Environment Canada Environnement Canada

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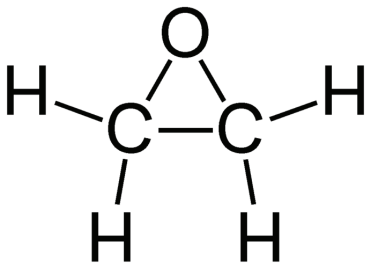
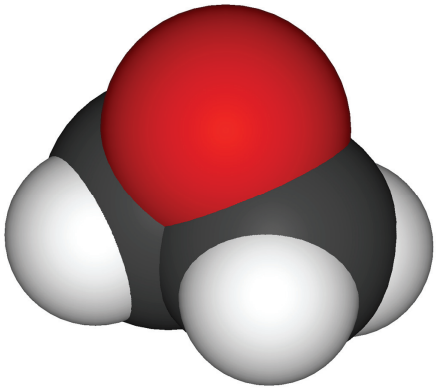
Determination of the Ethylene Oxide Control Efficiency from Catalytic Oxidizers

A Guidance Document





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Readers' Comments

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1. Applicability

This guidance document supports the Environment Canada document *"Reference Method for Source Testing: Determination of the Ethylene Oxide Control Efficiency from Catalytic Oxidizers"*. This guidance document provides background and direction regarding the collection of samples for the determination of control efficiency by experienced and trained stack samplers. The control efficiency of the catalytic oxidizer is based on an integrated bag sample collected over a period of approximately 50 to 60 minutes. This procedure applies to blends and pure mixtures of ethylene oxide during the evacuation phase of a sterilization cycle. It is not applicable to other emission control systems, such as acid water scrubbers.

2. Principle

The basic components of the catalytic oxidizer are illustrated in Figure 1. Essentially, the ethylene oxide (EtO) from the sterilizer enters the catalytic oxidizer, mixes with combustion air, and is then treated through a catalyst. This catalyst oxidizes the EtO into carbon dioxide (CO_2) and moisture, which is then vented to atmosphere. The chemical reaction for this process is represented as:

$$2C_2H_4O + 5O_2 \rightarrow 4CO_2 + 4H_2O$$

From the measured concentrations of CO_2 and EtO exiting the catalytic oxidizer, the control efficiency can be readily determined.

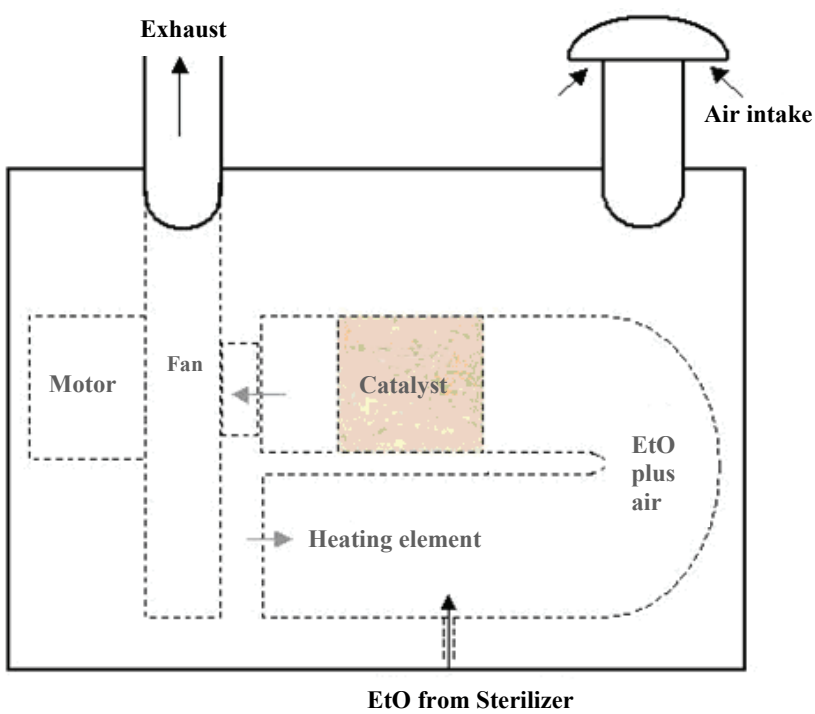

Figure 1. Catalytic Oxidizer Schematic

3. Procedure

The procedure for determining the control efficiency is detailed in *"Reference Method for Source Testing: Determination of the Ethylene Oxide Control Efficiency from Catalytic Oxidizers"*. The method requires two decisions for sampling the source. The first decision involves possible moisture condensation in the sample bag. The presence of condensate will lead to EtO losses in the sample. Two options are offered to address this condition, if applicable. The second choice deals with the sample extraction method – either constant or proportional flow. This is illustrated in Figure 2.

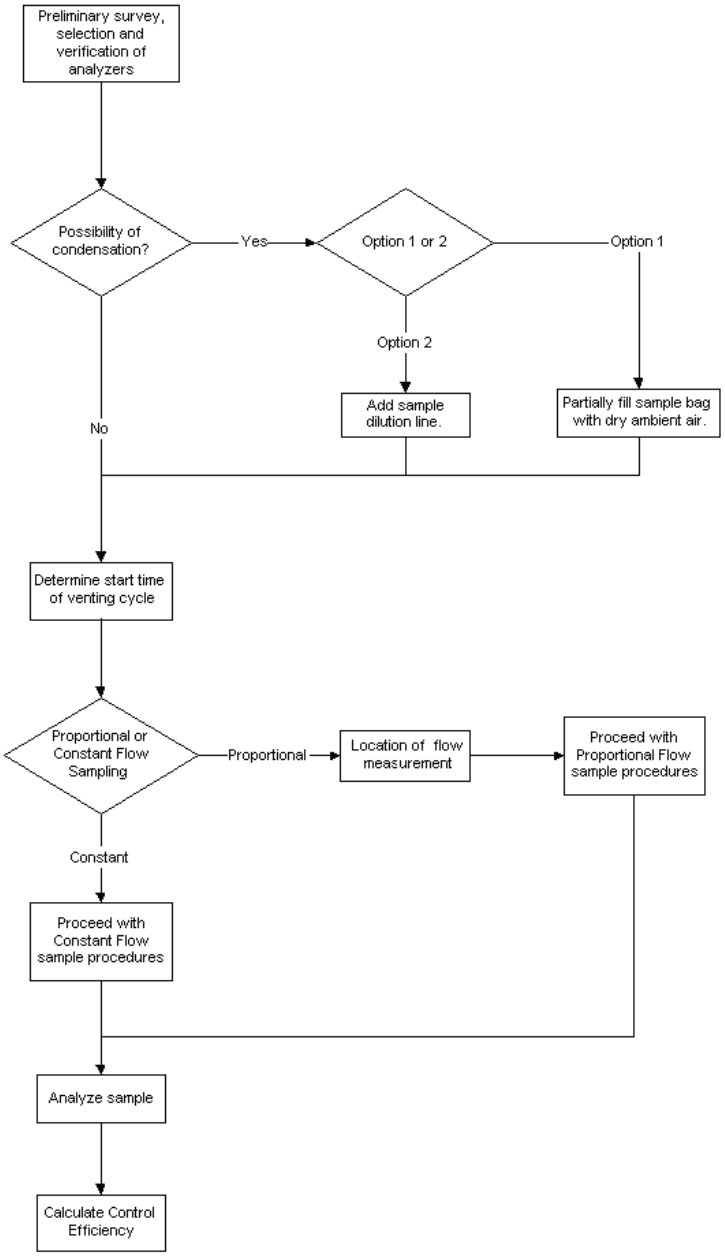

Figure 2. Summary Flow Chart

4. Sampling Strategy

The collection of the sample for the determination of control efficiency requires several decisions. A preliminary survey is mandatory to determine the location of the sampling port, to collect information on the cycle and to decide which sampling strategy is required to collect a representative sample. Steps are necessary to prevent condensation both during the collection of the integrated sample and the storage of the bag sample. The venting of gases through the bypass pipe may present a hazard to the personnel on site. These issues are addressed in the following subsections.

4.1 Location of Sampling Port

Two sampling ports, labelled “Upstream” and “Downstream” are located on the side of the catalytic oxidizer. The “Downstream” port should NOT be used for sampling emissions, as it may not provide a representative sample. The location of these sample ports is shown in Figure 3.

Figure 3. Unrepresentative Sampling Port

The sampling point for representative sampling must be in the exhaust stream of the abator, where the flow is well mixed. This applies to both the sample extraction port and the flow monitoring port when proportional sampling is required. Possible locations for the sample extraction and flow measurement ports are illustrated in Figure 4. Avoid ports near elbows and bends.

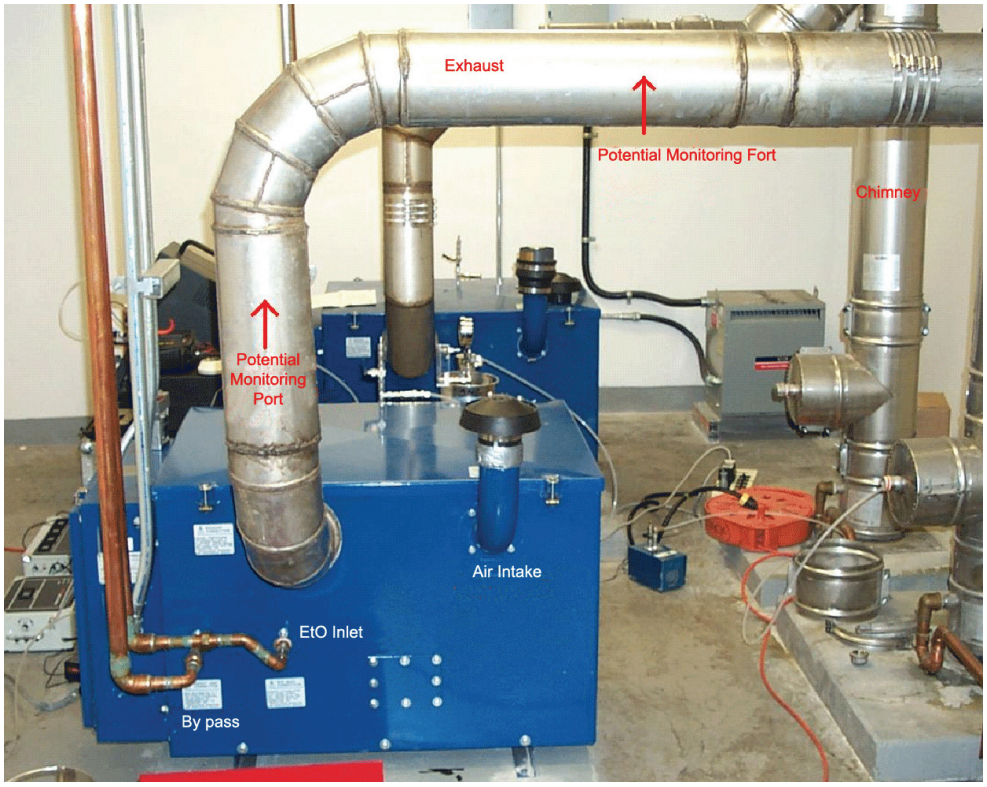

Figure 4. Exhaust Duct Sampling Locations

4.2 Determination of Sampling Period

The sampling is to be conducted during the evacuation phase of EtO from the sterilizer. In a typical sterilization cycle, this phase usually lasts about 50 to 60 minutes. Unfortunately, the start time cannot be determined precisely from the beginning of the cycle, as the duration of some phases depends on attaining specific values of vacuum, temperature, etc. In addition, when this stage of the cycle begins, the catalytic oxidizer may not provide any indication that it is processing EtO. The exhaust flow and temperature do not vary significantly when the EtO is fed to the catalytic oxidizer.

To address this issue, CO_2 can be monitored in the exhaust gas stream while the sterilization is occurring. When the CO_2 reaches twice the ambient level, the evacuation stage has begun and sampling may commence. Note that the CO_2 level increases rapidly; the sampler must pay close attention to this part of the cycle.

An alternative to monitoring the CO_2 levels is to retrofit the catalytic oxidizer with an indicator to signify that the evacuation stage has begun.

The sterilization cycle, expected concentrations at the outlet of the catalytic oxidizer and stack exhaust conditions (temperature and flow) are shown in Figure 5. The values shown on the x-axis may vary from sterilizer to sterilizer.

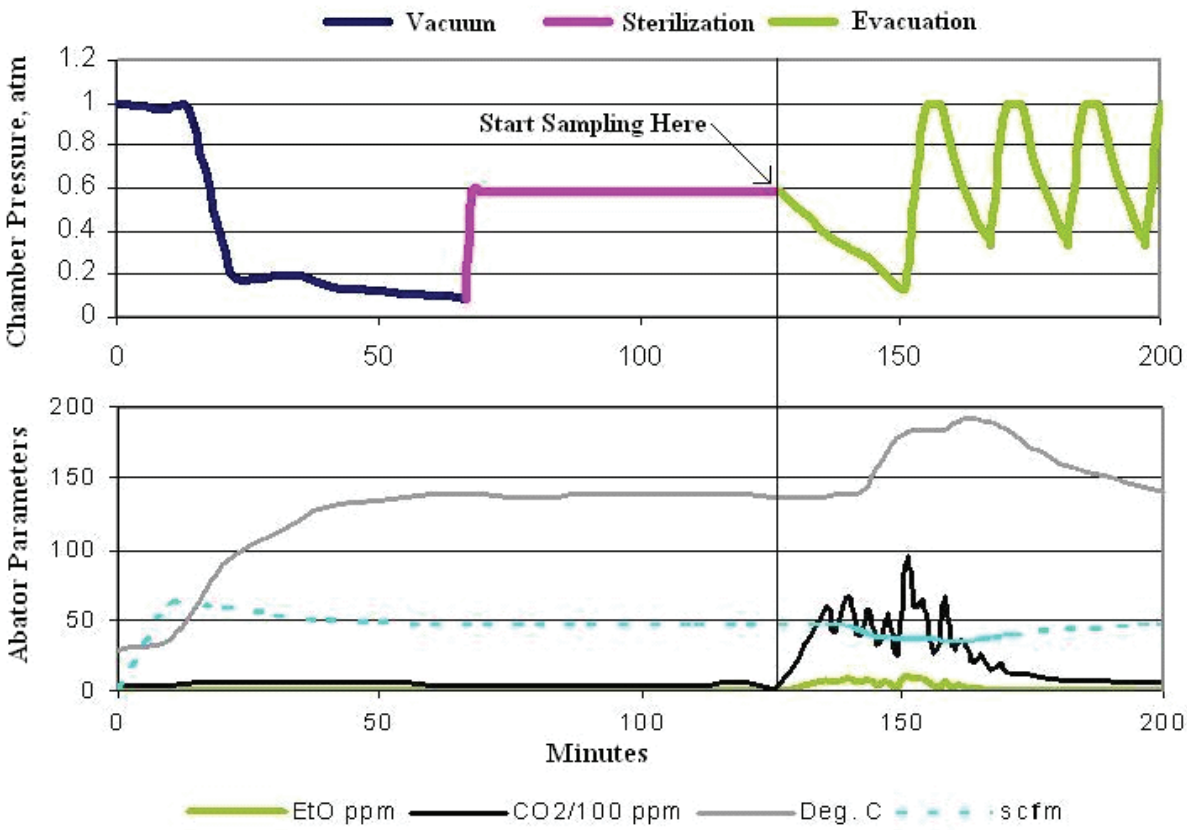

Figure 5. Typical Sterilization Cycle with Pure Ethylene Oxide

4.3 Proportional Versus Constant Flow Sampling

The ratio of EtO to combustion air is approximately 1:50. Usually, the flow in the exhaust does not vary by more than 15% over the sampling period. Under these conditions the constant flow sampling method is used to collect the integrated flue gas sample.

However, the constant flow sampling method is not suitable if the flow rate changes by more than 15% at any point during the cycle as measured using the procedures given in Method B (Determination of Stack Gas Velocity and Volumetric Flow) of Environment Canada Reference Method EPS 1/RM/8, *"Reference Method for Source Testing: Measurement of Emissions of Particulate from Stationary Sources"*. For proportional sampling a gas velocity port can be installed in the double-wall duct or a stack extension must be installed at the roof level. For locations where this port may be installed in the double-wall duct, see Figure 4.

A typical roof level schematic is shown in Figure 6. Note that this location is not recommended for sampling due to safety concerns and the proximity of the bypass pipe to the oxidizer exhaust.

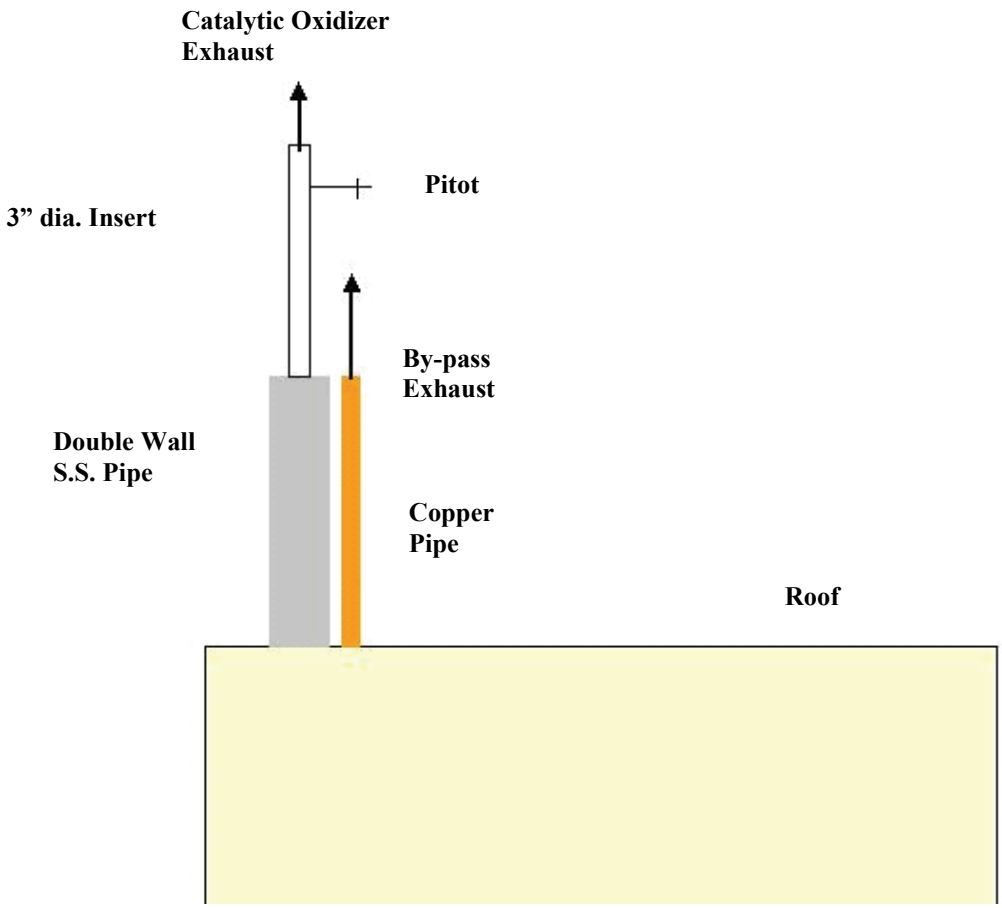

Figure 6. Typical Stack Schematic at Roof Level

4.4 Maintaining Sample Stability

Upon collection of the sample via proportional or constant flow sampling, the concentrations of EtO and CO_2 are to be measured using analyzers that meet the minimum performance specifications as stated in Tables 1 and 2 of the document *"Reference Method for Source Testing: Determination of the Ethylene Oxide Control Efficiency from Catalytic Oxidizers"*. Provided the sample was collected in the appropriate media, there should be no significant change in exhaust gas concentration up to one week after sample collection.

Ethylene oxide concentration rapidly depletes in the presence of condensation. Should the relative humidity of ambient air exceed 90%, then condensation avoidance measures should be taken as outlined in Section 7 of *"Reference Method for Source Testing: Determination of the Ethylene Oxide Control Efficiency from Catalytic Oxidizers"*.

Note: Do NOT refrigerate sample bags, as this may result in internal moisture condensation and EtO losses.

4.5 Catalytic Oxidizer Hazards

As EtO is a toxic compound, precautions should be taken when working in areas where it may be released in ambient air. At the completion of every cycle, a bypass pipe will discharge untreated low-concentration EtO to the atmosphere for several hours. This discharge occurs at the roof level and is identified by a small-diameter pipe (usually 1 in. diameter copper pipe), as illustrated in Figure 6. The unit may also vent all or part of the sterilizer burden at any time, with concentrations in the percent range, due to a malfunction of the system. While the collection of the sample on the roof is not encouraged, an individual located on the roof should take the necessary precautions to eliminate any contact with this untreated EtO.

5. Uncertainty

The error associated with the determination of the control efficiency may be estimated through an uncertainty analysis. The uncertainty is affected by the readings for each analyzed compound and their respective deviations. The standard deviation for the analysis of EtO and CO_2 may be determined by the replicate analysis of these compounds on the instrument(s) with a prepared mixture of known concentrations. A minimum of seven (7) repeats are required to determine the standard deviation. Note that the analysis of replicates, calibrations and analysis of the exhaust stream samples should be conducted under similar and stable ambient conditions.

The example calculation for measurements that yield a control efficiency of 99% shows that the uncertainty is about 0.1%. This means that the measured control efficiency was in the range of 98.9 to 99.1%. Analyzers that meet the performance specifications in *"Reference Method for Source Testing: Determination of the Ethylene Oxide Control Efficiency from Catalytic Oxidizers"* should yield uncertainties similar to those shown in Figure 7. For this reason, there is no requirement to meet uncertainty criteria for this sampling method.

$$CE = \frac{A - B}{A - B + 2 * C} * 100$$

Compound	Measured Value (ppm)		Standard Deviation (ppm)	
Carbon dioxide - sample	A	1500	D	50
Carbon dioxide - air	B	500	E	50
Ethylene oxide	C	5	F	0.5

Calculation

$\frac{(A+0.5*D)-B}{(A+0.5*D)-B+2*C}*100$	(G)	(H-G)	Uncertainty $\sqrt{(H-G)^2+(J-I)^2+(L-K)^2}$
$\frac{(A-0.5*D)-B}{(A-0.5*D)-B+2*C}*100$	(H)		
$\frac{A-(B+0.5*E)}{A-(B+0.5*E)+2*C}*100$	(I)	(J-I)	
$\frac{A-(B-0.5*E)}{A-(B-0.5*E)+2*C}*100$	(J)		
$\frac{A-B}{A-B+2*(C+0.5*F)}*100$	(K)	(L-K)	
$\frac{A-B}{A-B+2*(C-0.5*F)}*100$	(L)		

Example

$\frac{(1500+0.5*50)-500}{(1500+0.5*50)-500+2*5}*100$	(G) 99.03382	(H-G) -0.04904	Uncertainty $\sqrt{(-0.049)^2+(0.049)^2+(0.098)^2}$ 0.1201 0.12% (rounded)
$\frac{(1500-0.5*50)-500}{(1500-0.5*50)-500+2*5}*100$	(H) 98.98477		
$\frac{1500-(500+0.5*50)}{1500-(500+0.5*50)+2*5}*100$	(I) 98.98477	(J-I) 0.04904	
$\frac{1500-(500-0.5*50)}{1500-(500-0.5*50)+2*5}*100$	(J) 99.03382		
$\frac{1500-500}{1500-500+2*(5+0.5*0.5)}*100$	(K) 98.96091	(L-K) 0.09803	
$\frac{1500-500}{1500-500+2*(5-0.5*0.5)}*100$	(L) 99.05894		

$$CE = \frac{A - B}{A - B + 2 * C} * 100 = \frac{1500 - 500}{1500 - 500 + 2 * 5} * 100 = 99\% \pm 0.12\%$$

Figure 7. Uncertainty Calculation for Control Efficiency of Ethylene Oxide