efficiency, %
30	17.7	88.7
45	12.8	92.1
60	8.29	94.8

Table V. Effect of Solution pH on the Volume Percent and Cathode Efficiency

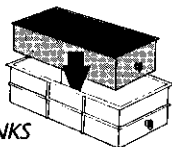| pH	Volume in Deposit, %	Cathode Efficiency, %
2.5	19.4	85.5
3.5	17.7	88.7
4.2	15.0	90.2

References

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