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Project Summary

Ethylene Oxide Control Technology Development for Hospital Sterilizers

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Hospital sterilize heat-sensitive items in gas sterilizers which use a mixture of ethylene oxide (EO) (12 wt%) and a chlorofluorocarbon (CFC), dichlorodifluoromethane (88 wt%). The active sterilizing agent is EO. The CFC is added as a flameproofing diluent.

Articles to be sterilized are placed in a sterilization chamber and exposed to this mixture (referred to as 12/88) until sterile, at which time the gas is drawn from the chamber by a vacuum pump and emitted to the environment. The sterile articles are then placed in an aeration camber where fresh air is continually circulated to allow residual EO to diffuse from them. This air (which contains low concentrations of EO) is also emitted to the environment.

The potential sterilizer emission control systems were tested, catalytic oxidation and acid hydrolysis. In catalytic oxidation, relatively dilute mixtures of air and EO (12/88) are passed through a catalyst bed at 149-177°C. The EO is oxidized to CO_2 and water; the CFC passes through unchanged. Field tests showed that the EO destruction efficiency of a system which had been installed in a hospital was greater than 99% of the EO that reached the control system. However, for sterilizers that use a water jacket seal, 61-78% of the EO was absorbed by the water of the once-through, water-sealed vacuum pump. The investigation focused on the efficiency of the control devices; therefore, other system losses were outside its scope. However, the potential for release of EO to the environment from the water should be considered in any overall system design. There was no detectable decomposition of the CFC.

In acid hydrolysis, EO is hydrolyzed to ethylene glycol using sulfuric acid (the CFC is unaffected). A full-scale system was tested under laboratory conditions, simulating a system that could be used for hospital sterilizers. The tests showed that the EO destruction efficiency was 99.99-99.999% of the EO reaching the control system. However, 45 - 60% of the EO was absorbed by the ethylene glycol used in the closed-circuit, liquid-ring vacuum pump. This requires a longer sterilizer cycle to permit desorption of the EO from the ethylene glycol into the emission stream to the control system.

In considering the relative costs of these systems, the advantages and limitations of each must be considered.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Ethylene oxide (EO) has been identified as a major toxic air pollutant.

EPA's Office of Air Quality Planning and Standards (OAQSP) designated EO as an Intent to List Compound in the Federal Register in early 1986. One of the major uncontrolled sources of EO emissions is hospital and clinic sterilizers. More than 400 Mg/yr of EO is estimated to be released to the atmosphere each year from these sources.

In the program to identify, develop, and evaluate viable control options for EO emissions from medical facility equipment: Phase I (Work Assignment 5) identified three potential devices for the control of EO emissions from hospital and clinical sources, and Phase II (Work Assignment 10) involved tests of selected technologies identified in Phase I.

Phase I - Potential Control Systems

Hospital Sterilizers

Almost all hospitals sterilize heat-sensitive items in gas sterilizers which use a mixture of ethylene oxide (EO) and a chlorofluorocarbon (CFC), dichlorodifluoromethane. The active sterilizing agent is EO. The CFC is a flameproofing diluent. This mixture, 12% by weight EO and 88% by weight CFC, is referred to as 12/88.

Hospital sterilizers are essentially enclosed chambers which can be pressurized with 12/88 to sterilize medical equipment. At the conclusion of the sterilization phase, the chamber is evacuated by a vacuum pump and brought to atmospheric pressure by introducing clean, filtered air. The combination of evacuation and air flushes is repeated. After the last air wash, the chamber door is opened, and the sterile products are removed and placed in an aeration cabinet. Aeration allows residual EO to diffuse out of the sterilized articles.

Ethylene Oxide Emissions

In the absence of control systems, EO emissions come primarily from four sources: the camber vacuum pump (75-95% of the total emission), the aeration cabinet (5-25%), the sterilizer door area (varies widely), and the EO storage tanks (from accidental leaks). If the vacuum pump is a once-through, water-sealed pump, substantial quantities of EO (60-80% of the total emission) can be discharged to the sewer in the vacuum pump water.

Potential Control Technologies

The chemical reactions of EO and the CFC were reviewed to evaluate sterilizer emission control options. Catalytic oxidation and acid hydrolysis were shown to be especially suitable. The following selection criteria were developed for EO control technology options (in order of priority): (1) cost, (2) effectiveness and environmental safety, (3) state of development, (4) complexity, (5) space requirements, and (6) safety.

Nine potential control options were examined. Six options were eliminated for the following reasons: carbon adsoption (high operating cost), thermal incineration (toxic by-product), condensation (explosion hazard), ozonation (high cost), corona discharge (toxic by-product), and ultraviolet photolysis (toxic by-product).

1. Catalytic Oxidation

A control system has been developed in which relatively dilute mixtures of air and EO (12/88) are passed through a catalyst bed at 149-177°C. The EO is oxidized to CO_2 and water; the CFC passes through unchanged. The system is characterized by relatively high flow rates (14,000-28,000 L/min-- or 500-1000 cfm-- and relatively dilute concentrations of EO (5-500 ppm). The system treats EO emissions in both the sterilizer exhaust and the ventilation air from the aeration cabinets and other areas. The system has had 2 years of apparently trouble-free operation at a hospital in Philadelphia. The unit is claimed to be 99.9 efficient in controlling EO.

2. Acid Hydrolysis

Another control system has been developed which consists of a counter-current packed column in which EO (in 12/88) is hydrolyzed to ethylene glycol using sulfuric acid at pH 1 (the CFC is unaffected). The system is characterized by relatively high concentrations of EO (250,000 ppm) and very low and highly variable flow rates, 2.8-42.5 L/min (0.1-1.5 cfm). Many industrial-sized units have been installed, and test data on these units show that they are 99+% efficient. A hospital system was installed in March 1987. Another type of acid hydrolysis system has been developed in which EO is bubbled through diffusers into aqueous sulfuric acid. A unit of this kind has been designed for hospitals and is claimed to be 99.2% efficient.

3. Adsorption/Reaction

Some exploratory work has been done on a proprietary process which uses a combination of adsorption and reaction The process is in the developmenta stage and is not ready for full-scale application.

Phase II - Control System Evaluation

Two potential control technologies catalytic oxidation and acid hydrolysis were selected for testing. Both systems demonstrated very high efficiencies (99+%) in destroying EO emissions discharged from hospital sterilizers However, only the catalytic oxidation system can treat EO emissions from hospital aerators, which typically accoun for 5-10% of all EO emitted.

Field Tests of Catalytic Oxidation

Field tests were performed to measure the EO destruction efficiency of a catalytic oxidation system which had been installed in a hospital. This system handled emissions from the sterilizer vacuum pump, an aeration cabinet, the sterilizer door area, and the EO storage tank area. Two types of experiments were performed: one involved the treatment of the sterilizer discharge; and in the other, sterilizer gas was added directly to the system.

In the sterilizer discharge experiments the observed EO destruction efficiency was high, 99+%. As expected for this type of system, the concentration of EO entering the catalyst system varied widely, reaching a maximum of 400-450 ppm. Flow rates were about 14,000 L/min (500 cfm).

In the sterilizer discharge experiments only about 10-13% of the EO in the sterilizer actually reached the catalyst system. A major fraction of the EO was absorbed by the water which was used in the once-through, water-sealed vacuum pump. Analysis of the aqueous discharge indicated that an unexpectedly large proportion of the EO in the sterilizer (61-78%) was discharged to the sewer in the water from the vaccum pump.

Additional experiments were performed to supplement the analytical data obtained during sterilizer discharge EO was added (at a controlled rate) to the system at a point upstream from the catalyst. Sufficient EO was added to bring the concentration of the stream to selected levels of EO. Three levels 125-250, 400-600, and 750-1500 ppm were tested. The results of these experiments indicated high catalyst efficiencies, 99.8% or better.

Of importance is that the EO addition experiments demonstrated that the catalytic oxidation system was capable of operating very efficiently at concentrations of sterilizer gases comparable to those developed if the total discharge from the sterilizer were directed into the system.

All of the tests were performed using the common sterilizing gas mixture (12/88) which is 12% ethylene oxide and 88% CFC. Separate tests demonstrated that there was no detectable decomposition of the CFC under the conditions of the catalytic oxidation.

Laboratory Tests of Acid Hydrolysis

A full-scale acid hydrolysis system was tested under laboratory conditions which closely simulated a system that could be used for hospital sterilizers. This system handled only the discharge from the vacuum pump (it was not designed to handle aeration discharges or other airflows containing low concentrations of EO). The tests demonstrated that the system was very efficient, destroying 99.99-99.999% of the EO that entered the control system.

Four tests involved actual discharges from a hospital-type sterilizer, and three tests involved the direct addition of EO (12/88). In the sterilizer discharge studies, only about 25-26% of the EO in the sterilizer was observed to reach the system. Evidence indicated that most of the EO was absorbed by the ethylene glycol used in the closed-circuit, liquid-ring vacuum pump, thus reducing the amount of EO reaching the system. The concentrations of EO reaching the system were 20,000-140,000 ppm (2-14%) and the flow rates were 2.8-42.5 L/min (0.1-1.5 scfm).

Of the EO reaching the system, more than 99.99% was removed from the gaseous stream.

Ethylene oxide (12/88) was also added directly to the system to determine efficiencies at levels of flow rate near the maximum for which the system was designed, 70.8 L/min (2.5 cfm). These studies also demonstrated the high efficiency of the hydrolysis system, 99.999+%.

Cost Effectiveness

Table 1 shows the estimated costs for the two potential control technologies, catalytic oxidation and acid hydrolysis.

In considering the relative costs of these systems, the advantages and limitations of each should be considered. The catalytic oxidation system is capable of treating all of the gaseous EO emissions from the sterilizer vacuum pump, the aeration cabinets, the sterilizer door area, the EO storage tanks, and any other areas that can be ventilated. However, there are EO emission problems related to the relatively large amounts of EO (60-80% of sterilizer charge) which can be lost to the environment through the aqueous discharge from once-through, water-sealed vacuum pumps. Recirculating vacuum pumps may prevent this emission, but most hospital sterilizers are apparently not currently equipped with recirculating vacuum pumps. (Installation of recirculating vacuum pumps will result in costs nearer the high side of the above capital cost estimates.) Furthermore, even with recirculating vacuum pumps, the substantial absorption of EO into the recirculating fluid produces a potential emissions problem.

The present acid hydrolysis system can treat only the direct discharge from the sterilizer (through the vacuum pump). EO emissions from the aeration cabinets, sterilizer door area, and other dilute emissions could probably not be handled efficiently by the acid hydrolysis systems. Recirculating vacuum pumps would ordinarily be used with acid hydrolysis systems; this would eliminate an immediate discharge of EO-contaminated sealant liquid, but methods of disposing of the contaminated sealant liquid would need to be devised.

As Table 2 shows, the catalytic oxidation system has a greater overall EO destruction efficiency than the acid hydrolysis system. This is primarily because the acid hydrolysis system cannot treat discharges from the aeration chamber or other dilute sources.

Table 1. *Estimated Costs for Catalytic Oxidation and Acid Hydrolysis*

	Catalytic Oxidation	Acid Hydrolysis
Capital costs		
Equipment	$25,000-$40,000	$15,000-$20,000
Installation	5,000-10,000	4,000-6,000
Total equipment cost	$30,000-$50,000	$19,000-$26,000
Annual operating cost	$5,700-$16,000	$600-$6,000

Table 2. *Comparison of System Efficiencies*

EO source	Approximate percentage of total EO emissions[a]	Emission reduction potential[b]	
		Catalytic oxidation (%)	Acid hydrolysis (%)
Sterilizer[c]	75-95	99.5 +	99.9 +
Aerator	5-25	99.5 +	0.0
Sterilizer room ventilation air	< 1	99.5 +	0.0
Total reduction potential		99.5 +	75-95

[a] The estimated percentages of total EO emissions were developed in Phase I of this program.

[b] The catalytic oxidation system has a greater overall EO emission reduction potential primarily because the acid hydrolysis system cannot treat the discharge from the aerator or other dilute sources.

[c] In these sterilizer discharge experiments, about 75% of the EO from the sterilizer wasabsorbed by the vacuum pump fluids and did not reach the control systems. However, other experiments demonstrated that the control systems were capable of handling the full discharge of the sterilizer The efficiencies indicated for both types of control devices are based on the assumption that the vacuum pump fluids are not discharged.

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The complete report, entitled "Ethylene Oxide Control Technology Development for Hospital Sterilizers," (Order No. PB 88-211 792/AS; Cost: $19.95, subject to change) will be available only from:
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