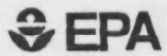


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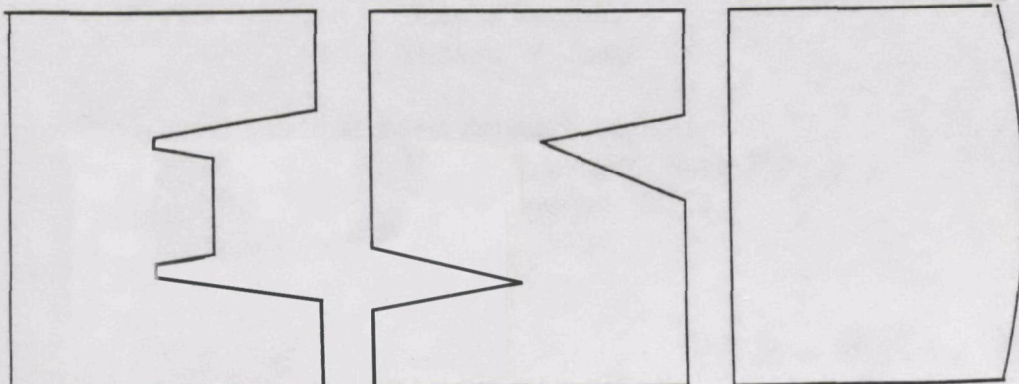
Office of Air Quality  
Planning and Standards  
Research Triangle Park NC 27711

EPA-450/4-91-020a  
August 1991

Air



# **The Measurement Solution: Using a Temporary Total Enclosure for Capture Efficiency Testing**



# **THE MEASUREMENT SOLUTION**

## **Using a Temporary Total Enclosure for Capture Efficiency Testing**

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## CHAPTER 1 INTRODUCTION

### PURPOSE

This document presents an overview of the gas/gas temporary total enclosure (TTE) method for measuring capture efficiency (CE). Information is also provided on the criteria for a permanent total enclosure (PTE) to aid in evaluating the necessity of testing for CE. The document is intended for use by State and local agency personnel who will oversee the CE testing procedures or by the facility personnel and their test contractors who will construct the TTE and perform all of the required test protocols. The procedures outlined in the following sections of this document are intended to present a straightforward approach to CE testing using a TTE.

This guidance document was prepared based on the U. S. Environmental Protection Agency's (EPA's) CE measurement procedures. The States are expected to adopt compatible measurement procedures; however, the reader should verify that the planned approach is consistent with State procedures.

### BACKGROUND

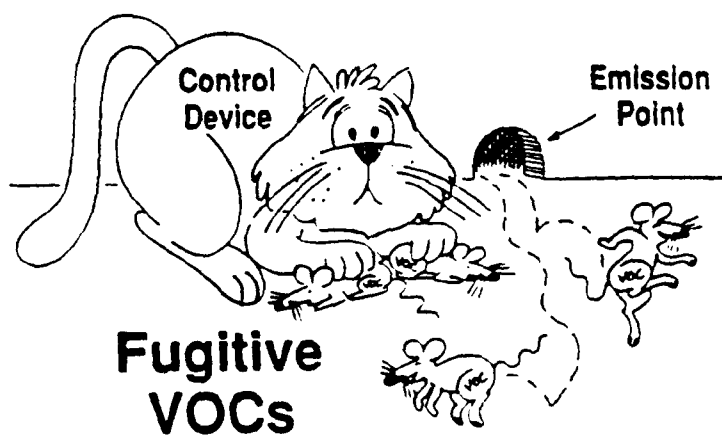
Persistent ozone problems in many areas of the United States have focused attention on reducing volatile organic compound (VOC) emissions. Early efforts resulted in reductions in VOC emissions from sources that are relatively easy to control. However, the need for additional reductions has brought about

increased attention to more difficult VOC control problems. With this attention has come an increased emphasis on maximizing, and measuring, CE. For example, EPA has promulgated five new source performance standards that include variations of the gas/gas TTE measurement procedure (40 CFR 60 Subparts RR, TT, FFF, SSS, and VVV).

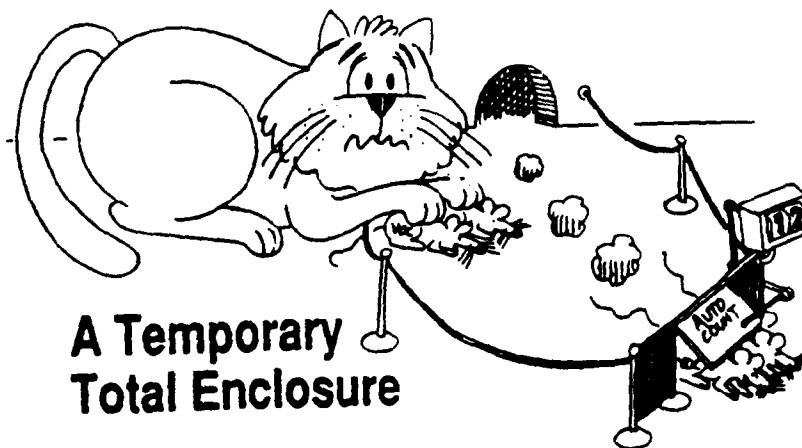
In April 1990, EPA issued guidance on CE measurement procedures, emphasizing procedures that require a total enclosure. Such methods are preferred because the estimated probable error is lower for these methods than for others. The EPA intends to add the CE measurement procedures (with minor revisions) to 40 CFR 51, Appendix M, as test methods.

There are two types of total enclosures: permanent and temporary. A TTE is erected solely to test the CE of a process. After the

### The Problem:



## The Measurement Solution:



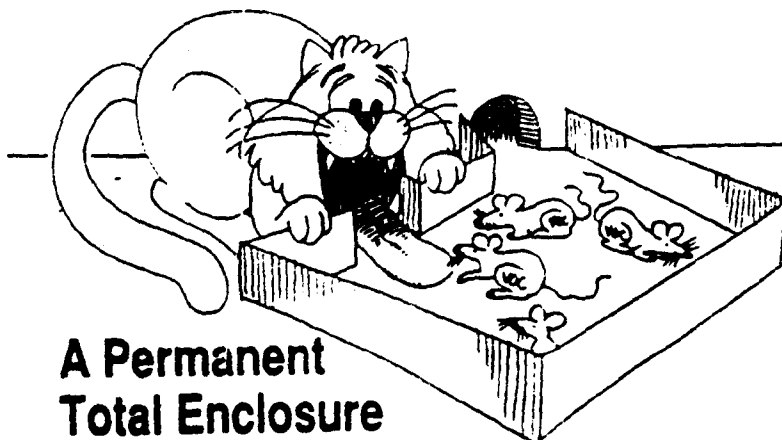
**A Temporary  
Total Enclosure**

test is completed, the TTE is dismantled until the next time the test must be performed. A PTE is put in place permanently to achieve "total" capture of the VOC emissions continuously. If the PTE meets certain criteria cited later in this document, EPA and the States permit CE to be assumed to be 100 percent, and testing to determine CE is not required. Remember that testing for the efficiency of the control device may still be required; only CE testing is waived.

### ORGANIZATION

In Chapter 2, the definition of CE is presented and explained. Chapter 3 discusses the need for CE measurements. The definition of a TTE is presented and explained in Chapter 4. In Chapter 5, a stepwise approach to the design and construction of a TTE is presented, and Chapter 6 discusses CE testing. Supplemental materials are presented in the Appendices that follow Chapter 6.

## The Emission Reduction Solution:



**A Permanent  
Total Enclosure**



## CHAPTER 2

### WHAT IS CAPTURE EFFICIENCY?

The formal definition for capture efficiency (CE), as measured by the gas/gas temporary total enclosure method, is: the fraction of all volatile organic compounds (VOC's) generated by and released at an affected facility that is directed to a control device. Perhaps this can be visualized better by use of the simplified diagram in Figure 2-1.

Simply, the capture efficiency is the percentage of the total VOC released by the process that is captured and delivered to the control device. In the sections below, we will look at the different parts of the definition to explain more fully what each part means.

What constitutes a VOC? A VOC is defined as any organic compound that

participates in atmospheric photochemical (sunlight) reactions. (A more exhaustive definition is included in the glossary at the end of this document.) In practical terms, this means that VOC's include many of the chemicals that are currently being used as solvents and many other commonly used liquids (or the liquid portions of mixtures). Some specific examples of types of chemicals that are typically VOC's are given in Table 2-1.

The only organic compounds that are not currently considered by EPA to be VOC's are presented in Table 2-2. These compounds have been exempted by EPA because of their negligible photochemical reactivity.

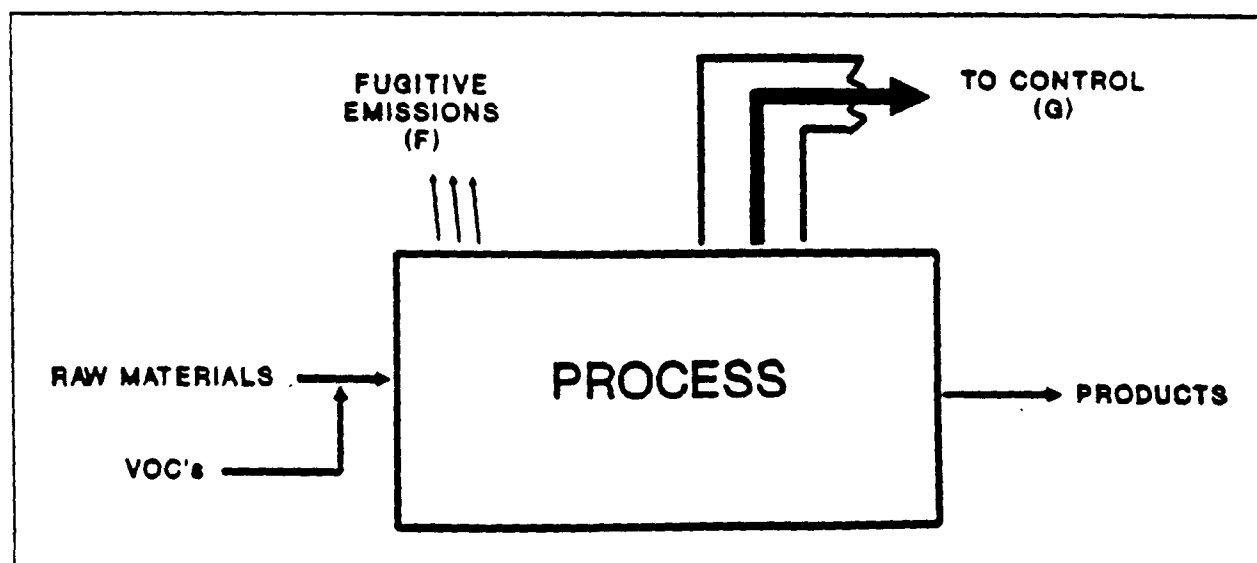


Figure 2-1. Simplified process/emissions diagram.

TABLE 2-1. EXAMPLES OF COMMON CHEMICALS REGULATED AS VOC's

Class	Examples
Alcohols	Methanol, ethanol, propyl alcohols, cyclohexanol, butyl alcohols, ethylene glycol, propylene glycol
Hydrocarbons—aliphatic	Hexane, pentane, cyclohexane, mineral spirits, VM&P naphtha
Hydrocarbons—aromatic	Benzene, toluene (toluol), ethylbenzene, xylenes (xylol)
Chlorinated hydrocarbons—aliphatic	Chloroform, ethylene dichloride, tetrachloroethylene (perc)
Chlorinated hydrocarbons—aromatic	Monochlorobenzene, dichlorobenzene, trichlorobenzene
Esters	Ethyl acetate, isopropyl acetate, butyl acetate, glycol ether acetate
Ketones	Acetone, methyl ethyl ketone, methyl isobutyl ketone, cyclohexanone, methyl iso-amyl ketone
Ethers	Ethyl ether, ethylene glycol mono-methyl ether, diethylene glycol mono-butyl ether, propylene glycol mono-methyl ether, tetrahydrofuran, ethylene glycol mono-ethyl ether
Aldehydes	Formaldehyde, acetaldehyde, benzaldehyde

TABLE 2-2. ORGANIC COMPOUNDS EXEMPTED AS VOC's

Current List	Proposed Additions <sup>a</sup>
Methane	2-Chloro-1,1,1,2-tetrafluoroethane (HCFC-124)
Ethane	Pentafluoroethane (HFC-125)
1,1,1-Trichloroethane (methyl chloroform)	1,1,1,2-Tetrafluoroethane (HFC-134)
1,1,2-Trichloro-1,2,2-trifluoroethane (CFC-113)	1,1,1-Trifluoroethane (HFC-143a)
Dichloromethane (methylene chloride)	1,1-Difluoroethane (HFC-152a)
Trichlorofluoromethane (CFC-11)	Cyclic, branched, or linear, completely fluorinated alkanes
Dichlorodifluoromethane (CFC-12)	Cyclic, branched, or linear, completely fluorinated ethers with no unsaturations
Chlorodifluoromethane (CFC-22)	Cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations
Trifluoromethane (FC-23)	Sulfur-containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC-114)	
Chloropentafluoroethane (CFC-115)	
1,1-Dichloro-2,2,2-trifluoroethane (HCFC-123)	
1,1,1,2-Tetrafluoroethane (FC-134a)	
1,1-Dichloro-1-fluoroethane (HCFC-141b)	
1-Chloro-1,1-difluoroethane (HCFC-142b)	

<sup>a</sup>Proposed in Federal Register (56 FR 11387, March 18, 1991); final action: expected in 1991.

**What is an affected facility?** An affected facility is the equipment or process to which the regulation applies and which must be tested for VOC capture efficiency. An example of an affected facility is a coil coating line or a flexographic press.

**What does "VOC's generated by and released at" mean?** This phrase means the VOC's that are released by the process as a gas in the immediate vicinity of the process. The VOC's generally enter the process as a component of the raw materials and are usually liquid. During the process, some or all of the VOC's evaporate due to heat or other causes. This CE procedure measures only the VOC's released in the gas phase in the vicinity of the process being tested. In cases where emissions outside the affected facility are covered by the applicable regulations, these emissions must be evaluated by some other means. Examples of such emissions include the gradual release of retained solvent from a product after it has left the manufacturing area and the evaporation of VOC's from waste coatings or inks during storage and disposal.

**What does "directed to a control device" mean?** The VOC's directed to a control device are those that are contained in or drawn into a capture device and vented to a control device. A capture device may be a drying oven, enclosed room, hood, floor sweep, or other means of containing or collecting VOC's and directing those VOC's into a duct.

In contrast to the "captured" emissions, which are directed to a control device, other VOC's are emitted into the ambient air of the plant (see Figure 2-1). These emissions may diffuse through the plant but eventually reach the atmosphere through the general ventilation system or open windows or doors. These are considered "fugitive" emissions.

Actually, at some facilities there may be emissions that are collected by a capture device and vented directly to the atmosphere through a stack or duct. Although these emissions are not typically considered fugitive emissions, within the context of this document all emissions that are not directed to a control device are considered fugitive emissions for the purpose of the calculations to be performed.

**What is a control device?** A control device is any equipment that reduces the quantity of VOC that is emitted to the atmosphere. Examples of control devices are incinerators, carbon adsorbers, and condensers.

**How is CE determined?** In theory, determining capture efficiency is a very simple and straightforward process. In short, the quantity of VOC directed to the control device divided by the total quantity of VOC released by the process (i.e., the quantity vented to the control device plus the quantity of fugitive

emissions) is the capture efficiency. This relationship is shown by the following equation:

$$\text{Capture efficiency (\%)} = \frac{G}{G + F} \times 100$$

(CE)

where:

G = quantity of VOC released by the process that is directed to the control device (i.e., the captured VOC).

F = quantity of VOC released by the process that escapes as fugitive emissions.

G + F = total VOC's generated by and released at the affected facility.

## CHAPTER 3

### WHY MEASURE CAPTURE EFFICIENCY?

Most volatile organic compound (VOC) regulations relate the allowable emissions for a process to the amount of raw material used in the process. Such regulations are frequently presented in terms of an overall percent reduction or in terms of the VOC content of the feedstock coating or ink. Regardless of how the standard is stated, when complying coatings or inks are not used, compliance is typically determined by evaluating the percentage of the input VOC that is prevented from reaching the atmosphere. This percentage is called the "control system efficiency" (CSE).

As illustrated in Figure 3-1, CSE has two components, capture efficiency (CE) and control device efficiency (CDE). While CDE has often received more attention, CE is equally important. A control device can act upon only those VOC's that have been captured and directed to the device. The device cannot control VOC's that do not reach it. For example, if only 50 percent of VOC emissions are captured, the maximum CSE that can be achieved is 50 percent, even with a control device that is 100 percent efficient. The use of improved CE measurement protocols, such as the one presented in this document, will allow the emphasis on CE to equal that long placed on CDE.

Mathematically, CSE is the product of the fractional capture and control device efficiencies. The equation is:

$$\text{CSE} = \text{CE} \times \text{CDE}$$

Examples of CSE calculations are:

<u>CE</u>	<u>x</u>	<u>CDE</u>	<u>=</u>	<u>CSE</u>
0.50		0.95		0.48
0.75		0.90		0.68
0.90		0.95		0.86
1.00		0.95		0.95

In most cases, to determine the CSE of a process accurately, both the CE and CDE must be measured. However, EPA and the States permit 100 percent capture efficiency to be assumed without measurement if it is shown that the process is contained in a permanent total enclosure (PTE). No capture efficiency testing is necessary if the process enclosure can meet the requirements for a PTE, although the CDE still must be measured. Figure 3-2 illustrates the use of PTE.

Another case where CE may not have to be measured is a process that is controlled with a solvent recovery device. If the quantity of VOC recovered can be directly compared to the quantity of VOC input to the process, CSE can be determined directly without measuring either CE or CDE. This situation is illustrated in Figure 3-3.

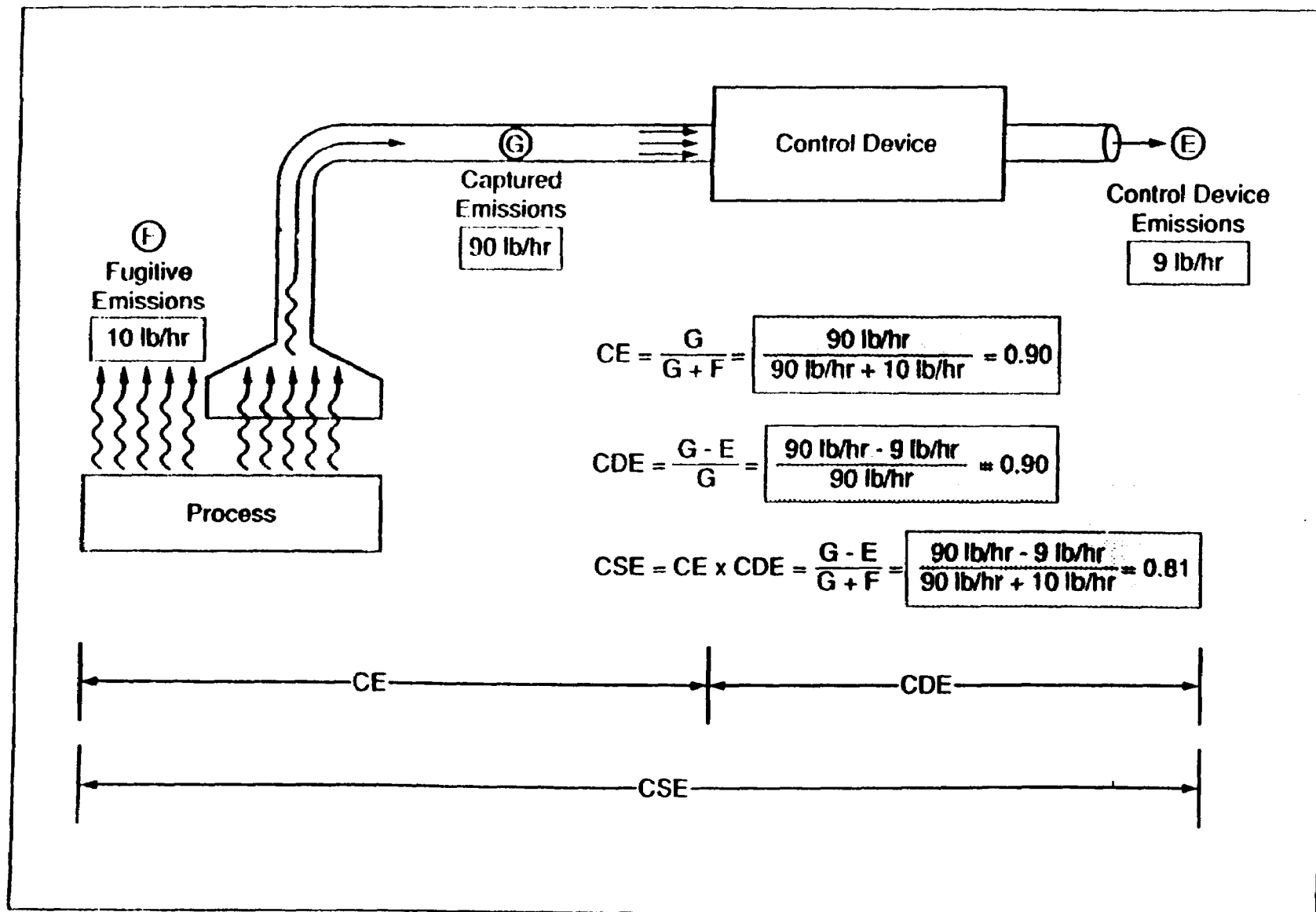


Figure 3-1. The components of control system efficiency.

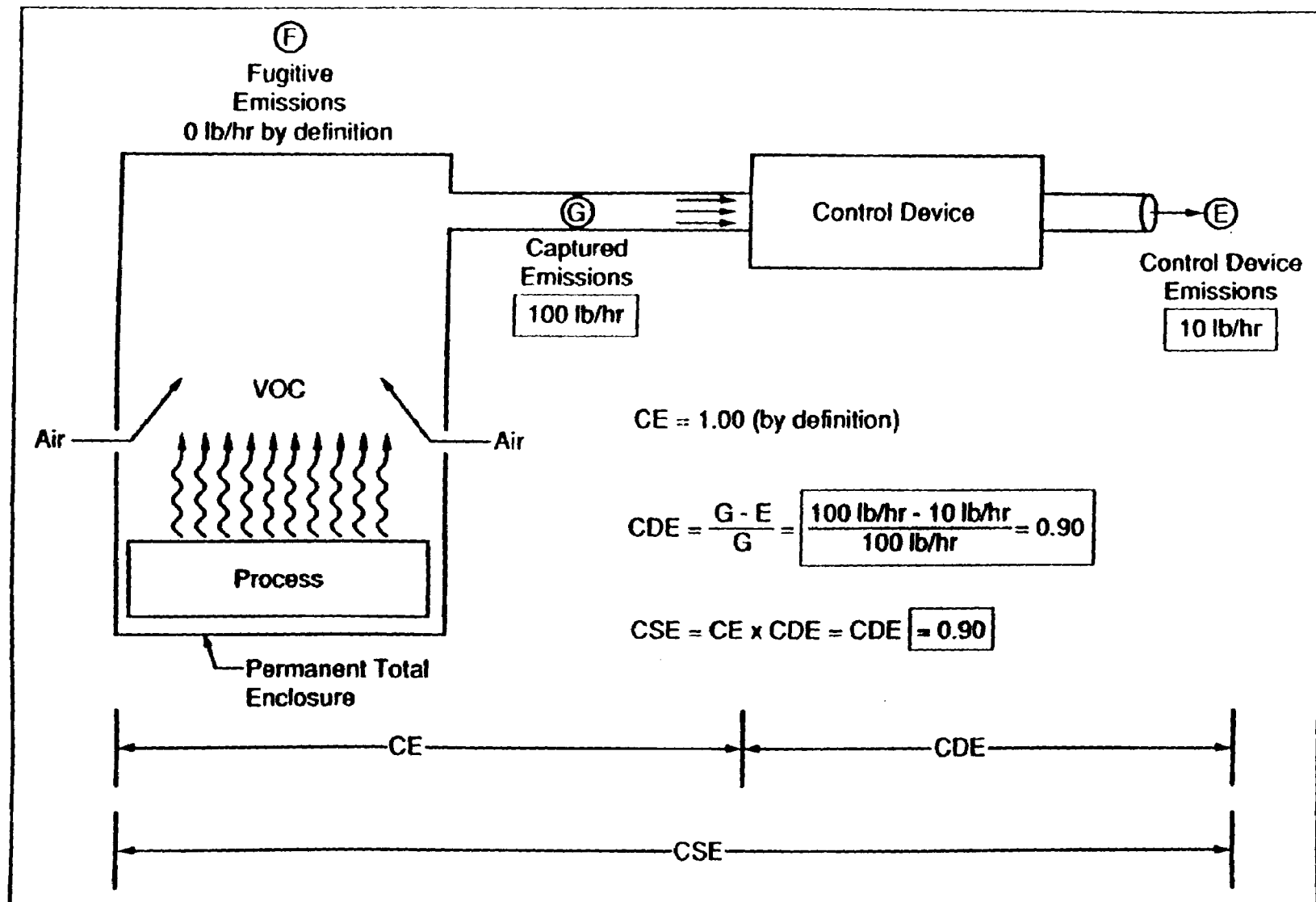


Figure 3-2. Control system efficiency with a permanent total enclosure.

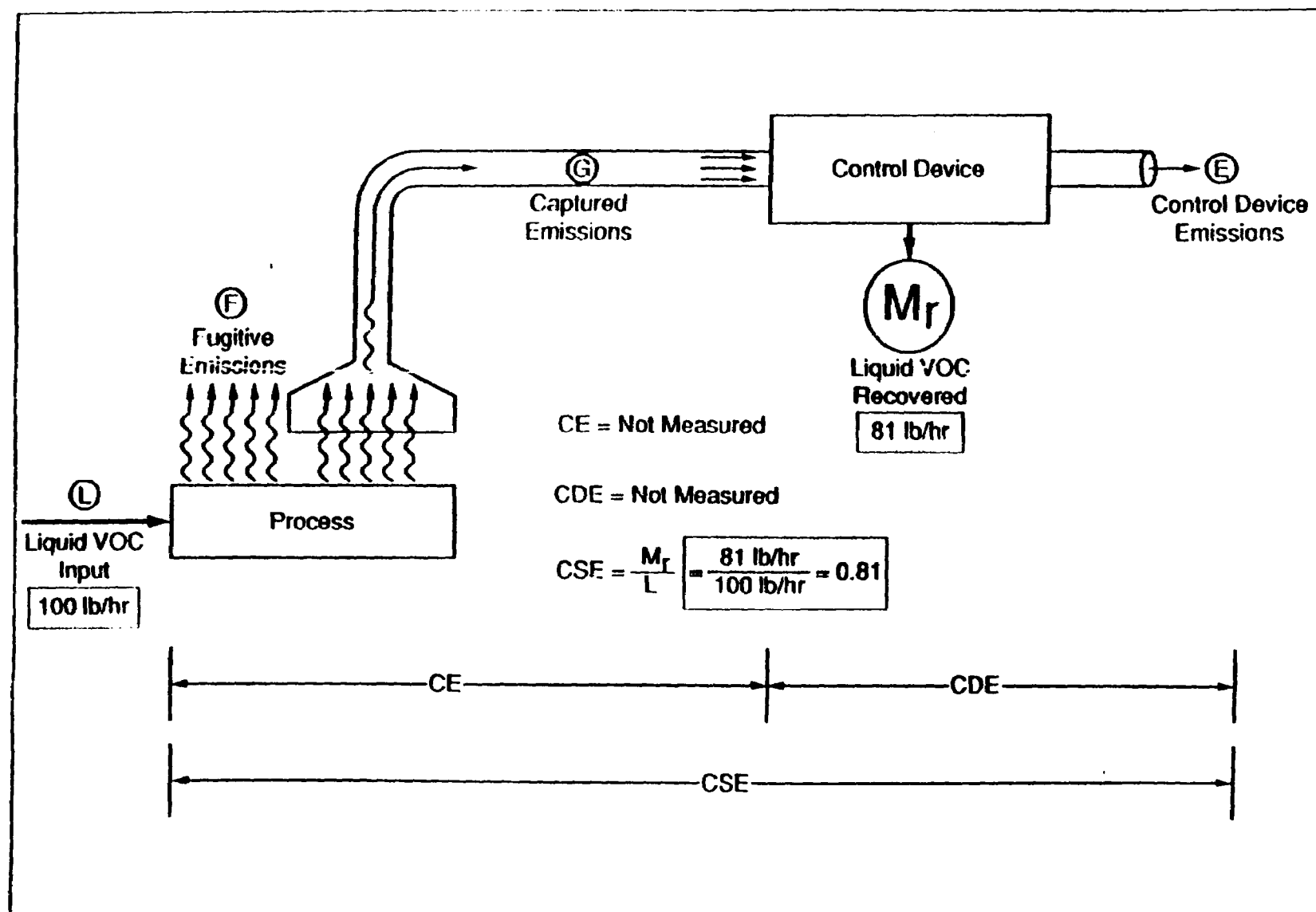


Figure 3-3. Control system efficiency with a solvent recovery device.



## **CHAPTER 4**

### **WHAT IS A TOTAL ENCLOSURE?**

A total enclosure is a structure that completely surrounds a process so that all volatile organic compound (VOC) emissions are captured for discharge through ducts or stacks. The only openings in a total enclosure are forced makeup air ducts, exhaust ducts leading to a control device or the atmosphere, and natural draft openings (NDO's) such as those that allow raw materials to enter and products to leave and those that are added to improve ventilation. It is very important that the airflow through the total enclosure be engineered to keep the concentration of VOC's within the enclosure below the Occupational Safety and Health Administration (OSHA) health requirements and vapor explosive limits. These two areas will be discussed in more detail later in this chapter.

There are two types of total enclosures: temporary and permanent. These are discussed below.

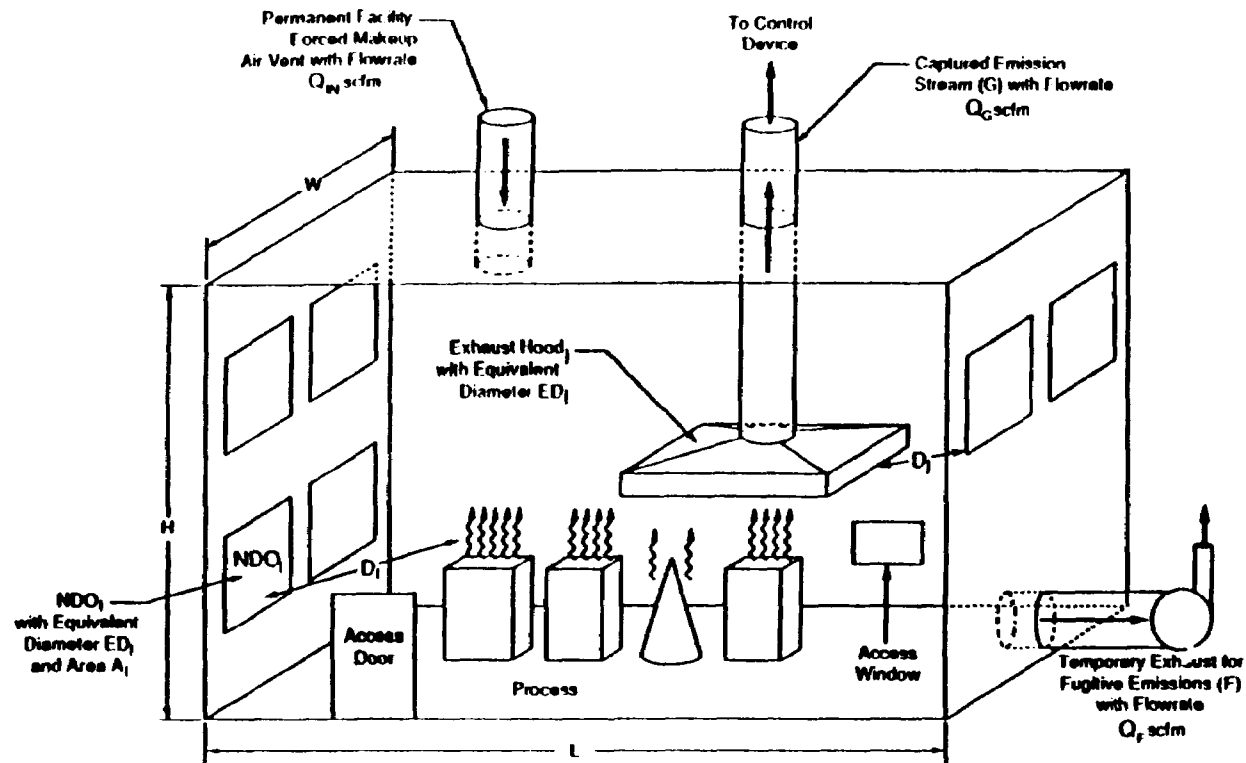
#### **WHAT IS A TEMPORARY TOTAL ENCLOSURE?**

A temporary total enclosure (TTE) is an enclosure temporarily installed specifically for the capture efficiency (CE) test. It completely surrounds the affected facility such that all VOC emissions are captured and discharged through ducts that allow for the accurate

measurement of VOC rates. More simply, it is a temporarily installed enclosure that ensures that no VOC escapes without being measured.

A TTE typically has two exhausts—a permanent duct through which captured VOC's are vented to the control device and a temporary exhaust duct (installed for the test) through which the VOC's normally emitted as fugitives are vented for measurement. The quantity of VOC passing through these ducts is accurately measured and used to calculate the capture efficiency. Of course, there may be multiple ducts leading to the control device(s) or multiple temporary exhaust ducts. Where a TTE includes a permanent hood or other exhaust that vents directly to the atmosphere, the exhaust duct is considered another temporary exhaust for purposes of measuring and calculating fugitive emissions.

Minimum criteria have been developed for an enclosure to be considered a TTE for purposes of the CE test. These criteria are intended to ensure that all VOC's are captured for measurement and to minimize disruption of the capture normally achieved by the existing capture device(s) in the absence of the enclosure. The criteria are presented below and illustrated in Figure 4-1.



Criterion 1:  $D_i \geq 4 \times ED_i$  for every NDO and VOC source.

Criterion 2:  $D_i \geq 4 \times ED_i$  for every exhaust point and NDO.

Criterion 3:  $\sum_{i=1}^n A_i \leq 0.05 \times [(2 \times L \times W) + (2 \times W \times H) + (2 \times L \times H)]$

Criterion 4:  $FV = \frac{Q_{EXIT} - Q_M}{\sum_{i=1}^n A_i} > 200 \text{ ft/min}$  and demonstrably inward.

Note:  $Q_{EXIT} = Q_G + Q_F$

Criterion 5: All access doors and windows closed during routine operation.

Figure 4-1. The criteria for a TTE.

1. Any NDO shall be at least 4 equivalent opening diameters from each VOC-emitting point. An "equivalent diameter" is the diameter of a circle that has the same area as the opening. The equation for an equivalent diameter (ED) is:

$$ED = \left( \frac{4 \times area}{\pi} \right)^{0.5}$$

For a circular NDO, this equation simply reduces to the diameter of the opening.

2. Any exhaust point from the enclosure shall be at least 4 equivalent duct or hood diameters from each NDO.
3. The total area of all NDO's shall not exceed 5 percent of the surface area of the enclosure's walls, floor, and ceiling.
4. The average face velocity (FV) of air through all NDO's shall be at least 200 ft/min. The direction of air through all NDO's shall be into the enclosure.
5. All access doors and windows whose areas are not included as NDO's and are not included in the calculation of FV shall be closed during routine operation of the process.

Some terms and concepts related to TTE's need to be explained because they are used frequently throughout the remainder of this document. These terms and concepts are described in the remainder of this section and in the glossary at the end of the Appendices.

A **natural draft opening (NDO)** is any opening that remains open during routine operation of the process and is not connected to a duct with a fan or blower attached. Thus, NDO's are any openings other than exhausts (forced or induced) and forced makeup air ducts. Examples are entrances and exits in the enclosure to allow raw materials to enter and products to leave. Natural draft openings that are not related to the process also may be added to improve the ventilation of the enclosure. The airflow direction and rate through the NDO depend on the difference in pressure inside and outside of the TTE.

**Face velocity** is the speed of the air flowing through the NDO. For these procedures, the average FV is calculated by dividing the net exhaust rate out of the enclosure by the total area of all NDO's. The volumetric flow rates are measured using EPA Method 2. The equation for FV and sample calculations are given in Appendix A-1.

**Isolation of affected emissions.** A CE measurement is made as part of a compliance determination for a particular affected facility or, possibly, group of affected facilities. Thus, it is important that only emissions from the affected facility are measured. A TTE should enclose only emission sources that are part of the affected facility. All other sources should be excluded. In cases where such isolation is not possible, determine whether the nonaffected emissions are significant; if so, these emissions must be accounted for in the CE determination.

Worker safety is very important in performing these tests. The VOC concentration within the TTE must level off at a concentration below the OSHA Permissible Exposure Limit (PEL) for all solvents used if human access to the TTE is required. If no one will enter the TTE, the allowable VOC concentration is dictated by the lower explosive limit (LEL). Generally the upper limit for fire insurance purposes is 25 percent of the LEL.

If these concentrations cannot be met, corrective action must be taken. Corrective actions could include repositioning the capture devices, relocating the TTE exhaust ducts, repositioning the NDO's, or increasing the exhaust flow rate either to the control device or through the temporary exhaust set up to measure fugitive emissions. Any changes to the permanent system components (e.g., capture devices, flow rates) must be maintained after testing so that the test data represent the situation that exists after completion of the tests.

Monitoring the ambient VOC concentration inside the TTE during testing to ensure that the appropriate level is not exceeded is strongly advised. Information on acceptable levels and monitoring considerations for VOC mixtures is included in Appendix C.

#### **WHAT IS A PERMANENT TOTAL ENCLOSURE?**

A permanent total enclosure (PTE) is an enclosure that completely surrounds a source of emissions such that all VOC emissions are

contained for discharge to a control device. The enclosure must be permanent, unlike a TTE, which is installed only for the duration of the CE test.

The PTE must meet all of the criteria stated for the TTE, except that there is no restriction on the distance between exhaust points and NDO's (see Figure 4-2). This criteria was included for TTE's (1) to avoid disruption of normal airflow patterns and (2) to avoid channeling between the NDO and the exhaust point, which could result in a VOC buildup in other areas of the TTE. These are of lesser concern in PTE's because in a PTE, the airflow patterns resulting from the interaction of the permanent NDO's and exhausts are the "normal" patterns. In addition, a PTE and its ventilation system are designed to minimize problems with VOC buildup. Any such problems within a PTE are detected and remedied in the course of complying with fire safety and OSHA requirements, instead of, perhaps, being undetected or uncorrected during the disruption of routine caused by a source test with a TTE.

If a facility meets the criteria for a PTE and all emissions are directed to a control device, the CE may be assumed to be 100 percent and--THE REQUIREMENT TO MEASURE THE CE IS WAIVED.

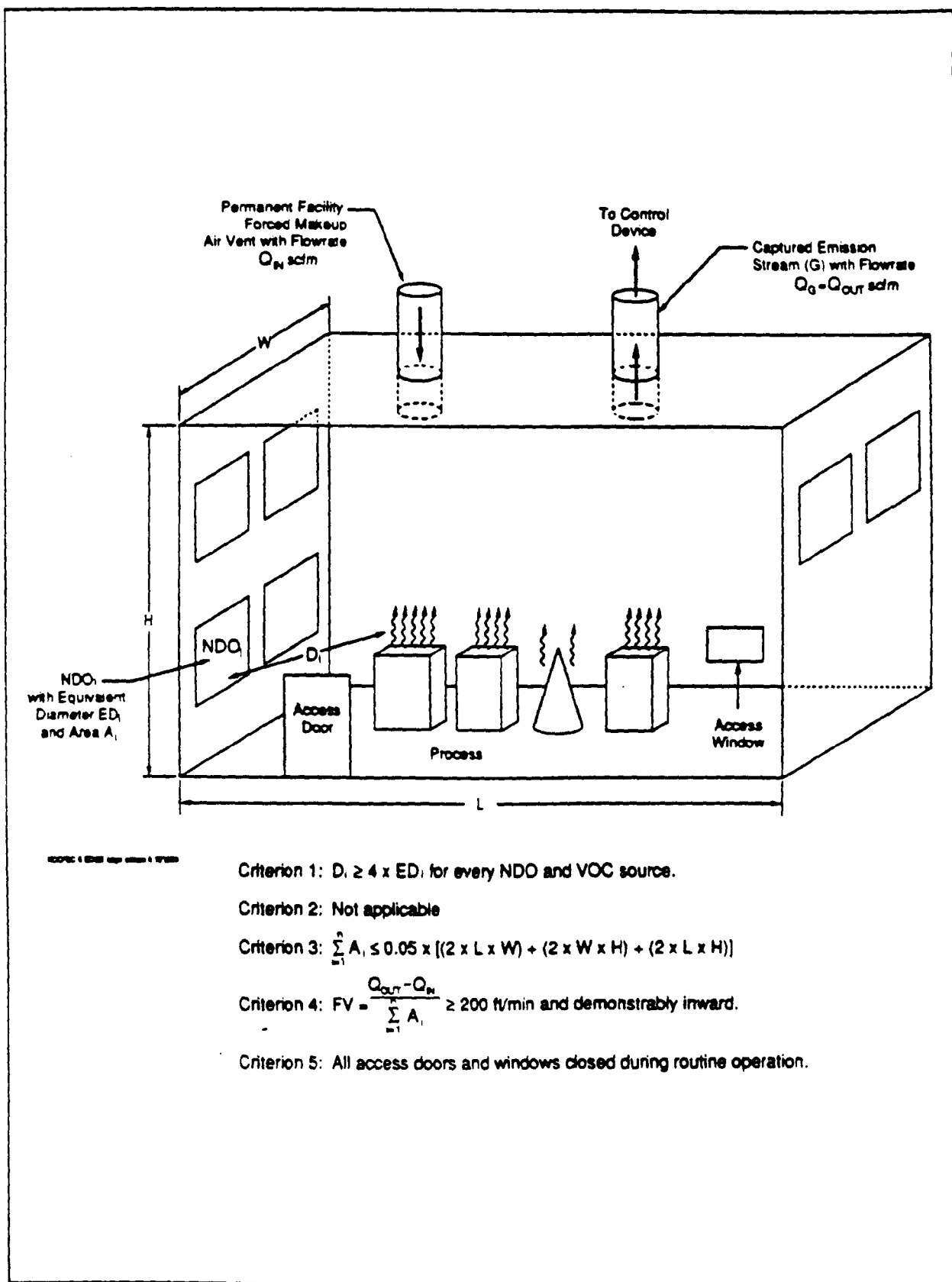


Figure 4-2. The criteria for a PTE.

Note: An entire building can qualify as a PTE if the building meets all of the requirements for a PTE. A PTE can be an entire building, one or more rooms in a building, or a structure built around one or more processes. However, if any of the requirements for a PTE are not met, the facility must undergo performance testing to measure the CE for the affected facility.

## CHAPTER 5

### HOW TO DESIGN AND CONSTRUCT A TEMPORARY TOTAL ENCLOSURE

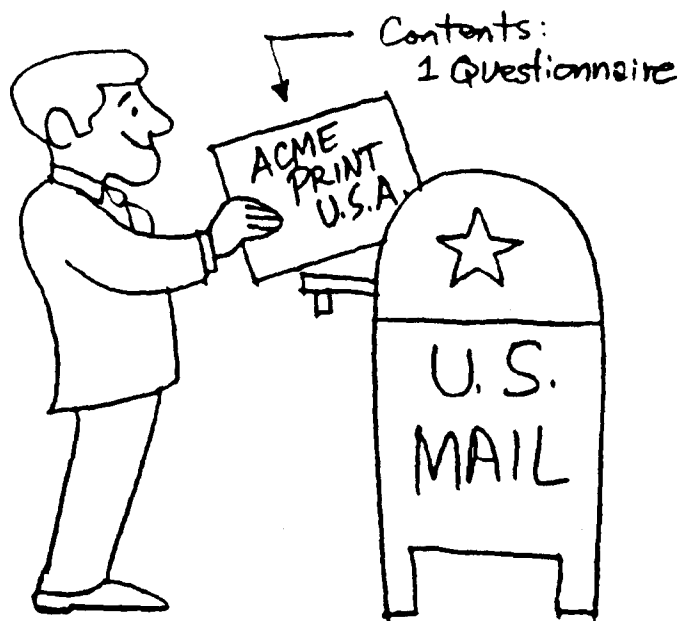
The design and construction of a temporary total enclosure (TTE) requires several steps to ensure that the enclosure meets all of the requirements for valid test results. All affected volatile organic compounds (VOC's) (and only affected VOC's) must be captured for measurement. In addition, the TTE should be designed to minimize any effect on the normal operation and performance of the permanent capture device(s). Another area of prime importance in designing and building the total enclosure is the safety and health of the workers and the test personnel. Health and safety concerns cannot be overemphasized.

#### DESIGN

An initial stage in the design procedure is a visit to the site of the facility to be tested. Prior to the site visit, State agency personnel and test contractors should prepare a list of specific information to be sought during the visit and send this list to the plant in advance of the visit. This allows the plant personnel time prior to the visit to assemble necessary data that are not readily available. A sample questionnaire is shown in Table 5-1 at the end of this chapter.

General process information is needed for each affected facility that is to be tested to

identify variables that could affect construction and operation of the TTE. If more than one process run is to be performed during the test, information is needed on the most common or longest jobs to help evaluate VOC composition and concentration. A basic understanding of process flow and air handling systems is necessary to properly evaluate the facility. Since considerable detailed knowledge is necessary to perform these tests, the plant is requested to provide blueprints and plans of the plant with as much detail as possible. The other information requested in the questionnaire will be required to evaluate the TTE design against the criteria for the TTE.



### The Plant Visit

Before visiting the plant, prepare a checklist. A sample checklist is shown in Table 5-2 at the end of this chapter. This checklist emphasizes the items that must be observed at the plant site. If possible, it helps to have a representative of the contractor (or plant personnel) who will construct the TTE present during the plant visit. These personnel may have valuable suggestions on construction techniques or may be able to resolve some questions about what is, or is not, practical in constructing the TTE.

Upon arrival at the plant, meet with the appropriate personnel to discuss the capture efficiency (CE) protocol and the purpose of the visit. Review the advance questionnaire for completion and any clarifications that are needed. Discuss any data gaps and how the information can be obtained.



At the site of the facility, one of the first steps is to evaluate whether the affected facility is enclosed in a permanent total enclosure (PTE), in which case a performance test to measure CE is not necessary. The criteria for qualification as a PTE were given in Chapter 4. If the affected facility is not enclosed in a PTE, either of two options can be exercised. One option is to modify the existing facility so it will qualify as a PTE; the second option is to conduct performance testing of the process to determine the CE, which will often require construction of a TTE.

If a TTE must be built, the VOC sources must be surveyed to determine which of the sources are "affected" (i.e., subject to the emission standard) and which sources in the immediate area are "nonaffected." The affected sources must be included in the TTE, and the enclosure, when constructed, must isolate the emissions from the affected facility from all other emissions.

During the visit, acquire the necessary information on the checklist (Table 5-2). Be sure to obtain the data necessary to estimate the temporary exhaust rate needed to keep the atmosphere inside the TTE safe and healthful. These data include information on the chemical composition of the VOC's to be encountered during the test and information to estimate the fugitive emission rate.

If a drying oven is part of the process, determine whether the oven must be enclosed within the TTE. If the oven contains all of the VOC released inside it (i.e., operates at

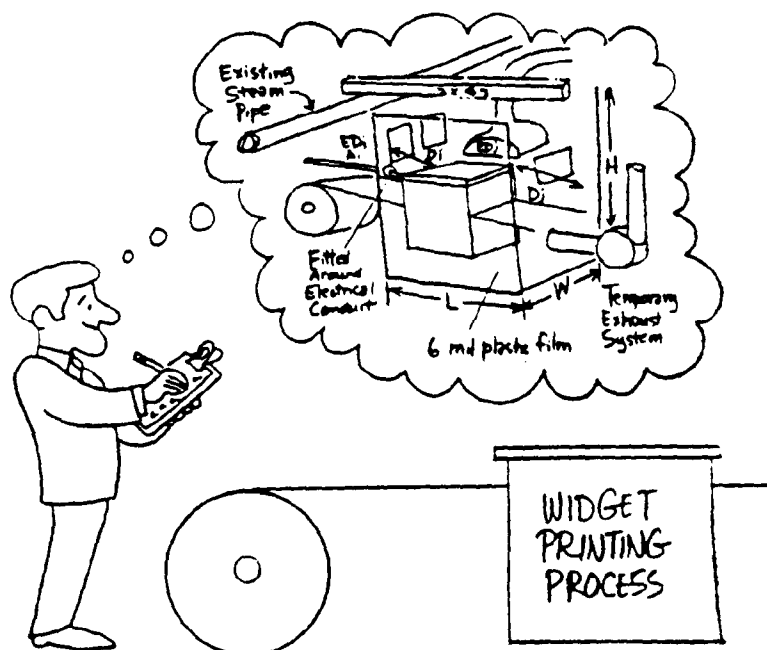


negative pressure), the oven can function as a component of the total enclosure for the test. If not, the oven must be enclosed along with the rest of the process. For the oven to remain outside the TTE, it must be demonstrated that air will be drawn into the oven at all openings rather than flowing outward, carrying VOC's with it. The oven can be evaluated either by using a smoke tube or plastic streamers or by performing an analysis of the exhaust and forced makeup air volumes as is done to evaluate face velocity (FV) across the natural draft openings (NDO's) in the TTE.

During the inspection of the facility, start to visualize one or more possible TTE configurations. As the data in the checklist are gathered, consider their impacts on the potential enclosure configurations. Some important practical aspects of construction to consider are:

- ◆ Can any existing structures (e.g., the roof, a wall) be used as part of the TTE?
- ◆ Will existing structures impede construction? If so, how can they be accommodated?
- ◆ Where are NDO's required for the process (e.g., entrance for continuous web)?
- ◆ Where are doors and windows needed?
- ◆ Will there be sufficient access for the workers and equipment?
- ◆ Will the structure impede other operations at the plant?

- ◆ In event of an emergency (e.g., fire), can personnel readily escape the area?
- ◆ How can the temporary exhaust be constructed? Can it be vented outdoors through accessible windows or roof or wall vents? If not, where can it be exhausted indoors? Where can the fan and ductwork be located?
- ◆ In the TTE area, note exhaust points, any forced makeup air outlets, existing windows and vents, etc. that serve the entire facility. How can they be accommodated by the TTE?



Check the existing duct work to the control device, other exhausts, and any forced makeup air ducts to ensure that EPA Method 2 testing can be performed. All exhausts from and forced makeup air to the TTE must be

measured to verify that the minimum average FV across the NDO's (200 ft/min) is achieved.

Before leaving the area, pick one or more potential TTE configurations and obtain sufficient data to evaluate them against the TTE criteria. Included in these data requirements are:

- ◆ Location and size of NDO's essential to the process
- ◆ Other desirable NDO locations and sizes in order to provide good air movement through the TTE and maintain constant air concentrations at health-protective levels
- ◆ Distances from NDO's to VOC sources
- ◆ Size of exhausts (including temporary exhaust to be installed specifically for the tests) and distances from NDO's

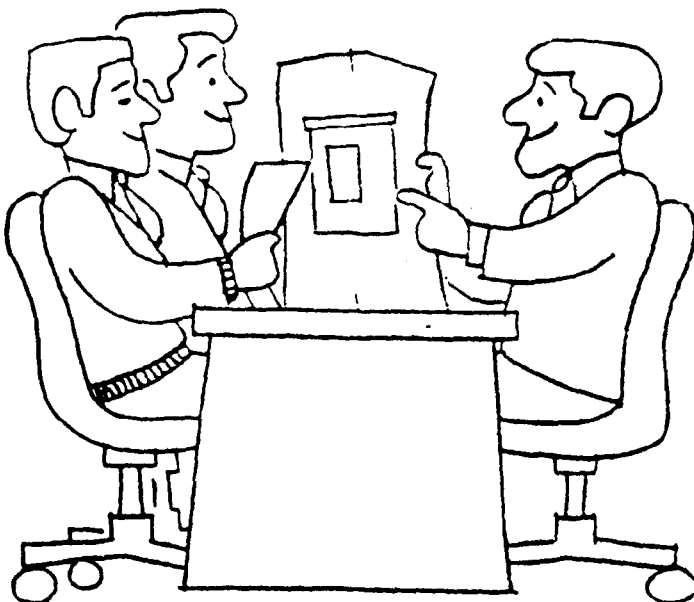
- ◆ Flow rates of exhausts and forced makeup air (test data, rated values, or fan and duct data, as available)
- ◆ Total dimensions of the prospective TTE (length, width, height)
- ◆ Probable locations of access doors and windows

These data will be needed after leaving the plant to design a TTE that meets all of the criteria.

After completing the plant tour, meet with facility representatives to review and verify the information that has been gathered. Identify any information gaps and make plans to obtain the missing information. Discuss alternative TTE configurations and test locations to determine whether facility representatives are concerned about any of the possibilities brought up during the visit.

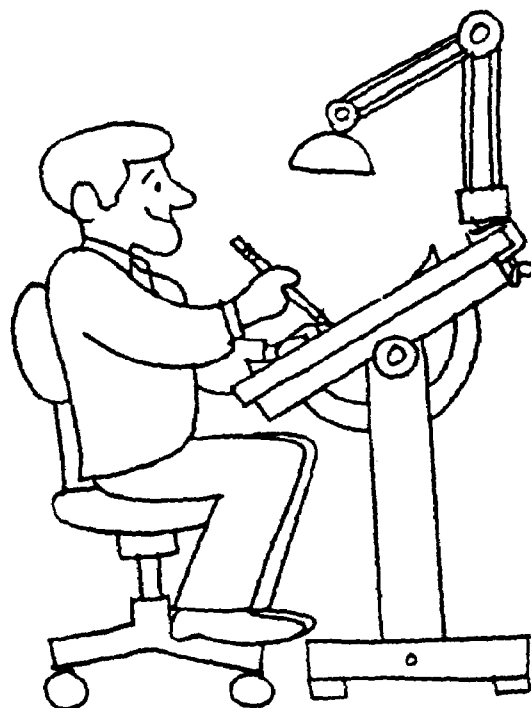
#### After the Plant Visit

The next step is to evaluate potential TTE designs against the criteria and pick one for further design work. In evaluating the criteria and designing the TTE, remember that some parameters are flexible. For example, certain NDO's may be required by the process, but additional NDO's (up to 5 percent of the total TTE area) can be added as desired to adjust FV or improve the ventilation of the TTE. Similarly, while the airflow volumes of existing, permanent exhausts and makeup air ducts are set, the temporary exhaust volume can be sized to achieve the desired FV. However, the higher the exhaust volumes, the greater the size and expense of the exhaust



system and the greater the likelihood of affecting normal airflow patterns.

Designing the NDO's and the temporary exhaust system is an interactive process because both affect FV. When adjustments are contemplated for either, the effect on FV must be determined in order to be sure that the FV criterion is met. Also, NDO's added to affect FV and/or improve TTE ventilation must be evaluated against the distance and 5 percent criteria. Finally, remember that the airflow volumes used for design are estimates that may vary under actual test conditions: changes to the NDO's and/or temporary exhaust rate may be needed when the actual flow rates are determined in the field.



#### *Steps for Evaluation and Design*

A general stepwise approach to evaluating potential TTE configurations and designing the selected TTE is presented below. An example case study is presented in Appendix D.

1. Determine the location and dimensions of any NDO's essential for normal operation of the process (e.g., the NDO's needed to allow the raw material to enter and the end product to exit). Evaluate the NDO distance criteria (NDO/VOC source distance and NDO/exhaust point distance) and the criterion that the total NDO area must be less than or equal to 5 percent of the total area of the TTE (see Chapter 4 for the criteria). Eliminate those potential

TTE configurations that cannot meet these requirements. In some cases, if the line-of-sight distances are inadequate to meet the distance criteria, temporary baffles may be installed to increase the effective distances. If baffles are used, make sure the baffles do not interfere with the normal airflow patterns.

2. Determine the volume of the permanent exhaust(s) from the TTE, such as the exhaust to the control device. If the facility has a forced makeup air system with a vent inside the TTE, determine the volume of air introduced into the enclosure.
3. Estimate the temporary exhaust rate needed to maintain the atmosphere

inside the TTE at a safe and healthful level. One approach to estimating this parameter involves the Crumpler Chart included in Method 204 (see Appendix B). Additional information on estimating the required temporary exhaust rate is included in Appendix C. If personnel must enter the TTE, the target VOC concentration must be less than the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for the VOC's being emitted by the process. If personnel are not inside the TTE during the test period, the target VOC concentration should be 25 percent or less of the lower explosion limit (LEL).

It is theoretically desirable to duplicate the ambient VOC concentration that would be present if the TTE were absent. However, this could require a very high exhaust rate, which could upset normal conditions within the TTE. In addition, an elevated exhaust rate increases the size of the system, making the logistics of installation more difficult and increasing the cost.

4. Using the data developed in Steps 2 and 3 above, calculate the estimated net total exhaust rate from the TTE. This rate is computed by summing

the various exhausts and subtracting any forced makeup air volume. Using this net exhaust rate and the area of the essential NDO's from Step 1 (i.e., the minimum NDO area), calculate the average FV and compare it with the 200 ft/min criterion (see Appendix A-1).

If the FV does not meet the criterion, the temporary exhaust rate can be increased so the velocity does meet the criterion. Typically, however, the total exhaust rate needed to maintain the TTE atmosphere below the OSHA PEL's is greater than the amount of air needed to maintain a FV of greater than 200 ft/min. This excess airflow allows installation of additional NDO's to improve the ventilation of the TTE.

5. After calculating the FV in Step 4, select a target FV that exceeds the minimum (to allow a margin for error) but is not excessively high (e.g., 250 ft/min). Using the selected target FV and the estimated net exhaust rate determined in Step 4, calculate the maximum NDO area that can achieve the target FV. Also, calculate the maximum NDO area that can be used and still meet the 5 percent criterion.
6. Select the smaller of the two maximum NDO area values

calculated in Item 5. Use this NDO area to evaluate possible locations and NDO sizes that will meet all the criteria and provide good ventilation of the TTE. Take care to minimize any disruption of normal VOC capture (i.e., avoid impinging on VOC sources or on airflow patterns near capture points).

As stated earlier, remember that the calculations performed here are approximations, and adjustments will be required in the field when actual flow rates are determined and the actual NDO and TTE areas are established.

#### *Other Design Considerations*

In addition to the TTE criteria that must be met, there are other considerations that should be factored into the potential TTE configuration. Some of these are:

- ◆ The TTE must isolate the emissions from the affected facility from all other emissions both in terms of pickup by the TTE and at measurement points within the ducts.
- ◆ The operation inside the TTE during the test should duplicate, as much as possible, normal operating conditions that would be encountered without the TTE.
- ◆ The NDO's should be at locations that will ensure good mixing of the air within the TTE. Try to eliminate stagnant areas where the VOC concentration could build up, such as the corners of the TTE away from the process and exhaust points. This ensures that VOC concentrations are uniform throughout the TTE.
- ◆ The NDO's and temporary exhaust intake(s) should be located so that the predominant flow of air through the enclosure will "sweep" the fugitive emissions from the TTE. For example, consistent with the TTE criteria and other considerations, the NDO's may be concentrated on one end of the TTE (at various elevations), while the temporary exhaust intake is placed at the opposite end of the enclosure. Where possible, it is also preferable to sweep fugitive emissions away from personnel work areas.
- ◆ Evaluate the proposed location of the NDO's relative to the locations of the exhaust pickups for the captured and fugitive emissions to ensure that air is not channelled directly from the NDO to the exhaust duct. If this happens, the TTE could be ventilated improperly. Keep in mind the four equivalent diameter distance criterion when evaluating the proposed location.
- ◆ Remember that the VOC concentration within the TTE must reach a constant level before testing can begin and that the constant level must be

protective of the health of the workers. The safety of the employees during the CE performance testing is paramount--stress this to those responsible for the design and construction of the TTE.

- ◆ To the extent possible, NDO's should be located away from VOC sources outside the TTE. Although the CE test procedures require that the "background" VOC concentration from such sources be measured and accounted for, it is preferable to avoid high-concentration sources.
- ◆ In the preliminary selection of a target FV, consider the potential impact of an excessively high flow rate. The pressure differential required to maintain a FV of 200 ft/min is about 0.004 inch of water (in. H<sub>2</sub>O); for a FV of 500 ft/min, about 0.024 in. H<sub>2</sub>O is required. These pressures are too small to appreciably affect the performance of the permanent capture devices, but, over a large TTE surface area, the total pressure becomes significant. Because the FV is created by the difference in pressure on either side of the TTE wall, the greater the FV, the greater the structural stresses that will be applied and the greater the structural support that will be required (and greater cost).

- ◆ If a large drying oven is part of the process, the TTE need not enclose the entire oven if the air flow is into the ovens so that VOC does not escape from the oven.

- ◆ During the actual capture efficiency performance testing, a number of tests will be required. Evaluate the proposed design to ensure that these tests can be conducted. The two major tests are:

1. Measuring flow rates in exhaust ducts and forced makeup air ducts to ensure that the average FV across the NDO's is at least 200 ft/min.
2. Measuring the CE, which is comprised of three components:
  - (a) captured VOC emissions test point(s);
  - (b) fugitive VOC emissions test point(s); and
  - (c) background VOC test point(s).

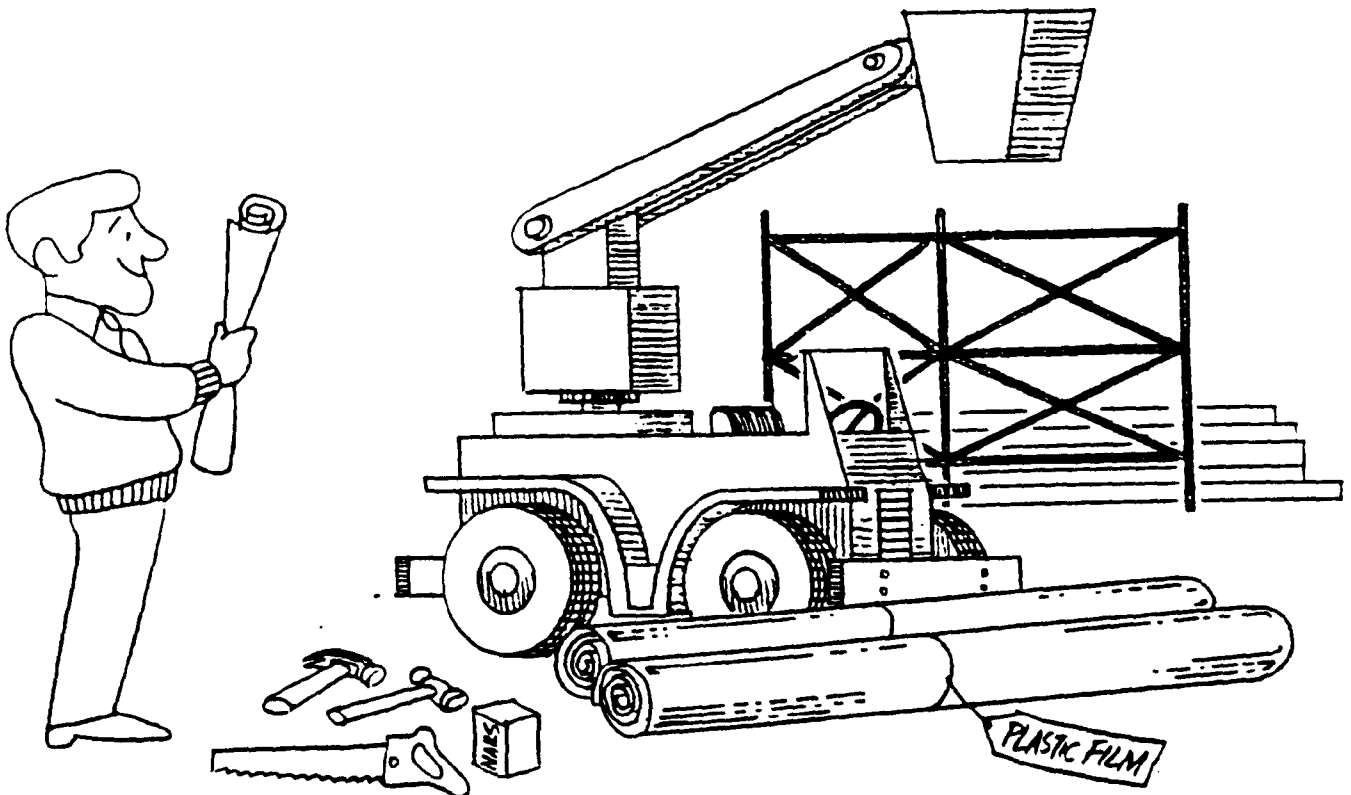
After evaluating the potential TTE configurations and selecting the most desirable, determine the quantities of materials, manpower, and equipment needed to build the TTE. In most cases, this step will be carried out by a building contractor or the appropriate facility personnel.

## Construction Materials

Various construction materials that may be used for the TTE are discussed below. Two basic types of TTE construction materials are discussed: plastic film and rigid materials. With any of these construction options, site-specific factors will influence the final configuration and support structure of the TTE. To the extent possible, existing walls and other structures at the plant should be incorporated into the TTE to minimize construction costs.

## *Plastic Film for TTE's*

Using plastic film for the surface of a TTE has a number of advantages. Its light weight minimizes the complexity and strength required of the TTE support structure. Because it is fairly transparent, process operation can be monitored from outside the TTE, and existing lighting outside the TTE will generally be adequate to light the interior. Plastic film is easy to work with; it can be cut to accommodate obstructions and taped or glued to form a seal around an obstruction.



Plastic film can be rapidly deployed when the supporting framework has been prepared. This property is useful for baseline testing without the TTE in place--the framework can be constructed, the plastic film put in place and then raised out of the way, baseline testing conducted, the plastic film deployed, and testing with the TTE in place begun with a minimum of lag time between test periods. Plastic film is also relatively inexpensive. Disadvantages include flimsiness, relatively low melting point, potential static buildup, and flammability.

Two basic options are available for supporting a plastic film TTE, depending on site-specific conditions. These options are:

**Self-supporting framework:** The framework is custom-constructed onsite to support the four walls and roof of the TTE or to augment any existing structures that could be incorporated into the TTE as walls or supports. Self-supporting frameworks can be constructed of such materials as wood, plastic piping, or scaffolding.

**Suspend from existing structures:** Where possible, an attractive option is to suspend plastic film walls from the facility ceiling, using the ceiling as the TTE's roof. This configuration does away with the need to provide a self-supporting framework for the TTE roof. Some support for the plastic sheeting may be needed against outside pressure on the walls, particularly for large TTE's. Wall support may be provided by the same types of materials mentioned above. Another option is using wire strung from the

ceiling and anchored to the floor at the corners and intermediate points.

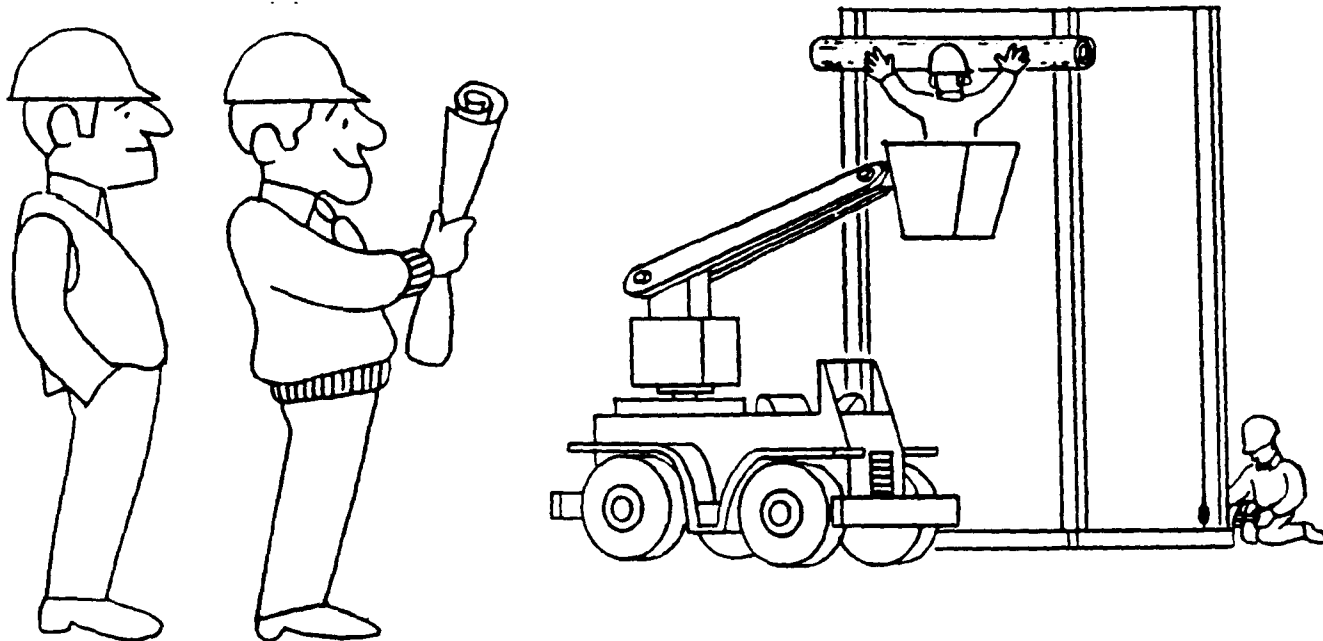
An impediment to suspending the TTE walls from the ceiling is the presence at many facilities of roof supports and other obstructions (e.g., steam piping, ventilation ductwork, and electrical conduit) near roof level. Tailoring the plastic film walls to accommodate these obstructions with a minimum of open area could become a lengthy and difficult task. At some facilities, this problem can be avoided by suspending the plastic walls from the obstructions themselves. In such cases, the open areas between the top of the plastic walls and the facility ceiling must be considered NDO's. This approach will only be feasible where these NDO's meet the criteria. Otherwise, a TTE roof must be constructed, or the TTE walls must be extended to the facility ceiling.

#### *Rigid Materials*

In some cases, TTE's may be constructed of rigid materials. These TTE's will lack the advantages of plastic film construction discussed previously, but other factors may outweigh such considerations. Two alternatives for constructing a TTE with rigid materials are:

**Insulation panels:** One facility at which a TTE/CE test was conducted used insulation panels joined with duct tape to construct the TTE. This type of construction is desirable where the panels can be anchored to existing structures to form a self-supporting TTE.





**Plywood:** A TTE constructed of plywood is desirable where great structural integrity is necessary. For example, an outdoor test might require such construction.

## CONSTRUCTION

The design of the TTE is unique to each site because the design depends on the specific arrangement of the process within the building and the proximity of other processes to the one being tested. It is important to remember that the TTE and the subsequent tests should allow for the normal operation of other facilities within the plant to avoid the costs of lost production, which can be substantial.

During construction of the TTE, it is helpful if State agency personnel who will oversee the performance testing are onsite to answer questions that will arise and to observe that the TTE is being constructed properly. Although it is the responsibility of the TTE contractor to build the structure correctly, the State will ultimately determine whether the TTE is acceptable for testing purposes.

Safety during construction is very important both in terms of worker safety and potential damage to processes operating in the immediate vicinity of the TTE construction. At any construction site where work is being conducted overhead, there is a significant potential for dropped tools and lumber that can injure workers beneath the structure.

Timing of the TTE construction is very important, and all concerned parties should develop and agree to a realistic schedule before beginning construction. Normally, power equipment or internal combustion cannot be used near VOC processes, so plan in advance how and where to cut lumber and perform other tasks requiring power equipment. If a hoist must be used, the hoist must be acceptable for use around VOC's (i.e., manual or explosion-proof) or the process must be stopped and all VOC's removed from the area.

After construction has been completed, a preliminary inspection of the TTE should be conducted to determine several factors, such as:

- ◆ Whether the sources of VOC emissions within the TTE are at least 4 equivalent diameters from each NDO and all exhaust ducts or hoods are at least four equivalent duct or hood diameters from each NDO.
- ◆ Whether the total area of the NDO's is less than or equal to 5 percent of the total area.
- ◆ Whether all access doors/windows can be closed during the conduct of the performance test (except for brief openings for the entry of personnel or necessary equipment).
- ◆ Whether the structure is constructed in a sound manner. Care must be taken to ensure that workers inside the TTE

during the test periods are not subjected to potentially unsafe conditions in terms of enclosure construction.

- ◆ Whether NDO's are adequately placed to prevent a VOC buildup. (VOC buildup could occur in the corners or other quiescent areas of the TTE.)
- ◆ Whether the structure isolates emissions from the process to be tested from emissions of all other processes occurring within the same facility.
- ◆ Whether all fugitive emissions are directed through ducts suitable for measuring gas stream volumetric flow rates and VOC concentration. Likewise, the captured emissions must be directed through a duct suitable for measuring gas stream volumetric flow rate and VOC concentration.

The preliminary inspection should be conducted during and immediately after the TTE is constructed. Points of inspection include criteria such as the total NDO area and distances from VOC sources and exhausts as well as the noncriteria items discussed previously. However, final judgment on the criteria cannot be made until the TTE structure and operating conditions have reached the final state at which the CE testing will be conducted. Only after all adjustments have been

made will a definitive criteria evaluation be conducted.

When the preliminary inspection indicates that the TTE is acceptable, you are ready to begin the tests in Chapter 6.

### TABLE 5-1. SAMPLE ADVANCE QUESTIONNAIRE

The following list presents the information that needs to be collected on the visit to your facility. It is likely that some items will have to be retrieved from facility records. Any information you can assemble prior to our visit will be greatly appreciated. A copy of the temporary total enclosure (TTE) protocol for determining capture efficiency is attached for your reference.

- I. Process information for the \_\_\_\_\_ process lines  
(Note: lines to be specified based on previous telephone contact.)
  - A. Type of process
  - B. Hours of operation (h/d, d/wk)
  - C. Is the process continuous or batch?
  - D. Is VOC-containing material applied at a constant or variable rate during a run?
  - E. Typical duration of a run
  - F. Is more than one coating/solvent system typically used?  
If so, what are the compositions (solvents and percents) of the three most commonly used coatings?
  - G. Personnel access requirements
    1. Individuals that need access
    2. Points in the process to which access is needed
    3. Frequency and duration of access
    4. Unrelated personnel traffic patterns that could affect TTE configuration or operation (e.g., foot traffic in aisle adjacent to process)
  - H. Material flows
    1. Within process
    2. To and from process
    3. Unrelated material flows that could affect TTE configuration or operation (e.g., forklift lane adjacent to process)
- II. To aid our understanding of your facility, please supply a simplified diagram of each process showing the process equipment, drying oven, air pollution control system, and air handling system (including any emission capture equipment, oven recirculation lines, makeup air intakes, combustion air intakes, etc.).

TABLE 5-1. (continued)

- III. To aid in our detailed planning, please supply existing blueprints or plans of each process area with as much detail as possible, such as:
- A. Floor plan (to scale) showing process equipment and permanent structures (walls, columns, windows, room vents, hoists, etc.)
  - B. Ceiling height and type of construction
  - C. Existing ventilation system
    - 1. Capture system with pickup locations, dimensions, and volumetric flow rates
    - 2. Wall/ceiling exhausts
    - 3. Makeup air system
  - D. Utilities (e.g., steam piping, air ducts, electrical conduit, etc.)
- IV. Applicable regulations
- A. Air pollution
    - 1. What are the "affected facilities" (i.e., equipment or processes) to which regulations apply?
    - 2. What are the applicable emission limitations?
    - 3. Have emission tests been conducted? At what locations? Please provide copies of test reports.
  - B. Fire Code or insurance carrier fire protection requirements. Any monitors or automatic equipment?
  - C. Worker health and safety requirements
    - 1. OSHA regulations limiting the solvent vapor concentration to which workers are exposed. Any solvent vapor concentration monitors?
    - 2. Noise?
    - 3. Others?
- V. To estimate the minimum exhaust rate that will maintain the atmosphere in the TTE at a safe and healthful level, we need to know the identities and proportions of the solvent vapors released into the TTE (the "fugitive" emissions) and the approximate maximum mass emission rate. In the absence of direct measurement data, the identities and proportions of fugitive emissions can be estimated from the coating solvent blend. To estimate the maximum mass emission rate of fugitives, one of the following information items is needed for the process conditions that generate the greatest mass emission rate of fugitives:

TABLE 5-1. (continued)

- A. The maximum fugitive VOC emission rate from past tests;
  - B. The approximate capture efficiency of existing capture system (from past tests);
  - C. The VOC mass flow rate to the control device (from past tests);
  - D. The volumetric flow rate and VOC concentration in all ducts leading to the control device (from past tests); or
  - E. If no representative test data are available, the VOC application rate and an estimate of the percentage emitted as fugitives. For instance, where a solvent recovery device is used, the fugitive emission rate might be estimated by subtracting the amount of solvent recovered from the amount used over some time period.
- VI. Information on the drying oven is needed to determine whether the oven can be considered part of the enclosure (or must be enclosed by the TTE), whether heat buildup inside the TTE could be a design constraint, and whether there are potential testing complications
- A. Is the oven operated under negative pressure (i.e., air flows into the oven at all openings)?
  - B. Are there any indications that solvent vapors escape from the oven during operation? If so, how is this determined?
  - C. Volumetric flow rate and temperature of oven exhaust
  - D. Volumetric flow rate and temperature of any forced makeup air to the oven
  - E. Locations and dimensions of any openings into the oven (e.g., entrance and exit slots)
  - F. Are any data available on the rate at which heat escapes from the oven into the room (e.g., measured value, estimated percent of heat input, etc.)?
  - G. Oven operating temperature
  - H. Dimensions of oven
  - I. Are there any other significant sources of heat in the process area?
  - J. How many process lines does the oven serve?
  - K. Is the oven direct fired? If so, what is the source of combustion air? Has the amount of solvent combusted by the burners ever been determined or estimated? If so, how?
  - L. Oven air recirculation? Are recirculation ducts internal or external to the oven? Flow diagrams available?
- VII. Air pollution control system
- A. Type of control device
  - B. Type of capture device(s) (e.g., canopy hood, floor sweeps, localized pickup hoods, etc.)
  - C. Gas streams controlled (e.g., oven exhaust, hoods, etc.)

**TABLE 5-2. SAMPLE CAPTURE EFFICIENCY PRETEST SITE VISIT CHECKLIST**

**I. Equipment**

- A. Typical safety equipment—hard hat, safety glasses, steel-toed boots, ear plugs
- B. Tape measure
- C. Anemometer
- D. VOC concentration meter
- E. Sketching materials—graph paper, pen/pencil, eraser, small ruler
- F. Calculator
- G. Watch
- H. Notebook
- I. Identification
- J. Copies of previous correspondence

**II. Preliminary meeting**

- A. Discuss TTE/CE protocol and purpose of site visit
- B. Discuss plant questionnaire (sent with site visit letter)
  - 1. Hand out copies of questionnaire
  - 2. Go through points briefly
  - 3. Scan any information that the plant has assembled for completeness, units (particularly acfm/scfm), etc. If possible, make preliminary determination of whether drying oven must be enclosed.
  - 4. Discuss availability of any missing information, particularly on solvents used, health/safety requirements, mass emission rate of fugitives, and drying oven

**III. Plant tour**

**A. Data for TTE construction**

- 1. Identify the affected facility across which CE is to be measured
- 2. Identify the emission points within the affected facility
- 3. Identify any nonaffected emission points in close proximity
- 4. Draw schematic of process (or verify and add to schematic supplied by plant) showing process equipment and all gas streams

TABLE 5-2. (continued)

5. Sketch plant layout (or verify and add to plant plan supplied by plant), including measurements; locate items below in 3 dimensions when applicable; if unsure whether drying oven will be within or outside TTE, take measurements for both possibilities
  - a. Locations and dimensions of all structural components (walls, columns, etc.)
  - b. Location and dimensions of each VOC source, affected and nonaffected
  - c. Location, dimensions, and destination of each exhaust duct or hood
  - d. Locations and dimensions of plant makeup air system (e.g., windows or forced supply ducts)
  - e. Note location, dimensions, and material of construction of any existing structure that can be used as a component of the TTE or to support the TTE (walls, columns, ceiling, ceiling supports, steam or water piping, air ducts, hoist frame, etc.); consider and note how TTE materials can be fastened to the existing structures
  - f. Note location and dimensions of any existing structures that could obstruct construction of the TTE (same as above); consider and note how the TTE can accommodate these structures
  - g. Note location of utilities that must be inside the TTE (e.g., lights)
  - h. Note location of any health or safety systems that must be within the TTE (e.g., automatic fire extinguishing system or noise abatement)
6. Identify personnel traffic patterns around affected facility and add to sketch as pertinent
  - a. To which points in process must operator have access during process operation? How often? For what duration?
  - b. How much clearance is needed around equipment?
  - c. Where else in plant must operator go, i.e., will the operator have to pass in and out of the TTE during testing? How often?
  - d. Other personnel (e.g., supervisor) with intermittent access needs? How often? For what duration?
  - e. Do unrelated personnel pass in vicinity? Are alternative routes available?
7. Identify material flow patterns and add to sketch as pertinent
  - a. Flow within process
  - b. Flow to and from process (e.g., delivery and mounting of new substrate at unwind station) with frequency and duration
  - c. Unrelated material flows in vicinity (e.g., forklift lane adjacent to process), availability of alternative routes



TABLE 5-2. (continued)

8. Consider alternative TTE configurations (smallest, largest, and any suggested by permanent structures that could be incorporated) and add to sketch
  - a. Take measurements in 3 dimensions
  - b. Identify and note any obstructions or other constraints suggested by above data
  - c. Consider personnel access and material flows; note the locations and dimensions of any prescribed NDO's
  - d. Consider construction issues such as how the TTE will be constructed in close areas and how personnel can be elevated to the height necessary to construct the TTE frame or hang plastic walls

B. Data for testing

1. Is previous test data available?
2. Can emissions from the affected facility be isolated from nonaffected emissions?
3. Identify gas streams and points that must be tested
4. Are ducts suitable for testing, or will modifications be necessary?
5. Are data sufficient to approximate the identities, proportions, and maximum mass emission rate of fugitives?
6. Are there any potentially complicating factors (e.g., recirculating or direct-fired ovens, significant differences between the components in the captured and fugitive gas streams, extremely dilute gas streams, interfering compounds)?

IV. Post-tour meeting

- A. Discuss information gathered
- B. Discuss additional information needs
- C. Discuss alternative TTE configurations and test locations to see if plant representatives have concerns



## CHAPTER 6

### WHAT TESTS ARE REQUIRED?

In order to conduct the gas/gas capture efficiency (CE) performance test protocol two basic tests must be performed:

1. Average face velocity (FV) tests; and
2. CE determination tests, which include the following measurements:
  - a. Fugitive volatile organic compound (VOC) emissions;
  - b. Captured VOC emissions; and
  - c. Background VOC concentration.

The average FV test must be conducted before beginning the CE performance test. The three components of the CE performance test are conducted simultaneously. The CE determination testing procedures presented in Appendix B require three sampling runs with a sampling time of from 3 to 8 hours for each run.

#### AVERAGE FACE VELOCITY TEST

Measure the volumetric flow rate, corrected to standard conditions, of each gas stream, including temporary exhaust streams, exiting the enclosure through an exhaust duct or hood using the procedures provided in Appendix B, Method 204, Section 5. Quality assurance procedures are given in Section 6 of the procedure.

The captured exhaust from a process is often the exhaust from the drying oven. Determining the temporary total enclosure (TTE) exhaust volume may be complicated if a large drying oven is not fully enclosed by the TTE. Typically, in such cases, the TTE is built onto the front of the dryer so that all emissions in the flashoff area are contained. Thus, the entrance to the dryer is within the TTE, and the makeup air drawn into the dryer through the entrance is, in effect, an exhaust from the TTE. In such cases, estimate the quantity or percentage of the captured exhaust from the dryer to the control device that is drawn out of the TTE. An approximation can be made by apportioning the total makeup air that enters the dryer through all openings (including those within the TTE) by the area of the openings.

If any of the facility's forced makeup air outlets are within the TTE, measure the volumetric flow rate, corrected to standard conditions, of each of the makeup air ducts. Using the exhaust and makeup volumes and the area of the natural draft openings (NDO's), calculate the average FV across the NDO's as shown in Appendix A-1. The average FV must be at least 200 feet per minute (ft/min). This test is illustrated in Figure 6-1.

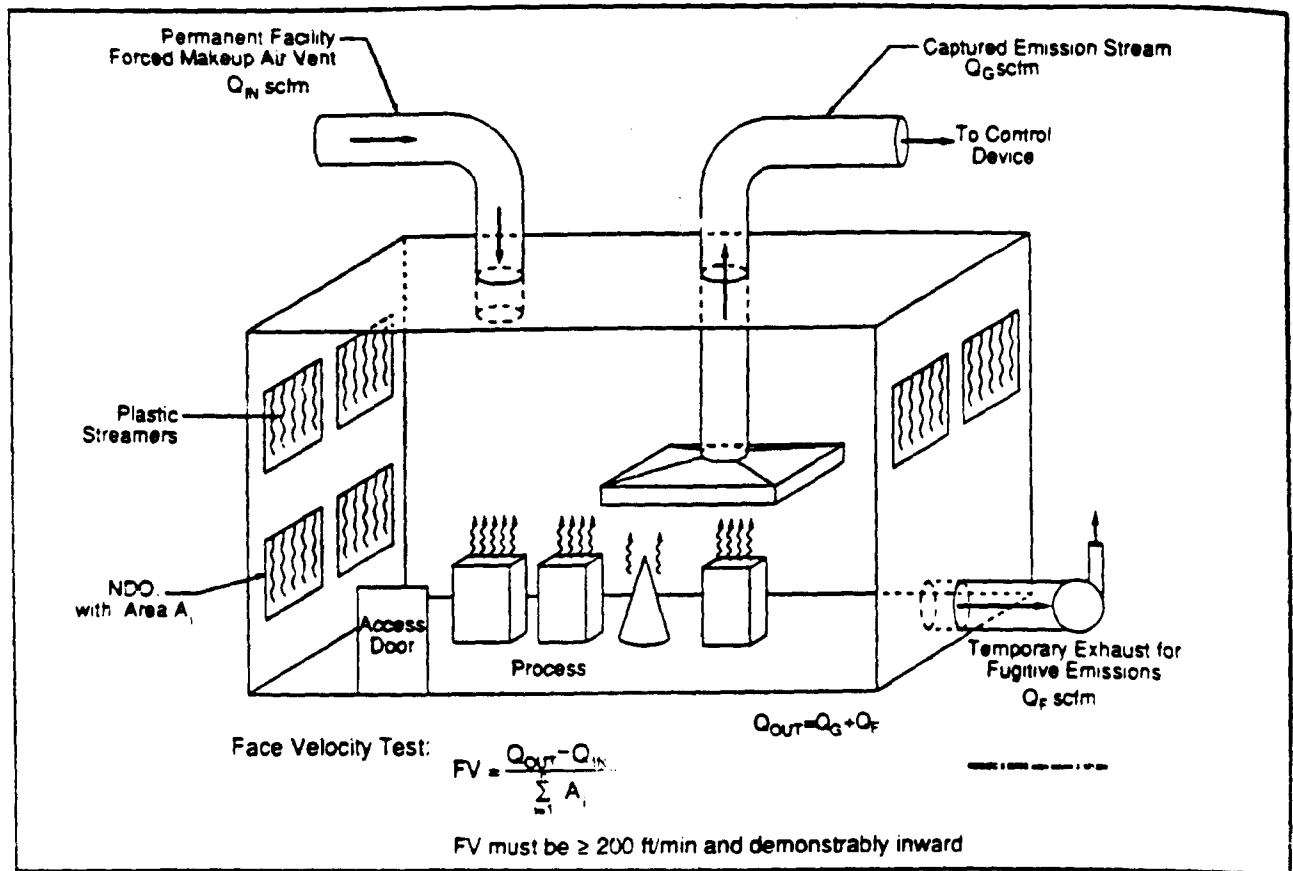


Figure 6-1. The average face velocity test.

In addition to calculating the FV, observe the actual direction of flow at the NDO's to verify that the direction of airflow through all of the NDO's is inward. This can be done using various methods, such as streamers, smoke tubes, or tracer gases. Strips of plastic wrapping film hung in the NDO's have been found to be an effective indicator. Monitor the direction of the airflow at intervals of 10 minutes for at least 1 hour.

After calculating the average FV and determining that the velocity criterion of greater than 200 ft/min has been met, inspect the TTE rigorously to verify that all of the other criteria are met. These criteria include

the distances from the NDO's to the exhausts and to the VOC sources, the NDO area ratio to the total TTE area, NDO directional airflow, and other criteria discussed in Chapters 4 and 5. If the TTE meets all of the criteria, the performance tests can be conducted. During the performance tests, verify that all access windows and doors are closed except for momentary use. If any of the TTE criteria are not met, adjust the TTE to correct the problem. If all the criteria are met during the FV testing, this period can be included in the first CE performance test run.

## PERFORMANCE TESTS FOR CAPTURE EFFICIENCY

The performance tests for CE with the TTE require measurement of the VOC emissions in the fugitive emissions duct(s) and in the captured emissions duct(s). The EPA procedures for these tests are presented in Appendix B, Methods 204B, 204C, and 204D. Concurrent with the sampling and analysis procedures for fugitives and captured emissions, the background VOC concentration in the makeup air entering through the NDO's

is determined. The background concentration is subtracted from the fugitive emissions and captured emissions in order to obtain a true evaluation of the CE for the VOC emissions due solely to the enclosed process. The equations required to calculate the VOC concentrations are provided in Appendix A. Figure 6-2 illustrates the CE performance test.

The CE test consists of at least three sampling runs. Each sampling run is required to be at least 3 hours long and to cover at least one complete production cycle (i.e., product run), except that the sampling time need not

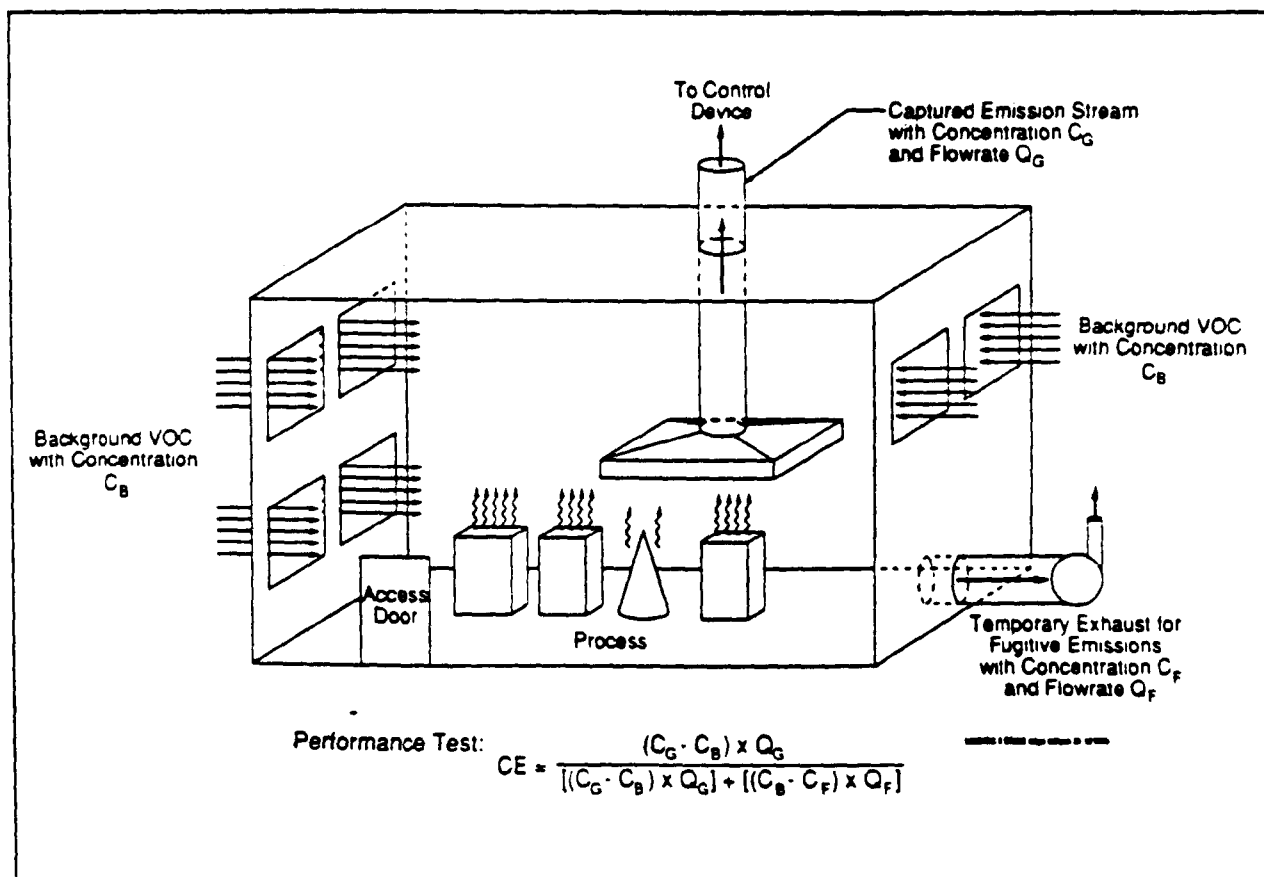


Figure 6-2. The capture efficiency performance test.

exceed 8 hours even if a product run has not been completed. A sampling run need not be limited to a single process run. These lengthy sampling runs are specified to ensure that the full range of normal operating conditions are included in the test results, including the types of process starts and stops that are part of routine operations. For example, if the process is frequently slowed or stopped for routine equipment adjustments, testing should continue during such periods. On the other hand, if changeover from one product to another takes several hours, this period may not be considered a normal operating condition, and testing should be suspended during the changeover. Agreement should be reached ahead of time on what constitutes "normal operations" to be included in the test and what constitutes a malfunction, breakdown, or nonoperating period during which testing should be suspended.

During the test, three measurements are being made simultaneously:

1. Fugitive VOC emissions—measure VOC concentration and volumetric flow rate
2. Captured VOC emissions—measure VOC concentration and volumetric flow rate
3. Background VOC—measure only the VOC concentration at up to six sampling points

For these measurements, the VOC concentration is typically measured with a flame ionization analyzer (FIA) according to EPA Method 25A, and the volumetric flow rate is

measured using EPA Methods 2, 2A, 2B, 2C, or 2D. Other reference methods that may be used are referenced at the end of this chapter.

The captured and the fugitive VOC emissions are measured in all of the ducts containing these emissions. If multiple sampling points are used for any of the three measurements (i.e., captured VOC's, fugitive VOC's, background), sampling is systematically switched from one sampling point to another so that an equal quantity of gas is sampled from each point. Procedures for changing from one sampling point to another are provided in Methods 204B, 204C, and 204D in Appendix B. Additionally, all pretest system checks and quality assurance (QA) requirements are provided in Methods 204B, 204C, and 204D.

### Fugitive VOC Emissions

The quantity of fugitive VOC emissions (F) from the TTE is the product of the VOC content, the flow rate, and the sampling time, summed over all of the fugitive emissions ducts. To run a test, set up a measurement system similar to Figure 204D-1 in Method 204D (see Appendix B) and measure the fugitive emission flow rate and VOC concentration for the duration of the test. Check several QA items before running the test (see Method 204D). The equations, including sample calculations, required to calculate fugitive VOC levels are provided in Appendix A.

## Captured VOC Emissions

This procedure is presented in Appendix B for the normal technique (Method 204B) and the dilution technique (Method 204C). The quantity of captured VOC emissions (G) is the sum over all the captured emission ducts of the product of the VOC content, the flow rate, and the sampling time for each duct. The dilution technique is used to allow the use of a single FIA to measure both captured VOC's and fugitive VOC's. The equations used to calculate the captured VOC emissions are presented in Appendix A.

## Background Tests

The average background VOC concentration in the ambient air flowing into the NDO's must be determined by sampling and analyzing the air in the immediate vicinity of the NDO's concurrent with the testing of fugitive and captured emissions. The procedure for measuring the background concentration is presented in Appendix B (Section 4.3 of Methods 204B, 204C, and 204D). Setup for the background tests includes the following steps:

1. Locate all NDO's of the TTE.
2. Place a sampling point at the center of each NDO.
3. If more than six NDO's are present in the TTE, choose six sampling points evenly spaced among the NDO's.
4. Assemble a sample train as shown in Methods 204B, 204C, and 204D.

This sample train must be separate from the one to measure captured or fugitive emissions. The sampling and analysis pretest procedures are the same as those used for measuring the VOC content of the captured and fugitive emissions. The equations, including sample calculations, required to calculate the background VOC concentration are provided in Appendix A.

## Applicable EPA Methods

The following list provides references for test methods that may be used during capture efficiency performance tests. Not all of these tests are referenced in this document. This comprehensive list is provided in the event that certain circumstances at a specific site may require one of the nonreferenced test methods.

Method 1 Sample and Velocity Traverses for Stationary Sources, 40 CFR 60, Appendix A.

Method 1A Sample and Velocity Traverses for Stationary Sources with Small Stacks or Ducts.

Method 2 Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube) 40 CFR 60, Appendix A.

Method 2A Direct Measurement of Gas Volume Through Pipes and Small Ducts, 40 CFR 60, Appendix A.

Method 2B Determination of Exhaust Gas Volume Flow Rate from Gasoline Vapor Incinerators, 40 CFR 60, Appendix A.

Method 2C Determination of Stack Gas Velocity and Volumetric Flow Rate from Small Stacks or Ducts (Standard Pitot Tube).

Method 2D Measurement of Gas Volume Flow Rates in Small Pipes and Ducts.

Method 3 Gas Analysis for the Determination of Dry Molecular Weight, 40 CFR 60, Appendix A.

Method 4 Determination of Moisture Content in Stack Gases, 40 CFR 60, Appendix A.

Method 18 Determination of Gaseous Organic Compounds by Gas Chromatography, 40 CFR 60, Appendix A.

Method 25 Determination of Total Gaseous Nonmethane Organic Emissions as Carbon, 40 CFR 60, Appendix A

Method 25A Determination of Total Gaseous Organic Concentrations Using a Flame Ionization Analyzer, 40 CFR 60, Appendix A.

Method 25B Determination of Total Gaseous Organic Concentration Using a Nondispersive Infrared Analyzer, 40 CFR 60, Appendix A.



## **APPENDIX A EXAMPLE CALCULATIONS**

- A-1      Average Face Velocity
- A-2      VOC Concentration of Fugitive Emissions at Each Sampling Site
- A-3      Total VOC Fugitive Emissions
- A-4      VOC Concentration of Captured Emissions at Each Sampling Site
- A-5      Total VOC Captured Emissions
- A-6      Background VOC Concentrations at Each Sampling Site
- A-7      Average Background Concentration
- A-8      Capture Efficiency

## A-1. AVERAGE FACE VELOCITY

---

Calculate average face velocity (FV) using the following equation:

$$FV = \frac{Q_O - Q_I}{A_N}$$

where:

$Q_O$  = the sum of the volumetric flow from all gas streams exiting the enclosure through an exhaust duct or hood, corrected to standard conditions.

$Q_I$  = the sum of the volumetric flow from all gas streams into the enclosure through a forced makeup air duct, corrected to standard conditions; zero if there is no forced makeup air into the enclosure.

$A_N$  = total area of all natural draft openings (NDO's) in the enclosure.

---

**Example 1. Simple case.** There are the minimum two exhausts from the enclosure, a single captured gas stream to the control device ( $Q_G = 3,000$  scfm) and a single temporary exhaust for fugitive emissions ( $Q_F = 3,000$  scfm). There are no forced makeup air inlets. There are two NDO's, the entrance and exit slots (each 6 ft x 2 ft) for a continuous web.

---

$$\begin{aligned} Q_O &= Q_G + Q_F \\ &= 3,000 \text{ scfm} + 3,000 \text{ scfm} \\ &= 6,000 \text{ scfm} \end{aligned}$$

---

$$Q_I = 0 \text{ scfm}$$

---

$$\begin{aligned}
 A_N &= A_1 + A_2 \\
 &= (6 \text{ ft} \times 2 \text{ ft}) + (6 \text{ ft} \times 2 \text{ ft}) \\
 &= 24 \text{ ft}^2
 \end{aligned}$$


---

$$\begin{aligned}
 FV &= \frac{Q_O - Q_I}{A_N} \\
 &= \frac{6,000 \text{ scfm} - 0 \text{ scfm}}{24 \text{ ft}^2} \\
 &= 250 \text{ ft/min}
 \end{aligned}$$


---

**Example 2. Complex case.** The enclosure is built around the application and flashoff areas of a coating process; only the entrance to the large drying oven is inside the enclosure. The oven exhaust ( $Q_{\text{oven}} = 6,000 \text{ scfm}$ ) is vented to the control device. All the oven makeup air is drawn in through its entrance slot (5 ft x 2 ft) and its exit slot (5 ft x 1 ft). Thus, the oven entrance slot functions as an exhaust from the enclosure ( $Q_{\text{oven entrance}}$ ). A permanent hood over the applicator exhausts to the atmosphere ( $Q_{\text{hood}} = 800 \text{ scfm}$ ). A temporary exhaust for the fugitive emissions ( $Q_F = 7,000 \text{ scfm}$ ) is necessary to maintain a healthful atmosphere. An outlet of the facility's forced makeup air system ( $Q_I = 6,000 \text{ scfm}$ ) is located inside the enclosure. The enclosure has an entrance slot for the web that is 4 ft x 2 ft. Additional NDO's have been provided to improve the ventilation of the enclosure (six at 17 in. x 17 in. and six at 1 ft x 1 ft).

---

In the absence of better data,  $Q_{\text{oven entrance}}$  can be approximated by apportioning the oven makeup air volume (which is equal to its exhaust rate,  $Q_{\text{oven}}$ ) among the openings in the oven according to each opening's area:

$$\begin{aligned}
 Q_{\text{oven entrance}} &= Q_{\text{oven}} \times \frac{A_{\text{oven entrance}}}{A_{\text{oven entrance}} + A_{\text{oven exit}}} \\
 &= 6,000 \text{ scfm} \times \frac{5 \text{ ft} \times 2 \text{ ft}}{(5 \text{ ft} \times 2 \text{ ft}) + (5 \text{ ft} \times 1 \text{ ft})} \\
 &= 4,000 \text{ scfm}
 \end{aligned}$$


---

$$\begin{aligned}
 Q_O &= Q_{\text{oven entrance}} + Q_{\text{hood}} + Q_F \\
 &= 4,000 \text{ scfm} + 800 \text{ scfm} + 7,000 \text{ scfm} \\
 &= 11,800 \text{ scfm}
 \end{aligned}$$


---

$$Q_I = 6,000 \text{ scfm}$$


---

$$\begin{aligned}
 A_N &= A_{\text{enclosure slot}} + A_{\text{added NDO's}} \\
 &= (4 \text{ ft} \times 2 \text{ ft}) + 6 \left( \frac{17 \text{ in.} \times 17 \text{ in.}}{144 \text{ in.}^2/\text{ft}^2} \right) + 6 (1 \text{ ft} \times 1 \text{ ft}) \\
 &= 8 \text{ ft}^2 + 12 \text{ ft}^2 + 6 \text{ ft}^2 \\
 &= 26 \text{ ft}^2
 \end{aligned}$$


---

$$\begin{aligned}
 FV &= \frac{Q_O - Q_I}{A_N} \\
 &= \frac{11,800 \text{ scfm} - 6,000 \text{ scfm}}{26 \text{ ft}} \\
 &= 223 \text{ ft/min}
 \end{aligned}$$

## A-2. VOC CONCENTRATION OF FUGITIVE EMISSIONS AT EACH SAMPLING SITE

---

$$C_{Fj} = (C_j - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}}$$

where:

- $C_{Fj}$  = corrected average VOC concentration of fugitive emissions at point j, ppm propane.  
 $C_j$  = uncorrected average VOC concentration measured at point j, ppm propane.  
 $C_{DO}$  = average system drift check concentration for zero concentration gas, ppm propane.  
 $C_H$  = actual concentration of the drift check calibration gas, ppm propane.  
 $C_{DH}$  = average measured concentration for the drift check calibration gas, ppm propane.
- 

**Example.** (See Method 204D in Appendix B for the details of the measurement and quality assurance procedures.) The concentration of fugitive emissions from a process is expected to be in the range of 200 ppm as propane. A flame ionization analyzer with a span value of 300 ppm as propane is used to measure the fugitive emissions. In addition to zero gas, calibration gases with propane concentrations of 75 ppm, 150 ppm, and 225 ppm are used. System drift checks are made with the 225 ppm calibration gas ( $C_H$ ) and the zero gas. The test contractor chooses to perform drift checks each hour during the sampling runs. For Run No. 1, the average value measured for the zero gas during drift checks ( $C_{DO}$ ) is 5 ppm propane. The average for the drift check calibration gas measurements ( $C_{DH}$ ) is 219 ppm propane. The average measured fugitive emissions concentration ( $C_j$ ) is 187 ppm as propane.

---

$$\begin{aligned} C_{Fj} &= (C_j - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}} \\ &= (187 \text{ ppm} - 5 \text{ ppm}) \frac{225 \text{ ppm}}{219 \text{ ppm} - 5 \text{ ppm}} \\ &= 191 \text{ ppm as propane} \end{aligned}$$

### A-3. TOTAL VOC FUGITIVE EMISSIONS

---

$$F = \sum_{j=1}^n (C_{Fj} - C_B) Q_{Fj} \theta_F K_1$$

where:

- F = total VOC content of fugitive emissions, kg.
  - $C_{Fj}$  = corrected average VOC concentration of fugitive emissions at point j, ppm propane.
  - $C_B$  = average background concentration, ppm propane.
  - $Q_{Fj}$  = average effluent volumetric flow rate corrected to standard conditions at fugitive emissions point j,  $m^3/min$ .
  - $\theta_F$  = total duration of fugitive emissions sampling run, min
  - $K_1$  =  $1.830 \times 10^{-6} \text{ kg}/(m^3 \cdot \text{ppm})$ .
  - n = number of measurement points.
- 

**Example.** A process is tested in which a permanent hood is exhausted to the atmosphere and a temporary exhaust is installed to supplement the ventilation of the enclosure. Both exhausts are considered fugitive emissions for purposes of the capture efficiency determination, and both are measured. The hood is designated fugitive exhaust No. 1; the temporary exhaust is designated fugitive exhaust No. 2. For Run No. 1, the hood exhaust is determined to have a corrected average VOC concentration ( $C_{F1}$ ) of 423 ppm as propane and an average volumetric flow rate ( $Q_{F1}$ ) of 23 standard  $m^3/min$ . For the same run, the temporary exhaust has a corrected average VOC concentration ( $C_{F2}$ ) of 157 ppm as propane and an average volumetric flow rate ( $Q_{F2}$ ) of 118 standard  $m^3/min$ . The average background concentration for the run ( $C_B$ ) is 24 ppm as propane; the duration of the run ( $\theta_F$ ) is 480 min.

---

$$\begin{aligned}
 F &= \sum_{j=1}^2 (C_{Fj} - C_B) Q_{Fj} \theta_F K_1 \\
 &= (423 \text{ ppm} - 24 \text{ ppm}) \times 23 \text{ m}^3/\text{min} \times 480 \text{ min} \times 1.830 \times 10^{-6} \text{ kg}/(\text{m}^3 \cdot \text{ppm}) + \\
 &\quad (157 \text{ ppm} - 24 \text{ ppm}) \times 118 \text{ m}^3/\text{min} \times 480 \text{ min} \times 1.830 \times 10^{-6} \text{ kg}/(\text{m}^3 \cdot \text{ppm}) \\
 &= 30 \text{ kg}
 \end{aligned}$$

#### A-4. VOC CONCENTRATION OF CAPTURED EMISSIONS AT EACH SAMPLING SITE

---

$$C_{Gj} = (C_j - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}}$$

where:

- $C_{Gj}$  = corrected average VOC concentration of captured emissions at point j, ppm propane.
- $C_j$  = uncorrected average VOC concentration measured at point j; ppm propane.
- $C_{DO}$  = average system drift check concentration for zero concentration gas, ppm propane.
- $C_H$  = actual concentration of the drift check calibration gas, ppm propane.
- $C_{DH}$  = average measured concentration for the drift check calibration gas, ppm propane.

---

**Example.** (See Method 204B in Appendix B for the details of the measurement and quality assurance procedures.) The concentration of captured emissions from a process is expected to be in the range of 1,200 ppm as propane. A flame ionization analyzer with a span value of 2,000 ppm as propane is used to measure the fugitive emissions. In addition to zero gas, calibration gases with propane concentrations of 500 ppm, 1,000 ppm, and 1,500 ppm are used. System drift checks are made with the 1,000 ppm calibration gas ( $C_H$ ) and the zero gas. The test contractor chooses to perform drift checks each hour during the sampling runs. For Run No. 1, the average value measured for the zero gas during drift checks ( $C_{DO}$ ) is 23 ppm propane. The average for the drift check calibration gas measurements ( $C_{DH}$ ) is 1,039 ppm propane. The average measured captured emissions concentration ( $C_j$ ) is 1,278 ppm as propane.

---

$$\begin{aligned} C_{Fj} &= (C_j - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}} \\ &= (1,278 \text{ ppm} - 23 \text{ ppm}) \frac{1,000 \text{ ppm}}{1,039 \text{ ppm} - 23 \text{ ppm}} \\ &= 1,235 \text{ ppm as propane} \end{aligned}$$

### A-5. TOTAL VOC CAPTURED EMISSIONS

$$G = \sum_{j=1}^n (C_{Gj} - C_B) Q_{Gj} \theta_C K_1$$

where:

- $G$  = total VOC content of captured emissions, kg.
- $C_{Gj}$  = corrected average VOC concentration of captured emissions at point  $j$ , ppm propane.
- $C_B$  = average background concentration, ppm propane.
- $Q_{Gj}$  = average effluent volumetric flow rate corrected to standard conditions at captured emissions point  $j$ ,  $m^3/\text{min}$ .
- $\theta_C$  = total duration of captured emissions sampling run, min.
- $K_1 = 1.830 \times 10^{-6} \text{ kg}/(\text{m}^3 \cdot \text{ppm})$ .
- $n$  = number of measurement points

**Example.** A process to be tested has a hood and a drying oven that are vented to a common control device, which also controls emissions from several other processes at the facility. Unfortunately, the two captured gas streams from the process of interest are not combined into a common duct before being mingled with gas streams from other processes. As a result, each of the two process exhausts must be measured individually. The hood is designated as captured emissions point No. 1; the oven exhaust is designated as point No. 2. For Run No. 1, the hood exhaust is determined to have a corrected average VOC concentration ( $C_{G1}$ ) of 423 ppm as propane and an average volumetric flow rate ( $Q_{G1}$ ) of 23 standard  $m^3/\text{min}$ . For the same run, the oven exhaust has a corrected average VOC concentration ( $C_{G2}$ ) of 1,761 ppm as propane and an average volumetric flow rate ( $Q_{G2}$ ) of 137 standard  $m^3/\text{min}$ . The average background concentration for the run ( $C_B$ ) is 24 ppm as propane; the duration of the run ( $\theta_C$ ) is 480 min.

$$\begin{aligned}
 G &= \sum_{j=1}^2 (C_{Gj} - C_B) Q_{Gj} \theta_C K_1 \\
 &= (423 \text{ ppm} - 24 \text{ ppm}) \times 23 \text{ m}^3/\text{min} \times 480 \text{ min} \times 1.830 \times 10^{-6} \text{ kg}/(\text{m}^3 \cdot \text{ppm}) + \\
 &\quad (1,761 \text{ ppm} - 24 \text{ ppm}) \times 137 \text{ m}^3/\text{min} \times 480 \text{ min} \times 1.830 \times 10^{-6} \text{ kg}/(\text{m}^3 \cdot \text{ppm}) \\
 &= 217 \text{ kg}
 \end{aligned}$$



**A-6. BACKGROUND VOC CONCENTRATIONS AT EACH SAMPLING SITE**

---

$$C_{Bi} = (C_i - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}}$$

where:

- $C_{Bi}$  = corrected average VOC concentration of background emissions at point i, ppm propane.
- $C_i$  = uncorrected average background VOC concentration measured at point i, ppm propane.
- $C_{DO}$  = average system drift check concentration for zero concentration gas, ppm propane.
- $C_H$  = actual concentration of the drift check calibration gas, ppm propane.
- $C_{DH}$  = average measured concentration for the drift check calibration gas, ppm propane.
- 

**Example.** The background VOC concentration in the building housing the process to be tested is expected to be in the range of 60 ppm as propane. A flame ionization analyzer with a span value of 100 ppm propane is used for the background measurements. Calibration gases with propane concentrations of 25 ppm, 50 ppm, and 75 ppm are used. System drift checks are performed each hour during the sampling runs using zero concentration gas and 50 ppm calibration gas ( $C_H$ ). At one background measurement point, the average measured VOC concentration ( $C_i$ ) for one sampling run is 67 ppm as propane. For the same run, the average drift check concentration for the calibration gas ( $C_{DH}$ ) is 53 ppm, and the average for the zero gas ( $C_{DO}$ ) is 2 ppm.

---

$$\begin{aligned} C_{Bi} &= (C_i - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}} \\ &= (67 \text{ ppm} - 2 \text{ ppm}) \frac{50 \text{ ppm}}{53 \text{ ppm} - 2 \text{ ppm}} \\ &= 64 \text{ ppm as propane} \end{aligned}$$

## A-7. AVERAGE BACKGROUND CONCENTRATION

$$C_B = \frac{\sum_{i=1}^n C_{Bi} A_i}{A_N}$$

where:

$C_B$  = average background concentration, ppm propane.

$C_{Bi}$  = corrected average VOC concentration of background emissions at point i, ppm propane.

$A_i$  = area of NDO i, ft<sup>2</sup>.

$A_N$  = total area of all NDO's in the enclosure, ft<sup>2</sup>.

$n$  = number of measurement points.

**NOTE:** If the concentration at each point is within 20 percent of the average concentration of all points, the arithmetic average concentration may be used:

$$C_B = \frac{\sum_{i=1}^n C_{Bi}}{n}$$

**Example 1. Few NDO's.** A test enclosure is constructed with three NDO's ( $n=3$ ): (1) a 6 ft x 3 ft web entrance slot ( $A_1 = 18$  ft<sup>2</sup>) in one end, (2) a 6 ft x 1 ft web exit slot ( $A_2 = 6$  ft<sup>2</sup>) at the opposite end, and (3) a 3 ft x 5 ft opening for an overhead crane ( $A_3 = 15$  ft<sup>2</sup>) near the top of one side. Thus, the total NDO area ( $A_N$ ) is 39 ft<sup>2</sup>. The end of the enclosure with the web entrance slot is located near the mix area for the plant, where the ambient VOC concentration is much higher than in other areas. For the test, sampling lines are placed at the center of each of the NDO's. The corrected average background concentrations as propane at the three measurement points are determined to be 83 ppm ( $C_{B1}$ ), 26 ppm ( $C_{B2}$ ), and 23 ppm ( $C_{B3}$ ), respectively.

Step 1. Determine whether the average concentration can be used.

$$\frac{\sum_{i=1}^n C_{Bi}}{n} = \frac{83 \text{ ppm} + 26 \text{ ppm} + 23 \text{ ppm}}{3}$$
$$= 44 \text{ ppm as propane}$$

$$83 \text{ ppm} \neq 44 \text{ ppm} \pm 20 \text{ percent}$$

∴ The average cannot be used.

Step 2. Calculate the weighted average concentration.

$$C_B = \frac{\sum_{i=1}^n C_{Bi} A_i}{A_N}$$
$$= \frac{(83 \text{ ppm} \times 18 \text{ ft}^2) + (26 \text{ ppm} \times 6 \text{ ft}^2) + (23 \text{ ppm} \times 15 \text{ ft}^2)}{39 \text{ ft}^2}$$
$$= 51 \text{ ppm as propane}$$

---

**Example 2.** Many NDO's. A large test enclosure is built with many small NDO's widely spaced over the surface to ensure that no stagnant air pockets develop inside. For the test, six sampling lines are spaced evenly among the NDO's around the enclosure ( $n = 6$ ). Under these circumstances, when the sampling points cannot be correlated directly to particular NDO's, an average of the individual concentrations is computed regardless of the variation among the individual values. For the six sampling points, the corrected average background concentrations as a propane ( $C_{Bi}$ 's) are determined to be 44 ppm, 53 ppm, 39 ppm, 47 ppm, 57 ppm, and 54 ppm, respectively.

---

$$C_B = \frac{\sum_{i=1}^n C_{Bi}}{n}$$
$$= \frac{44 \text{ ppm} + 53 \text{ ppm} + 39 \text{ ppm} + 47 \text{ ppm} + 57 \text{ ppm} + 54 \text{ ppm}}{6}$$
$$= 49 \text{ ppm as propane}$$

### A-8. CAPTURE EFFICIENCY

---

$$CE = \frac{G}{G + F}$$

where:

CE = VOC capture efficiency.

G = total VOC content of captured emissions, kg.

F = total VOC content of fugitive emissions, kg.

---

**Example.** Using the procedures presented previously, it is determined that the total quantity of VOC emissions from the tested process that are captured during a test run (G) is 290 kg. The total quantity of fugitive VOC emissions (F) is determined to be 36 kg.

---

$$\begin{aligned} CE &= \frac{G}{G + F} \\ &= \frac{290}{290 + 36} \\ &= 0.89 \text{ or } 89 \text{ percent} \end{aligned}$$

## **APPENDIX B TEST PROCEDURES**

<b>Method 204</b>	<b>Criteria for and Verification of a Permanent or Temporary Total Enclosure</b>
<b>Method 204B</b>	<b>Volatile Organic Compound Emissions in Captured Stream</b>
<b>Method 204C</b>	<b>Volatile Organic Compound Emissions in Captured Stream (Dilution Technique)</b>
<b>Method 204D</b>	<b>Volatile Organic Compound Emissions in Fugitive Stream from Temporary Total Enclosure</b>

## **Method 204 - Criteria for and Verification of a Permanent or Temporary Total Enclosure**

### **1. INTRODUCTION**

**1.1 Applicability.** This procedure is used to determine whether a permanent or temporary enclosure meets the criteria of a total enclosure.

**1.2 Principle.** An enclosure is evaluated against a set of criteria. If the criteria are met and if all the exhaust gases from the enclosure are ducted to a control device, then the volatile organic compounds (VOC) capture efficiency (CE) is assumed to be 100 percent and CE need not be measured. However, if part of the exhaust gas stream is not ducted to a control device, CE must be determined.

### **2. DEFINITIONS**

**2.1 Natural Draft Opening (NDO) --** Any permanent opening in the enclosure that remains open during operation of the facility and is not connected to a duct in which a fan is installed.

**2.2 Permanent Total Enclosure (PTE) --** A permanently installed enclosure that completely surrounds a source of emissions such that all VOC emissions are captured and contained for discharge to a control device.

**2.3 Temporary Total Enclosure (TTE) --** A temporarily installed enclosure that completely surrounds a source of emissions such that all VOC emissions are captured and contained for discharge through ducts that allow for the accurate measurement of VOC emissions.

### **3. CRITERIA FOR TEMPORARY TOTAL ENCLOSURE**

**3.1** Any NDO shall be at least 4 equivalent opening diameters from each VOC emitting point unless otherwise specified by the Administrator.

**3.2** Any exhaust point from the enclosure shall be at least 4 equivalent duct or hood diameters from each NDO.

**3.3** The total area of all NDO's shall not exceed 5 percent of the surface area of the enclosure's four walls, floor, and ceiling.

3.4 The average facial velocity (FV) of air through all NDO's shall be at least 3,600 m/hr (200 fpm). The direction of air flow through all NDO's shall be into the enclosure.

3.5 All access doors and windows whose areas are not included in Section 3.3 and are not included in the calculation in Section 3.4 shall be closed during routine operation of the process.

#### 4. CRITERIA FOR A PERMANENT TOTAL ENCLOSURE

4.1 Same as Sections 3.1 and 3.3 - 3.5.

4.2 All VOC emissions must be captured and contained for discharge through a control device.

#### 5. PROCEDURE

5.1 Determine the equivalent diameters of the NDO's and determine the distances from each VOC emitting point to all NDO's. Determine the equivalent diameter of each exhaust duct or hood and its distance to all NDO's. Calculate the distances in terms of equivalent diameters. The number of equivalent diameters shall be at least 4.

5.2 Measure the total area ( $A_T$ ) of the enclosure and the total area ( $A_N$ ) of all NDO's of the enclosure. Calculate the NDO to enclosure area ratio (NEAR) as follows:

$$NEAR = \frac{A_N}{A_T} \quad \text{Eq. 204-1}$$

The NEAR must be  $\leq 0.05$ .

5.3 Measure the volumetric flow rate, corrected to standard conditions, of each gas stream exiting the enclosure through an exhaust duct or hood using EPA Method 2. In some cases (e.g., when the building is the enclosure), it may be necessary to measure the volumetric flow rate, corrected to standard conditions, of each gas stream entering the enclosure through a forced makeup air duct using Method 2. Calculate FV using the following equation:

$$FV = \frac{Q_O - Q_I}{A_N} \quad \text{Eq. 204-2}$$

where:

$Q_O$  = the sum of the volumetric flow from all gas streams exiting the enclosure through an exhaust duct or hood.

$Q_I$  = the sum of the volumetric flow from all gas streams into the enclosure through a forced makeup air duct; zero, if there is no forced makeup air into the enclosure.

$A_N$  = total area of all NDO's in enclosure.

The FV shall be at least 3,600 m/hr (200 fpm).

5.4 Verify that the direction of air flow through all NDO's is inward. Streamers, smoke tubes, tracer gases may be used. Strips of plastic wrapping film have been found to be effective. Monitor the direction of air flow at intervals of at least 10 minutes for at least 1 hour.

## 6. QUALITY ASSURANCE

6.1 The success of this protocol lies in designing the TTE to simulate the conditions that exist without the TTE, i.e., the effect of the TTE on the normal flow patterns around the affected facility or the amount of fugitive VOC emissions should be minimal. The TTE must enclose the application stations, coating reservoirs, and all areas from the application station to the oven. The oven does not have to be enclosed if it is under negative pressure. The NDO's of the temporary enclosure and a fugitive exhaust fan must be properly sized and placed.

6.2. Estimate the ventilation rate of the TTE that best simulates the conditions that exist without the TTE, i.e., the effect of the TTE on the normal flow patterns around the affected facility or the amount of fugitive VOC emissions should be minimal. Figure 204-1 may be used as an aid. Measure the concentration ( $C_G$ ) and flow rate ( $Q_G$ ) of the captured gas stream, specify a safe concentration ( $C_F$ ) for the fugitive gas stream, estimate the CE, and then use the plot in Figure 204-1 to determine the volumetric flow rate of the fugitive gas stream ( $Q_F$ ). A fugitive VOC emission exhaust fan that has a variable flow control is desirable.

6.3 After the TTE is constructed, monitor the VOC concentration inside the TTE. This concentration shall not continue to increase and must not exceed the safe level according to Occupational Safety and Health Administration requirements for permissible exposure limits. An increase in VOC concentration indicates poor TTE design or poor capture efficiency.



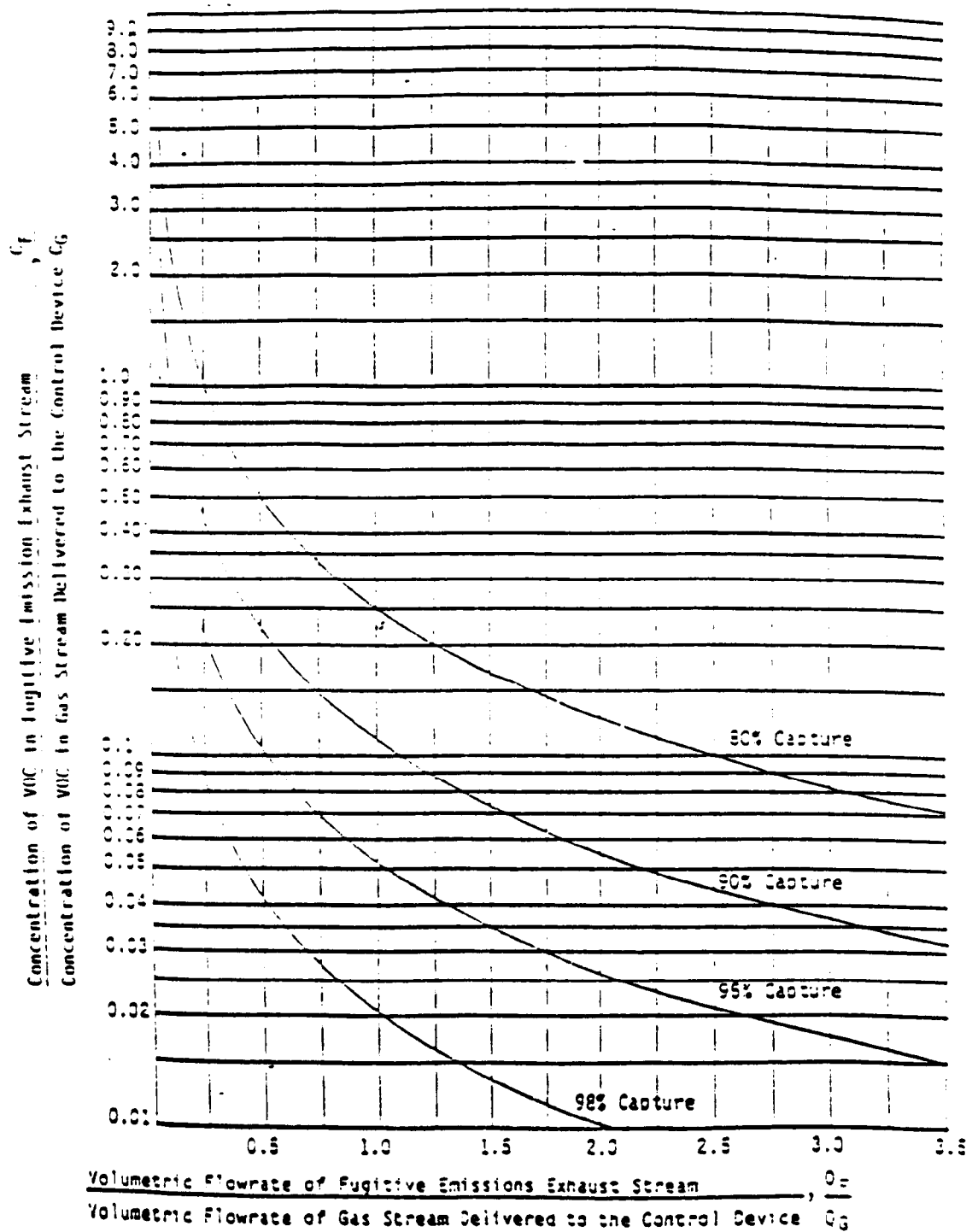


Figure 204-1. The crumpler chart.

## Method 204B - Volatile Organic Compound Emissions in Captured Stream

### 1. INTRODUCTION

**1.1 Applicability.** This procedure is applicable for determining the volatile organic compounds (VOC) content of captured gas streams. It is intended to be used in the development of liquid/gas or gas/gas protocols for determining VOC capture efficiency (CE) for surface coating and printing operations. The procedure may not be acceptable in certain site-specific situations, e.g., when: (1) direct-fired heaters or other circumstances affect the quantity of VOC at the control device inlet; and (2) particulate organic aerosols are formed in the process and are present in the captured emissions.

**1.2 Principle.** The amount of VOC captured ( $G$ ) is calculated as the sum of the products of the VOC content ( $C_{Gj}$ ), the flow rate ( $Q_{Gj}$ ), and the sample time ( $\theta_C$ ) from each captured emissions point.

**1.3 Estimated Measurement Uncertainty.** The measurement uncertainties are estimated for each captured or fugitive emissions point as follows:  $Q_{Gj} = \pm 5.5$  percent and  $C_{Gj} = \pm 5.0$  percent. Based on these numbers, the probable uncertainty for  $G$  is estimated at about  $\pm 7.4$  percent.

**1.4 Sampling Requirements.** A capture efficiency test shall consist of at least three sampling runs. Each run shall cover at least one complete production cycle but shall be at least 3 hours long. The sampling time for each run need not exceed 8 hours even if the production cycle has not been completed. Alternative sampling times may be used with the approval of the Administrator.

**1.5 Notes.** Because this procedure is often applied in highly explosive areas, caution and care should be exercised in choosing appropriate equipment and installing and using the equipment. Mention of trade names or company products does not constitute endorsement. All gas concentrations (percent, ppm) are by volume, unless otherwise noted.

### 2. APPARATUS AND REAGENTS

**2.1 Gas VOC Concentration.** A schematic of the measurement system is shown in Figure 204B-1. The main components are as follows:

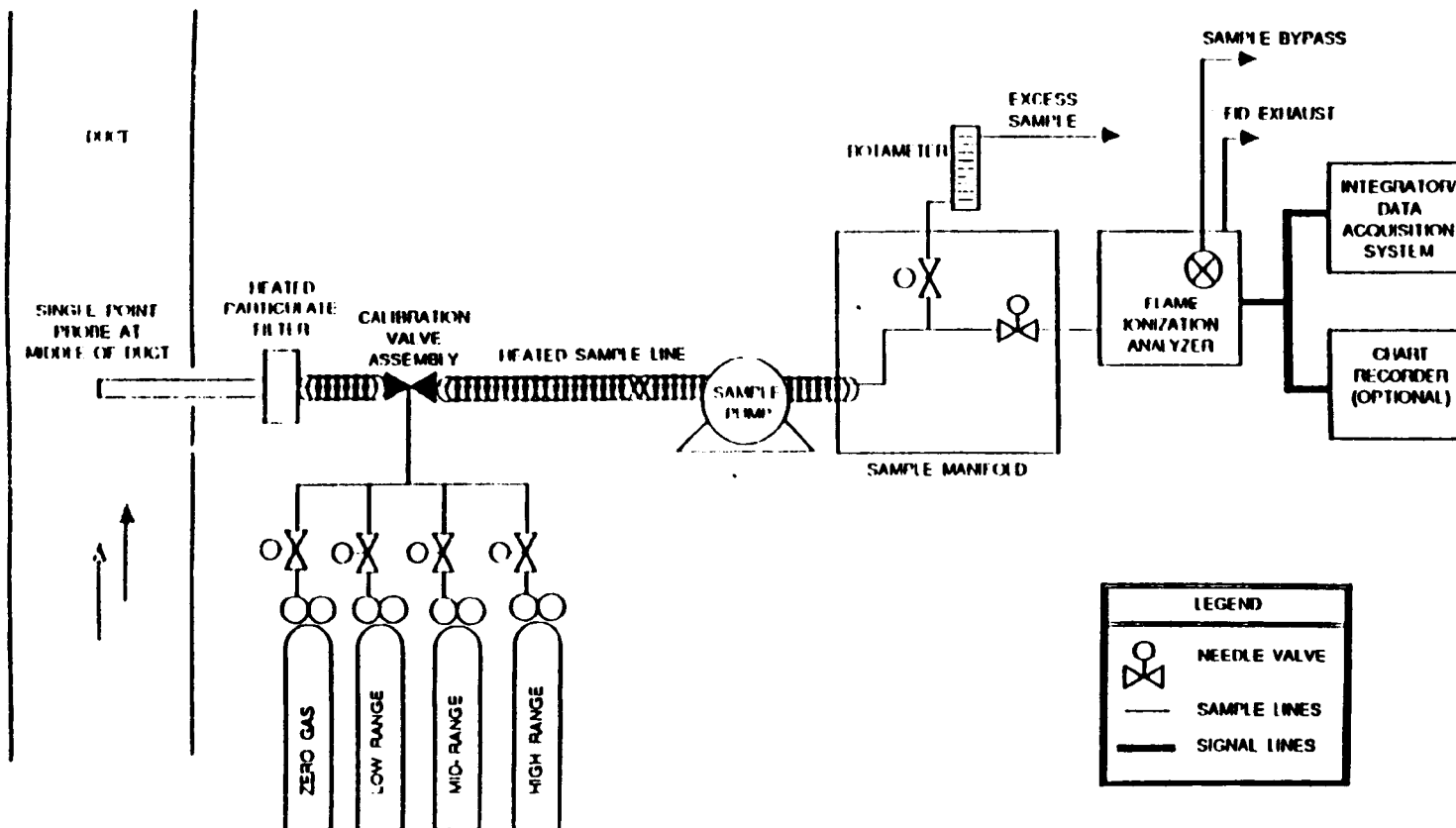


Figure 204B-1. Gas VOC concentration measurement system.

**2.1.1 Sample Probe.** Stainless steel, or equivalent. The probe shall be heated to prevent VOC condensation.

**2.1.2 Calibration Valve Assembly.** Three-way valve assembly at the outlet of the sample probe to direct the zero and calibration gases to the analyzer. Other methods, such as quick-connect lines, to route calibration gases to the outlet of the sample probe are acceptable.

**2.1.3 Sample Line.** Stainless steel or Teflon tubing to transport the sample gas to the analyzer. The sample line must be heated to prevent condensation.

**2.1.4 Sample Pump.** A leak-free pump, to pull the sample gas through the system at a flow rate sufficient to minimize the response time of the measurement system. The components of the pump that contact the gas stream shall be constructed of stainless steel or Teflon. The sample pump must be heated to prevent condensation.

**2.1.5 Sample Flow Rate Control.** A sample flow rate control valve and rotameter, or equivalent, to maintain a constant sampling rate within 10 percent. The flow rate control valve and rotameter must be heated to prevent condensation. A control valve may also be located on the sample pump bypass loop to assist in controlling the sample pressure and flow rate.

**2.1.6 Sample Gas Manifold.** Capable of diverting a portion of the sample gas stream to the flame ionization analyzer (FIA), and the remainder to the bypass discharge vent. The manifold components shall be constructed of stainless steel or Teflon. If captured or fugitive emissions are to be measured at multiple locations, the measurement system shall be designed to use separate sampling probes, lines, and pumps for each measurement location and a common sample gas manifold and FIA. The sample gas manifold and connecting lines to the FIA must be heated to prevent condensation.

**2.1.7 Organic Concentration Analyzer.** An FIA with a span value of 1.5 times the expected concentration as propane; however, other span values may be used if it can be demonstrated to the Administrator's satisfaction that they would provide more accurate measurements. The system shall be capable of meeting or exceeding the following specifications:

**2.1.7.1 Zero Drift.** Less than  $\pm 3.0$  percent of the span value.

**2.1.7.2 Calibration Drift.** Less than  $\pm 3.0$  percent of the span value.

**2.1.7.3 Calibration Error.** Less than  $\pm 5.0$  percent of the calibration gas value.

**2.1.7.4 Response Time.** Less than 30 seconds.

**2.1.8 Integrator/Data Acquisition System.** An analog or digital device or computerized data acquisition system used to integrate the FIA response or compute the average response and record measurement data. The minimum data sampling frequency for computing average or integrated values is one measurement value every 5 seconds. The device shall be capable of recording average values at least once per minute.

**2.1.9 Calibration and Other Gases.** Gases used for calibration, fuel, and combustion air (if required) are contained in compressed gas cylinders. All calibration gases shall be traceable to National Institute of Standards and Technology standards and shall be certified by the manufacturer to  $\pm 1$  percent of the tag value. Additionally, the manufacturer of the cylinder should provide a recommended shelf life for each calibration gas cylinder over which the concentration does not change more than  $\pm 2$  percent from the certified value. For calibration gas values not generally available, alternative methods for preparing calibration gas mixtures, such as dilution systems, may be used with the approval of the Administrator.

**2.1.9.1 Fuel.** A 40 percent  $H_2$ /60 percent He or 40 percent  $H_2$ /60 percent  $N_2$  gas mixture is recommended to avoid an oxygen synergism effect that reportedly occurs when oxygen concentration varies significantly from a mean value.

**2.1.9.2 Carrier Gas.** High purity air with less than 1 ppm of organic material (as propane or carbon equivalent) or less than 0.1 percent of the span value, whichever is greater.

**2.1.9.3 FIA Linearity Calibration Gases.** Low-, mid-, and high-range gas mixture standards with nominal propane concentrations of 20-30, 45-55, and 70-80 percent of the span value in air, respectively. Other calibration values and other span values may be used if it can be shown to the Administrator's satisfaction that more accurate measurements would be achieved.

**2.1.10 Particulate Filter.** An in-stack or an out-of-stack glass fiber filter is recommended if exhaust gas particulate loading is significant. An out-of-stack filter must be heated to prevent any condensation unless it can be demonstrated that no condensation occurs.

## **2.2 Captured Emissions Volumetric Flow Rate.**

**2.2.1 Method 2 or 2A Apparatus.** For determining volumetric flow rate.

**2.2.2 Method 3 Apparatus and Reagents.** For determining molecular weight of the gas stream. An estimate of the molecular weight of the gas stream may be used if approved by the Administrator.

**2.2.3 Method 4 Apparatus and Reagents.** For determining moisture content, if necessary.

## **3. DETERMINATION OF VOLUMETRIC FLOW RATE OF CAPTURED EMISSIONS**

**3.1** Locate all points where emissions are captured from the affected facility. Using Method 1, determine the sampling points. Be sure to check each site for cyclonic or swirling flow.

**3.2** Measure the velocity at each sampling site at least once every hour during each sampling run using Method 2 or 2A.

## **4. DETERMINATION OF VOC CONTENT OF CAPTURED EMISSIONS**

**4.1 Analysis Duration.** Measure the VOC responses at each captured emissions point during the entire test run or, if applicable, while the process is operating. If there are multiple captured emission locations, design a sampling system to allow a single FIA to be used to determine the VOC responses at all sampling locations.

### **4.2 Gas VOC Concentration.**

**4.2.1** Assemble the sample train as shown in Figure 204B-1. Calibrate the FIA according to the procedure in Section 5.1.

**4.2.2** Conduct a system check according to the procedure in Section 5.3.

**4.2.3** Install the sample probe so that the probe is centrally located in the stack, pipe, or duct, and is sealed tightly at the stack port connection.

**4.2.4** Inject zero gas at the calibration valve assembly. Allow the measurement system response to reach zero. Measure the system response time as the time required for the system to

reach the effluent concentration after the calibration valve has been returned to the effluent sampling position.

**4.2.5** Conduct a system check before and a system drift check after each sampling run according to the procedures in Sections 5.2 and 5.3. If the drift check following a run indicates unacceptable performance (see Section 5.3), the run is not valid. The tester may elect to perform system drift checks during the run not to exceed one drift check per hour.

**4.2.6** Verify that the sample lines, filter, and pump temperatures are  $120 \pm 5^{\circ}\text{C}$ .

**4.2.7** Begin sampling at the start of the test period and continue to sample during the entire run. Record the starting and ending times and any required process information as appropriate. If multiple captured emission locations are sampled using a single FIA, sample at each location for the same amount of time (e.g., 2 minutes) and continue to switch from one location to another for the entire test run. Be sure that total sampling time at each location is the same at the end of the test run. Collect at least four separate measurements from each sample point during each hour of testing. Disregard the measurements at each sampling location until two times the response time of the measurement system has elapsed. Continue sampling for at least 1 minute and record the concentration measurements.

### **4.3 Background Concentration.**

**NOTE:** Not applicable when the building is used as the temporary total enclosure (TTE).

**4.3.1** Locate all natural draft openings (NDO's) of the TTE. A sampling point shall be at the center of each NDO, unless otherwise specified by the Administrator. If there are more than six NDO's, choose six sampling points evenly spaced among the NDO's.

**4.3.2** Assemble the sample train as shown in Figure 204B-2. Calibrate the FIA and conduct a system check according to the procedures in Sections 5.1 and 5.3. **NOTE:** This sample train shall be a separate sampling train from the one to measure the captured emissions.

**4.3.3** Position the probe at the sampling location.

**4.3.4** Determine the response time, conduct the system check and sample according to the procedures described in Sections 4.2.4 to 4.2.7.

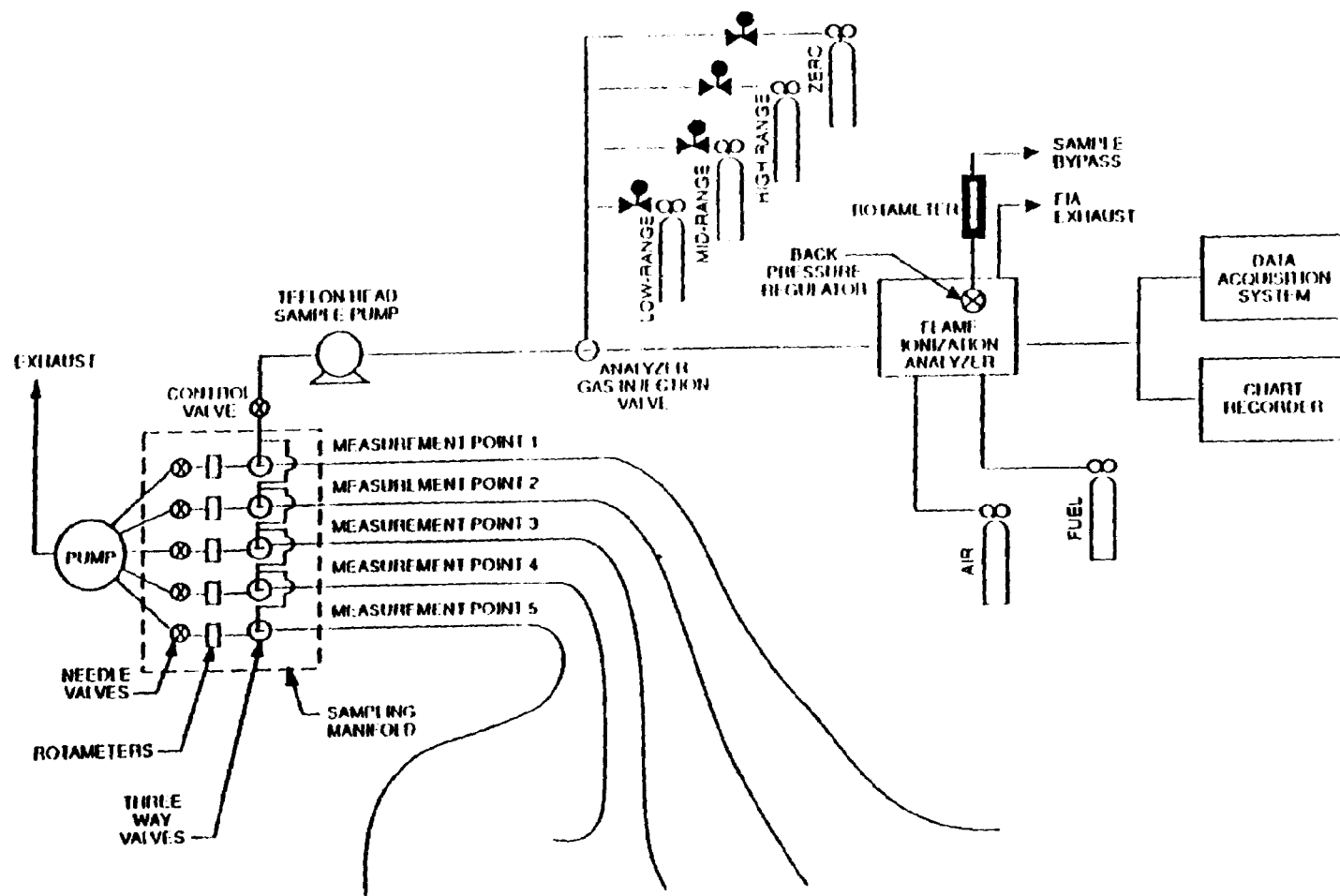


Figure 204B-2. Background measurement system.



**4.4 Alternative Procedure.** The direct interface sampling and analysis procedure described in Section 7.2 of Method 18 may be used to determine the gas VOC concentration. The system must be designed to collect and analyze at least one sample every 10 minutes.

## **5. CALIBRATION AND QUALITY ASSURANCE**

**5.1 FIA Calibration and Linearity Check.** Make necessary adjustments to the air and fuel supplies for the FIA and ignite the burner. Allow the FIA to warm up for the period recommended by the manufacturer. Inject a calibration gas into the measurement system and adjust the back-pressure regulator to the value required to achieve the flow rates specified by the manufacturer. Inject the zero- and the high-range calibration gases and adjust the analyzer calibration to provide the proper responses. Inject the low- and mid-range gases and record the responses of the measurement system. The calibration and linearity of the system are acceptable if the responses for all four gases are within 5 percent of the respective gas values. If the performance of the system is not acceptable, repair or adjust the system and repeat the linearity check. Conduct a calibration and linearity check after assembling the analysis system and after a major change is made to the system.

**5.2 Systems Drift Checks.** Select the calibration gas that most closely approximates the concentration of the captured emissions for conducting the drift checks. Introduce the zero and calibration gas at the calibration valve assembly and verify that the appropriate gas flow rate and pressure are present at the FIA. Record the measurement system responses to the zero and calibration gases. The performance of the system is acceptable if the difference between the drift check measurement and the value obtained in Section 5.1 is less than 3 percent of the span value. Conduct the system drift checks at the end of each run.

**5.3 System Check.** Inject the high range calibration gas at the inlet of the sampling probe and record the response. The performance of the system is acceptable if the measurement system response is within 5 percent of the value obtained in Section 5.1 for the high range calibration gas. Conduct a system check before and after each test run.

**5.4 Analysis Audit.** Immediately before each test, analyze an audit cylinder as described in Section 5.2. The analysis audit must agree with the audit cylinder concentration within 10 percent.

## **6. NOMENCLATURE**

$A_i$  = area of NDO i, ft<sup>2</sup>.

$A_N$  = total area of all NDO's in the enclosure, ft<sup>2</sup>.

$C_{Bi}$  = corrected average VOC concentration of background emissions at point i, ppm propane.

- $C_B$  = average background concentration, ppm propane.  
 $C_{Gj}$  = corrected average VOC concentration of captured emissions at point j, ppm propane.  
 $C_{DH}$  = average measured concentration for the drift check calibration gas, ppm propane.  
 $C_{D0}$  = average system drift check concentration for zero concentration gas, ppm propane.  
 $C_H$  = actual concentration of the drift check calibration gas, ppm propane.  
 $C_i$  = uncorrected average background VOC concentration measured at point i, ppm propane.  
 $C_j$  = uncorrected average VOC concentration measured at point j, ppm propane.  
 $G$  = total VOC content of captured emissions, kg.  
 $K_1 = 1.830 \times 10^{-6} \text{ kg}/(\text{m}^3\text{-ppm})$ .  
 $n$  = number of measurement points.  
 $Q_{Gj}$  = average effluent volumetric flow rate corrected to standard conditions at captured emissions point j,  $\text{m}^3/\text{min}$ .  
 $\theta_C$  = total duration of captured emissions sampling run, min.

## 7. CALCULATIONS

### 7.1 Total VOC Captured Emissions.

$$G = \sum_{j=1}^n (C_{Gj} - C_B) Q_{Gj} \theta_C K_1 \quad \text{Eq. 204B-1}$$

### 7.2 VOC Concentration of the Captured Emissions at Point j.

$$C_{Gj} = (C_j - C_{D0}) \frac{C_H}{C_{DH} - C_{D0}} \quad \text{Eq. 204B-2}$$

### 7.3 Background VOC Concentration at Point i.

$$C_{Bi} = (C_i - C_{D0}) \frac{C_H}{C_{DH} - C_{D0}} \quad \text{Eq. 204B-3}$$

**7.4 Average Background Concentration.**

$$C_B = \frac{\sum_{i=1}^n C_{Bi} A_i}{A_N}$$

Eq. 204B-4

**NOTE:** If the concentration at each point is within 20 percent of the average concentration of all points, then use the arithmetic average.

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## Method 204C - Volatile Organic Compound Emissions in Captured Stream (Dilution Technique)

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### 1. INTRODUCTION

**1.1 Applicability.** This procedure is applicable for determining the volatile organic compounds (VOC) content of captured gas streams. It is intended to be used in the development of a gas/gas protocol in which fugitive emissions are measured for determining VOC capture efficiency (CE) for surface coating and printing operations. A dilution system is used to reduce the VOC concentration of the captured emission to about the same concentration as the fugitive emissions. The procedure may not be acceptable in certain site-specific situations, e.g., when: (1) direct fired heaters or other circumstances affect the quantity of VOC at the control device inlet; and (2) particulate organic aerosols are formed in the process and are present in the captured emissions.

**1.2 Principle.** The amount of VOC captured ( $G$ ) is calculated as the sum of the products of the VOC content ( $C_{Gj}$ ), the flow rate ( $Q_{Gj}$ ), and the sampling time ( $\theta_C$ ) from each captured emissions point.

**1.3 Estimated Measurement Uncertainty.** The measurement uncertainties are estimated for each captured or fugitive emissions point as follows:  $Q_{Gj} = \pm 5.5$  percent and  $C_{Gj} = \pm 5$  percent. Based on these numbers, the probable uncertainty for  $G$  is estimated at about  $\pm 7.4$  percent.

**1.4 Sampling Requirements.** A capture efficiency test shall consist of at least three sampling runs. Each run shall cover at least one complete production cycle but shall be at least 3 hours long. The sampling time for each run need not exceed 8 hours even if the production cycle has not been completed. Alternative sampling times may be used with the approval of the Administrator.

**1.5 Notes.** Because this procedure is often applied in highly explosive areas, caution and care should be exercised in choosing appropriate equipment and installing and using the equipment. Mention of trade names or company products does not constitute endorsement. All gas concentrations (percent, ppm) are by volume, unless otherwise noted.

### 2. APPARATUS AND REAGENTS

**2.1 Gas VOC Concentration.** A schematic of the measurement system is shown in Figure 204C-1. The main components are as follows:

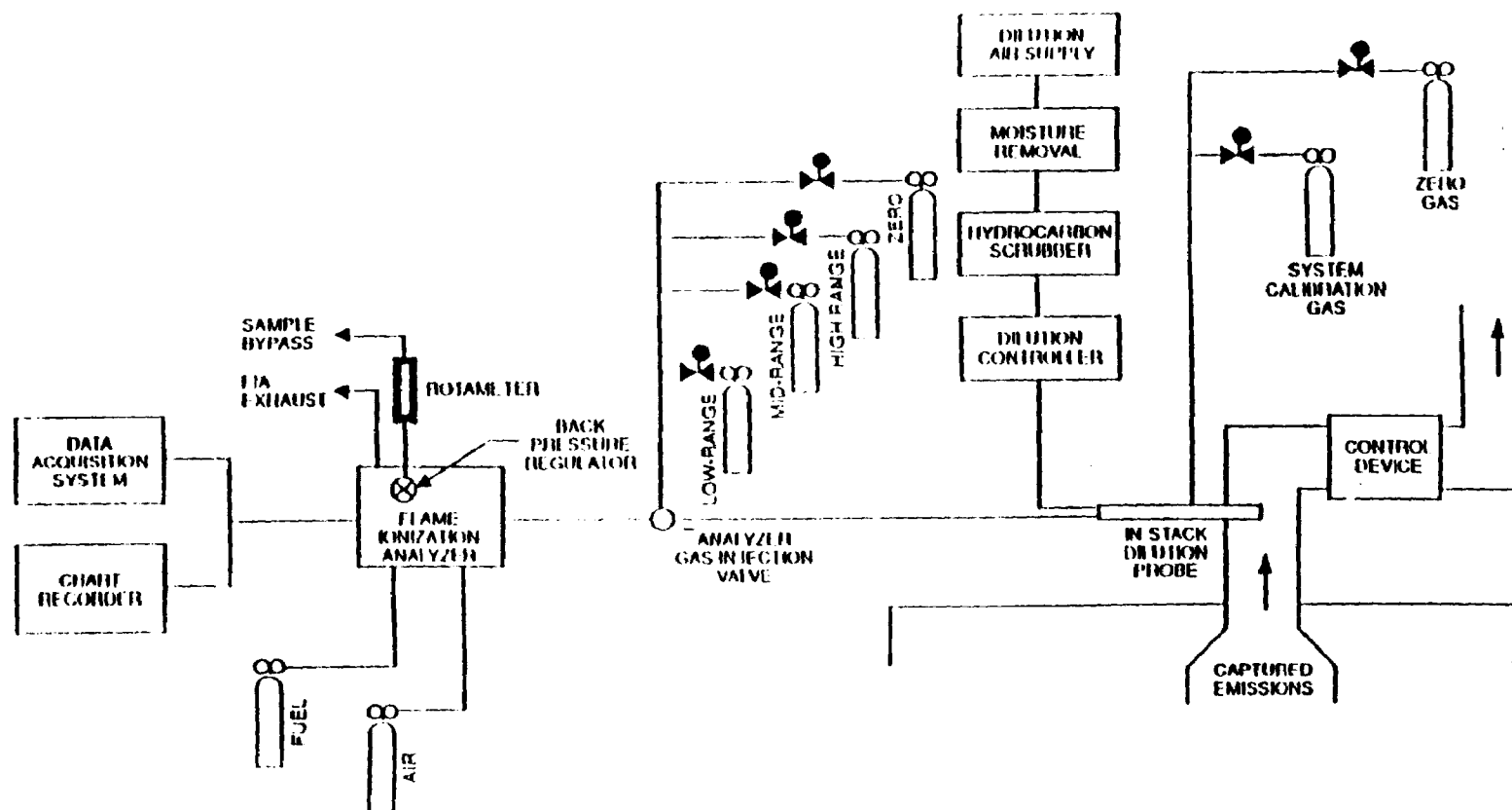


Figure 204C-1. Captured emissions measurement system.

**2.1.1 Dilution System.** A Kipp in-stack dilution probe and controller or similar device may be used. The dilution rate may be changed by substituting different critical orifices or adjustments of the aspirator supply pressure. The dilution system shall be heated to prevent VOC condensation. **Note:** An out-of-stack dilution device may be used.

**2.1.2 Calibration Valve Assembly.** Three-way valve assembly at the outlet of the sample probe to direct the zero and calibration gases to the analyzer. Other methods, such as quick-connect lines, to route calibration gases to the outlet of the sample probe are acceptable.

**2.1.3 Sample Line.** Stainless steel or Teflon tubing to transport the sample gas to the analyzer. The sample line must be heated to prevent condensation.

**2.1.4 Sample Pump.** A leak-free pump, to pull the sample gas through the system at a flow rate sufficient to minimize the response time of the measurement system. The components of the pump that contact the gas stream shall be constructed of stainless steel or Teflon. The sample pump must be heated to prevent condensation.

**2.1.5 Sample Flow Rate Control.** A sample flow rate control valve and rotameter, or equivalent, to maintain a constant sampling rate within 10 percent. The flow control valve and rotameter must be heated to prevent condensation. A control valve may also be located on the sample pump bypass loop to assist in controlling the sample pressure and flow rate.

**2.1.6 Sample Gas Manifold.** Capable of diverting a portion of the sample gas stream to the flame ionization analyzer (FIA), and the remainder to the bypass discharge vent. The manifold components shall be constructed of stainless steel or Teflon. If captured or fugitive emissions are to be measured at multiple locations, the measurement system shall be designed to use separate sampling probes, lines, and pumps for each measurement location and a common sample gas manifold and FIA. The sample gas manifold and connecting lines to the FIA must be heated to prevent condensation.

**2.1.7 Organic Concentration Analyzer.** An FIA with a span value of 1.5 times the expected concentration as propane; however, other span values may be used if it can be demonstrated to the Administrator's satisfaction that they would provide more accurate measurements. The system shall be capable of meeting or exceeding the following specifications:

**2.1.7.1 Zero Drift.** Less than  $\pm 3.0$  percent of the span value.

**2.1.7.2 Calibration Drift.** Less than  $\pm 3.0$  percent of the span value.

**2.1.7.3 Calibration Error.** Less than  $\pm 5.0$  percent of the calibration gas value.

**2.1.7.4 Response Time.** Less than 30 seconds.

**2.1.8 Integrator/Data Acquisition System.** An analog or digital device or computerized data acquisition system used to integrate the FIA response or compute the average response and record measurement data. The minimum data sampling frequency for computing average or integrated values is one measurement value every 5 seconds. The device shall be capable of recording average values at least once per minute.

**2.1.9 Calibration and Other Gases.** Gases used for calibration, fuel, and combustion air (if required) are contained in compressed gas cylinders. All calibration gases shall be traceable to National Institute of Standards and Technology standards and shall be certified by the manufacturer to  $\pm 1$  percent of the tag value. Additionally, the manufacturer of the cylinder should provide a recommended shelf life for each calibration gas cylinder over which the concentration does not change more than  $\pm 2$  percent from the certified value. For calibration gas values not generally available, alternative methods for preparing calibration gas mixtures, such as dilution systems, may be used with the approval of the Administrator.

**2.1.9.1 Fuel.** A 40 percent  $H_2$ /60 percent He or 40 percent  $H_2$ /60 percent  $N_2$  gas mixture is recommended to avoid an oxygen synergism effect that reportedly occurs when oxygen concentration varies significantly from a mean value.

**2.1.9.2 Carrier Gas and Dilution Air Supply.** High purity air with less than 1 ppm of organic material (as propane or carbon equivalent) or less than 0.1 percent of the span value, whichever is greater.

**2.1.9.3 FIA Linearity Calibration Gases.** Low-, mid-, and high-range gas mixture standards with nominal propane concentrations of 20-30, 45-55, and 70-80 percent of the span value in air, respectively. Other calibration values and other span values may be used if it can be shown to the Administrator's satisfaction that more accurate measurements would be achieved.

**2.1.9.4 Dilution Check Gas.** Gas mixture standard containing propane in air, approximately half the span value after dilution.

**2.1.10 Particulate Filter.** An in-stack or an out-of-stack glass fiber filter is recommended if exhaust gas particulate loading is significant. An out-of-stack filter must be heated to prevent any condensation unless it can be demonstrated that no condensation occurs.

## **2.2 Captured Emissions Volumetric Flow Rate.**

**2.2.1 Method 2 or 2A Apparatus.** For determining volumetric flow rate.

**2.2.2 Method 3 Apparatus and Reagents.** For determining molecular weight of the gas stream. An estimate of the molecular weight of the gas stream may be used if approved by the Administrator.

**2.2.3 Method 4 Apparatus and Reagents.** For determining moisture content, if necessary.

## **3. DETERMINATION OF VOLUMETRIC FLOW RATE OF CAPTURED EMISSIONS**

**3.1** Locate all points where emissions are captured from the affected facility. Using Method 1, determine the sampling points. Be sure to check each site for cyclonic or swirling flow.

**3.2** Measure the velocity at each sampling site at least once every hour during each sampling run using Method 2 or 2A.

## **4. DETERMINATION OF VOC CONTENT OF CAPTURED EMISSIONS**

**4.1 Analysis Duration.** Measure the VOC responses at each captured emissions point during the entire test run or, if applicable, while the process is operating. If there are multiple captured emissions locations, design a sampling system to allow a single FIA to be used to determine the VOC responses at all sampling locations.

### **4.2 Gas VOC Concentration.**

**4.2.1** Assemble the sample train as shown in Figure 204C-1. Calibrate the FIA according to the procedure in Section 5.1.



**4.2.2** Set the dilution ratio and determine the dilution factor according to the procedure in Section 5.3.

**4.2.3** Conduct a system check according to the procedure in Section 5.4.

**4.2.4** Install the sample probe so that the probe is centrally located in the stack, pipe, or duct, and is sealed tightly at the stack port connection.

**4.2.5** Inject zero gas at the calibration valve assembly. Measure the system response time as the time required for the system to reach the effluent concentration after the calibration valve has been returned to the effluent sampling position.

**4.2.6** Conduct a system check before and a system drift check after each sampling run according to the procedures in Sections 5.2 and 5.4. If the drift check following a run indicates unacceptable performance (see Section 5.4), the run is not valid. The tester may elect to perform system drift checks during the run not to exceed one drift check per hour.

**4.2.7** Verify that the sample lines, filter, and pump temperatures are  $120 \pm 5^{\circ}\text{C}$ .

**4.2.8** Begin sampling at the start of the test period and continue to sample during the entire run. Record the starting and ending times and any required process information as appropriate. If multiple captured emission locations are sampled using a single FIA, sample at each location for the same amount of time (e.g., 2 min.) and continue to switch from one location to another for the entire test run. Be sure that total sampling time at each location is the same at the end of the test run. Collect at least four separate measurements from each sample point during each hour of testing. Disregard the measurements at each sampling location until two times the response time of the measurement system has elapsed. Continue sampling for at least 1 minute and record the concentration measurements.

#### **4.3 Background Concentration.**

**NOTE:** Not applicable when the building is used as the temporary total enclosure (TTE).

**4.3.1** Locate all natural draft openings (NDO's) of the TTE. A sampling point shall be at the center of each NDO, unless otherwise approved by the Administrator. If there are more than six NDO's, choose six sampling points evenly spaced among the NDO's.

**4.3.2** Assemble the sample train as shown in Figure 204C-2. Calibrate the FIA and conduct a system check according to the procedures in Sections 5.1 and 5.4.

**4.3.3** Position the probe at the sampling location.

**4.3.4** Determine the response time, conduct the system check and sample according to the procedures described in Sections 4.2.4 to 4.2.8.

**4.4 Alternative Procedure.** The direct interface sampling and analysis procedure described in Section 7.2 of Method 18 may be used to determine the gas VOC concentration. The system must be designed to collect and analyze at least one sample every 10 minutes.

## **5. CALIBRATION AND QUALITY ASSURANCE**

**5.1 FIA Calibration and Linearity Check.** Make necessary adjustments to the air and fuel supplies for the FIA and ignite the burner. Allow the FIA to warm up for the period recommended by the manufacturer. Inject a calibration gas into the measurement system after the dilution system and adjust the back-pressure regulator to the value required to achieve the flow rates specified by the manufacturer. Inject the zero- and the high-range calibration gases and adjust the analyzer calibration to provide the proper responses. Inject the low- and mid-range gases and record the responses of the measurement system. The calibration and linearity of the system are acceptable if the responses for all four gases are within 5 percent of the respective gas values. If the performance of the system is not acceptable, repair, or adjust the system, and repeat the linearity check. Conduct a calibration and linearity check after assembling the analysis system and after a major change is made to the system.

**5.2 Systems Drift Checks.** Select the calibration gas that most closely approximates the concentration of the diluted captured emissions for conducting the drift checks. Introduce the zero and calibration gas at the calibration valve assembly and verify that the appropriate gas flow rate and pressure are present at the FIA. Record the measurement system responses to the zero and calibration gases. The performance of the system is acceptable if the difference between the drift check measurement and the value obtained in Section 5.1 is less than 3 percent of the span value. Conduct the system drift check at the end of each run.

**5.3 Determination of Dilution Factor.** Inject the dilution check gas into the measurement system before the dilution system and record the response. Calculate the dilution factor using Equation 204C-3.

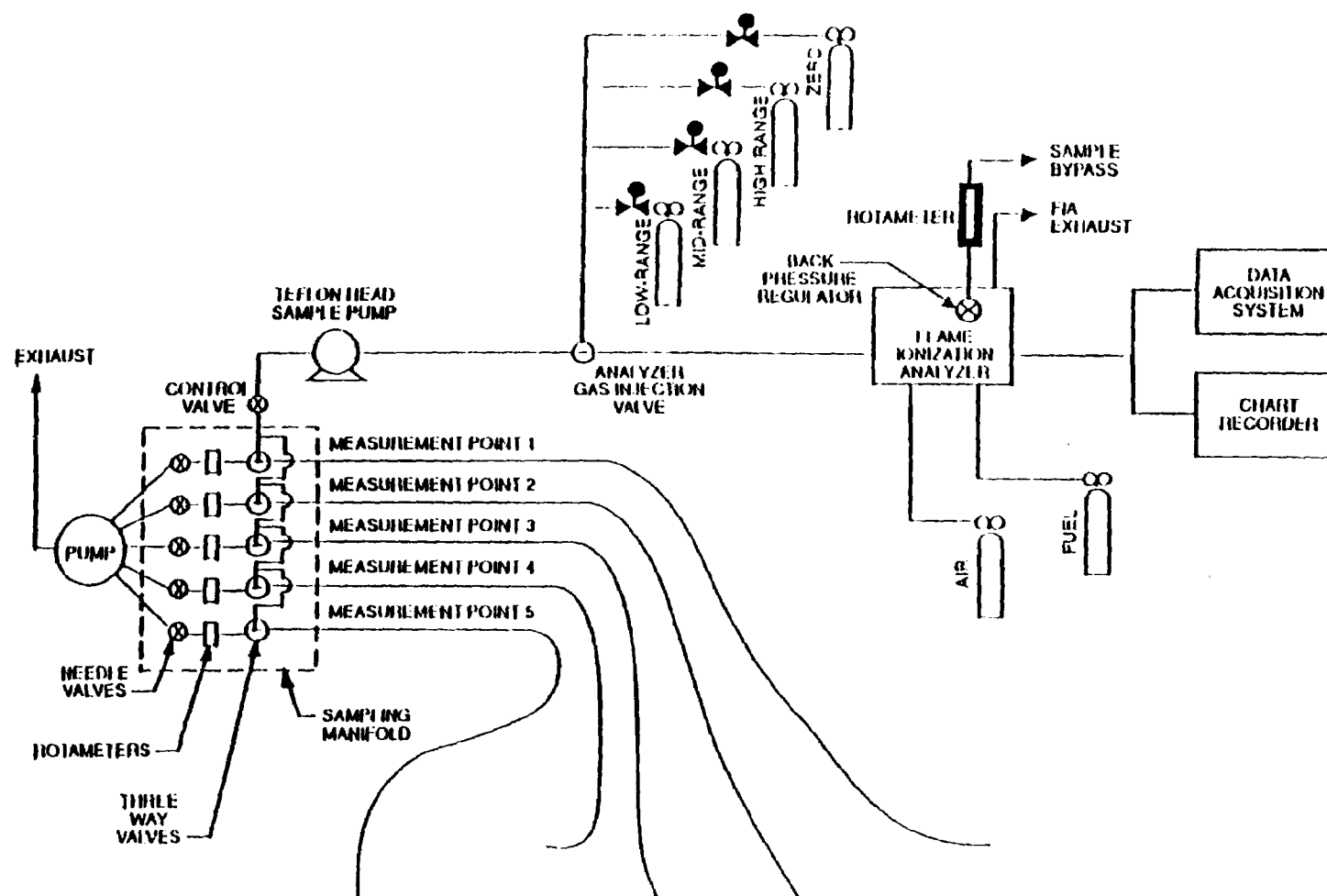


Figure 204C-2. Background measurement system.

**5.4 System Check.** Inject the high range calibration gas at the inlet to the sampling probe while the dilution air is turned off. Record the response. The performance of the system is acceptable if the measurement system response is within 5 percent of the value obtained in Section 5.1 for the high range calibration gas. Conduct a system check before and after each test run.

**5.5 Analysis Audit.** Immediately before each test, analyze an audit cylinder as described in Section 5.2. The analysis audit must agree with the audit cylinder concentration within 1 percent.

## 6. NOMENCLATURE

$A_i$  = area of NDO i, ft<sup>2</sup>.

$A_N$  = total area of all NDO's in the enclosure, ft<sup>2</sup>.

$C_A$  = actual concentration of the dilution check gas, ppm propane.

$C_{Bi}$  = corrected average VOC concentration of background emissions at point i, ppm propane.

$C_B$  = average background concentration, ppm propane.

$C_{DH}$  = average measured concentration for the drift check calibration gas, ppm propane.

$C_{D0}$  = average system drift check concentration for zero concentration gas, ppm propane.

$C_H$  = actual concentration of the drift check calibration gas, ppm propane.

$C_i$  = uncorrected average background VOC concentration measured at point i, ppm propane.

$C_j$  = uncorrected average VOC concentration measured at point j, ppm propane.

$C_M$  = measured concentration of the dilution check gas, ppm propane.

DF = dilution factor.

G = total VOC content of captured emissions, kg.

$K_1 = 1.830 \times 10^{-6}$  kg/(m<sup>3</sup>-ppm).

n = number of measurement points.

$Q_{Gj}$  = average effluent volumetric flow rate corrected to standard conditions at captured emissions point j, m<sup>3</sup>/min.

$\theta_C$  = total duration of capture efficiency sampling run, min.

## 7. CALCULATIONS

### 7.1 Total VOC Captured Emissions.

$$G = \sum_{j=1}^n (C_{Gj} - C_B) Q_{Gj} \theta_c K_1 \quad \text{Eq. 204C-1}$$

### 7.2 VOC Concentration of the Captured Emissions at Point j.

$$C_{Gj} = DF (C_j - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}} \quad \text{Eq. 204C-2}$$

### 7.3 Dilution Factor.

$$DF = \frac{C_A}{C_M} \quad \text{Eq. 204C-3}$$

### 7.4 Background VOC Concentration at Point i.

$$C_{Bi} = (C_i - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}} \quad \text{Eq. 204C-4}$$

### 7.5 Average Background Concentration.

$$C_B = \frac{\sum_{i=1}^n C_{Bi} A_i}{A_N} \quad \text{Eq. 204C-5}$$

**NOTE:** If the concentration at each point is within 20 percent of the average concentration of all points, then use the arithmetic average.



## **Method 204D - Volatile Organic Compound Emissions in Fugitive Stream from Temporary Total Enclosure**

### **1. INTRODUCTION**

**1.1 Applicability.** This procedure is applicable for determining the fugitive volatile organic compounds (VOC) emissions from a temporary total enclosure (TTE). It is intended to be used as a segment in the development of liquid/gas or gas/gas protocols for determining VOC capture efficiency (CE) for surface coating and printing operations.

**1.2 Principle.** The amount of fugitive VOC emissions (F) from the TTE is calculated as the sum of the products of the VOC content ( $C_{Fj}$ ), the flow rate ( $Q_{Fj}$ ), and the sampling time ( $\theta_F$ ) from each fugitive emissions point.

**1.3 Estimated Measurement Uncertainty.** The measurement uncertainties are estimated for each fugitive emission point as follows:  $Q_{Fj} = \pm 5.5$  percent and  $C_{Fj} = \pm 5.0$  percent. Based on these numbers, the probable uncertainty for F is estimated at about  $\pm 7.4$  percent.

**1.4 Sampling Requirements.** A capture efficiency test shall consist of at least three sampling runs. Each run shall cover at least one complete production cycle but shall be at least 3 hours long. The sampling time for each run need not exceed 8 hours even if the production cycle has not been completed. Alternative sampling times may be used with the approval of the Administrator.

**1.5 Notes.** Because this procedure is often applied in highly explosive areas, caution and care should be exercised in choosing appropriate equipment and installing and using the equipment. Mention of trade names or company products does not constitute endorsement. All gas concentrations (percent, ppm) are by volume, unless otherwise noted.

### **2. APPARATUS AND REAGENTS**

**2.1 Gas VOC Concentration.** A schematic of the measurement system is shown in Figure 204D-1. The main components are as follows:

**2.1.1 Sample Probe.** Stainless steel, or equivalent. The probe shall be heated to prevent VOC condensation.



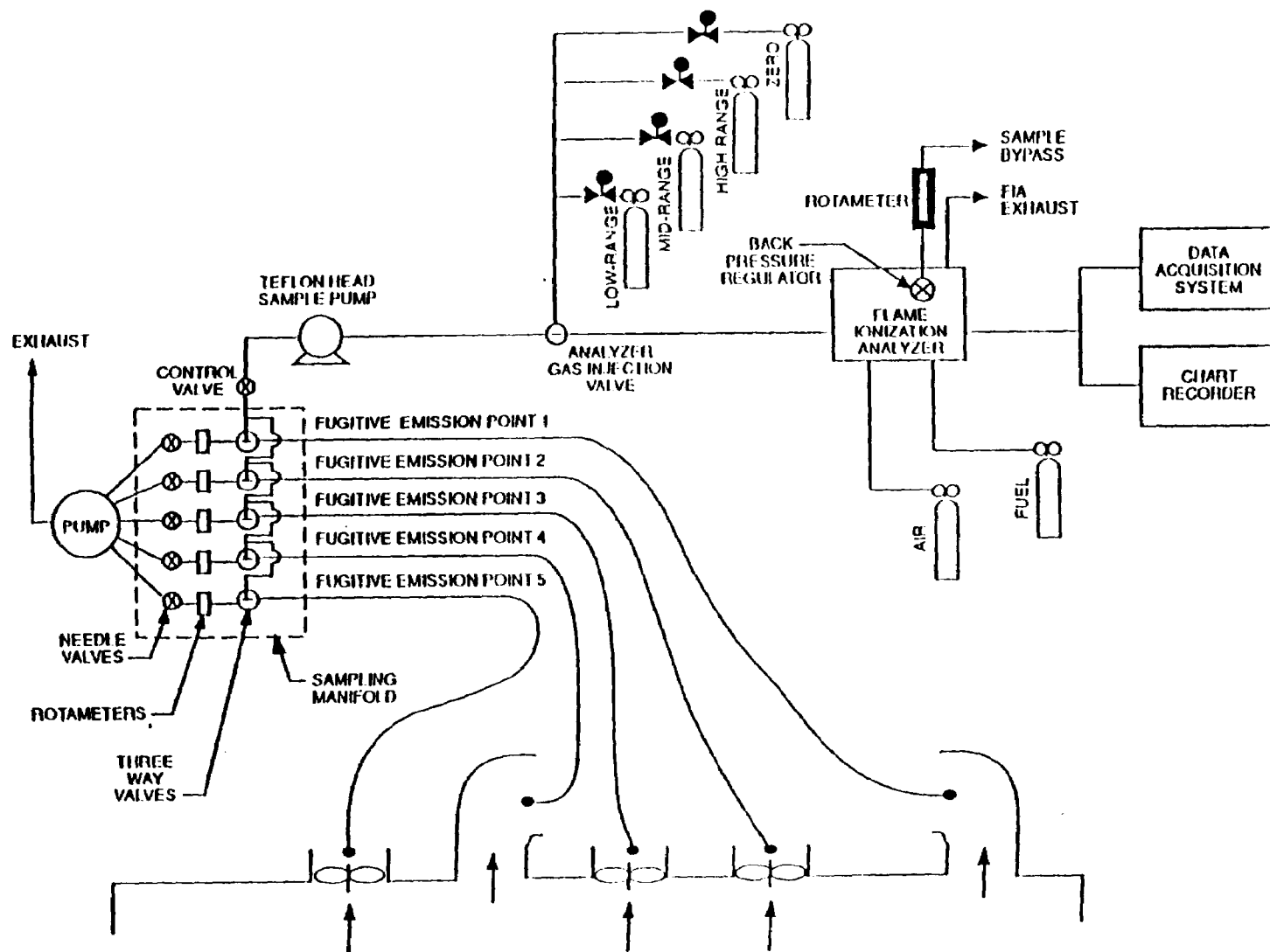


Figure 204D-1. Fugitive emissions measurement system.

**2.1.2 Calibration Valve Assembly.** Three-way valve assembly at the outlet of the sample probe to direct the zero and calibration gases to the analyzer. Other methods, such as quick-connect lines, to route calibration gases to the outlet of the sample probe are acceptable.

**2.1.3 Sample Line.** Stainless steel or Teflon tubing to transport the sample gas to the analyzer. The sample line must be heated to prevent condensation.

**2.1.4 Sample Pump.** A leak-free pump, to pull the sample gas through the system at a flow rate sufficient to minimize the response time of the measurement system. The components of the pump that contact the gas stream shall be constructed of stainless steel or Teflon. The sample pump must be heated to prevent condensation.

**2.1.5 Sample Flow Rate Control.** A sample flow rate control valve and rotameter, or equivalent, to maintain a constant sampling rate within 10 percent. The flow control valve and rotameter must be heated to prevent condensation. A control valve may also be located on the sample pump bypass loop to assist in controlling the sample pressure and flow rate.

**2.1.6 Sample Gas Manifold.** Capable of diverting a portion of the sample gas stream to the flame ionization analyzer (FIA), and the remainder to the bypass discharge vent. The manifold components shall be constructed of stainless steel or Teflon. If emissions are to be measured at multiple locations, the measurement system shall be designed to use separate sampling probes, lines, and pumps for each measurement location and a common sample gas manifold and FIA. The sample gas manifold and connecting lines to the FIA must be heated to prevent condensation.

**2.1.7 Organic Concentration Analyzer.** An FIA with a span value of 1.5 times the expected concentration as propane; however, other span values may be used if it can be demonstrated to the Administrator's satisfaction that they would provide more accurate measurements. The system shall be capable of meeting or exceeding the following specifications:

**2.1.7.1 Zero Drift.** Less than  $\pm 3.0$  percent of the span value.

**2.1.7.2 Calibration Drift.** Less than  $\pm 3.0$  percent of the span value.

**2.1.7.3 Calibration Error.** Less than  $\pm 5.0$  percent of the calibration gas value.

**2.1.7.4 Response Time.** Less than 30 seconds.

**2.1.8 Integrator/Data Acquisition System.** An analog or digital device or computerized data acquisition system used to integrate the FIA response or compute the average response and record measurement data. The minimum data sampling frequency for computing average or integrated values is one measurement value every 5 seconds. The device shall be capable of recording average values at least once per minute.

**2.1.9 Calibration and Other Gases.** Gases used for calibration, fuel, and combustion air (if required) are contained in compressed gas cylinders. All calibration gases shall be traceable to National Institute of Standards and Technology standards and shall be certified by the manufacturer to  $\pm 1$  percent of the tag value. Additionally, the manufacturer of the cylinder should provide a recommended shelf life for each calibration gas cylinder over which the concentration does not change more than  $\pm 2$  percent from the certified value. For calibration gas values not generally available, alternative methods for preparing calibration gas mixtures, such as dilution systems, may be used with the approval of the Administrator.

**2.1.9.1 Fuel.** A 40 percent  $H_2$ /60 percent He or 40 percent  $H_2$ /60 percent  $N_2$  gas mixture is recommended to avoid an oxygen synergism effect that reportedly occurs when oxygen concentration varies significantly from a mean value.

**2.1.9.2 Carrier Gas.** High purity air with less than 1 ppm of organic material (as propane or carbon equivalent) or less than 0.1 percent of the span value, whichever is greater.

**2.1.9.3 FIA Linearity Calibration Gases.** Low-, mid-, and high-range gas mixture standards with nominal propane concentrations of 20-30, 45-55, and 70-80 percent of the span value in air, respectively. Other calibration values and other span values may be used if it can be shown to the Administrator's satisfaction that more accurate measurements would be achieved.

**2.1.10 Particulate Filter.** An in-stack or an out-of-stack glass fiber filter is recommended if exhaust gas particulate loading is significant. An out-of-stack filter must be heated to prevent any condensation unless it can be demonstrated that no condensation occurs.

## **2.2 Fugitive Emissions Volumetric Flow Rate.**

**2.2.1 Method 2 or 2A Apparatus.** For determining volumetric flow rate.

**2.2.2 Method 3 Apparatus and Reagents.** For determining molecular weight of the gas stream. An estimate of the molecular weight of the gas stream may be used if approved by the Administrator.

**2.2.3 Method 4 Apparatus and Reagents.** For determining moisture content, if necessary.

**2.3 Temporary Total Enclosure.** The criteria for designing an acceptable TTE are specified in Method 204.

### **3. DETERMINATION OF VOLUMETRIC FLOW RATE OF FUGITIVE EMISSIONS**

**3.1** Locate all points where emissions are exhausted from the TTE. Using Method 1, determine the sampling points. Be sure to check each site for cyclonic or swirling flow.

**3.2** Measure the velocity at each sampling site at least once every hour during each sampling run using Method 2 or 2A.

### **4. DETERMINATION OF VOC CONTENT OF FUGITIVE EMISSIONS**

**4.1 Analysis Duration.** Measure the VOC responses at each fugitive emission point during the entire test run or, if applicable, while the process is operating. If there are multiple emission locations, design a sampling system to allow a single FIA to be used to determine the VOC responses at all sampling locations.

#### **4.2 Gas VOC Concentration.**

**4.2.1** Assemble the sample train as shown in Figure 204D-1. Calibrate the FIA and conduct a system check according to the procedures in Sections 5.1 and 5.3, respectively.

**4.2.2** Install the sample probe so that the probe is centrally located in the stack, pipe, or duct, and is sealed tightly at the stack port connection.

**4.2.3** Inject zero gas at the calibration valve assembly. Allow the measurement system response to reach zero. Measure the system response time as the time required for the system to reach the effluent concentration after the calibration valve has been returned to the effluent sampling position.

**4.2.4** Conduct a system check before and a system drift check after each sampling run according to the procedures in Sections 5.2 and 5.3. If the drift check following a run indicates unacceptable performance (see Section 5.3), the run is not valid. The tester may elect to perform system drift checks during the run not to exceed one drift check per hour.

**4.2.5** Verify that the sample lines, filter, and pump temperatures are  $120 \pm 5^{\circ}\text{C}$ .

**4.2.6** Begin sampling at the start of the test period and continue to sample during the entire run. Record the starting and ending times and any required process information as appropriate. If multiple emission locations are sampled using a single FIA, sample at each location for the same amount of time (e.g., 2 min.) and continue to switch from one location to another for the entire test run. Be sure that total sampling time at each location is the same at the end of the test run. Collect at least four separate measurements from each sample point during each hour of testing. Disregard the response measurements at each sampling location until two times the response time of the measurement system has elapsed. Continue sampling for at least 1 minute and record the concentration measurements.

#### **4.3 Background Concentration.**

**4.3.1** Locate all natural draft openings (NDO's) of the TTE. A sampling point shall be at the center of each NDO, unless otherwise approved by the Administrator. If there are more than six NDO's, choose six sampling points evenly spaced among the NDO's.

**4.3.2** Assemble the sample train as shown in Figure 204D-2. Calibrate the FIA and conduct a system check according to the procedures in Sections 5.1 and 5.3.

**4.3.3** Position the probe at the sampling location.

**4.3.4** Determine the response time, conduct the system check and sample according to the procedures described in Sections 4.2.3 to 4.2.6.

**4.4 Alternative Procedure.** The direct interface sampling and analysis procedure described in Section 7.2 of Method 18 may be used to determine the gas VOC concentration. The system must be designed to collect and analyze at least one sample every 10 minutes.

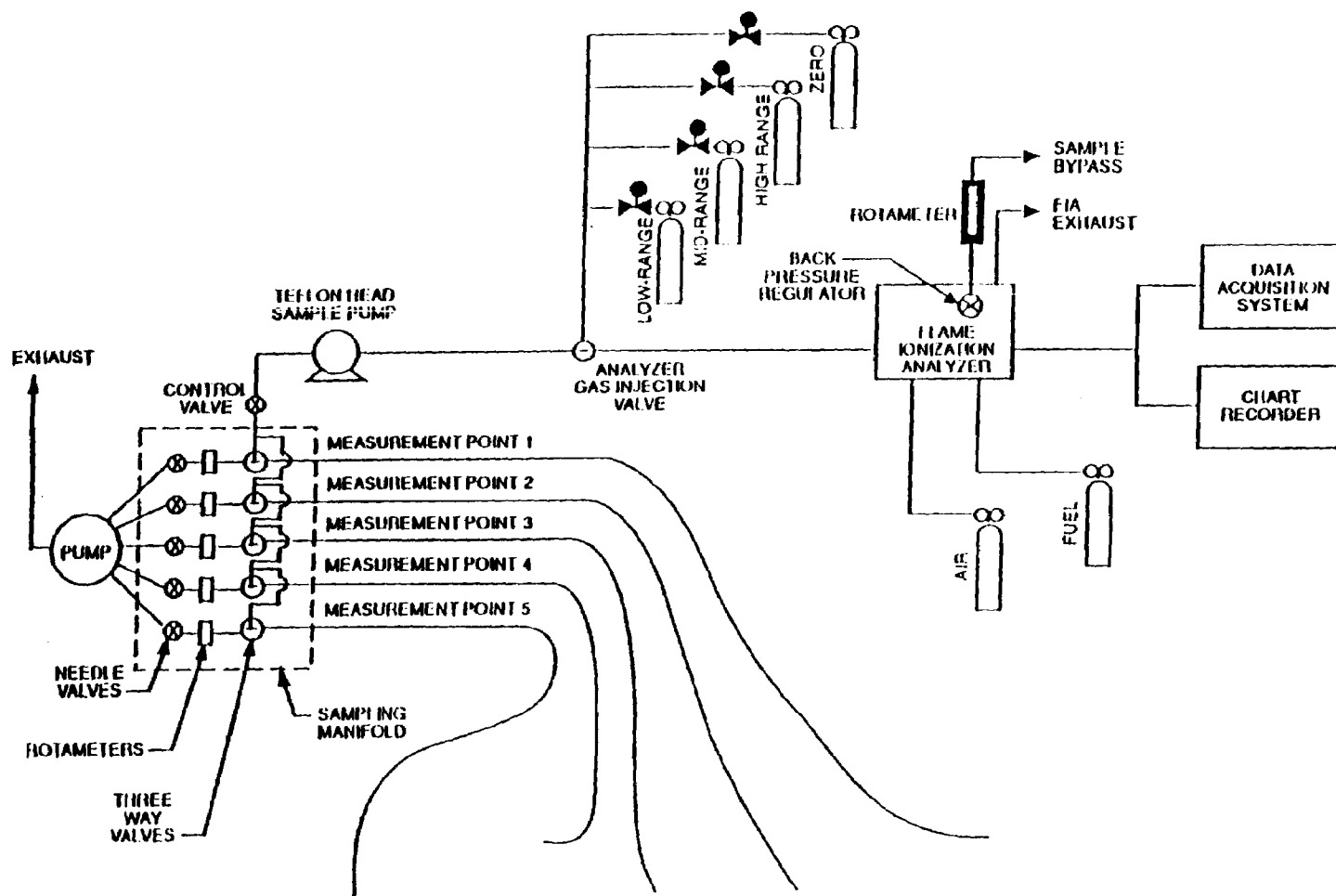


Figure 204D-2. Background measurement system.

## 5. CALIBRATION AND QUALITY ASSURANCE

**5.1 FIA Calibration and Linearity Check.** Make necessary adjustments to the air and fuel supplies for the FIA and ignite the burner. Allow the FIA to warm up for the period recommended by the manufacturer. Inject a calibration gas into the measurement system and adjust the back-pressure regulator to the value required to achieve the flow rates specified by the manufacturer. Inject the zero- and the high-range calibration gases and adjust the analyzer calibration to provide the proper responses. Inject the low- and mid-range gases and record the responses of the measurement system. The calibration and linearity of the system are acceptable if the responses for all four gases are within 5 percent of the respective gas values. If the performance of the system is not acceptable, repair or adjust the system, and repeat the linearity check. Conduct a calibration and linearity check after assembling the analysis system and after a major change is made to the system.

**5.2 Systems Drift Checks.** Select the calibration gas concentration that most closely approximates that of the fugitive gas emissions to conduct the drift checks. Introduce the zero and calibration gas at the calibration valve assembly and verify that the appropriate gas flow rate and pressure are present at the FIA. Record the measurement system responses to the zero and calibration gases. The performance of the system is acceptable if the difference between the drift check measurement and the value obtained in Section 5.1 is less than 3 percent of the span value. Conduct a system drift check at the end of each run.

**5.3 System Check.** Inject the high range calibration gas at the inlet of the sampling probe and record the response. The performance of the system is acceptable if the measurement system response is within 5 percent of the value obtained in Section 5.1 for the high range calibration gas. Conduct a system check before each test run.

**5.4 Analysis Audit.** Immediately before each test, analyze an audit cylinder as described in Section 5.2. The analysis audit must agree with the audit cylinder concentration within 10 percent.

## 6. NOMENCLATURE

- $A_i$  = area of NDO-i,  $\text{ft}^2$ .
- $A_N$  = total area of all NDO's in the enclosure,  $\text{ft}^2$ .
- $C_{Bi}$  = corrected average VOC concentration of background emissions at point i, ppm propane.
- $C_B$  = average background concentration, ppm propane.
- $C_{DH}$  = average measured concentration for the drift check calibration gas, ppm propane.
- $C_{D0}$  = average system drift check concentration for zero concentration gas, ppm propane.
- $C_{Fj}$  = corrected average VOC concentration of fugitive emissions at point j, ppm propane.

- $C_H$  = actual concentration of the drift check calibration gas, ppm propane.  
 $C_i$  = uncorrected average background VOC concentration at point i, ppm propane.  
 $C_j$  = uncorrected average VOC concentration measured at point j, ppm propane.  
 $F$  = total VOC content of fugitive emissions, kg.  
 $K_1 = 1.830 \times 10^{-6} \text{ kg}/(\text{m}^3\text{-ppm})$ .  
 $n$  = number of measurement points.  
 $Q_{Fj}$  = average effluent volumetric flow rate corrected to standard conditions at fugitive emissions point j,  $\text{m}^3/\text{min}$ .  
 $\theta_F$  = total duration of fugitive emissions sampling run, min.

## 7. CALCULATIONS

### 7.1 Total VOC Fugitive Emissions.

$$F = \sum_{j=1}^n (C_{Fj} - C_B) Q_{Fj} \theta_F K_1 \quad \text{Eq. 204D-1}$$

### 7.2 VOC Concentration of the Fugitive Emissions at Point j.

$$C_{Fj} = (C_j - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}} \quad \text{Eq. 204D-2}$$

### 7.3 Background VOC Concentration at Point i.

$$C_{Bi} = (C_i - C_{DO}) \frac{C_H}{C_{DH} - C_{DO}} \quad \text{Eq. 204D-3}$$

### 7.4 Average Background Concentration.

$$C_B = \frac{\sum_{i=1}^n C_{Bi} A_i}{A_N} \quad \text{Eq. 204D-4}$$



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**NOTE:** If the concentration at each point is within 20 percent of the average concentration of all points, then use the arithmetic average.

## **APPENDIX C**

### **SAFETY AND HEALTH CONSIDERATIONS**

## **SAFETY AND HEALTH CONSIDERATIONS**

In any workplace where volatile organic compounds (VOC's) are used, care must be taken to maintain a healthful and safe atmosphere. These considerations are paramount when designing and operating a temporary total enclosure (TTE), which, after all, is constructed for the express purpose of containing the VOC's generated within it. Fortunately, the hazards presented by using a TTE are no different from those encountered in any setting where VOC's are used, and industrial hygiene practices for worker protection are well established.

There are two potential hazards associated with gaseous VOC's: worker health effects and fire. These areas of concern are discussed below.

### **WORKER HEALTH PROTECTION**

A much lower ambient VOC concentration must be maintained to protect worker health than to protect against fire. Thus, in any TTE that workers must enter, health protection considerations predominate.

#### **Allowable Exposure Levels**

To protect the health of the worker, the Occupational Safety and Health Administration (OSHA) has established maximum acceptable exposure levels for many substances, including most of the commonly used solvents. The Permissible Exposure Limit (PEL) for a substance is the maximum time-weighted average airborne concentration to which a worker may be exposed in any 8-hour work shift of a 40-hour work week. For solvents, PEL's range typically between 50 and 1,000 parts per million by volume (ppmv).

For some substances, in addition to a PEL, OSHA has set a Short Term Exposure Limit (STEL). The STEL is the maximum 15-minute, time-weighted average concentration to which a worker may be exposed at any time during a work day. (Some STEL's specify other averaging periods.) For those solvents for which an STEL has been established, the STEL is typically about 50 percent higher than the REL.

For some substances, OSHA has set ceiling levels, which are never to be exceeded for any time period. Ceilings are primarily established for acutely toxic materials; these substances generally are not subject to a PEL or STEL. Ceilings have been set for very few common solvents.

The PEL's, STEL's, and ceilings established by OSHA, as well as other pertinent information, are located in the Code of Federal Regulations, Title 29, Part 1910 (29 CFR 1910). Listings for over 600 substances can be found at 29 CFR 1910.1000. Other substances are regulated individually.

For a mixture of VOC's, OSHA and industrial hygiene practice dictate that the effects of the various component compounds be considered as additive.<sup>1,2</sup> This means that the PEL for a mixture of compounds has been reached when the following equation is satisfied:<sup>1,2</sup>

$$\frac{C_1}{PEL_1} + \frac{C_2}{PEL_2} + \dots + \frac{C_n}{PEL_n} = 1 \quad (\text{Equation 1})$$

where:

$C_1, C_2, \dots, C_n$  = the individual concentrations of the compounds that make up the mixture, ppmv

$PEL_1, PEL_2, \dots, PEL_n$  = the individual PEL's of the compounds that makeup the mixture, ppmv

The atmosphere is below the PEL for the mixture when the sum is less than one.

### Sizing the Temporary Exhaust System

The temporary exhaust system installed to draw the fugitive emissions out of a TTE for measurement must be designed to keep the VOC concentration in the enclosure at healthful levels. The system must be sized so that the air that enters the enclosure to replace the air exhausted by the temporary exhaust system is sufficient to dilute the VOC's that are not captured by the permanent capture device(s) to below the PEL. The rate at which this dilution air enters the TTE is equal to the temporary exhaust rate.

Unfortunately, to calculate the necessary temporary exhaust rate accurately, some of the very information that is to be gathered during the capture efficiency (CE) test is needed. As a result, the appropriate temporary exhaust rate must be estimated. To ensure the safety of the workers, the

estimate should be based on conservative assumptions. For the test, a temporary exhaust system with a variable flowrate is advisable, and the VOC concentration in the TTE should be monitored.

There are two basic methods for estimating the temporary exhaust rate that is needed to maintain a healthful atmosphere inside the TTE: the Crumpler Chart method and the calculation method. The accuracy of each method relies on an accurate estimate of one of the parameters that is to be measured subsequently. The selection between the methods often hinges on the information that is available about the process in question and its emissions.

### *The Crumpler Chart Method*

This approach to estimating the necessary temporary exhaust rate is included in Method 204 (see Appendix B). It is especially useful when test data from the process are available.

The Crumpler Chart (see Figure C-1) illustrates the relationship among five parameters: the VOC concentration in the captured gas stream ( $C_G$ ), the VOC concentration in the temporary exhaust stream ( $C_F$ ), the volumetric flowrate of the captured gas stream ( $Q_G$ ), the volumetric flowrate of the temporary exhaust stream ( $Q_F$ ), and the CE. The chart is based on the following equation:

$$CE = \frac{C_G Q_G}{C_G Q_G + C_F Q_F} \quad (\text{Equation 2a})$$

which can be rearranged to the form

$$\frac{Q_F}{Q_G} = \frac{1-CE}{CE} \times \frac{C_G}{C_F} \quad (\text{Equation 2b})$$

where:

- CE = capture efficiency, dimensionless
- $C_F$  = the VOC concentration in the temporary exhaust stream (i.e., the fugitive emissions), ppmv
- $C_G$  = the VOC concentration in the captured gas stream (i.e., the captured emissions), ppmv
- $Q_F$  = the volumetric flowrate of the temporary exhaust stream corrected to standard conditions of 68°F and 29.92 inches of mercury (in. Hg), standard cubic feet per minute (scfm)

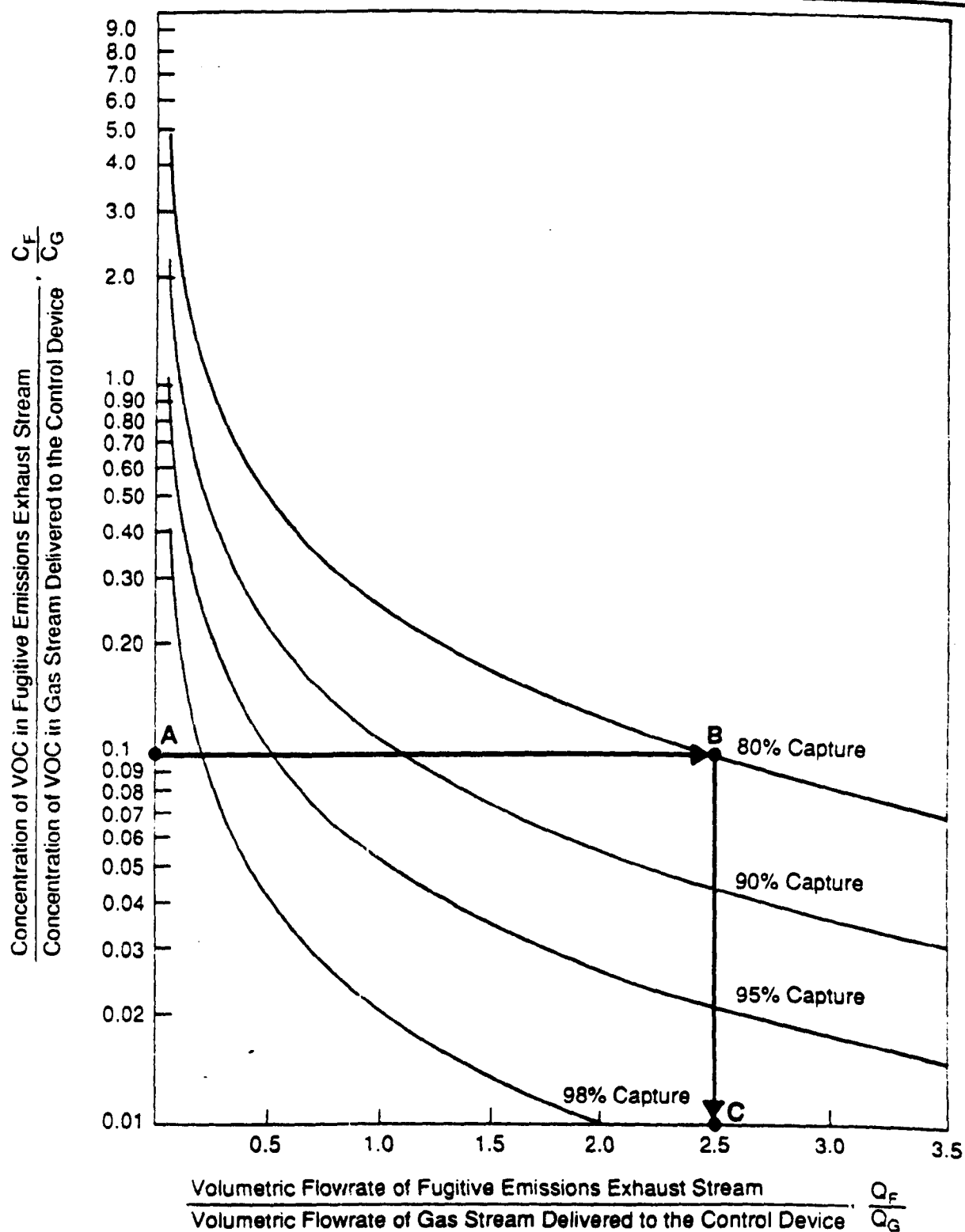


Figure C-1. The crumpler chart.

$Q_G$  = the volumetric flowrate of the captured gas stream, scfm

(Because the units cancel, the concentrations and flowrates actually can be in any units, provided they are consistent.)

The Crumpler Chart method uses test data from the captured gas stream to estimate the necessary temporary exhaust rate. Often, such data are available from a previous test of control device efficiency. Alternatively, a test can be conducted specifically for this purpose. In either case, the VOC concentration and volumetric flowrate of the captured gas stream ( $C_G$  and  $Q_G$ , respectively) are known from the test results. The desired VOC concentration in the temporary exhaust stream ( $C_F$ ) can be selected based on the PEL. Using an estimated value for the CE, the necessary temporary exhaust rate ( $Q_F$ ) can be determined from the Crumpler Chart or from Equation 2b.

#### EXAMPLE 1.

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*An industrial fabric coating operation is to be tested for CE. The coating line applies a rubber coating in which toluene is the only VOC. The test report from a previous control device efficiency test conducted at the maximum normal production rate indicates that the average toluene concentration at the inlet to the control device during the test was 984 ppmv and the average volumetric flowrate was 6,159 scfm. What temporary exhaust rate should be used for the CE test?*

*Solution. The values of  $C_G$  (984 ppmv) and  $Q_G$  (6,159 scfm) are given in the test report. In order to use the Crumpler Chart, values for  $C_F$  and CE also must be determined. Typically,  $C_F$  is assigned the value of the VOC's PEL; the PEL for toluene is 100 ppmv. Based on an inspection of the facility, the CE is estimated to be 80 percent. This value is believed to be conservatively low because the flashoff area between the coating applicator and the entrance to the drying oven is very short and because the drying oven is operated at negative pressure so that very little, if any, of the VOC emitted within the oven escapes.*

*The use of the Crumpler Chart is illustrated in Figure C-1. First, the value of  $C_F/C_G$  is determined and located on the y-axis of the chart. In this case,  $C_F/C_G$  is equal to 100/984, or approximately 0.10. Point A in Figure C-1 represents this step.*

*From Point A, a line is drawn parallel to the x-axis until it intersects the curve that represents the estimated CE value. The intersection point is designated as Point B in Figure C-1.*

*From Point B, a line is drawn downward, parallel to the y-axis, until it intersects the x-axis. Point C represents the intersection point in Figure C-1. The value at Point C is read from the*

*x-axis. In this case, the value, which is equal to  $Q_F/Q_G$ , is approximately 2.5. Thus,  $Q_F$  is equal to  $2.5 \times 6,159$ , or about 15,400 scfm.*

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In the example above, it is assumed that the process operates at close to standard conditions (i.e., 68°F and 29.92 in. Hg) so that the volume determined in scfm can be used without adjusting for temperature or pressure. However, when the expected conditions vary significantly from standard conditions, the temporary exhaust rate should be adjusted to reflect the difference. As a general rule of ventilation system design, no corrections are necessary between the temperatures of 40 and 100°F and at elevations within 1,000 feet of sea level.<sup>3</sup> Outside these ranges, the temporary exhaust rate in scfm should be converted to actual cubic feet per minute (acfm). The adjustment is made by multiplying the volume calculated in scfm by the ratio of absolute temperatures and by the ratio of standard pressure to the actual pressure:

$$\text{acfm} = \text{scfm} \times \frac{460 + \text{actual } ^\circ\text{F}}{460 + 68^\circ\text{F}} \times \frac{29.92 \text{ in. Hg}}{\text{actual in. Hg}} \quad (\text{Equation 3})$$

When using the Crumpler Chart method, it is important to use conservative assumptions in the CE estimate, the target temporary exhaust VOC concentration ( $C_F$ ), or both. When the PEL for the VOC is used as the value of  $C_F$ , the resulting temporary exhaust rate is such that the concentration in the exhaust duct will equal the PEL if the CE has been accurately estimated. The temporary exhaust stream concentration reflects the average concentration within the TTE, but, because of imperfect mixing, there is no guarantee that the concentration in the breathing zone of the workers will be at or below the PEL under these circumstances.

Generally, the TTE can be designed to keep the concentration in the breathing zone below the PEL by strategically locating the natural draft openings and exhaust system intake, but in some cases, process and spatial constraints may interfere with the desired design. In addition, the Crumpler Chart method does not account for any background VOC content in the makeup air that enters the enclosure. Thus, it is advisable to allow for a margin of safety when estimating the CE and selecting the target value for the temporary exhaust stream VOC concentration. For more information on safety factors and background VOC concentration adjustments, see the section on the calculation method for sizing the temporary exhaust system.

A complication in using the Crumpler Chart method can result from the fact that VOC concentration measurements typically are expressed in terms of a reference gas (e.g., "as propane"), rather than in terms of the actual compound(s) in use. To use the Crumpler Chart, the reported reference compound value must be converted to the corresponding value for the actual compound(s)



based on the measurement principle of the method used to measure the VOC concentration. Alternatively, the value selected for  $C_F$  can be converted to the corresponding value for the reference compound. See the section on monitoring considerations for information on converting flame ionization analyzer readings in terms of a reference gas to concentration in terms of the actual compound(s).

Such conversions can be especially troublesome when a VOC mixture is used. In such cases, it may be advisable to size the temporary exhaust system as if the entire mixture consisted of the single most restrictive VOC in the mixture. This assumption greatly simplifies the process of estimating the necessary temporary exhaust rate and provides a margin of safety to the extent that the other components in the VOC mixture require less dilution air. However, this simplification may result in a much higher temporary exhaust rate than necessary if the selected VOC is much more restrictive than the other components and comprises a small fraction of the mixture. For information on determining which VOC in a mixture is the most restrictive, see the section on monitoring considerations where the analogous simplifying assumption for monitoring is discussed.

The preceding discussion of the Crumpler Chart method has been based on the use of test data from the captured gas stream. The method also can be used when test data are not available if there is adequate information with which to estimate the VOC concentration and volumetric flowrate of the captured gas stream. Again, in cases where multiple VOC's are used, basing the estimation on the most restrictive component greatly simplifies the process and provides a margin of safety. To determine the most restrictive VOC in the mixture for this purpose, see Expression A in the section on the calculation method where the analogous simplifying assumption is discussed.

### *The Calculation Method*

To use this method to estimate the necessary temporary exhaust rate, the first step is to estimate the fugitive emission rate that will prevail during the CE test. This fugitive emission rate should be estimated using the best available data, such as past CE tests, other emission tests, material balances, etc. In addition, the background VOC concentration must be estimated if it is significant. The likeliest source of information on which to base background estimates is the facility's OSHA compliance monitoring. An alternative is to take measurements around the periphery of the process area using a portable instrument during the pretest plant visit.

**Single VOC.** Using the estimated fugitive emission rate, the exhaust rate for a process that uses a single VOC can be calculated using Equation 4 below. This equation is based on standard temperature and pressure as defined in EPA Method 2, i.e., 68°F and 29.92 in. Hg. As discussed

previously in the section on the Crumpler Chart method, the temporary exhaust rate must be adjusted using Equation 3 if the actual temperature or pressure differ significantly from standard conditions.

$$Q = \frac{385 \times \rho \times ER \times K}{(PEL - C_B) \times 10^{-6} \times MW} \quad \text{(Equation 4)}$$

where:

- Q = temporary exhaust rate, scfm
- 385 = the volume occupied by 1 pound-mole (lb-mol) of an ideal gas at standard conditions, standard cubic feet (std. ft<sup>3</sup>) VOC/lb-mol
- $\rho$  = the density of the liquid VOC, pounds per gallon (lb/gal)
- ER = the fugitive emission rate in terms of the amount of liquid VOC evaporating, gallons per minute (gal/min)
- K = a safety factor to allow for incomplete mixing, dimensionless
- PEL = the PEL for the gaseous VOC, ppmv
- $C_B$  = the background concentration of the VOC in the dilution air entering the enclosure, ppmv
- $10^{-6}$  = a factor to adjust for the fact that the PEL and  $C_B$  unit "ppmv" is actually "std. ft<sup>3</sup> VOC/ $10^6$  std. ft<sup>3</sup> total gas" (i.e., air plus VOC)
- MW = the molecular weight of the VOC, lb/lb-mol

(When the fugitive emission rate [ER] is more readily estimated as a mass emission rate, the value in terms of lb/min can be used in Equation 4, and the density of the VOC [ $\rho$ ] can be omitted.)

The safety factor, K, ranges between 1 and 10. It is selected based on a judgement of site-specific conditions. The considerations that enter into the selection of the K value include the efficiency of mixing and the distribution of the dilution air entering the TTE, the toxicity of the VOC, and other factors that may affect worker exposure, such as the duration of the process, the location of the workers relative to the VOC sources, and how long the workers remain inside the TTE.<sup>4</sup> The following factors contribute to a lower K value (and lower temporary exhaust rate):

- Good mixing and distribution of dilution air
- VOC "swept" away from workers' breathing zone (to minimize worker exposure, the ideal configuration has the dilution air introduced behind the worker and then passing through the breathing zone, over the VOC emission points, and out through the exhaust)
- VOC with low toxicity (generally associated with higher PEL's)
- Workers inside the TTE for short periods
- Other conditions that result in a low VOC concentration in the workers' breathing zone

Consult Reference 4 for additional guidance on selecting a K value. A well designed TTE (with natural draft openings and fugitive exhaust positioned to provide good mixing and "sweep" the work area) should have a low K value, especially in cases where workers remain inside for only short periods.

#### **EXAMPLE 2.**

---

*An industrial fabric coating operation is to be tested for CE. The coating line applies a rubber coating that consists of 35 percent solids by volume and 65 percent toluene by volume as applied. Using the results of a previous control device efficiency test conducted at the maximum normal production rate, it is determined that approximately 87 lb/hr of toluene are vented to the inlet of the control device. Under these process conditions, the line applies about 20 gal/hr of coating. Ambient testing for OSHA compliance purposes indicates that the background concentration of toluene is about 20 ppmv. What temporary exhaust rate should be used for the CE test?*

*Solution. This coating operation uses a single VOC, toluene. The pertinent parameters for toluene are as follows:*

$\rho$  = 7.21 lb/gal  
 PEL = 100 ppmv  
 MW = 92.13 lb/lb-mol

*The first step is to estimate the fugitive emission rate of toluene. The total amount of toluene applied per hour on the coating line is calculated as indicated below:*

$$20 \text{ gal coating/hr} \times 0.65 \text{ toluene/gal coating} = 13 \text{ gal toluene/hr}$$

*The amount of toluene vented to the control device (i.e., captured) per hour is found as follows:*

$$\frac{87 \text{ lb toluene/hr}}{7.21 \text{ lb toluene/gal toluene}} \approx 12 \text{ gal toluene/hr}$$

*The approximate toluene fugitive emission rate is the difference between the amount applied and the amount captured:*

$$ER = \frac{13 \text{ gal/hr} - 12 \text{ gal/hr}}{60 \text{ min/hr}} \approx 0.017 \text{ gal/min}$$

*After the fugitive emission rate has been estimated, the only missing parameter in Equation 4 is the safety factor, K. For this example, a K value of 4 is selected. This value is based on the relatively high toxicity of toluene (PEL = 100 ppmv) and on the assumption that the TTE has been well designed for good mixing and distribution of the dilution air but that the workers spend much of the time inside the TTE in fairly close proximity to the coating applicator where the fugitive emissions are generated.*

*Now that values have been assigned to all the parameters, the temporary exhaust rate can be calculated using Equation 4:*

$$Q = \frac{385 \times 7.21 \times 0.017 \times 4}{(100 - 20) \times 10^{-6} \times 92.13}$$
$$\approx 25,600 \text{ scfm}$$

*If the process operates at conditions significantly different from standard conditions, the temporary exhaust rate should be adjusted using Equation 3.*

---

As discussed earlier in the section on the Crumpler Chart method, the mass flow rates presented in test reports are typically in terms of a reference compound (e.g., "as propane") rather than in terms of the actual compound(s) in use. For a discussion of conversions from a reference compound value to the corresponding value for the actual compound(s) when a flame ionization analyzer is used (EPA Method 25A), see the section on monitoring considerations. The same considerations may apply to background VOC concentration measurements.

**Mixture of VOC's.** To calculate the total temporary exhaust rate required for a mixture of VOC's, the fugitive emission rate and background concentration for each component are estimated, and the temporary exhaust rate necessary for each is calculated using Equation 4 above. The sum of the exhaust rates for the individual components is the total temporary exhaust rate that is needed.

**EXAMPLE 3.**

A multiple-station packaging rotogravure press is to be tested for CE. Under the production conditions planned for the test, the inks applied by the press in 1 hr contain approximately 1 gal of toluene, 5 gal of isopropyl acetate, and 17 gal of ethanol. (A simplified, three-solvent system is used here for purposes of illustration.) A previous test using liquid/gas material balancing techniques indicated that the CE for the press is about 80 percent. Background concentrations are estimated at 5 ppmv toluene, 15 ppmv isopropyl acetate, and 45 ppmv ethanol. What temporary exhaust rate should be used for the CE test?

*Solution.* The pertinent parameters for the three VOC's are as follows:

	$\rho$ , lb/gal	PEL, ppmv	MW, lb/lb-mol	K
Toluene	7.21	100	92.13	1
Isopropyl acetate	7.27	250	102.13	1
Ethanol	6.57	1,000	46.07	1

The  $K$  values were assigned based on a TTE that has been well designed to provide good mixing and distribution of the dilution air in a configuration that sweeps the fugitive emissions from the workers' breathing zone. It is further assumed that the workers will only occasionally enter the TTE for a few minutes at a time to make minor adjustments. Under such optimum conditions,  $K$  values of 1 can be justified despite the relatively low PEL's of toluene (100 ppmv) and isopropyl acetate (250 ppmv). However, even under these favorable circumstances, the interior of the TTE should be monitored during testing to ensure that the STEL's for toluene (150 ppmv) and isopropyl acetate (310 ppmv) are not violated.

Based on the previous CE test, approximately 20 percent of the input VOC's are released as fugitive emissions. This percentage amounts to about 0.2 gal/hr of toluene, 1 gal/hr of isopropyl acetate, and 3.4 gal/hr of ethanol. The volume of dilution air needed for each VOC is calculated below using Equation 4 (with a factor of 60 min/hr added to the denominator to convert the fugitive emission rates listed above into terms of gal/min):

$$\begin{aligned} \text{Toluene } Q &= \frac{385 \times 7.21 \times 0.2 \times 1}{(100-5) \times 10^{-6} \times 92.13 \times 60} \\ &\approx 1,100 \text{ scfm} \end{aligned}$$

$$\text{Isopropyl acetate } Q = \frac{385 \times 7.27 \times 1 \times 1}{(250-15) \times 10^{-6} \times 102.13 \times 60}$$

$$\approx 1,900 \text{ scfm}$$

$$\text{Ethanol } Q = \frac{385 \times 5.57 \times 3.4 \times 1}{(1,000-45) \times 10^{-6} \times 46.07 \times 60}$$

$$\approx 3,300 \text{ scfm}$$

*The total temporary exhaust rate necessary for proper dilution is the sum of the rates calculated for each constituent VOC. For this example, the total is approximately 6,300 scfm. If the temperature or pressure differ significantly from standard conditions, the temporary exhaust rate could be adjusted using Equation 3.*

---

A simpler approach may be taken for a VOC mixture. The temporary exhaust rate may be calculated assuming that the entire mixture is composed of the single component that requires the greatest quantity of dilution air per unit liquid volume. This component is the one that has the largest value for the following expression:

$$\frac{\rho \times K}{(\text{PEL}-C_B) \times \text{MW}} \quad (\text{Expression A})$$

where the symbols have the meanings defined for Equation 4. (When the fugitive emission rate [ER] has been estimated in terms of lb/min, the density of the VOC [ $\rho$ ] can be omitted from Expression A to determine which component requires the greatest quantity of dilution air per unit mass.) However, as demonstrated in the following example, this approach can result in a much higher exhaust rate than actually is necessary.

#### **EXAMPLE 4.**

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*For the multiple-station packaging rotogravure press presented in Example 3, it is not known what product will be being printed during the CE test. The same three VOC's (toluene, isopropyl acetate, and ethanol) are used in the inks for all products, but the relative quantities vary with the product being printed. The maximum VOC application rate is known to be about 23 gal/hr. What temporary exhaust rate should be used for the CE test to ensure a healthful atmosphere inside the TTE?*

**Solution.** To determine which VOC to base the temporary exhaust rate on, calculate the value of Expression A (presented above) for each of the known constituents:

$$\begin{array}{lcl}
 \text{Toluene} & \frac{7.21 \times 1}{(100 - 5) \times 92.13} & \approx 0.0008 \\
 \text{Isopropyl acetate} & \frac{7.27 \times 1}{(250 - 15) \times 102.13} & \approx 0.0003 \\
 \text{Ethanol} & \frac{6.57 \times 1}{(1,000 - 45) \times 46.07} & \approx 0.0001
 \end{array}$$

Because the value for toluene is the largest, the temporary exhaust rate is calculated assuming that the entire VOC mixture is composed of toluene. Assuming that approximately 20 percent of the total 23 gal/hr of VOC's escapes as fugitive emissions (based on an earlier liquid/gas material balance CE test as presented in Example 3), the fugitive emission rate is about 4.6 gal/hr. Using Equation 4 (with a factor of 60 in the denominator to convert the emission rate to gal/min), the temporary exhaust rate is calculated as follows:

$$\begin{aligned}
 Q &= \frac{385 \times 7.21 \times 4.6 \times 1}{(100-5) \times 10^{-6} \times 92.13 \times 60} \\
 &\approx 24,300 \text{ scfm of air}
 \end{aligned}$$

If the actual temperature or pressure differ significantly from standard conditions, the temporary exhaust rate should be adjusted using Equation 3.

### Monitoring Considerations for Health Protection

Because the temporary exhaust rate is determined based on an estimation of the fugitive emission rate, it is advisable to ensure that healthful concentration levels are maintained within the enclosure during testing. The instrument measuring the VOC concentration in the temporary exhaust stream is, in effect, a continuous monitor of the average concentration in the TTE. However, periodic monitoring of concentrations in the breathing zone of the workers is advisable to identify any "hot spots" within the TTE.

The TTE and exhaust system should be designed and operated to maintain VOC concentrations at or below the PEL in both the temporary exhaust stream and the breathing zone of the workers. However, remember that the PEL is an 8-hour, time-weighted average, so short-term excursions above the PEL in the breathing zone can be tolerated as long as they are balanced by periods below the PEL. Infrequent readings above the PEL need not result in an immediate cessation of testing and removal of the TTE. Of course, for compounds for which an STEL or ceiling has been set, the VOC concentration must not violate these limits.

Monitoring VOC concentrations is complicated by the fact that the monitors typically are not calibrated with the actual compounds that are in use. For example, according to Method 204D (see Appendix B), the VOC concentration in the temporary exhaust stream is to be measured using a flame ionization analyzer (FIA) calibrated with propane. In most cases, the TTE interior is monitored using a sampling line connected to this FIA or to the FIA used to take background readings (also calibrated with propane). Thus, to track worker exposure, one must be able to translate FIA readings "as propane" into the concentrations of the actual compounds being used. Fortunately, the FIA translation can be made with reasonable accuracy provided the identities and relative amounts of the compounds are known.

The FIA works essentially by breaking down organic compounds and counting the carbon atoms. However, the counting is affected by the types of bonds and the noncarbon atoms in the molecule. Therefore, to predict the response an FIA will have to a given compound, the "effective carbon number" (ECN) is used.

For the type of FIA used for source testing, Table C-1 presents one set of parameters that can be used to calculate the ECN for a compound within about  $\pm 20$  percent. To use this table, first assign each carbon atom in the compound a value based on the type of bonds it is involved in, then modify this value by the indicated amount for each noncarbon atom bonded to it. The ECN for the compound is the sum of the modified values for all the carbons. To illustrate the use of Table C-1, the ECN's for a few VOC's are derived in Figure C-2.

Experimental results for many compounds and more refined approaches to predicting FIA responses can be found in the scientific literature, such as References 6, 7, and 8. Other possible sources of data on FIA response include data from the instrument manufacturer and experimental data generated in advance of the test by exposing the instrument to known concentrations of the compounds of interest. Note that portable, hand-held FIA's (e.g., OVA's) do not conform to the information presented in Table C-1; another source of response data is needed if such an instrument is used to monitor VOC levels inside a TTE.



TABLE C-1. CONTRIBUTIONS TO EFFECTIVE CARBON NUMBER<sup>a</sup>

Atom	Type	Effective carbon number contribution
C	Aliphatic	1.0
C	Aromatic	1.0
C	Olefinic	0.95
C	Acetylenic	1.30
C	Carbonyl	0.0
C	Nitrile	0.3
O	Ether	-1.0
O	Primary alcohol	-0.6
O	Secondary alcohol	-0.75
O	Tertiary alcohol, esters	-0.25
Cl	Two or more on single aliphatic C	-0.12 each
Cl	On olefinic C	+0.05
N	In amines	Similar to O in corresponding alcohols

<sup>a</sup>Reference 5.

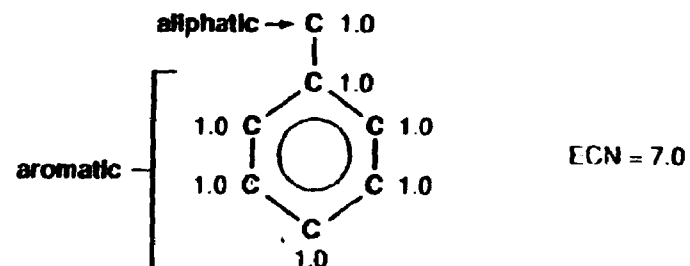
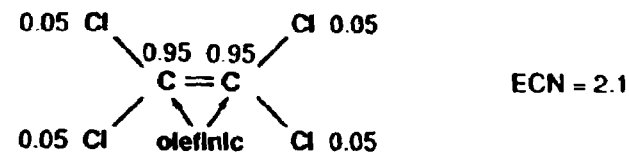
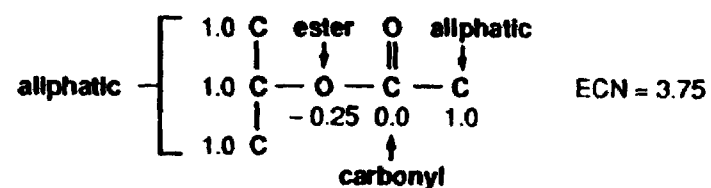
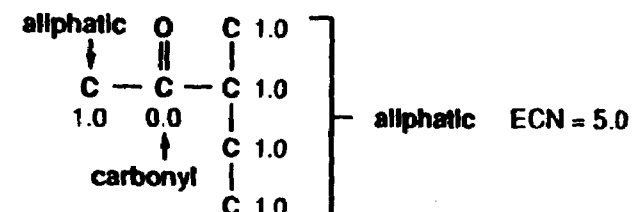
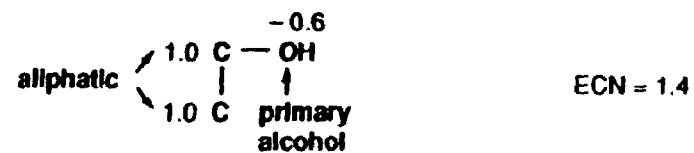
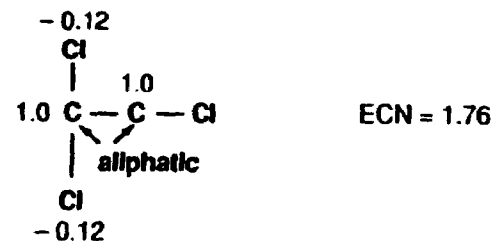
**Toluene:****Perchloroethylene:****Isopropyl acetate:****Methyl isobutyl ketone:****Ethanol:****1, 1, 2 Trichloroethane:**

Figure C-2. Examples of ECN derivations.

**Single VOC.** For a single VOC, monitoring considerations are relatively straightforward. The first step is to determine the relative response of the FIA to the VOC in terms of the FIA calibration gas (assumed to be propane) using the following equation:

$$RR_{VOC} = ECN_{VOC} \div 3.0 \quad (\text{Equation 5})$$

where:

$RR_{VOC}$  = the relative response of the FIA to the VOC, ppmv propane per ppmv of the VOC (ppmv propane/ppmv VOC)

$ECN_{VOC}$  = the effective carbon number of the compound, effective carbon atoms/molecule VOC

3.0 = the effective carbon number of propane, effective carbon atoms/molecule propane

**Note:** If a calibration gas other than propane is used, the ECN of the actual calibration gas is used in Equation 5.

Next, the maximum acceptable monitor reading is calculated by the equation below:

$$MR_{max} = RR_{VOC} \times C_{max} \quad (\text{Equation 6})$$

where:

$MR_{max}$  = the maximum monitor reading that is considered acceptable, ppmv propane

$RR_{VOC}$  = the relative response of the FIA to the VOC, ppmv propane/ppmv VOC

$C_{max}$  = the maximum acceptable concentration of the VOC, ppmv VOC

As discussed previously, the maximum acceptable VOC concentration in the temporary exhaust stream is typically considered the PEL, while the maximum for points within the TTE may be somewhat higher, provided that the exposure of the workers over time does not exceed the PEL and that no STEL or ceiling level is violated.

EXAMPLE 5.

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*For the fabric coating operation presented in Example 2, what is the maximum acceptable monitor reading during CE testing?*

*Solution. The coating operation uses a single VOC, toluene. As illustrated in Figure C-2, the ECN for toluene is 7.0. The relative response for toluene, assuming that the calibration gas for the test instruments is propane, is found as follows:*

$$\begin{aligned} RR &= 7.0 \div 3.0 \\ &\approx 2.3 \text{ ppmv propane/ppmv toluene} \end{aligned}$$

*The maximum acceptable toluene concentration in the TTE's temporary exhaust stream is equal to the PEL, which is 100 ppmv. Using Equation 6, the maximum acceptable monitor reading is calculated below:*

$$\begin{aligned} MR_{\max} &= 2.3 \text{ ppmv propane/ppmv toluene} \times 100 \text{ ppmv toluene} \\ &= 230 \text{ ppmv propane} \end{aligned}$$

*Thus, an FIA reading of 230 ppmv as propane in the temporary exhaust stream corresponds to a toluene concentration of 100 ppmv and indicates that the average concentration in the TTE is at the PEL.*

*An STEL of 150 ppmv also has been established for toluene by OSHA. The STEL is the maximum 15-min, time-weighted average concentration to which workers can be exposed. Thus, points in the breathing zone of the workers inside the TTE should not exceed this level. The monitor reading corresponding to the STEL can be calculated using Equation 6:*

$$\begin{aligned} MR_{\max} &= 2.3 \text{ ppmv propane/ppmv toluene} \times 150 \text{ ppmv toluene} \\ &= 345 \text{ ppmv propane} \end{aligned}$$

---

**Mixture of VOC's.** Where VOC mixtures are used, the process is analogous but more complicated. As with single-VOC systems, the first step is to calculate the relative response of the FIA to the VOC mixture in terms of the FIA calibration gas (again assumed to be propane). However, to calculate this composite relative response, three substeps are required:

1. First, calculate the relative response for each of the VOC compounds that make up the mixture using Equation 5 above.

2. Next, calculate the mole fraction of each of the compounds in the gas phase. In the absence of better data, assume that the mole fractions in the gas phase are equal to the mole fractions in the liquid phase. This calculation is illustrated in Equation 7 below:

$$MF_i = \frac{(V_{liq\ i} \times \rho_i) / MW_i}{\sum_{j=1}^m [(V_{liq\ j} \times \rho_j) / MW_j]} \quad (\text{Equation 7})$$

where:

$MF_i$  = the mole fraction of VOC  $i$  of the mixture, lb-mole  $VOC_i$  per lb-mol of the VOC mixture (lb-mol  $VOC_i$ /lb-mol  $VOC_{tot}$ ) (The calculation yields the mole fraction in the liquid phase, which is assumed to be equal to the mole fraction in the gas phase.)

$V_{liq\ i}$  = the volume fraction of VOC  $i$  in the liquid phase, gal  $VOC_i$ /gal  $VOC_{tot}$

$\rho_i$  = the density of VOC  $i$  in the liquid phase, lb/gal  $VOC_i$

$MW_i$  = the molecular weight of VOC  $i$ , lb/lb-mol

$V_{liq\ j}$  = the volume fraction of VOC  $j$  in the liquid phase, gal  $VOC_j$ /gal  $VOC_{tot}$

$\rho_j$  = the density of VOC  $j$  in the liquid phase, lb/gal  $VOC_j$

$MW_j$  = the molecular weight of VOC  $j$ , lb/lb-mol

$m$  = the number of different VOC's comprising the mixture

**Note:** The liquid volume fractions ( $V_{liq\ i}$  and  $V_{liq\ j}$ ) can be expressed relative to the total volatile portion of the coating, ink, etc. (as expressed above) or to the total volume of the entire coating, ink, etc. (e.g., gal  $VOC_i$ /gal coating), provided that all are expressed in consistent terms.

3. Finally, calculate the relative response of the FIA to the VOC mixture using the following equation:

$$RR_{tot} = \sum_{i=1}^n MF_i \times RR_i \quad (\text{Equation 8})$$

where:

$RR_{tot}$  = the relative response of the FIA to the VOC mixture, ppmv propane/ppmv  $VOC_{tot}$

$MF_i$  = the mole fraction of VOC  $i$  of the mixture, expressed as ppmv  $VOC_i$ /ppmv  $VOC_{tot}$

$RR_i$  = the relative response of the FIA to VOC  $i$  of the mixture, ppmv propane/ppmv  $VOC_i$

$n$  = the number of different VOC's comprising the mixture

**Note:** The mole fraction is expressed above in terms of ppmv  $\text{VOC}_i/\text{ppmv VOC}_{\text{tot}}$ . These units are equivalent to lb-mol  $\text{VOC}_i/\text{lb-mol VOC}_{\text{tot}}$  because, according to the ideal gas laws, the mole fraction is equal to the gaseous volume fraction and because concentration in ppmv is based on the volume occupied by the gas.

After the relative response for the VOC mixture has been calculated, the maximum acceptable monitor reading is calculated by the equation below:

$$\text{MR}_{\text{max}} = \text{RR}_{\text{tot}} \times \frac{C_{\text{max}1} \times C_{\text{max}2} \times \dots \times C_{\text{max}n}}{\sum_{i=1}^n [\text{MF}_i \times (C_{\text{max}1} \times C_{\text{max}2} \times \dots \times C_{\text{max}n})/C_{\text{max}i}]} \quad (\text{Equation 9})$$

where:

$\text{MR}_{\text{max}}$  = the maximum monitor reading that is considered acceptable, ppmv propane

$\text{RR}_{\text{tot}}$  = the relative response of the FIA to the VOC mixture, ppmv propane/ppmv  $\text{VOC}_{\text{tot}}$

$C_{\text{max}1}, \dots, C_{\text{max}i}, \dots, C_{\text{max}n}$  = the maximum acceptable concentration of the indicated VOC component of the mixture, ppmv VOC

$\text{MF}_i$  = the mole fraction of VOC  $i$  of the mixture, expressed as ppmv  $\text{VOC}_i/\text{ppmv VOC}_{\text{tot}}$

$n$  = the number of different VOC's in the mixture for which a maximum acceptable concentration is defined

For the temporary exhaust stream, the PEL of the mixture is typically considered the maximum acceptable concentration. The corresponding monitor reading (in ppmv propane) is calculated by substituting the PEL's of the component VOC's into Equation 9. If PEL's have not been established for all the components, only those components with a PEL are included in the Equation 9 calculation. However, the calculation of mole fractions (Equation 7) and relative response (Equation 8) should include all component VOC's, whether assigned a PEL or not.

Although the PEL of the mixture can be exceeded briefly inside the TTE (provided that the 8-hour, time-weighted average exposure of the workers does not exceed the PEL), any STEL's or ceilings cannot be exceeded. Equation 9 can be used to calculate the monitor reading that

corresponds to the STEL for the mixture by substituting in the STEL's for those components for which one has been established. Likewise, any ceilings that have been designated can be used to calculate the monitor reading that corresponds to the mixture ceiling. As discussed above for PEL's, the mole fractions and relative response used in Equation 9 must be calculated including all component VOC's, although only the components for which an STEL or ceiling (depending on which is to be calculated) has been established are included when the maximum monitor reading is calculated.

Note that it is implicit in Equation 9 that the effects of the component VOC's are additive. Thus, when the PEL's of the component VOC's are substituted into Equation 9, the resulting  $MR_{max}$  is the estimated monitor reading when the concentration is at the PEL of the mixture, i.e., when the concentrations of the components are such that Equation 1 is true. Similarly, when Equation 9 is used for STEL's or ceilings, the resulting  $MR_{max}$  represents a situation analogous to Equation 1. This approach is recommended unless there is definitive information that the effects of the components are not additive.

#### EXAMPLE 6.

*For the multiple-station packaging rotogravure press presented in Example 3, what is the maximum acceptable monitor reading during CE testing?*

*Solution. This simplified printing process uses a mixture of toluene, isopropyl acetate, and ethanol. To calculate the relative response for the mixture, the relative response and mole fraction for each of the component VOC's must first be determined. Using the ECN's for these compounds derived in Figure C-2, the relative responses are calculated using Equation 5 for an FIA calibrated with propane:*

$$\begin{aligned}
 \text{Toluene RR} &= 7.0 \div 3.0 \\
 &\approx 2.3 \text{ ppmv propane/ppmv toluene} \\
 \text{Isopropyl acetate RR} &= 3.75 \div 3.0 \\
 &\approx 1.3 \text{ ppmv propane/ppmv isopropyl acetate} \\
 \text{Ethanol RR} &= 1.4 \div 3.0 \\
 &\approx 0.47 \text{ ppmv propane/ppmv ethanol}
 \end{aligned}$$

*The mole fraction of each VOC is calculated using Equation 7. The volume fraction ( $V_{liq}$ ) for each VOC, which is needed to use Equation 7, is calculated by dividing the volume of the individual VOC applied per hr (given in Example 3) by the total volume of VOC applied per hr (23 gal/hr).*

$$\begin{aligned} \text{Toulene MF} &= \frac{(1/23) \times 7.21/92.13}{[(1/23) \times 7.21/92.13] + [(5/23) \times 7.27/102.13] + [(17/23) \times 6.57/46.07]} \\ &\approx 0.03 \text{ lb-mol toluene/lb-mol VOC}_{\text{tot}} \end{aligned}$$

$$\begin{aligned} \text{Isopropyl acetate MF} &= \frac{(5/23) \times 7.27/102.13}{[(1/23) \times 7.21/92.13] + [(5/23) \times 7.27/102.13] + [(17/23) \times 6.57/46.07]} \\ &\approx 0.12 \text{ lb-mol isopropyl acetate/lb-mol VOC}_{\text{tot}} \end{aligned}$$

$$\begin{aligned} \text{Ethanol MF} &= \frac{(17/23) \times 6.57/46.07}{[(1/23) \times 7.21/92.13] + [(5/23) \times 7.27/102.13] + [(17/23) \times 6.57/46.07]} \\ &\approx 0.85 \text{ lb-mol ethanol/lb-mol VOC}_{\text{tot}} \end{aligned}$$

*When the relative responses and mole fractions have been calculated for each VOC in the mixture, the relative response for the mixture can be calculated using Equation 8:*

$$\begin{aligned} \text{RR}_{\text{tot}} &= (0.03 \times 2.3) + (0.12 \times 1.3) + (0.85 \times 0.47) \\ &\approx 0.62 \text{ ppmv propane/ppmv VOC}_{\text{tot}} \end{aligned}$$

*The maximum acceptable VOC concentration in the TTE's temporary exhaust stream is the PEL of the mixture. Using the results of the previous calculations and the PEL's of the component VOC's, the maximum acceptable monitor reading for this exhaust stream can be calculated using Equation 9:*

$$\begin{aligned} \text{MR}_{\text{max}} &= 0.62 \times \frac{100 \times 250 \times 1,000}{(0.03 \times 250 \times 1,000) + (0.12 \times 100 \times 1,000) + (0.85 \times 100 \times 250)} \\ &\approx 380 \text{ ppmv propane} \end{aligned}$$



*In addition to PEL's, OSHA has established STEL's for toluene (150 ppmv) and isopropyl acetate (310 ppmv). No STEL has been established for ethanol. To determine the monitor reading when the STEL for the mixture has been reached, which is the maximum acceptable reading in the breathing zone of the workers, the individual STEL's are substituted into Equation 9. Only toluene and isopropyl acetate are included in this calculation:*

$$\begin{aligned} MR_{\max} &= 0.62 \times \frac{150 \times 310}{(0.03 \times 310) + (0.12 \times 150)} \\ &\approx 1,056 \text{ ppmv propane} \end{aligned}$$

*Note that the monitor reading at the STEL is nearly three times the PEL value. This fact means that a worker exposed at the STEL level for some period must spend about twice as long at zero VOC concentration (or correspondingly longer at some VOC concentration between zero and the PEL) for the time-weighted average exposure to equal the PEL. Thus, the PEL level should generally be considered the maximum acceptable monitor reading for the ambient air inside the TTE, with the understanding that some readings in close proximity to the VOC sources may be higher.*

A simpler approach may be taken for a VOC mixture. The maximum acceptable monitor reading may be calculated assuming that the entire mixture is composed of the single component with the most restrictive combination of relative response and acceptable maximum concentration. This component is the one with the smallest value of  $MR_{\max}$  as determined using Equation 6. The highest acceptable monitor reading is equal to this smallest  $MR_{\max}$  value. As shown in the following example, this approach can be more restrictive than necessary. However, this approach is sure to avoid exceeding healthful levels and can be used when the relative amounts of component VOC's are not known.

#### **EXAMPLE 7.**

*As in Example 4, all the inks used on a multiple-station packaging rotogravure press contain toluene, isopropyl acetate, and ethanol, but the relative quantities to be used during CE testing are not known. What is the maximum acceptable monitor reading to ensure that the VOC concentration does not exceed healthful levels?*

*Solution. To determine the maximum acceptable monitor reading, the relative response for each VOC in the mixture is determined using Equation 5, and the value of  $MR_{\max}$  for each is calculated using Equation 6. The maximum acceptable monitor reading is the lowest of these  $MR_{\max}$  values.*

*For the TTE's temporary exhaust stream, the  $MR_{max}$  values should be based on the PEL's of the VOC's. Using the relative response values determined in Example 6 and the PEL's, the  $MR_{max}$  values for each VOC are calculated as follows:*

$$\begin{aligned}\text{Toluene } MR_{max} &= 2.3 \times 100 \\ &= 230 \text{ ppmv propane}\end{aligned}$$

$$\begin{aligned}\text{Isopropyl acetate } MR_{max} &= 1.3 \times 250 \\ &= 325 \text{ ppmv propane}\end{aligned}$$

$$\begin{aligned}\text{Ethanol } MR_{max} &= 0.47 \times 1,000 \\ &= 470 \text{ ppmv propane}\end{aligned}$$

*Based on these calculations, the maximum acceptable monitor reading in the temporary exhaust stream is 230 ppmv propane, which results from treating the entire VOC mixture as if it were toluene. This value is well under the maximum acceptable monitor reading determined in Example 7 using the actual proportion of each VOC in the mixture.*

*Generally, the level calculated above also should be considered the maximum acceptable monitor reading in the ambient air of the TTE's work areas. However, the workers may be exposed briefly to levels up to the STEL. To determine the monitor reading that corresponds to the most restrictive combination of relative response and STEL, the same procedure is followed using the STEL's in place of the PEL's. For this example, the  $MR_{max}$  for toluene (345 ppmv propane) is lower than the value for isopropyl acetate (403 ppmv propane) and should be considered the maximum acceptable monitor reading for any point in the breathing zone of the workers. (No STEL has been established for ethanol.)*

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## **FIRE SAFETY**

The approach to fire safety is very similar to that for worker health protection. The greatest difference is in the higher VOC concentrations that are allowable when workers are not exposed.

### **Allowable VOC Levels**

For fire safety, the critical parameter is the lower explosive limit (LEL) of a compound or mixture. The LEL is the lowest concentration of a gas or vapor in air that will sustain combustion. Above this concentration (up to the upper explosive limit), a transient spark or flame will ignite the gas or vapor, which will continue to burn until a lack of fuel or oxygen extinguishes it. Below the LEL, the gas or vapor will not ignite. The LEL is typically expressed in percent by volume.

Lower explosive limits for many compounds can be found in most handbooks on hazardous materials. For solvents, LEL's typically range from about 1 to 3 percent. Considering that 1 percent by volume corresponds to 10,000 ppmv, it is clear that health considerations come into play long before fire safety is of concern.

### **Sizing the Temporary Exhaust System**

The principles of dilution for fire prevention are identical to those for health protection. The temporary exhaust system must be designed so that the rate at which dilution air enters the enclosure (which is equal to the temporary exhaust rate) is sufficient to keep the VOC concentration below the LEL in all parts of the TTE. The Crumpler Chart method or the calculation method can be used to estimate the temporary exhaust rate necessary for this purpose.

#### *The Crumpler Chart Method*

The use of this estimation method for fire safety closely parallels the procedure for worker health protection. Typically, the VOC concentration ( $C_G$ ) and volumetric flowrate ( $Q_G$ ) of the captured gas stream are known from test results, and the CE is estimated conservatively. When the target VOC concentration in the temporary exhaust stream ( $C_F$ ) has been selected, the Crumpler Chart or Equation 2b can be used to estimate the necessary temporary exhaust rate ( $Q_F$ ). For additional information on using the Crumpler Chart, see the section below on worker health protection.

When workers will not enter the enclosure, the target VOC concentration for the temporary exhaust stream is based on the LEL. To allow for incomplete mixing, common fire safety practice is to use 25 percent of the LEL for properly ventilated processes that release VOC's at a uniform rate. See the section on the calculation method for more information on safety factors.

#### **EXAMPLE 8.**

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*For the industrial fabric coating operation introduced in Example 1, what temporary exhaust rate should be used for the CE test if no workers will enter the TTE?*

**Solution.** As in Example 1, the values of  $C_G$  (984 ppmv) and  $Q_G$  (6,159 scfm) are known, and the CE is conservatively estimated at 80 percent. The VOC used in the process is toluene, which has an LEL of 1.3 percent, or 13,000 ppmv. Assuming a well ventilated TTE, 25 percent of the LEL (3,250 ppmv) is the appropriate value for  $C_F$  for this continuous process.

*In this case, it is preferable to use Equation 2b rather than the Crumpler Chart. The value of  $C_F/C_G$  equals 3,250/984, or about 3.3. On the Crumpler Chart, this value is near the extreme of the plotted 80-percent CE curve, and reading the chart in this range is difficult. To use Equation 2b, the four known parameter values ( $C_G$ ,  $Q_G$ ,  $C_F$ , and CE) are substituted in, and the equation is solved for  $Q_F$ :*

$$Q_F = 6,159 \times \frac{1 - 0.80}{0.80} \times \frac{984}{3,250}$$
$$\approx 470 \text{ scfm}$$

*If the process operates at conditions significantly different from standard conditions, the temporary exhaust rate should be adjusted using Equation 3.*

*Note that the exhaust rate calculated above for fire safety is only about 3 percent of that determined in Example 1 for worker health protection.*

---

Use of the Crumpler Chart method to estimate the temporary exhaust rate necessary for fire safety is subject to the same complications discussed previously in the section on worker health protection. Consult that section for additional information.

When a VOC mixture is used, common fire safety practice is to base the ventilation rate on the single most restrictive component of the mixture. If the Crumpler Chart method is to be used in conjunction with test data in terms of a reference gas (e.g., "as propane"), the most restrictive component can be determined as discussed in the section on monitoring considerations for worker health protection. For use with the Crumpler Chart, the reported VOC concentration in the captured gas stream ( $C_G$ ) in terms of the reference gas must then be converted, based on the measurement principle of the test method, to the corresponding value for the most restrictive VOC in the mixture. If test data are not available and the VOC concentration in the captured gas stream is to be estimated directly in terms of the most restrictive of the actual VOC's, Expression B can be used to determine which VOC is the most restrictive (see the section below on the calculation method for fire safety).

#### *The Calculation Method*

The first step in using the calculation method to determine the temporary exhaust rate necessary for fire safety is to estimate the fugitive emission rate that will prevail during the CE test. When this parameter has been estimated, the necessary fugitive exhaust rate can be calculated as discussed below.

**Single VOC.** The temporary exhaust rate for a single VOC system can be calculated using Equation 10, which is very similar to Equation 4. As previously discussed, standard conditions are those defined for EPA testing, i.e., 68°F and 29.92 in. Hg. If the actual temperature or pressure differ significantly from these standard conditions, the temporary exhaust rate should be adjusted using Equation 3.

$$Q = \frac{385 \times \rho \times ER \times S_f}{LEL \times 10^{-2} \times MW \times B} \quad (\text{Equation 10})$$

where:

- Q = the temporary exhaust rate, scfm
- 385 = the volume occupied by 1 lb-mol of an ideal gas at standard conditions, std. ft<sup>3</sup> VOC/lb-mol
- $\rho$  = the density of the liquid VOC, lb/gal
- ER = the fugitive emission rate in terms of the amount of liquid VOC evaporating, gal/min
- $S_f$  = a safety factor to allow for incomplete mixing, dimensionless
- LEL = the LEL for the gaseous VOC, percent
- $10^{-2}$  = a factor to adjust for the fact that the LEL is in terms of percent by volume, which is actually "std. ft<sup>3</sup> VOC/10<sup>2</sup> std. ft<sup>3</sup> total gas" (i.e., air plus VOC)
- MW = the molecular weight of the VOC, lb/lb-mol
- B = a factor to take into account the fact that the LEL decreases at elevated temperature, dimensionless

(When the fugitive emission rate [ER] is more readily estimated as a mass emission rate, the value in lb/min can be used in Equation 10, and the density of the VOC [ $\rho$ ] can be omitted.)

The safety factor,  $S_f$ , is determined by the percent of the LEL that is considered safe. In most cases, it is desirable to keep the concentration at or below 25 percent of the LEL at all points. (In the absence of sophisticated controls, 25 percent of the LEL is typically the maximum allowed by fire insurance carriers.) Thus, for a continuous process and a properly ventilated TTE, the value of  $S_f$  is 4, corresponding to 25 percent of the LEL. For a batch process in a properly ventilated TTE, the existence of a peak emission rate requires a  $S_f$  value of 10 or 12. For poorly ventilated TTE's, a higher  $S_f$  value may be required.<sup>9</sup>

The factor B is included because the LEL decreases at high temperatures. Up to 250°F, a value of 1 should be used; above 250°F the value should be 0.7.<sup>9</sup>

Note that for these calculations, the background concentration of the VOC is not accounted for as it was in Equation 4 for health ventilation. Because background levels are typically well under 100 ppmv, this factor is negligible at LEL concentrations. However, in any case where background level is significant, it should be considered.

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**EXAMPLE 9.**

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*For the fabric coating operation first introduced in Example 2, what temporary exhaust rate should be used for the CE test if no workers will enter the TTE?*

*Solution. The fugitive emission rate for this single-VOC process was estimated in Example 2 at 0.017 gal/min of toluene. The LEL for toluene is 1.3 percent, the density is 7.21 lb/gal, and the molecular weight is 92.13 lb/lb-mol. For this continuous process, assuming a properly ventilated TTE, the appropriate value for  $S_f$  is 4. The TTE operates at the facility's ambient temperature, so the appropriate value for  $B$  is 1. Using these parameter values, the temporary exhaust rate necessary for fire prevention is calculated using Equation 10:*

$$Q = \frac{385 \times 7.21 \times 0.017 \times 4}{1.3 \times 10^{-2} \times 92.13 \times 1}$$

$$Q \approx 160 \text{ scfm}$$

*If the actual temperature or pressure are significantly different from standard conditions, the temporary exhaust rate should be adjusted to reflect the difference using Equation 3.*

*Note that the exhaust rate required for fire safety is less than one percent of that calculated in Example 2 for worker health protection.*

---

**Mixture of VOC's.** In fire safety calculations, it is common practice to assume that the entire mixture is composed of the single component that requires the greatest quantity of dilution air per unit liquid volume. This component is the one with the largest value for the following expression:

$$\frac{\rho}{\text{LEL} \times \text{MW}} \quad (\text{Expression B})$$

where the symbols have the meanings defined for Equation 10. (When the fugitive emission rate [ER] has been estimated in terms of lb/min, the density of the of the VOC [ $\rho$ ] can be omitted from Expression B to determine which component requires the greatest quantity of dilution air per unit mass.) This approach may result in a greater temporary exhaust rate than is absolutely necessary, but

at the dilution volumes necessary for fire prevention, this consideration is not typically a major concern.

#### EXAMPLE 10.

*For the multiple-station packaging rotogravure press first introduced in Example 3, what temporary exhaust rate should be used for the CE test if no workers will enter the TTE?*

*Solution. To determine which VOC to base the temporary exhaust rate on, calculate the value of Expression B (presented above) for each of the known constituents. The LEL for toluene is 1.3 percent, the LEL of isopropyl acetate is 1.8 percent, and the LEL of ethanol is 3.3 percent. Densities and molecular weights are given in Example 3.*

$$\text{Toluene} \quad \frac{7.21}{1.3 \times 92.13} \approx 0.06$$

$$\text{Isopropyl acetate} \quad \frac{7.27}{1.8 \times 102.13} \approx 0.04$$

$$\text{Ethanol} \quad \frac{6.57}{3.3 \times 46.07} \approx 0.04$$

*Because the value for toluene is the largest, the temporary exhaust rate is calculated assuming that the entire VOC mixture is composed of toluene. Assuming that approximately 20 percent of the total 23 gal/hr of VOC's escapes as fugitive emissions (based on an earlier liquid/gas material balance CE test as presented in Example 3), the fugitive emission rate is about 4.6 gal/hr. Using Equation 10 (with a factor of 60 in the denominator to convert the emission rate to gal/min), the temporary exhaust rate is calculated as follows:*

$$Q = \frac{385 \times 7.21 \times 4.6 \times 4}{1.3 \times 10^{-2} \times 92.13 \times 1 \times 60}$$

$$Q \approx 710 \text{ scfm}$$

*If actual conditions are significantly different from standard conditions, the temporary exhaust rate should be adjusted using Equation 3.*

*The exhaust rate calculated for fire safety in the example above is only about 11 percent of the exhaust rate calculated for health protection in Example 3 (based on the individual emission rates of the component VOC's) and only about 2 percent of the health protection exhaust rate calculated in Example 4 (based on the worst-case VOC).*

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### **Monitoring Considerations for Fire Safety**

As is the case when health protection is the concern, it is advisable to monitor the VOC concentration in the TTE during CE testing to ensure that fire safety is maintained. The principles and calculations for fire safety monitoring are the same as previously discussed for health protection.

The instrument measuring VOC concentration in the temporary exhaust stream during the CE test serves as a continuous monitor of the average concentration in the TTE. At no time should the concentration in this exhaust stream exceed 25 percent of the LEL. If the TTE is not well ventilated to achieve good mixing, it is advisable to set a lower maximum acceptable concentration for the temporary exhaust stream.

In addition, various points within the TTE should be periodically monitored after the TTE has been erected. Here again, the maximum acceptable VOC concentration at any location away from the fugitive emission points themselves is 25 percent of the LEL.

The monitor reading that corresponds to the selected maximum acceptable VOC concentration can be determined using the information and equations presented previously in the section on monitoring considerations for health protection. To use the equations in that section as written, it is necessary to express the LEL in ppmv rather than in percent by volume. For this conversion, each 1 percent by volume is equal to 10,000 ppmv.

### **EXAMPLE 11.**

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*For the multiple-station packaging rotogravure press first introduced in Example 3, what is the maximum acceptable monitor reading during CE testing if no workers will enter the TTE? What is the maximum acceptable monitor reading if the relative quantities of the VOC's are not known, as in Example 4?*

*Solution. The solution to the first part of this example parallels Example 6. The relative response and mole fraction for each of the VOC's that make up the mixture are determined using Equations 5 and 7, respectively, and these parameters are used to calculate the relative response for the mixture using Equation 8. The maximum allowable VOC concentration for the TTE is 25 percent of the LEL. The corresponding maximum acceptable monitor reading is calculated using Equation 9. For use in Equation 9, the LEL's for the component VOC's (listed above in Example 10) must be converted to ppmv by multiplying each by 10,000, and each must be*



multiplied by 0.25 to correct to 25 percent of the LEL. The resulting values of  $C_{max}$  for toluene, isopropyl acetate, and ethanol are 3,250 ppmv, 4,500 ppmv, and 8,250 ppmv, respectively. Using these values and the mole fractions and relative response for the mixture determined in Example 6, the calculation is as follows:

$$\begin{aligned} MR_{max} &= 0.62 \times \frac{3,250 \times 4,500 \times 8,250}{(0.03 \times 4,500 \times 8,250) + (0.12 \times 3,250 \times 8,250) + (0.85 \times 3,250 \times 4,500)} \\ &\approx 4,500 \text{ ppmv propane} \end{aligned}$$

(Alternatively, the LEL in terms of percent by volume can be used in Equation 9, and the result multiplied by 2,500 to correct for both ppmv and the limitation to 25 percent of the LEL.)

For the case where the components of the mixture are known, but the mole fractions cannot be calculated, the determination of the maximum acceptable monitor reading parallels the process illustrated in Example 7. The relative response for each VOC in the mixture is determined using Equation 5. This value and the  $C_{max}$  value for each VOC (computed from the LEL as discussed above) are used in Equation 6 to determine the  $MR_{max}$  for each VOC. The maximum acceptable monitor reading is the lowest of these  $MR_{max}$  values. For the example rotogravure press that uses toluene, isopropyl acetate, and ethanol, the Equation 6 calculations are illustrated below:

$$\begin{aligned} \text{Toluene } MR_{max} &= 2.3 \times 3,250 \\ &\approx 7,500 \text{ ppmv propane} \end{aligned}$$

$$\begin{aligned} \text{Isopropyl acetate } MR_{max} &= 1.3 \times 4,500 \\ &\approx 5,800 \text{ ppmv propane} \end{aligned}$$

$$\begin{aligned} \text{Ethanol } MR_{max} &= 0.47 \times 8,250 \\ &\approx 3,900 \text{ ppmv propane} \end{aligned}$$

Based on these calculations, the maximum acceptable monitor reading for the TTE is 3,900 ppmv propane, which results from treating the entire VOC mixture as ethanol. This value is not much lower than the value determined above using the individual VOC's because ethanol is both the most restrictive component (lowest  $MR_{max}$ ) and the most plentiful.

## REFERENCES FOR APPENDIX C

1. Occupational Safety and Health Administration. Air Contaminants—Permissible Exposure Limits. Title 29, Code of Federal Regulations, Part 1910.1000. 1989.

2. Industrial Ventilation, 20th Ed. Lansing, Michigan, American Conference of Governmental Industrial Hygienists, Inc. 1988. p. 2-6.
3. Reference 2, p. 5-23.
4. Reference 2, pp. 2-4 and 2-5.
5. Modern Practice of Gas Chromatography, 2nd Ed.; Robert L. Grob, ed. New York, John Wiley & Sons, p. 248.
6. Dietz, W.A. Response Factors for Gas Chromatographic Analyses. Journal of Gas Chromatography. February 1967.
7. Ackman, R.G. Fundamental Groups in the Response of Flame Ionization Detectors to Oxygenated Aliphatic Hydrocarbons. Journal of Gas Chromatography. 6:173-179. June 1964.
8. Ettre, L.S. Relative Response of the Flame Ionization Detector. Journal of Chromatography. 8:525-530. August 1962.
9. Reference 2, p. 2-7.

## **APPENDIX D**

### **TEMPORARY TOTAL ENCLOSURE DESIGN CASE STUDY**

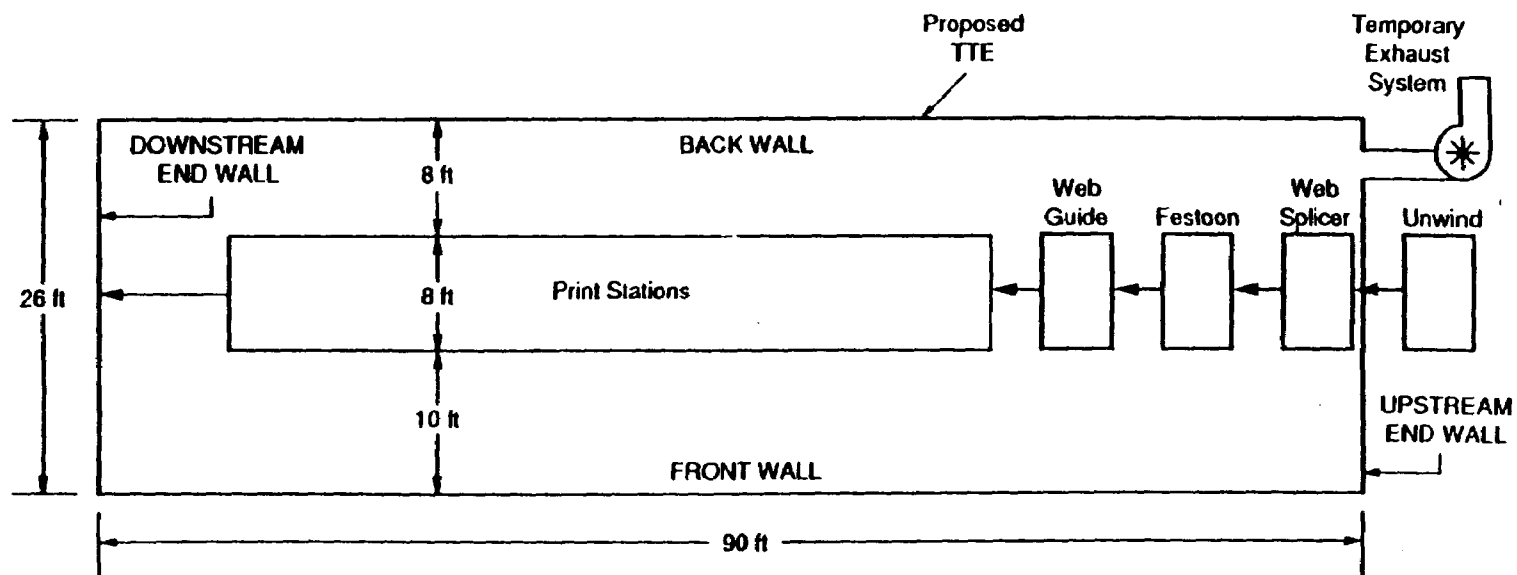
## TEMPORARY TOTAL ENCLOSURE DESIGN CASE STUDY

A packaging manufacturing company is required to determine the capture efficiency (CE) achieved by one of its multiple-color, web-fed rotogravure presses. From the unwind equipment through the cutting and stacking equipment, the press is about 120 feet (ft) long. The printing stations of the press, where the inks are applied and dried and the volatile organic compounds (VOC's) are emitted, constitute about 60 ft of the press. The maximum web width that the press can accommodate is 4 ft. The overall width of the press is about 8 ft.

Based on a survey of the facility, the most practical temporary total enclosure (TTE) configuration consists of walls paralleling the length of the press, front and back, with end walls crossing the path of the web to enclose the print stations. The easiest place to cross the line upstream of the print stations is between the unwind equipment and the web splicer, about 20 ft from the first print station. Downstream from the print stations, the best place to erect the end wall is between the final print station and the cutting equipment, about 10 ft from the final print station. To allow adequate room for working both inside and outside the TTE, the wall along the front of the press is best placed midway across the aisle between the test press and the back of the adjacent press, about 10 ft from the front of the print stations. The wall along the back of the press, where very limited access is required, can be erected most easily about 8 ft from the back of the print stations. It is easier and less disruptive to the operation of the press during construction to extend the TTE walls all the way up to the plant ceiling than to construct a TTE roof spanning the press. The most practical, least disruptive location for the temporary exhaust system is at the unwind end of the press at floor level, with the pickup extending through the end wall of the TTE on the back side of the press. A schematic of the proposed TTE configuration is presented in Figure D-1. In the paragraphs below, the steps for TTE evaluation and design presented in Chapter 5 are applied to this example case.

**Step 1. Evaluate the essential natural draft openings (NDO's) and exhaust points against the TTE criteria.**

**Criterion 1:** The separation between NDO's and VOC sources must be at least four times the equivalent diameter (ED) of the NDO.



NCODC 8 edge sc.m 2 050391

Figure D-1

Essential NDO's and associated ED's:

- Web entrance slot -- 6 ft wide by 3 ft high  
(This height needed to allow worker access to the web splicer.)  
$$ED = \left( \frac{4 \times \text{area}}{\pi} \right)^{0.5} = 4.8 \text{ ft}; 4 \times ED = 19.2 \text{ ft}$$

- Web exit slot -- 6 ft wide by 5 inches (in.) high  
(No worker access needed at exit.)  
$$ED = 1.8 \text{ ft}; 4 \times ED = 7.2 \text{ ft}$$

Separation of NDO's and nearest VOC sources:

- Web entrance slot to first print station -- 20 ft  
$$20 \text{ ft} > 4 \times ED$$
- Web exit slot to final print station -- 10 ft  
$$10 \text{ ft} > 4 \times ED$$

Criterion 1 is satisfied.

**Criterion 2:** The separation between exhaust points and NDO's must be at least four times the ED of the exhaust opening.

Exhaust points and associated ED's:

- Print station dryers' entrance and exit slots -- 5 ft by 4 in.  
(Each print station has a dryer mounted above the print cylinder.)  
$$ED = 1.5 \text{ ft}; 4 \times ED = 6 \text{ ft}$$
- Temporary exhaust system pickup -- 3 ft  $\times$  3 ft  
(Dimensions approximate; actual duct size determined later when flow rate estimated.)  
$$ED = 3.4 \text{ ft}; 4 \times ED = 13.6 \text{ ft}$$

Separation of exhaust points and nearest NDO's:

- Dryer slots to TTE web slots -- closest is final print station dryer to web exit slot, about 10 ft  
$$10 \text{ ft} > 4 \times ED$$
- Temporary exhaust pickup to web entrance slot -- about 5 ft  
$$5 \text{ ft} < 4 \times ED$$

- Add a baffle joining the TTE end wall to the web splicer housing between the temporary exhaust pickup and the web entrance slot -- airflow path between the exhaust and the NDO is increased to over  $4 \times ED$

Criterion 2 is satisfied.

**Criterion 3:** The total area of the NDO's must be no more than 5 percent of the total area of the TTE's wall, ceiling, and floor.

Area of NDO's:

- Web entrance slot -- 18 square feet ( $\text{ft}^2$ )
- Web exit slot --  $2.5 \text{ ft}^2$
- Total --  $20.5 \text{ ft}^2$

Area of TTE:

- Dimensions -- 90 ft long by 26 ft wide by 26 ft high
- Front and back walls -- 90 ft by 26 ft each
- End walls -- 26 ft by 26 ft each
- Ceiling and floor -- 90 ft by 26 ft each
- Total area --  $10,712 \text{ ft}^2$

Ratio of areas -- less than 0.2 percent

Criterion 3 is satisfied.

**Criteria 4 and 5:** Not evaluated at this stage.

**Step 2. Determine the volume of the permanent exhausts and forced makeup air in the TTE.**

**Exhausts:** The only permanent exhausts are those from the dryers on the print stations. These exhausts are joined into a common duct to the control device. The dryers have dampers that are positioned automatically based on the VOC concentration, so the total exhaust from the press can vary from about 3,000 actual cubic feet per minute (acfm) to 12,000 acfm depending on the quantity of VOC being applied in the inks. The press exhaust temperature is typically about 110°F.

**Makeup air:** One of several forced makeup air units at the facility is within the proposed TTE.

However, the unit is not configured to allow volumetric flow measurements using EPA methods. Therefore, the unit will not be operated during the test, and its openings will be sealed to prevent air from passing in or out. The effective forced makeup air volume during testing is zero.

**Step 3. Estimate the temporary exhaust rate needed to maintain a safe and healthful atmosphere inside the TTE.** As discussed in detail in Appendix C, there are two methods for estimating the necessary temporary exhaust rate: the Crumpler Chart method and the calculation method. Both methods are illustrated below.

**Quantity of VOC's:** The facility indicates that a maximum of 150 to 200 pounds per hour (lb/hr) of VOC's are contained in the inks applied on the press. The CE is estimated to be in the range of 80 percent. Thus, a maximum of about 160 lb/hr of VOC's are captured and vented to the control device, and the greatest fugitive VOC generation rate is about 40 lb/hr.

**Identity of VOC's:** The many inks used by the facility contain a wide range of VOC formulations. Alcohols and acetates generally predominate, but a significant quantity of toluene also is used. The exact proportions that will prevail at the time of the test are unknown. To be on the safe side, the mixture is considered to be 100 percent toluene for the exhaust estimations. This approach results in a more restrictive (higher) exhaust rate. (See Appendix C for background information.)

**Appropriate safety factor:** Workers will enter the TTE from time to time during testing, so worker exposure considerations, rather than fire safety, take precedence. As discussed in Appendix C, the calculation method for estimating the necessary temporary exhaust rate uses a safety factor (K) to account for incomplete mixing within the TTE. However, because a "safety factor" has already been introduced in this case by treating the entire VOC mixture as toluene, a K value of 1 can be used in the temporary exhaust rate calculation.



**Background VOC concentration:** Measurements made by the facility indicate a background VOC concentration of 20 parts per million by volume (ppmv). Information on the identity of the reference compound and the measurement method is unavailable. For the calculation method of estimating the necessary temporary exhaust rate, the background concentration is assumed to be 20 ppmv toluene.

**Exhaust rate estimation:**

Crumpler Chart Method. This method is best suited for use when test results from the process being evaluated are available. However, even in the absence of test data, the method can be used if the VOC concentration and volumetric flowrate of the captured gas stream can be estimated. For this process, the volumetric flowrate of the captured gas stream is known, and the VOC concentration can be estimated based on this flowrate and the VOC mass emission rate in the captured gas stream, which also is known.

As indicated above in Step 2, the volumetric flowrate of the captured gas stream varies from about 3,000 acfm to 12,000 acfm at 110°F. Assuming that the process operates at near standard pressure (29.92 in. of mercury [in. Hg]), this range equals approximately 2,800 standard cubic feet per minute (scfm) to 11,100 scfm (see Appendix C, Equation 3). For this example, a value of 10,000 scfm is selected. (Any value in the range could be selected without affecting the outcome because, given a fixed VOC mass flowrate, the volumetric flowrate and VOC concentration of the captured gas stream are inversely proportional.) Given that the volume occupied by 1 pound-mole (lb-mol) of an ideal gas at standard conditions (68°F and 29.92 in. Hg) is 385 standard cubic feet (std. ft<sup>3</sup>) and that the molecular weight of toluene is 92.13 lb/lb-mol, the VOC concentration is calculated as follows for the selected volumetric flowrate:

$$\frac{160 \frac{\text{lb toluene}}{\text{hr}} \times 385 \frac{\text{std. ft}^3 \text{ toluene}}{\text{lb-mol toluene}} \times 10^6}{60 \frac{\text{min}}{\text{hr}} \times 92.13 \frac{\text{lb toluene}}{\text{lb-mol toluene}} \times 10,000 \text{ scfm total exhaust}} \approx 1,100 \text{ ppmv}$$

(The factor  $10^6$  that appears in the numerator is necessary to convert the expression into terms of ppmv.)

Based on the results of the calculation above, the VOC concentration in the captured gas stream ( $C_G$ ) (assuming 100 percent toluene) is about 1,100 ppmv at a volumetric flowrate ( $Q_G$ ) of 10,000 scfm. The Permissible Exposure Limit (PEL) for toluene is 100 ppmv; this value is used as the target value for the VOC concentration in the temporary exhaust stream ( $C_F$ ). As indicated previously, the CE is estimated at 80 percent. With these four values, the Crumpler Chart can be used to estimate the appropriate temporary exhaust rate ( $Q_F$ ). The use of the Crumpler Chart is illustrated in Figure D-2 and explained below.

The value of  $C_F/C_G$  is  $100/1,100$ , or about 0.09. This point on the y-axis of Figure D-2 is represented by Point A. From Point A, a line parallel to the x-axis is drawn to the curve representing the estimated CE; the point of intersection is represented by Point B in Figure D-2. From Point B, a line parallel to the y-axis is drawn downward to the x-axis. The intersection is at Point C in Figure D-2; the value at this point is about 2.75. Thus,  $Q_F/Q_G$  is equal to 2.75, and  $Q_F$  equals 27,500 scfm.

**Calculation Method.** By this method, the temporary exhaust rate necessary to maintain healthful conditions is estimated using Equation 4 from Appendix C. Because the emission rate (ER) is already known in terms of mass, this value (40 lb/hr) can be used directly in the equation without being multiplied by the density ( $\rho$ ), as is necessary when the emission rate is in terms of liquid volume. Also, a factor of 60 is included in the denominator of the equation to convert the emission rate from lb/hr to lb/minute. The molecular weight of toluene is 92.13 lb/pound-mole, and the PEL is 100 ppmv. Using the parameter values given above,

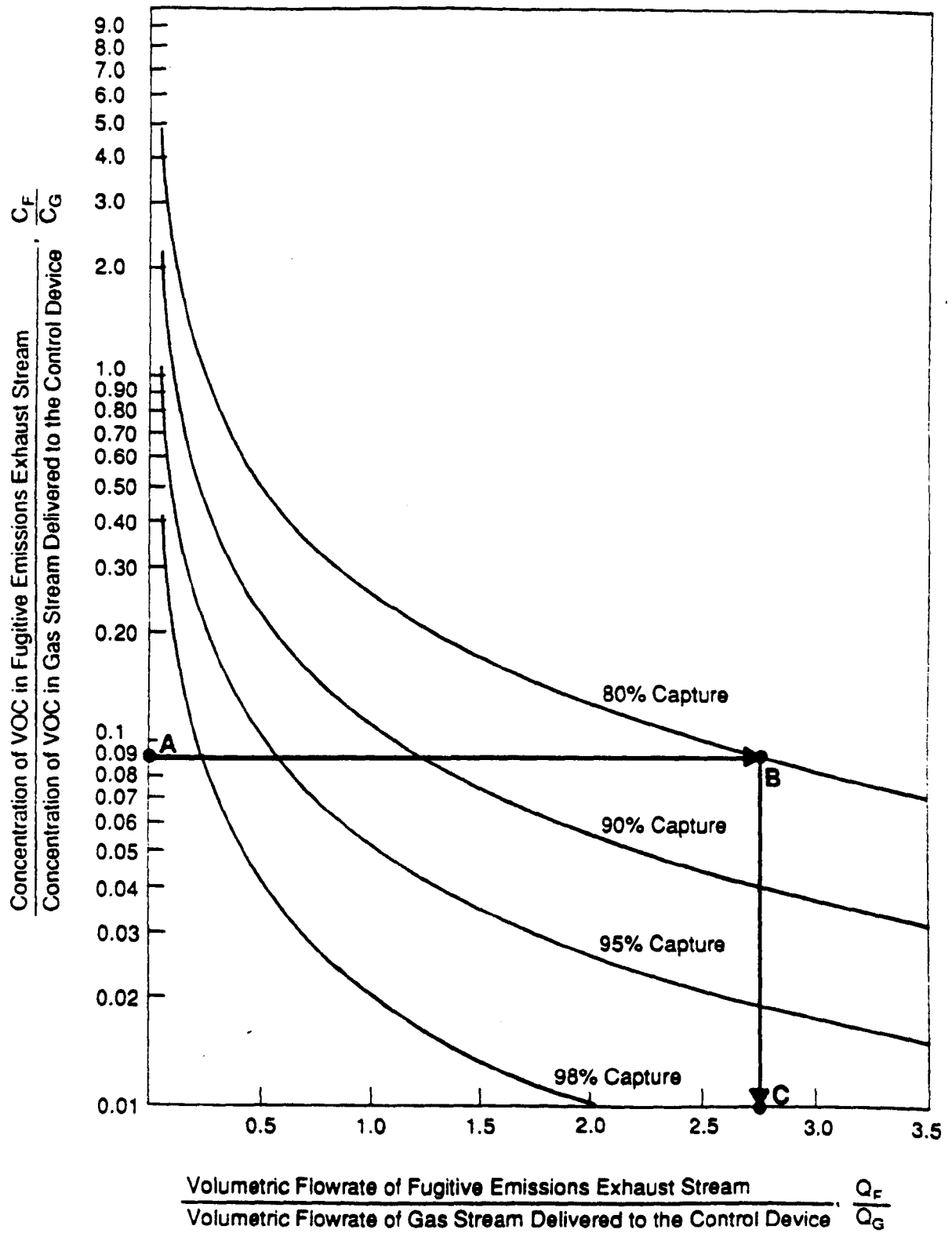


Figure D-2

the necessary temporary exhaust rate is estimated as follows:

$$Q = \frac{385 \times 40 \times 1}{(100 - 20) \times 10^{-6} \times 92.13 \times 60} \approx 35,000 \text{ scfm}$$

The difference between this estimate and that derived using the Crumpler Chart method results from the inclusion of the background VOC concentration in this calculation. In this case, the assumption that all the VOC is toluene is so conservative that the temporary exhaust rate estimated using the Crumpler Chart is very likely to be sufficient to maintain a healthful atmosphere inside the TTE. This example emphasizes, however, how important it is to use conservative assumptions and estimates when estimating the necessary temporary exhaust rate using the Crumpler Chart method.

Adjustments for Temperature and Pressure. Regardless of which estimation method is used, the estimated temporary exhaust rate may have to be adjusted for temperature and pressure. See Appendix C for information on flowrate adjustments to compensate for differences between actual and standard conditions.

For the process in this case study, which operates at ambient temperature, the volume determined above at standard temperature (68°F) can be used without adjusting for temperature. Also, it is assumed that the facility is located at an elevation of less than 1,000 ft above sea level and operates at ambient atmospheric pressure, so no adjustment for pressure is necessary. Thus, the actual temporary exhaust rate needed is a maximum of 35,000 acfm.

Because of the conservative assumptions used in calculating this value (e.g., largest possible fugitive emission rate, 100 percent toluene), this is the maximum exhaust rate that should ever be needed. Field conditions may not warrant such a high exhaust rate, so a system with variable flowrate is advisable.

Note that with the temporary exhaust rate estimated at a maximum of 35,000 acfm, the system pickup and duct dimensions assumed for Step 1 (3 ft by 3 ft) are acceptable. With this size duct and this exhaust rate, the flow rate in the duct is somewhat less than 4,000 feet per minute (ft/min), which is certainly acceptable for a temporary test system such as this.

**Step 4. Determine the net total exhaust rate, calculate the average face velocity (FV) across the essential NDO's, and compare this FV to the required value.**

**Net total exhaust rate:** The CE test procedures require FV calculations to be carried out in terms of scfm (see Appendix B, Method 204). From Step 2 above, the dryer exhaust totals 3,000 to 12,000 acfm at 110°F, which is equivalent to about 2,800 to 11,100 scfm (see Appendix C, Equation 3). The forced makeup air is zero. From Step 3, the estimated maximum temporary exhaust volume is 35,000 scfm. However, this temporary exhaust volume was determined using a series of conservative assumptions, so it is likely that under test conditions the actual exhaust rate will not be so high. Because the average FV ultimately must be determined under field conditions, it is important not to overestimate the temporary exhaust rate during this step. For a conservative evaluation in this step, a value of one-half the calculated value is used, and the minimum permanent exhaust value is used. (These values were selected based on the information presented in this case study. In other situations, other values would be appropriate. For example, if the temporary exhaust rate were estimated based on a known VOC mixture, the total calculated exhaust rate might be used.) The net total exhaust rate is calculated below:

$$\begin{aligned}\text{net total exhaust} &= \text{permanent exhaust} - \text{permanent forced makeup} + \text{temporary exhaust} \\ &= 2,800 \text{ scfm} - 0 + 17,500 \text{ scfm} \\ &= 20,300 \text{ scfm}\end{aligned}$$

**Average FV across the essential process NDO's:** In Step 1, it was determined that the total area of the web entrance and exit slots is 20.5 ft<sup>2</sup>. If these were the only NDO's, the average face velocity across them would be calculated as follows:

$$\begin{aligned}
 FV &= \frac{\text{net exhaust}}{\text{total NDO area}} \\
 &= \frac{20,300 \text{ scfm}}{20.5 \text{ ft}^2} \\
 &= 990 \text{ ft/min}
 \end{aligned}$$

**Criterion 4:** The average FV across all NDO's must not be less than 200 ft/min.

Criterion 4 is satisfied.

**Step 5. Select a target FV and determine the maximum NDO area that will meet the criteria.**

**Target FV:** A value of 250 ft/min gives some room for error but is not excessive.

**Maximum NDO area that meets Criterion 4:**

$$\begin{aligned}
 \text{NDO area} &= \frac{\text{net total exhaust}}{\text{target FV}} \\
 &= \frac{20,300 \text{ scfm}}{250 \text{ ft/min}} \\
 &= 81 \text{ ft}^2
 \end{aligned}$$

**Maximum NDO area that meets Criterion 3:** The total area of the NDO's cannot exceed 5 percent of the surface area of the TTE structure. Using the TTE area determined in Step 1, the maximum NDO area is calculated below:

$$\begin{aligned}
 \text{NDO area} &= 0.05 \times \text{TTE area} \\
 &= 0.05 \times 10,712 \text{ ft}^2 \\
 &\approx 536 \text{ ft}^2
 \end{aligned}$$

**Step 6. Evaluate possible locations and sizes of supplemental NDO's to improve ventilation of the TTE.**

**Allowable area of supplemental NDO's:** As indicated in Step 5, Criterion 4 is far more restrictive than Criterion 3. Thus, the total NDO area should not exceed the  $81 \text{ ft}^2$  dictated by Criterion 4. Given that the NDO's essential to the process (the web entrance and exit slots) total  $20.5 \text{ ft}^2$ , supplemental NDO's up to a total of  $60.5 \text{ ft}^2$  may be added.

Although supplemental NDO's are not necessary to meet the TTE criteria, it is advisable to add as much supplemental NDO area as possible. The supplemental NDO's not only improve the ventilation of the TTE, but they reduce the pressure differential between the outside of the TTE and the inside, thereby reducing the stress on the TTE structure.

**Arrangement of supplemental NDO's:** The supplemental NDO's are located so as to improve the ventilation of the TTE. This aim is accomplished by providing for good mixing of the air in the TTE to prevent high VOC concentrations from building up in stagnant areas and by generally sweeping the VOC's from the breathing zone of the workers. To accomplish good mixing, numerous NDO's are provided at all levels and on all sides of the TTE. In this case, to sweep the breathing zone, the predominant flow of air should be along the length of the TTE toward the upstream wall where the temporary exhaust system pickup is located and from the front side of the press (where personnel sometimes work) toward the back side (where access is seldom needed). To produce this airflow pattern, relatively larger/more numerous NDO's are provided at the opposite end of the TTE from the temporary exhaust system pickup and in the TTE wall paralleling the front side of the press. One possible configuration of NDO's is presented in Figure D-3.

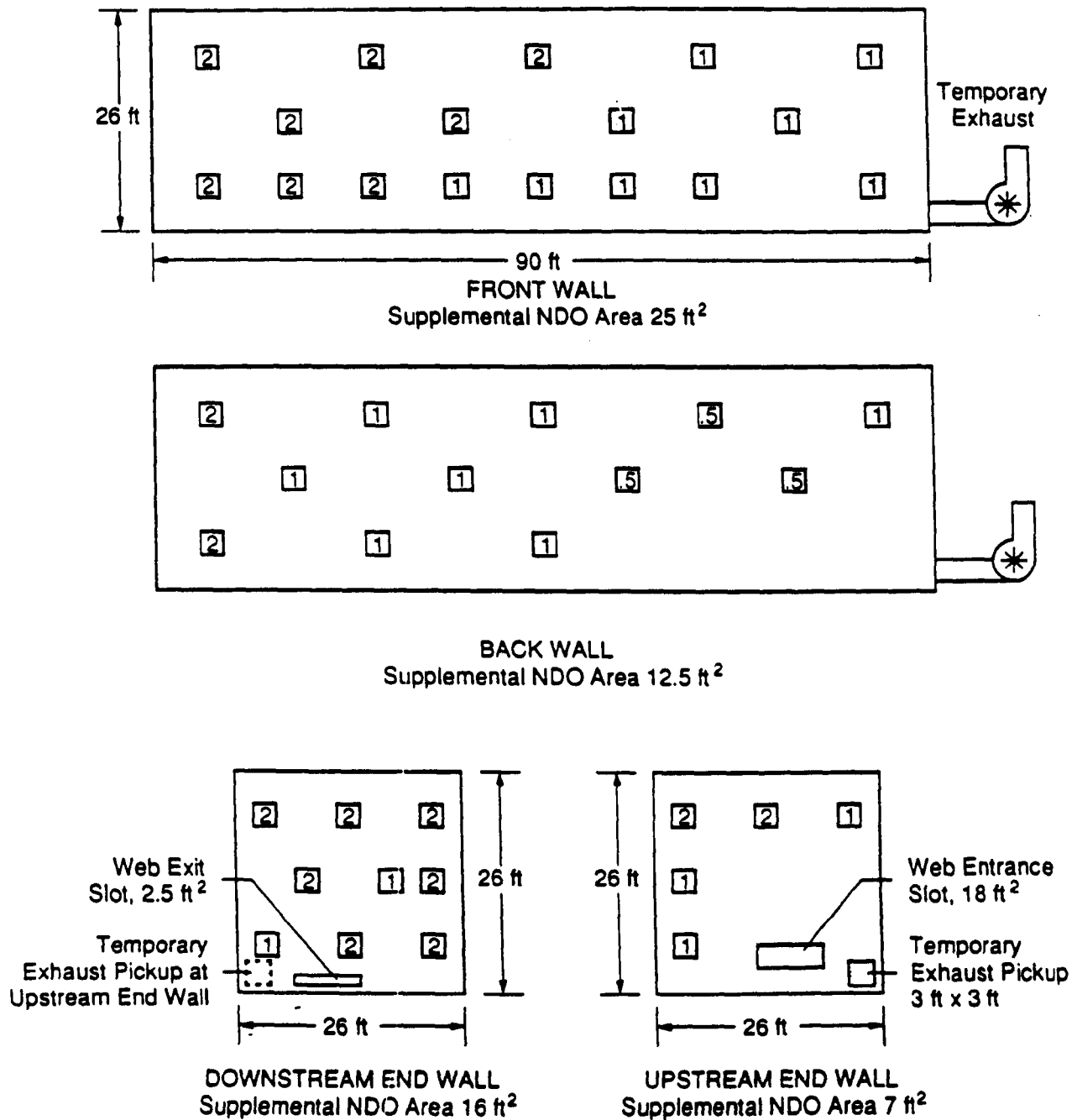


Figure D-3



## GLOSSARY OF TERMS

- |   |   |
|---|---|
| ■ | <u>Affected facility</u> means any process, line, or operation that is subject to a regulation or standard.   |
| ■ | <u>Captured emissions (G)</u> means all emissions that are delivered to a control device.   |
| ■ | <u>Capture device</u> means a hood, enclosure, room, floor sweep, or other means of containing or collecting VOC's and directing those VOC's into a duct.   |
| ■ | <u>Capture efficiency</u> means the fraction of all VOC generated by and released at an affected facility that is directed to a control device.   |
| ■ | <u>Control device</u> means any equipment that reduces the quantity of VOC that is emitted to the atmosphere. The device may destroy the VOC or secure it for subsequent recovery or disposal. Examples of control devices are incinerators, carbon adsorbers, and condensers.  |
| ■ | <u>Control device efficiency</u> means the ratio of the VOC destroyed or recovered by a control device to the VOC delivered to the control device, usually expressed as a percentage.   |
| ■ | <u>Control system</u> means any combination of capture and control devices.   |
| ■ | <u>Control system efficiency</u> means the fraction of gaseous VOC that is generated at an affected facility that is prevented from entering the atmosphere as a result of the performance of its capture and control devices. Mathematically, it is the product of the efficiencies of the capture and control devices.  |
| ■ | <u>Equivalent diameter</u> means the square root of the quantity four times the area of an opening divided by pi, i.e., $[(4 \times \text{area})/\pi]^{0.5}$ .  |
| ■ | <u>Exhaust rate</u> means the volumetric flow rate of gas that is withdrawn from a given space.   |
| ■ | <u>Forced makeup air</u> means air blown into an enclosure or oven by one or more fans to replace air that has been exhausted.  |
| ■ | <u>Fugitive emissions (F)</u> are traditionally defined as emissions that do not pass through a stack or duct that allows for their measurement. However, within the context of this document, fugitive emissions means all emissions that escape to the atmosphere without passing through a control device, regardless of how they are emitted.   |
| ■ | <u>Natural draft opening (NDO)</u> means any permanent opening in a room, building, or total enclosure that remains open during operation of the facility and is not connected to a duct in which a fan is installed. The "natural draft" rate and direction across the opening is a consequence of the difference in pressures on either side of the wall containing the opening.  |
| ■ | <u>Overall control efficiency</u> means the fraction of all the VOC's generated by an affected facility that is prevented from entering the atmosphere as a result of the performance of the control system that serves the affected facility. The overall control efficiency may be less than the control system efficiency because of additional VOC emissions downstream of the affected facility, such as evaporation of VOC from spray booth wastewater or of solvent retained in the product. |
| ■ | <u>Permanent total enclosure</u> means a permanently installed total enclosure from which all exhaust streams are discharged to a control device.   |

## GLOSSARY OF TERMS

■	<p><b><u>Temporary total enclosure</u></b> means a total enclosure that is constructed for the sole purpose of measuring fugitive emissions from an affected facility.</p>
■	<p><b><u>Total enclosure</u></b> means a structure that completely surrounds a source of emissions so that all VOC emissions are contained for discharge. With a total enclosure, there will be no fugitive emissions, only stack emissions. The only openings in a total enclosure are forced makeup air and exhaust ducts and any NDO's, such as those that allow raw materials to enter and exit the enclosure for processing. All access doors or windows are closed during routine operation of the enclosed source.</p>
■	<p><b><u>Volatile organic compound (VOC)</u></b> means any organic compound that participates in atmosphere photochemical reactions. This includes any organic compound other than the following compounds: methane, ethane, methyl chloroform (1,1,1-trichloroethane), CFC-113 (1,1,2-trichloro-1,2,2-trifluoroethane), methylene chloride, CFC-11 (trichlorofluoromethane), CFC-12 (dichlorodifluoromethane), CFC-22 (chlorodifluoromethane), FC-23 (trifluoromethane), CFC-114 (1,2-dichloro-1,1,2,2-tetrafluoroethane), CFC-115 (chloropentafluoroethane), HCFC-123 (1,1-dichloro-2,2,2-trifluoroethane), HFC-134a (1,1,1,2-tetrafluoroethane), HCFC-141b (1,1-dichloro-1-fluoroethane), and HCFC-142b (1-chloro-1,1-difluoroethane). These compounds have been determined to have negligible photochemical reactivity. For purposes of determining compliance with emission limits, VOC will be measured by the approved test methods. Where such a method also inadvertently measures compounds with negligible photochemical reactivity, an owner or operator may exclude these negligibly reactive compounds when determining compliance with an emissions standard. (The following compounds and classes of compounds have been proposed in the <u>Federal Register</u> [56 FR 11387, March 18, 1991] for addition to the list of negligibly photochemically reactive compounds: HCFC-124 (2-chloro-1,1,1,2-tetrafluoroethane; HFC-125 (pentafluoroethane); HFC-134 (1,1,2,2-tetrafluoroethane); HFC-143a (1,1,1-trifluoroethane); HFC-152a (1,1-difluoroethane); cyclic, branched, or linear, completely fluorinated alkanes; cyclic, branched, or linear, completely fluorinated ethers with no unsaturations; cyclic, branched, or linear, completely fluorinated tertiary amines with no unsaturations; and sulfur-containing perfluorocarbons with no unsaturations and with sulfur bonds only to carbon and fluorine.)</p>

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17. KEY WORDS AND DOCUMENT ANALYSIS		
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