

A Novel New Approach to VOC and HAP Emission Control

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ABSTRACT

HAP (Hazardous Air Pollutant) and VOC (Volatile Organic Compound) thermal emission control devices (ECD) usually require large amounts of energy to operate. They also require large capital investments in heat recovery options and large amounts of real estate. Non-thermal VOHAP (Volatile Organic Hazardous Air Pollutant) emission control devices require additional maintenance. They also require the replacement of costly consumables such as activated carbon or they use large amounts of energy to regenerate the adsorbent. Large air flow rates and low VOHAP concentrations are frequently encountered in industrial processes. This combination of variables makes the capture and destruction or recovery of VOHAP emissions an extremely energy intensive task to perform.

A new technology is being developed and tested that addresses all of these issues. It utilizes a novel combination of existing and proven technologies to solve all of these problems simultaneously. This presentation will be the first public disclosure of this new technology and its applications.

INTRODUCTION

The Clean Air Act Amendment of 1990 led to new emissions requirements. Currently 189 chemicals are listed as HAPs. Emissions of HAPs are required to be reduced by 90% by the year 2000. (Zahodiakin, 1995) Sites which emit more than 10 tons of any one HAP per year or 25 tons (Devanny, 1999) of any combination of HAPs will be required to install Maximum Achievable Control Technologies (MACT).

There are two primary ways to reduce emissions. The first is source control. Source control consists primarily of implementing substitute technology that reduces emissions at the source by using less VOHAPs. The second involves treatment of the emissions at the stack. Two primary categories of treatment are recovery (capture) and destruction. Some treatment technologies use a combination of both capture and destruction.

One of the most difficult VOHAP emission sources to treat is from paint spray booth operations. One of the primary applications for this new technology is the reduction of paint spray booth

VOHAP emissions. Paint spray booth emissions are one of the most problematic sources to control for other VOHAP control technologies. Other applications that will be discussed will involve reducing the need for waste water treatment and disposal.

CURRENT TECHNOLOGY STATUS

Most small to medium sized facilities often can not afford the large capital outlays required to reduce VOHAP emissions. Many of these facilities have gone out of business in the U.S. and their production has moved overseas. Solving these technical problems is critical to maintaining the U.S. manufacturing industry's competitiveness.

Source Control

The most effective source control method in use today for reducing paint spray booth emissions is powder coating. Powder coatings are expected to ultimately capture up to 33-40% of the industrial coating market. Powder coatings require elevated bake oven temperatures to cure the powder. This results in higher energy costs to bake the coating than with air dry or catalyzed paints. Powder typically requires a bake cycle of 10 to 30 minutes at 360 °F (Whitall, 1999). Precleaning steps and humidity control needed for powder coating requires additional energy not needed by older coating technologies. Most plastics, wood and certain metal alloy products cannot handle the bake oven temperatures required by current powder coating technology.

Other factors such as frequent color changes, available colors, environmental conditions the coating will be exposed to, maximum allowable coating thickness and many other factors will inhibit the use of powder coating technology in many areas. Large structural items such as airplanes, ships, and other large structural units that are too large to fit in ovens or that contain components that can not withstand the powder coating bake oven temperatures will still require liquid self curing coatings.

Other source reduction technologies (SRTs) exist including solvent substitutes such as CO₂, high efficiency paint equipment such as electrostatic hand guns, bells, disks and HVLP (High Volume Low Pressure) paint guns. Low VOC coatings such as waterborne and high solids coatings are being used to

reduce emissions. All of these products have found niche markets but they still produce VOHAP emissions. CO₂ emissions will probably be regulated as green house gas emissions in the very near future. None of the SRTs are universal solutions.

Capture and Concentration Methods

Low concentrations of VOHAP emissions can be concentrated as a first step by various methods. These include absorption and adsorption. Liquid scrubbers are used in various applications using liquid absorbents to capture VOHAP emissions. They are also capable of capturing particulate emissions such as PM-10 particulates as well as VOHAP emissions.

Liquid absorbents require further treatment. Usually the liquid absorbents are recycled and reused after the VOHAPs have been separated from the absorbent. Water and various non-volatile organic fluids are used as absorbents. The choice of which to use usually depends on the VOHAPs solubility in water.

One of the advantages of packed tower liquid scrubbers is their comparatively low operating costs. They are easier to operate and maintain and generally safer than most other emission control technologies. They are characterized by very low pressure drops through the scrubber which results in lower energy costs. The most significant drawback to absorption scrubbers usually involves the scrubber fluid recycling step.

Scrubber fluid recycling can be accomplished with a distillation stage. Other more complicated schemes exist such as liquid / liquid extraction, nitrogen stripping, heated low air flow rate stripping followed by incineration and many others. The key factor is usually the value of the recyclable solvent and whether it is a single compound or a mixture of various solvents. Mixtures of solvents are frequently more difficult to purify and reuse. Liquid scrubbers will be discussed in more detail in the New Technology section later in this article.

Condensation systems require very low condenser temperatures. They are only used on low flow rate exhaust streams that have very high concentrations of condensable VOHAPs in the range of 10,000 ppm. and higher. They are not cost effective (fig. 1) on low concentration high flow rate exhaust streams.

Low molecular weight non polar compounds require too low of a condenser temperature to be practical candidates for condensation methods. Adding a compressor stage to raise the operating

pressure is required to condense low molecular weight organic compounds. Water condensation takes place as well and must be dealt with before recycling the captured solvent. Some pharmaceutical companies are reported to be using liquid nitrogen expansion to capture some VOHAPs where the nitrogen is already used in the plant and expansion cooling is freely available.

The third method of VOHAP capture and concentration uses a solid phase adsorbent such as activated carbon, a zeolite or a molecular sieve to capture and concentrate the VOHAPs. These adsorption systems are also relatively inexpensive to build when compared to incineration devices such as RTOs. However when the adsorbent is saturated it must be taken offline and regenerated or replaced. During this down time a second adsorbent bed is usually available and cycled into service.

Saturated adsorbents are either burned to destroy the captured VOHAPs or heated to a point at which the VOHAPs are released in a concentrated flow to another step or process. The release of VOHAPs at elevated temperatures is the desorption step. Dry heat or wet steam is used in various systems to desorb the VOHAPs thereby regenerating the adsorbent. Once regenerated the adsorbent is reused.

Activated carbon is a very versatile adsorbent and is used in many applications. Activated carbon reuse does have limitations. Compounds with boiling points above 300°F are difficult to desorb. Reactive monomeric compounds such as styrene and di-isocyanates commonly found in urethane coatings tend to polymerize on carbon irreversibly blinding the carbon pores and permanently deactivating adsorption sites. Organic compounds with molecular weights below 40 AMU (Atomic Mass Unit) do not adsorb well (Devinsky, 1999).

High relative humidity can substantially reduce adsorption capacity (Haberlein and Boyd, 1995). High emission temperatures such as bake oven exhausts would require substantial cooling and removal of water condensate prior to adsorption in a carbon adsorption bed.

EPA recently published warnings to LEPCs (Local Emergency Planning Committees) concerning spontaneous combustion of carbon adsorption systems. Ketones reportedly adsorb exothermically onto carbon and can react causing bed fires. Carbon monoxide detectors and deluge systems are recommended for carbon adsorption systems where ketones may be used (Knaebel, 1999).

Synthetic zeolites, also called molecular sieves, are used to capture and recover more valuable solvents and sometimes are used in combination with catalytic incineration system designs. Synthetic zeolites are generally more expensive than carbon but can withstand much higher temperatures and are non combustible. Captured VOHAPs can be incinerated as a final step.

VOHAP Recycling

After capturing and concentrating VOHAPs you then have a choice of recycling or destroying them. A large number of methods are available for both. The particular solvents or compounds involved, their physical properties and the method used to capture and concentrate the compounds must all be considered.

Destruction Technologies

These include incineration, catalytic oxidation, bio-conversion and new AOTs (Advanced Oxidation Technologies).

Bio-conversion

Bio-conversion is the capture and conversion of VOHAPs by microorganisms into biomass, CO₂ and water. Biofilter operation and efficiency is very dependent on temperature and humidity conditions (Devanny, 1999). Particulates in the exhaust stream can plug and blind off the media or kill the microorganisms if the emissions carry metals or organics that act as biocides at elevated concentrations (Webster, 1999).

Bio-trickling filters and stationary air biofilters use fixed microorganisms but the bio-trickling filters use a flowing water phase. Bio-scrubbers use a suspended biomass and a flowing water phase. Biofilters do not produce CO, NO_x, and only produce small amounts of CO₂.

Incineration

They typically oxidize VOHAPs to CO₂ and water at elevated temperatures as high as 2,200EF. Due to safety considerations VOHAP emissions are typically diluted to a point below 25% of the LEL (Lower Explosive Limit) by the exhaust systems. This results in the need for additional fuel to support combustion by heating the air stream to the required combustion temperatures. As the VOHAP concentration falls the makeup fuel requirements needed go up. Even though direct combustion is the least costly incineration technology from a capital standpoint the additional cost of auxiliary fuel needed for low concentration VOHAP control makes it too costly to operate.

Catalytic oxidation

Catalytic oxidation operates at lower temperatures than incineration. This can result in lower auxiliary fuel requirements when compared to incineration. Operating temperatures as low as 300EC are possible with thermal catalysts that are commercially available today. Disadvantages of catalytic oxidation systems include catalyst deactivation by contaminants in the VOHAP air stream such as halogens, sulfur and metals.

Incineration with heat recovery

Heat recovery can reduce the auxiliary fuel costs of thermal destruction methods. The addition of heat recovery increases the complexity of the design, its capital cost and maintenance costs. Incineration technologies (including catalytic incineration) with heat recovery have large pressure drops that result in increased electrical requirements for the blower motors.

A recent article (Huntington, 1999) described a 125,000 SCFM RTO (Regenerative Thermal Oxidizer) with dual 500 HP exhaust fans. The electrical utility requirement for these fans is 125 SCFM (Standard Cubic Feet per Hour) per HP. A 1,000 HP motor operated 24 hrs./day uses approximately 6,550,000 kWh per year (Peters and Timmers, 1991) at a cost of \$655,000 per year based on an average price of \$0.10 / kWh for electricity. The pressure drop through the RTO is listed as 19" SP. High pressure drops result in large power requirements to overcome the pressure losses. The large pressure drop in the RTO is required by the heat recovery section to achieve 75 % heat recovery.

Several EPA reports and databases (Whitall, 1999) show an average annual fuel cost of \$3.00 per SCFM for RTOs even at a 70 % heat recovery rate. On that basis a 100,000 SCFM RTO would use \$300,000 per year of additional fuel. This is in addition to the electrical requirements list above.

Other problems encountered with thermal destruction methods include:

1. Possible acid gas formation requiring cooling and acid gas scrubber add on devices that produce additional waste streams.
2. CO and NO_x emissions are produced.
3. High capital costs.
4. High installation costs.

5. Requires a large amount of real estate.
6. High utility operating costs.
7. High maintenance costs for moving parts and catalysts.
8. High operating temperature safety hazards.
9. Not designed for batch operations. Start up times of 8 hrs. and more are typical. Designed only for high volume continuous operations.

Destruction after pre-concentration

Many system designs use low concentration adsorption followed by high concentration desorption. This process increases the fuel value of the gas stream and reduces the supplemental fuel costs of the combustion stage. The additional equipment and controls needed to concentrate the VOCs further increase the capital cost of these systems.

Advanced Oxidation Processes

Several AOP processes exist utilizing various combinations of catalysts and oxidizers such as hydrogen peroxide and UV, Titanium Dioxide and UV and Ozone and UV. Although they offer alternative methods of dealing with VOHAPs none appear to have a distinct operating or capital cost advantage over other technologies at this time.

Summary

Currently available BACT (Best Available Control Technology) technologies require very large capital investments and use inordinate amounts of auxiliary energy. When heat recovery options are added to increase the energy efficiency they also increase the capital costs. Additional controls on green house gas emissions will increase the cost of combustion technologies in the future.

RECENT R & D EFFORTS

The Navy has been investigating a pilot scale bio-trickling filter (Webster, 1999) for treating off gases from spray paint booths. The project was funded by the Navy's Small Business Innovative Research (SBIR) Program. Test results indicated that VOHAPs could be biodegraded with a bio-trickling filter.

The major drawback to their method is the size of the bio-trickling filter needed to handle a typical 10,000 SCFM paint booth. The report indicated the need for a vapor contact time of 16 seconds. The empty bed volume required would be 2,666 cubic feet. Additional room would be required for the biomedial packing. The pilot scale unit was only 2 feet

in diameter and 18 feet high. The full size system would need to be 10 feet in diameter and approximately 40 feet tall to accommodate a flow rate of 10,000 SCFM.

Another drawback is the need to keep the biomass warm. The thermal energy required to reheat the water feed to the bio-trickling filter would substantially increase operating costs. Winter time operation would result in cold ambient spray booth air cooling the feed water like a cooling tower unless costly makeup air systems were included to preheat the spray paint booth air.

Recent work at Ford Research (Kim, 1998) concluded that activated sludge bioreactors could be used to biodegrade spray paint booth VOHAPs. Their tests included automotive water wash spray paint booth waste water containing captured paint and associated VOHAPs. Their tests included Toluene, MEK, butyl cellosolve, and n-butanol.

THE NEW TECHNOLOGY

The new technology proposed here is a synergistic blend of several existing technologies merged into a complete system that simultaneously addresses today's pollution prevention goals, today's emission limits and tomorrow's probable emission limits, today. It is designed specifically for low concentration VOHAP emissions and nuisance odor emissions in small and large air flow streams. It is also designed to capture and treat PM-10 particulates as well as PM-2.5 emissions.

The new technology does not produce NO_x, CO, large amounts of CO₂ or hazardous waste byproducts requiring further treatment. The technology has an attractively low capital and electrical operating cost. This new technology can re-enable the use of older lower energy cost technologies that have lost favor in the market place due to VOHAP restrictions. It can also be used to convert hazardous wastes into non-hazardous wastes. In many cases it can be used to convert what would become hazardous waste into a reusable product.

Within these parameters this new technology is expected to be a cost effective pollution prevention control technology for annual emission rates of as little as 5 tons per year of VOHAPs.

Theory of Operation

The premise of this new technology is to use limited amounts of energy to neutralize and convert VOHAPs into biomass. The technology avoids the inherent high costs of total VOHAP destruction. The

process converts certain volatile compounds in the waste gas stream into non-volatile compounds and less volatile compounds. The non-volatile compounds produced in the reactor merge with a recyclable scrubber fluid and are used to aid in the capture of additional volatile compounds. The non-volatile compounds that are formed act as absorbents, adsorbents, surfactants and emulsifiers and work in combination with the recyclable scrubber fluid. This technology takes advantage of hydrogen bonding chemistry and its ability to reduce the volatility of low molecular weight compounds.

Example #1

Paint booth emissions are one of the most difficult to treat. Wet sticky particulate matter that slowly releases VOHAPs and large air flow rates characterize the typical paint booth operation. The large air flow rates are used to dilute VOHAP concentrations below their lower explosive limits.

Many water wash spray paint booths have been replaced in recent years with dry filter booth systems to avoid the escalating cost of spray booth wash water waste disposal. Spray booth wash water containing MEK is a hazardous waste if the concentration of MEK (or Xylene, Toluene, Ethylbenzene, and others under some state regulations) exceeds 200 ppm. Leachable concentrations of hexavalent chromium, lead, silver and several other hazardous waste metals can also be a problem if present in the paint formula.

EcoShield Technology eliminates the water wash booth waste water disposal problem. Existing water wash booth designs are capable of 99.9 % particulate overspray capture efficiency. In the process of capturing paint particulate overspray a significant portion of the VOHAPs are captured with the particulate. A significant portion of the VOHAPs are still in the liquid particulate phase at the time of capture. Further VOHAP capture is accomplished by absorbing and adsorbing gas phase VOHAPs into the paint booth scrubber's recyclable water - emulsion - absorbent - adsorbent scrubber solution.

Water wash paint booth scrubbers can effectively capture PM-10 and PM-2.5 particulates as well as VOHAPs. Water wash scrubbers by their very nature represent a reduced fire hazard compared to dry filter booth systems. NFPA (National Fire Protection Agency) fire safety codes require the use of fire suppression automatic sprinklers on dry filter booths but not on water wash booths. This can represent a substantial savings in capital costs and insurance premiums. Dry filters require frequent booth shut down to replace used filters. OSHA and NFPA

require that used paint booth filters be placed in barrels of water to avoid possible spontaneous combustion of solvent wet paint booth filters. This increases the amount of hazardous waste that needs disposal. Using wet catalyzed self cure coatings eliminates the energy requirements needed to bake low VOHAP powder coatings.

EcoShield Reactor

In order to maintain the capture efficiency of the scrubber fluid captured VOHAPs must be removed and either recycled, destroyed or converted into something else. The EcoShield Reactor #1 converts captured aromatic (hydrophobic) compounds into hydrophilic compounds that act as emulsifying surface active (surfactants) agents. These surfactants are typically hydrophobic on one end and hydrophilic on the other end of the molecule. This dual property allows them to capture (absorb) volatile hydrophobic VOHAPs and emulsify them in the bulk water phase.

By converting captured aromatic VOHAPs into water soluble surfactants, versus complete conversion to CO₂ and water, the energy consumed in the process is reduced by several orders of magnitude. The first reactor is a packed bed flash column where scrubber water containing captured VOHAPs is first preheated (fig. 1, HE-1, H-1) to increase VOHAP volatility and then fed into the top of the packed column where it gravity flows to a collection point at the bottom of the column. As the liquid flows down the packing captured VOHAPs evaporate (flash) from the liquid emulsion into the gas phase. The bulk of the organics in the scrubber fluid remain in the liquid phase while the most volatile components flash into the gas phase.

An ozone rich gas is feed to the reactor column countercurrent to the liquid flow. Since ozone is almost totally insoluble in water at elevated temperatures it reacts directly, quantitatively and primarily with the gas phase aromatic compounds (first order reaction rate) and other gas phase unsaturated hydrocarbons. The reaction proceeds through several short lived intermediate species that quickly yield one of many various surfactant species.

The terminal reaction products have hydrophilic functional groups bound to the original VOHAP molecule. The result of this reactive conversion process is first to convert a highly volatile VOHAP into a reusable emulsifying surfactant with a substantially lower vapor pressure. The volatility of the hydrophilic products is orders of magnitude lower (the result of hydrogen bonding) than the original VOHAP reactant. These reaction products are then

used in the regenerated scrubber fluid to help capture and hold more VOHAPs in the scrubber solution as it is reused in the water wash paint booth scrubber. The gas phase reaction avoids the Henry's Law limits on the solubility of ozone in water. It also eliminates undesired reactions with liquid phase compounds that would increase ozone consumption.

Additional benefits include the detackification of the water wash paint booth scrubber solution. Detackification is normally a costly step that is required to keep the water wash booth working correctly. It is normally done by adding chemicals (at great additional cost) to the booth water to kill the sticky nature of the paint. Without detackification the paint sticks and loads up on surfaces and clogs pipes and nozzles. Non uniform air washing results as the nozzles clog up. The ozone reaction not only converts volatile VOHAPs into nonvolatile and less volatile surfactants it also detackifies the paint and eliminates the need for any addition of detackification chemistry. This results in substantial savings to the end user.

The second reactor column is a bioconversion scrubber reactor column. Gasses that are vented out of the first reactor are feed to the bioconversion reactor scrubber column where biodegradable VOHAPs are captured and converted into biomass and some CO₂. When O₂ is feed to the ozone generator (resulting in increased ozone yields and substantially reduced energy and capital costs) it results in an oxygen rich feed to the bioconversion reactor scrubber column. This increases the biomass limiting density by nearly 500% and results in a smaller footprint for the bioreactor scrubber column. It also reduces the power costs typically required to feed air (oxygen) to the bioconversion reactor scrubber column.

The entire system takes up only 3 ft. by 4 ft. of floor space for a five ton per year capacity of VOHAPs system. Improvements in ozone generator technology have lowered ozone production costs by nearly 1,000% in the last 10 years. Depending on the availability of waste heat recovery options, the power requirements (fuel consumption is zero with electric heat assumed in the design) for a five ton per year capacity system will be in the range of 2 to 4 kWh. At \$0.10/KWh the annual energy cost per ton of VOHAP treated will range from \$350.00 to \$700.00 per ton year.

Several options exist for handling the accumulation of solids in the water wash paint booth scrubber. A dedicated booth using one formula of white that is high in Titanium Dioxide could produce a recyclable product for the recovery of Titanium

Dioxide. Another option is to convert the booth solids into a low cost primer.

An additional benefit of the technology is the improved filtration and dewatering ability of the waterwash booth scrubber solution. Dewatering of water wash booth scrubber solution is normally a sticky mess unless a chemical detackification program has been followed at great additional cost. It should be noted that chemical additions to detackify paint in scrubber water increase the final sludge volume and weight by 500% or more. Ozone treated booth water looses it sticky tacky properties and does not blind off or coat filter media in filter presses. Ozonation does not add to the sludge volume or weight. Increased flow rates through the filter press fabric and decreased flow volume (80% less sludge to dewater) can reduce the filter size requirement (capital cost) and lower the power requirements needed to pump the scrubber solution through the filter press by as much as 90%.

Example #2 Waste Water Evaporators

A new trend in waste water treatment and disposal has been to boil and evaporate waste water. Nearly a dozen companies are actively advertising and producing these devices today. Offsite disposal and POTW (Publicly Owned Treatment Works) discharge restrictions increased the disposal costs of aqueous based cleaning solutions and similar aqueous wastes. Prices as high as \$18.00 per gallon for high COD (Chemical Oxygen Demand), high solids, high oil and grease content aqueous wastes are common.

The electrical energy cost to evaporate water is \$0.26 / gal. or \$260,000 / million gallons based on the heat of vaporization of water at a \$0.10/Kwh (Timmers and Peters, 1991) average electrical utility cost. Another recent phenomena is the switch to burn off ovens to remove grease from parts (automotive rebuilding industry) prior to shotblast cleaning and to remove paint from parts and part racks. Grease removal and paint stripping which were accomplished with recyclable solvents in the past are now being cleaned in ovens which add thermal pollution and green house gasses into the atmosphere.

Waste water with .5 ppm of benzene is considered to be hazardous waste. Refineries and SOCM (Synthetic Organic Chemical Manufacturers) are currently using activated carbon to capture Benzene (NESHAP regulations) and other VOHAPs. They could use this technology for capturing airborne VOHAPs and to convert waterborne VOHAPs into nonvolatile and less volatile compounds prior to aerobic bioconversion to biomass.

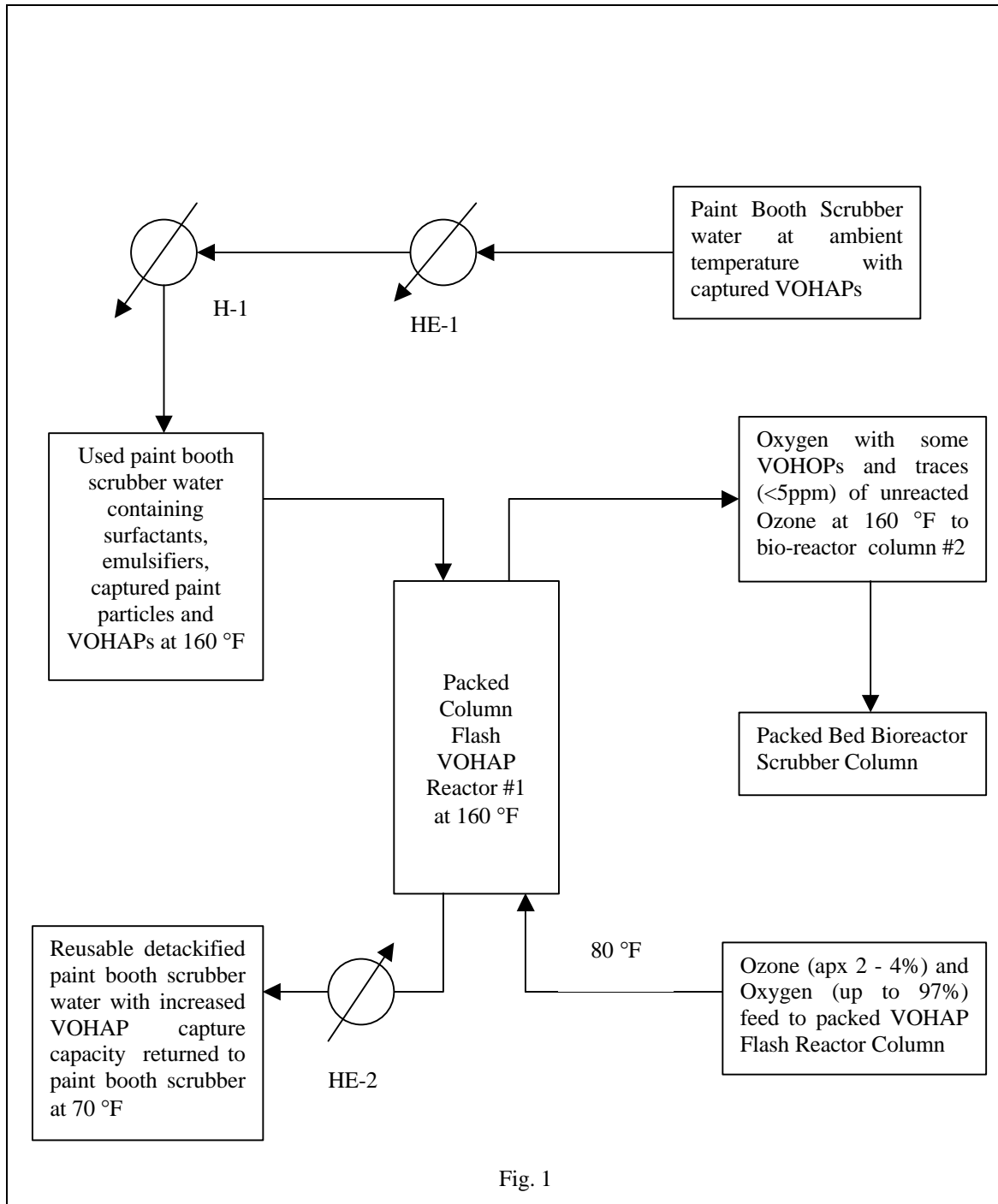


Fig. 1

Other promising applications include fast food broiler vent emissions control which is currently underway in California, VOHAP contaminated ground water cleanup, hazardous waste and mixed wastes treatment, storage tank VOHAP vents, VOHAP emissions from paint bake ovens, solvent cleaning process vents and others listed in Table 1 below.

needed for some applications. They also assume the availability of utilities such as 100 PSI steam for

carbon regeneration and do not include the added capital cost of steam plants where they do not already exist.

EcoShield costs per ton are based on the same data base assumptions and equivalent calculations as those used in the EPA and Navy studies. As the graph

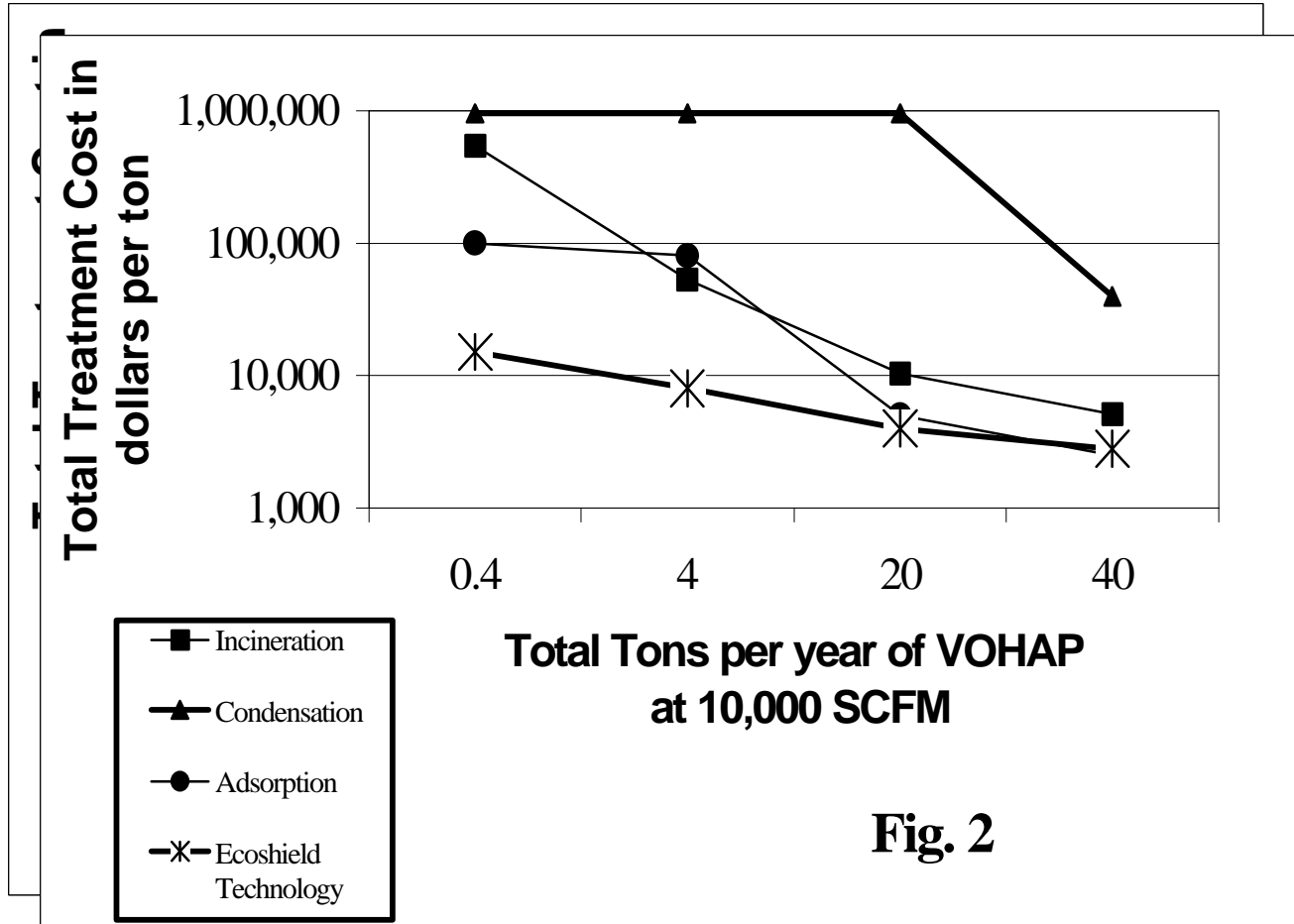


Fig. 2

indicates EcoShield technology represents an order of

Cost per ton of VOHAP treated in Fig. 2 is based on several EPA and Navy reports.... , which include operating costs (fuel, power and steam utilities as well as replacement carbon where applicable), maintenance labor and administrative supervision costs and capital depreciation expenses. They do not include costs of possible pretreatment (prefiltration for condensation or adsorption) or post treatment (acid gas scrubber for incineration) that may be

magnitude reduction in the annual per ton treatment costs for a 4 to 5 ton per year system. Actual energy operating costs would be about 5% of total ton per year costs.

VOHAP emissions of 10 tons per year are now regulated under Title V. This has resulted in the need for small scale energy efficient VOHAP emission

control technologies. This new technology should allow industry to deploy a cost effective solution to the increasing requirements for VOHAP controls. Table one lists some of the emission sources where this technology may be applied.

TABLE 1

Other VOHAP Emission Sources	
1.	Engine and Turbine Test Facilities
2.	Boiler Emissions
3.	Petroleum and Natural Gas Production and Refining
4.	Gasoline Distribution
5.	Marine Vessel Loading Operations
6.	Organic Liquids Distribution (Non-Gasoline)
7.	Metal Products Surface Coating Operations
8.	Manufacture of Paints, Coatings, and Adhesives
9.	Plastic Parts and Products (Surface Coating)
10.	Printing, Coating, and Dyeing of Fabrics
11.	Printing/Publishing (Surface Coating)
12.	Wood Building Products (Surface Coating)
13.	Wood Furniture (Surface Coating)
14.	Waste Treatment and Disposal
15.	Publicly Owned Treatment Works (POTW) Emissions
16.	Sewage Sludge Incineration
17.	Site Remediation (Soil)
18.	Boat Manufacturing (Fiberglass)
19.	Halogenated Solvent Cleaners
20.	Industrial Cleaning
21.	Hazardous Waste Treatment and Disposal
22.	Dry Cleaning (Perchloroethylene)
23.	Paint Stripping Operations
24.	Ground Water Remediation
25.	Leather Tanning and Finishing Operations
26.	Plywood and Composite Wood Products

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