VOLUME II: CHAPTER 15

PREFERRED AND ALTERNATIVE METHODS FOR ESTIMATING AIR EMISSIONS FROM THE PRINTING, PACKAGING, AND GRAPHIC ARTS INDUSTRY

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Prepared for:
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Emission Inventory Improvement Program

DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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INTRODUCTION

The purposes of the preferred methods guidelines are to describe emission estimation techniques for point sources in a clear and unambiguous manner and to provide concise example calculations to aid in the preparation of emission inventories. While emissions factors are not provided, the information presented in this document can be used to select the emission estimation technique best suited to a particular application. This chapter describes the process and recommends the approaches for estimating volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions from printing and graphic arts operations. This chapter is intended to be a useful guide for industry, federal, state, and local agencies.

Section 2 of this chapter contains a general description of the printing and graphic arts source category; the various printing processes used by the printing and graphic arts industry; and the common emission sources. Section 3 of this chapter provides an overview of available emission estimation methods.

Section 4 presents the preferred methods for estimating emissions from printing and graphic arts operations. Although preferred methods are identified, this document does not mandate any method. Preferred methods are desirable when data are readily available, when expected emissions are high, or when their use is cost-effective. Alternative methods may be used when preferred methods are not cost-effective. Section 5 presents the alternative emission estimation techniques. Quality Assurance and Quality Control are described in Section 6. Section 7 of this chapter contains coding procedures used for data input and storage. Some states use their own unique identification codes, so individual state agencies should be contacted to determine the appropriate coding scheme to use. Complete citations for all references are provided in Section 8.

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SOURCE CATEGORY DESCRIPTIONS

This section presents a brief overview of the printing and graphic arts industry and a description of the various printing processes involved in the graphic arts industry. For a more detailed discussion of printing processes, refer to *EPA Office of Compliance Sector Notebook Project: Profile of the Printing and Publishing Industry* (EPA, 1995a), and the *Sector Notebook Data Refresh* (EPA, 1998a).

The printing and graphic arts industry, defined most broadly, includes:

- Firms whose business is dominated by printing operations;
- Firms performing operations commonly associated with printing, such as platemaking or bookbinding; and
- Publishers, whether or not they actually print their own material (EPA, 1995a).

This document will focus on the first group, firms whose business is dominated by printing operations. Products printed include newspapers, books, greeting cards, checks, annual reports, magazines, flexible packaging, corrugated cartons, and vinyl and urethane products, such as resilient flooring, wallpaper, upholstery, and shower curtains. The United States Bureau of Census' Standard Industrial Classification (SIC) code 27 corresponds to this category. Some 58,000 firms and 62,000 facilities were identified within SIC code 27 by the Census (Census Bureau, 1997). This figure does not include the large number of "in-plant" printing operations located throughout the manufacturing sectors, which could bring the total number of operations well in excess of 100,000 (EPA, 1995a).

The markets for printing can be international, national, regional, or local in scope. Some facilities, such as those printing books, periodicals, and newspapers, serve national and international markets; while other printers may serve regional and local customers. As a result, the geographic distribution of printing facilities parallels U.S. population distribution. The printing and graphic arts industry is dominated by small firms. Almost one-half of all printing facilities have fewer then five employees; while approximately 84 percent employ fewer than 20 (EPA, 1995a).

From the printing industry's perspective, the industry is organized according to the type of printing process used. Types of printing processes include:

- Lithography;
- Flexography;
- Gravure;
- Screen printing;
- Letterpress; and
- Digital.

Historically, facilities tended to exclusively use one of these processes, with some larger facilities in operation that operated using some combination of these processes. Recently, it is becoming more common to have more than one process located at a facility. Based on 1997 estimated shipment values, the industry breaks down as 68.5 percent lithography, 6.4 percent flexography, 5.4 percent gravure, 0.6 percent digital, 4.5 percent letterpress, 9.0 percent screen printing, and 5.7 percent quick printing.[1] (Census Bureau, 1997).

The equipment, applications, and chemicals vary for each of these six printing processes. However, they all print an image on a substrate following the same basic sequence. The fundamental steps in printing are:

- **Pre-press operations** - The entire goal of the prepress operation is to produce an image carrier. The image carrier is used on a press to transfer an inked image from the image area to substrate. There are a variety of image carriers used and the specific one depends upon the particular printing process that will be utilized. The most common image carriers are planographic plates (lithography), relief plates (flexography and letterpress), screens (screen printing), and engraved cylinders (rotogravure).

  In order to create the image carrier, often times a film negative or positive is created. The film negative or positive can be produced in a conventional manner, where the type is set with a computer and original photographs and

[1]Quick printers are engaged in traditional printing activities, such as short-run offset printing or prepress services, in combination with providing document photocopying service. 91% of all quick printers utilize offset lithographic printing presses.

artwork are separated into the four primary colors and a film flat is assembled. Over the past decade, these conventional steps have been computerized and films can be imaged directly from the computer. The film negative or positive is used to transfer the image to the image carrier. More recently, image carriers are now imaged directly from the computer.

The other important step very common in the prepress operations is that of proofing. Prior to the final imaging setup, a proof of the job is made for customer approval. Not all printing jobs are proofed prior to image carrier preparation.

- Printing operations - Ink is applied to the image carrier, and the image is transferred to a substrate.

- Post-press step - The printed material may receive any one of numerous finishing operations, depending on the desired form of the finished product. The post-press step includes such processes as cutting, folding, collating, binding, perforating, drilling, coating, gluing, and laminating.

2.1 Process Descriptions

The printing and graphic arts industry as well as trade associations, technical foundations, and suppliers can be divided into six main categories by the printing process used:

- Lithography;
- Flexography;
- Gravure;
- Screen printing;
- Letterpress; and
- Digital or electronic printing.

Digital printing is any printing completed via digital files, not restricted to short runs and is able to provide variable printing such as incorporating data directly for a compact database and printing not using traditional methods of film or printing plates. Calculating emissions from digital printing is not discussed in this document. Such plateless printing processes include electronic (e.g., laser printers), electrostatic (e.g., xerographic copiers), magnetic, thermal (e.g., facsimile machines), and ink jet printing. Electrostatic toners and ink jet printers may contain HAPs; however, the quantities emitted at any location are small (EIIP, 1996a).

2.1.1 LITHOGRAPHY

Lithography is a planographic printing technique, that is, the printing and non-printing surfaces are essentially in the same plane. The image area of that plane is hydrophobic and oleophilic, while the non-image area is hydrophilic and chemically repellant to oil-based inks. The "offset" in offset lithography refers to the use of a rubber blanket to transfer the image from the plate to the substrate. Figure 15.2-1 presents a process flow diagram of the sheetfed offset lithographic printing process.

Fountain solution, a mixture of water and other volatile and non-volatile chemicals and additives that maintain the quality of the printing plate and reduces the surface tension of the water so that is spreads easily across the printing plate surface, is applied to the plate. The fountain solution wets the nonimage area so that the ink is maintained within the image areas. Non-volatile additives include mineral salts and hydrophilic gums. Alcohol and alcohol substitutes, including isopropyl alcohol, glycol ethers, and ethylene glycol, are the most common VOC additives used to reduce the surface tension of the fountain solution. There is also a type of lithography called waterless, in which no fountain solution is used. The non-image areas have a silicon coating which repels ink.

Lithography can be divided into two broad subdivisions based upon ink drying and substrate feed mechanisms:

- **Sheetfed press** - The substrate is fed into the press one sheet at a time. Sheetfed printing is typically used for printing books, posters, brochures, and artwork. Sheetfed inks dry by a combination of penetration and oxidation.

- **Web-press** - Prints on a continuous roll of substrate, known as a web. Web-fed lithography can be divided into heatset and non-heatset, the difference being that heatset web lithography dries the ink by evaporating the ink oils with indirect hot air dryers, and non-heatset web inks dry principally by absorption. Web-fed printing is commonly used for high speed production of magazines, catalogs, newspapers, and other periodicals.

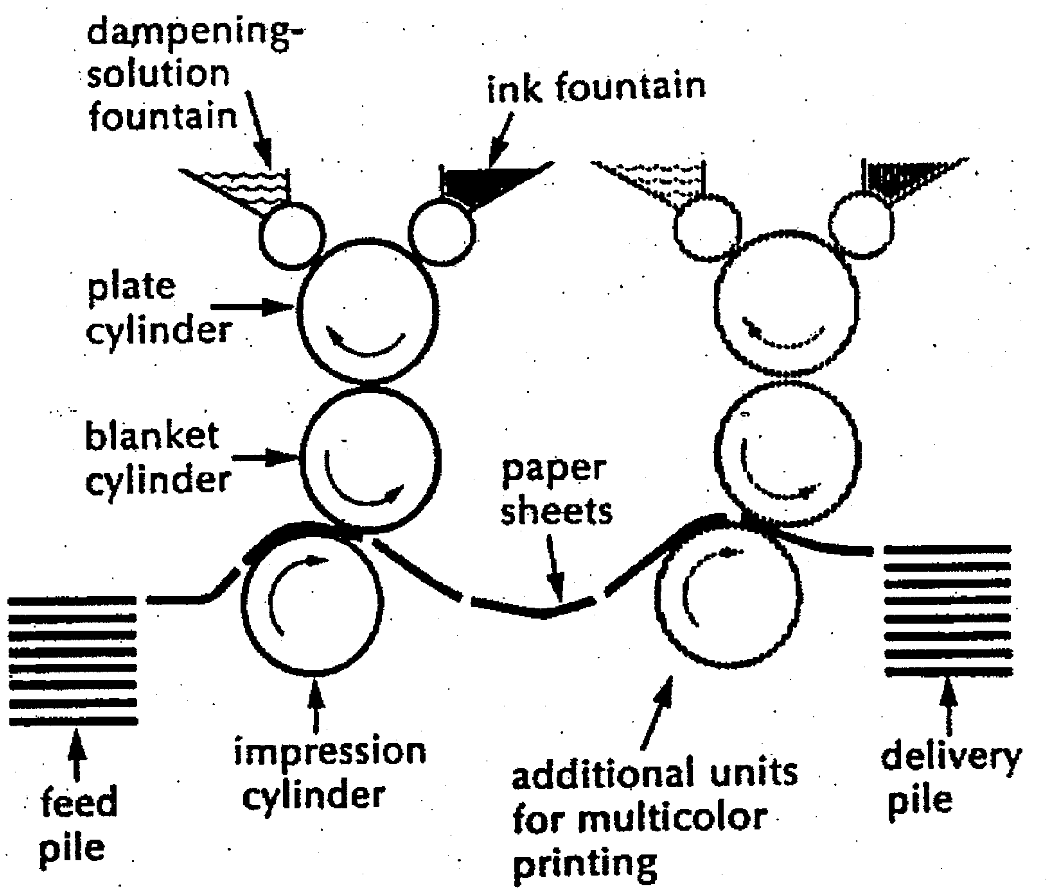


Figure 15.2-1. The Sheetfed Offset Lithographic Printing Process

Source: EPA, 1994b.

2.1.2 FLEXOGRAPHY

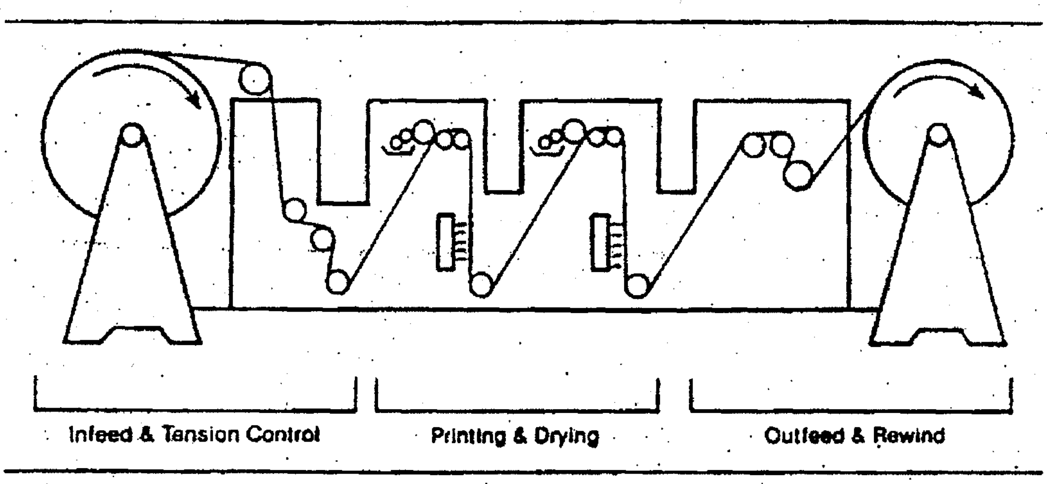
Flexographic printing uses flexible plates with raised images to transfer fluid inks to a substrate. The plates are typically rubber or photopolymer and are attached to a roller cylinder. Traditionally, four rollers are used to transfer an ink to a substrate. The first roller transfers an ink from an ink fountain to an engraved roller, known as an anilox roller. The anilox roller meters the ink to a uniform thickness for transfer to the third roller, the plate cylinder. The fourth roller is the impression cylinder. The impression cylinder applies pressure to the substrate as it passes between the plate cylinder and impression cylinder during printing. The substrate will pass through a dryer before another ink is printed. Flexography presses with a common impression cylinder are also frequently used. Doctor blade systems can be used in place of the first ink transfer roller. In a single doctor-blade system, the anilox roller is in direct contact with the ink fountain, and a single, reverse-angle doctor blade in employed to scrape off excess ink. In a double-blade system, the anilox roller rotates in an enclosed ink chamber with two doctor blades. Figure 15.2-2 shows a process flow diagram of the flexographic printing process.

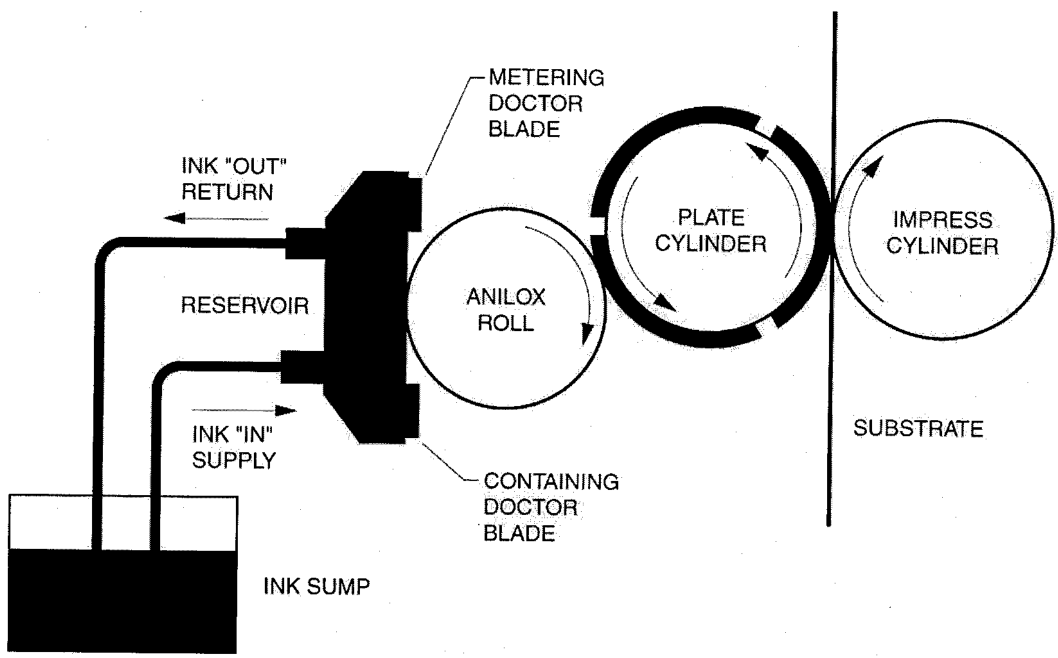
Flexographic printing presses can be either sheetfed or webfed. Flexographic inks can be used on both absorbent (paper, corrugated cardboard) and non-absorbent substrates (film and foil). Flexographic inks need to be fast-drying, low-viscosity inks. These inks lie on the surface of substrates and solidify when solvents are removed, making flexography ideal for printing on impervious materials, such as plastics or metallized surfaces. The soft plates allow quality printing on compressible surfaces, such as cardboard packaging, as well.

2.1.3 GRAVURE

Almost all gravure is webfed (GATF, 1993). The image area of a gravure cylinder consists of small, recessed cells, which are typically electro-mechanically engraved. The engraved surface of a gravure cylinder consists of millions of minute cells engraved into a copper cylinder and is protected with a very thin electroplated layer of chromium. Chemical etching, formerly the most common method of gravure cylinder engraving, accounts for only a small fraction of the etching done today.

During gravure printing, a low viscosity ink floods the lower portion of the gravure cylinder. The ink is then wiped from the surface of the cylinder with a doctor blade, leaving ink only in the image area. The ink left in the recessed cells is then pressed onto the substrate as the substrate is pressed against the gravure cylinder with a rubber-covered impression roll. The substrate is then passed through a high volume, recirculated air dryer before the next ink or coating is applied. Low-boiling point organic solvents are commonly used to achieve the low viscosity, fast drying properties required of inks used in a rotogravure process. Inks in the press fountain can contain





Enclosed Doctor Blade System Diagram

Figure 15.2-2. The Flexographic Printing Process as much as 75 percent solvent by weight (GATF, 1993). Figure 15.2-3 shows a process flow diagram of the gravure printing process.

2.1.4 SCREEN PRINTING

Screen printing differs from the other printing processes in that ink is transferred to a substrate through a porous mesh rather than on an impervious surface. Mesh is stretched across a frame and a stencil applied to the mesh defines the print image. Mesh thread count and diameter control the volume of ink applied to the substrate. A rubber or synthetic blade known as a squeegee applies pressure to the ink, causing the ink to flow through the imaged mesh and onto the substrate. Once the substrate has been printed, it is placed either on drying racks or on a conveyor into a dryer. Due to the flexibility in the screen printing process, a wide variety of substrates are possible, including, but not limited to, textiles, plastics, metals, and paper. Figure 15.2-4 shows a process flow diagram of the screen printing process.

2.1.5 LETTERPRESS

Similar to flexography, letterpress printing uses metal or plastic plates with a raised printing image to transfer ink to a substrate. There are three types of letterpresses:

- Platen;
- Flatbed; and
- Rotary.

In a platen press, the raised plate is locked on a flat surface, while the substrate is pressed between the raised plate and another flat surface. In both flatbed presses and rotary presses, the substrate passes between the plate cylinder and an impression cylinder during printing. With a flatbed press, only one side of the substrate is printed at a time, whereas rotary presses are designed to print both sides simultaneously. The web-fed rotary letterpress is the most common letterpress used today. Figure 15.2-5 shows a process flow diagram of the letterpress printing process.

Letterpress, once the predominant used printing process, is being replaced by lithography, flexography, and gravure. Lithography and flexography have been replacing letterpress in the printing of newspapers. Flexography has also been replacing letterpress in the printing of paperbacks, labels, business forms, and corrugated cartons. Gravure has largely replaced

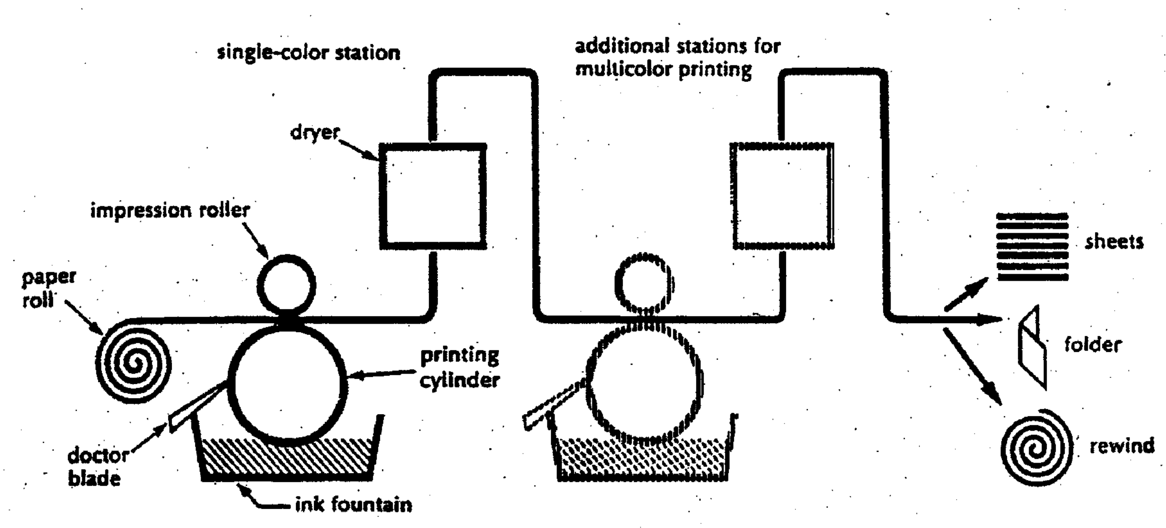


Figure 15.2-3. The Gravure Printing Process

Source: EPA, 1994b.

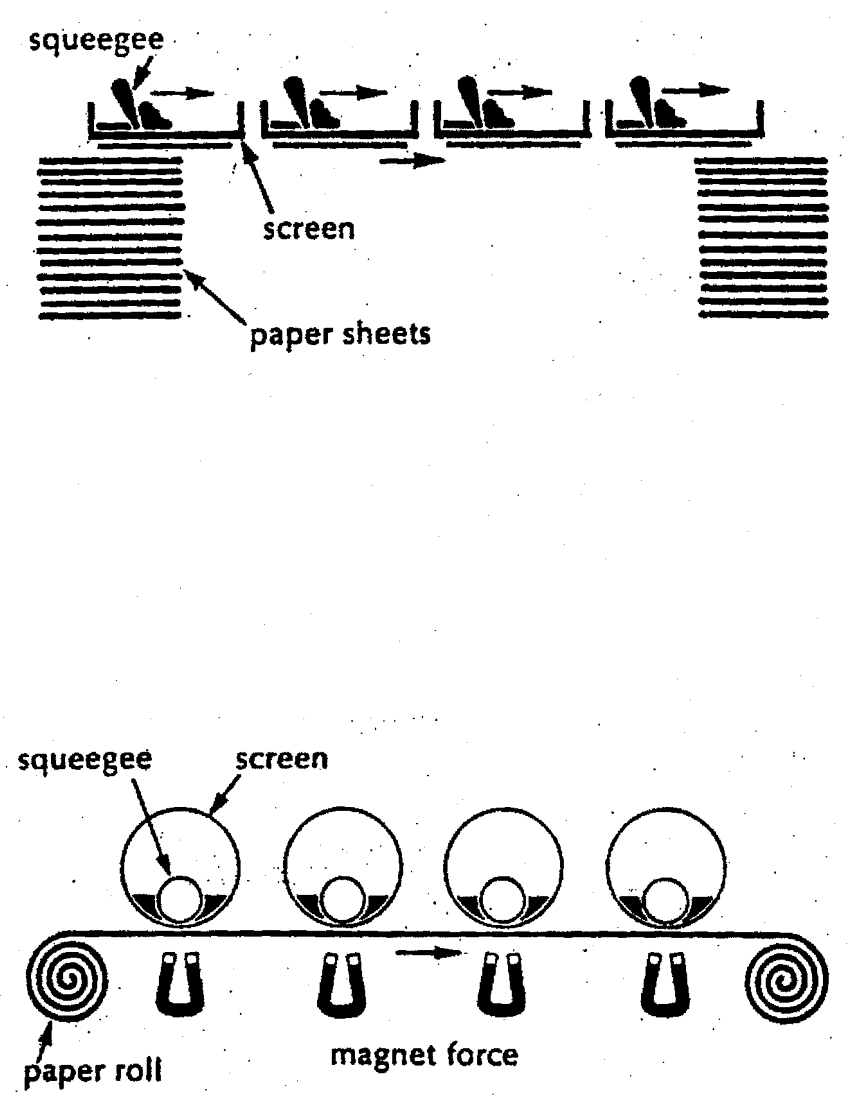


Figure 15.2-4. The Screen Printing Process

Source: EPA, 1994b.

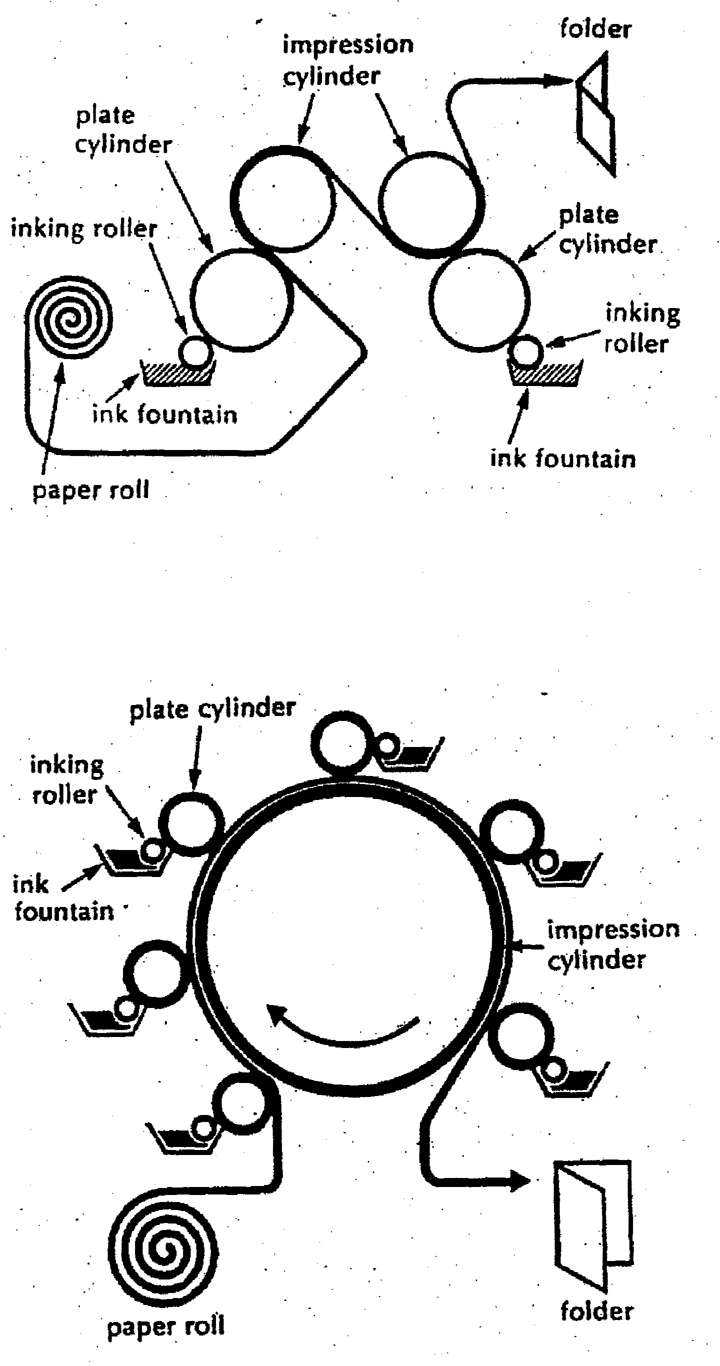


Figure 15.2-5. The Letterpress Printing Process

Source: EPA, 1994b.

letterpress for long-run magazine and catalog print jobs. Today, letterpress is used primarily for the printing of books, business cards, and advertising brochures.

2.2 Emission Points

Each of the printing processes follows the same basic sequence of imaging, pre-press, printing, and post-press.

Pre-Press

Pre-press operations include those operations used to create a positive or negative image which is then in turn used to create a plate, cylinder, or screen. The input materials used in the creation of the image are very similar to the input materials used in other fields of photography. Emissions may be the result of the use of developers, fixers, photographic processing solutions, or cleaning solutions. Emissions from the imaging step are minimal and are usually considered insignificant. The plate, cylinder, or screen produced will be used in the printing stage to transfer ink in the form of the image to the substrate. Emissions from the lithographic platemaking operation are minimal and typically considered insignificant. In flexographic platemaking, emissions may result from platemaking using perchloroethylene (PERC) or VOC-containing perchloroethylene alternative solvents (PAS) to wash photopolymer plates. PERC is being phased out as a solvent for flexographic platemaking. Most prepress operations now use PASs or water washable plates. Figure 15.2-6 presents examples of the various image carriers used in the printing and graphic arts industry.

Printing

The majority of releases in the printing and graphic arts industry occur during the printing step, during the process of transferring the ink and coating to a substrate. For the purpose of emission estimation, the printing step includes cleanup operations, which may occur during or between print runs. Emissions result from the evaporation of VOC contained in the inks and cleaning solutions. Lithography will also produce emissions from the evaporation of VOC contained in fountain solutions. In lithography, a portion of the VOC in inks can be retained on the substrate, thus reducing the amount available to volatilize into the atmosphere. The use of retention factor to account for this substrate retention is discussed in Section 4.1.1 of this document, along with a list of references on this subject.

Combustion of fuel, such as natural gas or oil, to provide heat for dyers also produces some emissions. In some cases, recovered solvent may be used as a supplemental fuel (EIIP, 1996a). A detailed discussion of the methodology used to calculate emissions associated with fuel

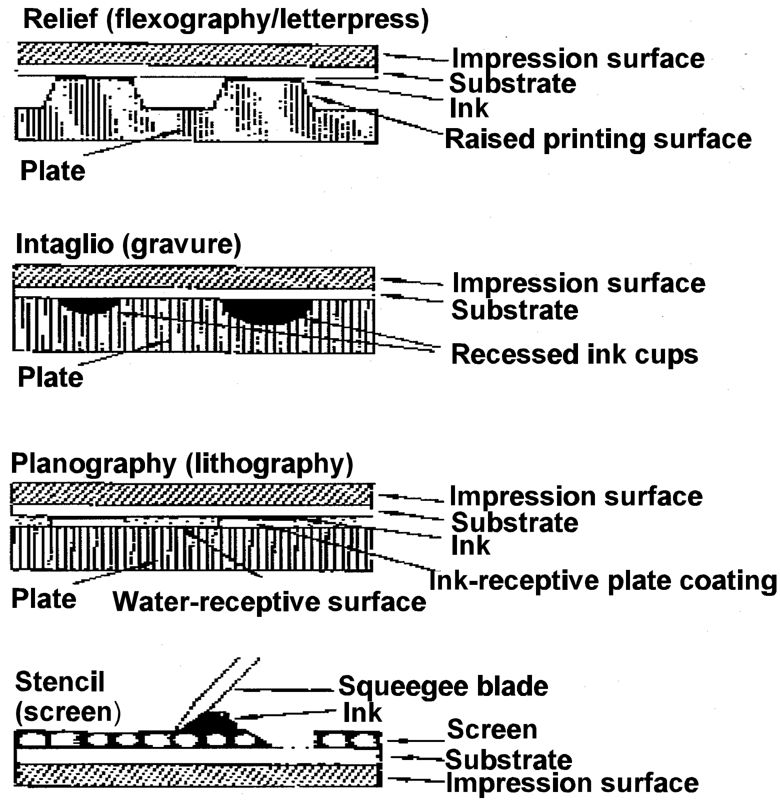


Figure 15.2-6. Typical Image Carriers Used in the Printing and Graphic Arts Industry

Source: EPA, 1994b.

combustion is presented in EIIP Volume 2, Chapter 2, *Preferred and Alternative Methods for Estimating Air Emissions from Boilers* (EIIP, 1996a).

Post-Press

The post-press step includes such processes as cutting, folding, collating, binding, perforating, and drilling. From an emissions perspective, binding is the most significant of the various post-press operations. Emissions may result from the volatilization of VOC contained in the adhesives used in the binding operation and solvents found in some types of ink jets inks, coatings, and some laminates used in the finishing process.

2.3 Control Equipment and Pollution Prevention Techniques

There are several methods by which VOC/HAP emissions at a facility can be reduced. These include material substitution, and control devices.

Material Substitution

Switching to cleaning solutions with lower hazardous air pollutant (HAP) and VOC contents or low volatility cleaners (those with VOC composite vapor pressure of less than 10mm Hg at 20°C) have been shown to reduce emissions. In lithography, the use of isopropyl alcohol has been replaced in many operations with alcohol substitutes. Some printers have also had success in reducing their emissions by switching from solvent-based inks to water-based inks and ultra violet (UV) curable inks. Some lithographic operations use vegetable oil-based inks. HAPs associated with printing and publishing industries are listed in Table 15.2-1.

Control Devices

Another strategy to control emissions is the installation of control devices. Control techniques commonly used in the printing and graphics arts industry and their typical control efficiency ranges are presented in Table 15.2-2. Control devices used by the printing and graphics arts industry can be described as either destructive or nondestructive. Destructive control devices are combustion devices, such as thermal oxidizers and catalytic oxidizers, designed to destroy volatile organic compounds in the vent stream prior to release into the atmosphere. Nondestructive control devices are recovery devices, such as carbon adsorbers or cooler/condenser filtration units. Recovery devices control emissions by recovering VOC for other uses, rather than destroying them.

TABLE 15.2-1

HAPs ASSOCIATED WITH PRINTING AND GRAPHIC ARTS INDUSTRIES

1,4-Dioxane	Glycol Ethers
2-Nitropropane	Hydrochloric Acid (Hydrogen Chloride gas only)
4-4'-Methylenediphenyl Diisocyanate	Lead & Compounds
Acrylic Acid	Maleic Anhydride
Benzene	Methanol
Bis 2-ethylhexyl phthalate	Methyl Ethyl Ketone
Cadmium & Compounds	Methyl Isobutyl Ketone
Chromium & Compounds	Methylene Chloride
Cobalt Compounds	Nickel & Compounds
Cumene	Phthalic Anhydride
Cyanide Compounds	Tetrachloroethylene
Dibutylphthalate	Toluene
Ethylbenzene	Trichloroethylene
Ethylene Glycol	Vinyl Acetate
Formaldehyde	Xylenes (includes o, m, and p)

Source: EPA, 1998a.

TABLE 15.2-2
TYPICAL GRAPHIC ARTS INDUSTRY EMISSION CONTROL TECHNIQUES

Pollutant	Control Device Type	Average Control Device Efficiency (%)
VOC	Recuperative Thermal Oxidizer[a]	95 - 99.8
	Regenerative Thermal Oxidizer[b]	90 - 99
	Catalytic oxidizer[c]	95 - 99
	Regenerative Catalytic Oxidizer[b]	90 - 99
	Carbon Adsorber[d,e]	95 - 98

[a] EIIP, 2000
[b] EPA, 1999c
[c] EPA, 1999d
[d] EPA, 1999e
[e] For concentrations between 500 and 2000 ppm

Other Process Changes

In lithography, refrigerated circulators are used to control emissions of isopropyl alcohol from fountain solutions by cooling the solution to between 55 and 60°F. Using refrigerated circulators reduces the evaporation of isopropyl alcohol, thereby reducing emissions of isopropyl alcohol and stabilizing the ink/water balance, as well as providing operators with better control of ink emulsification and hot weather scumming. There is no such equivalent reduction when alcohol substitutes are used. Refrigeration of fountain solutions with alcohol substitutes is not appropriate as a control technology.

In flexography, enclosed doctor blade systems have been used to reduce emissions from the printing process. While enclosed doctor blade systems are not control devices or material substitution, they can reduce VOC emissions due to reduced evaporation and more efficient cleaning.

3

Overview of Available Methods

3.1 Emission Estimation Methods

Several methods are available for calculating emissions from printing and graphic arts operations. The "best" method to use depends upon available data, available resources, and the degree of accuracy required in the estimate. In general, site-specific data that are representative of normal operating conditions are preferred over industry-average data, such as the emission factors presented in *Compilation of Air Pollution Emission Factors* (AP-42) (EPA, 1995c).

This section discusses and compares the methods available for calculating emissions from printing and graphic arts operations and identifies the preferred method of calculation on a pollutant basis. Although preferred methods are identified, this document does not mandate any emission estimation method. Industry personnel using this manual should contact the appropriate state or local air pollution control agency regarding suggested methods prior to calculating emissions estimates.

3.1.1 Material Balance

Material balance utilizes the raw material usage rates, fraction of the pollutant in the raw material, and portion (if any) of the pollutant in the raw material that is retained in the substrate to estimate the amount of pollutant emitted. Material balance is used most often where a relatively consistent amount of material is emitted during use. The material balance emission rate is calculated by multiplying the raw material usage by the amount of pollutant in the raw material, and subtracting the amount of the pollutant retained in the substrate. For VOC/HAP-containing materials, the amount of pollutant emitted is assumed to be 100 percent of the amount of pollutant contained in the material, unless a control device is used to remove or destroy VOC/HAP in the exhaust stream or a known portion of ink, for example, is retained in the substrate. To estimate VOC/HAP emissions where a control device is being used, it is necessary to establish the efficiency of the capture system and the control device. Regardless of whether a control device is being used, it is necessary to utilize all accepted retention factors and emission factors to accurately perform the mass balance equations. Guidance on retention factor utilization can also be found at the EPA's Technology Transfer Network (TTN) web site (EPA, 1998b).

3.1.2 Source Testing

Source sampling provides a "snapshot" of emissions during the period of the test. EPA has promulgated several test methods for performing source testing at printing and graphic arts facilities. These methods are outlined in Section 5.1 of this document. Because there are many steps in the source sampling procedures were errors can occur, only experienced source testers should perform such tests. Source sampling methods are available to measure VOC and HAP emissions. For further guidance on when source testing may be appropriate/required, contact your federal, state, or local agencies.

3.1.3 Emission Factors

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant (e.g., pound of VOC emitted per gallon of ink applied). Emission factors are available for some printing operations and are based on the results of source tests or material balances performed for one or more facilities within an industry. Chapter 1, *Introduction to Point Source Emission Inventory Development*, contains a detailed discussion of the reliability and quality of available emission factors. The EPA provides compiled emission factors for criteria and hazardous air pollutants in AP-42 (EPA, 1995c) and the Factor Information Retrieval (FIRE) System (EPA, 1999a). Refer to Chapter 1, *Introduction to Point Source Emission Inventory Development*, of this series for a complete discussion of available information sources for locating, developing, and using emission factors as an estimation technique.

Due to their availability and acceptance, emission factors are commonly used to prepare emission inventories. However, the emissions estimate obtained from using emission factors is likely to be based upon emission testing performed at similar but not identical facilities and may not accurately reflect emissions at a single source. Thus, the user should recognize that, in most cases, emission factors are averages of available industry-wide data with varying degrees of quality and uncertainty, and may not be representative for an individual facility within that industry.

Source-specific emission factors can be developed from multiple source test data, predictive emissions monitoring data, or from single source tests. These factors, when used for the specific operations for which they are intended, are generally more representative than the average emission factors found in AP-42 (EPA, 1995c) or FIRE (EPA, 1999a).

3.2 COMPARISON OF AVAILABLE EMISSION ESTIMATION METHODOLOGIES

Table 15.3-1 identifies the preferred and alternative emission estimation approaches for selected pollutants for the printing and graphic arts industry. For many of the pollutants emitted from the printing and graphic arts industry, several of the previously defined emission estimation methodologies can be used.

TABLE 15.3-1

SUMMARY OF PREFERRED AND ALTERNATIVE EMISSION ESTIMATION METHODS FOR THE PRINTING AND GRAPHIC ARTS INDUSTRY

Parameter	**Preferred Emission Estimation Approach**	**Alternative Emission Estimation Approach**
VOC	Material Balance	Source Testing Emission Factor
HAP	Material Balance	Source Testing Emission Factor

The preferred method for estimating VOC and HAP emissions is material balance. Source testing may provide accurate emission estimates, but the quality of the data will depend on a variety of factors, including the number of data points generated, the representativeness of those data points, and the proper operation and maintenance of the equipment being used to record the measurements.

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4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

4.1 MATERIAL BALANCE APPROACH

Emissions from the materials used in the four fundamental process operations (imaging, pre-press, printing, and post-press processes) can be calculated using the mass balance approach described below. The equations presented below apply to more than one process operation (i.e., emission point). For example, cleaning solutions may be used in both the pre-press step and the printing step.

4.1.1 CALCULATION OF EMISSIONS FROM EACH EMISSIONS SOURCE

If control devices are in place, the emissions from each VOC/HAP-containing material (i.e., inks, fountain solutions, cleaning solvents, and coatings) can be calculated as follows:

$$E_{material} = V * (1 - R/100) * (1 - [K/100 * J/100]) \qquad (15.4\text{-}1)$$

Where: $V = U * (W/100)$ or $G * C$

Where:

$E_{material}$	=	Emissions, of VOC/HAP material, lb
U	=	Material Usage, lb
W	=	VOC/HAP Content, % by weight
R	=	% VOC/HAP Retained on Substrate
K	=	Control Efficiency, %
J	=	Capture Efficiency, %
V	=	VOC/HAP Content, lb
G	=	Material Usage, gal
C	=	VOC/HAP Content, lb/gal

VOCs/HAPs that are captured and re-introduced to the process do not count as being controlled. If no control device is in place, the equation simplifies to:

$$E_{material} = V * (1 - R/100). \qquad (15.4\text{-}2)$$

A detailed discussion of the factors assumed for the amount of each material retained on the substrate can be found in *Control Of Volatile Organic Compound Emissions From Offset Lithographic Printing, Guideline Series {Draft}* (EPA, 1995b) and *Alternative Control Techniques Document: Offset Lithographic Printing (ACT)* (EPA, 1994a). The documents addressing retention factors address lithography only. Similar materials are often used in letterpress operations, so it is reasonable to assume the same retention factors in letterpress emission estimates, depending on the specific material and process configuration. The specific retention factors in these documents are not applicable for flexography, gravure, or screen printing, though the concept of retention may apply.

A detailed discussion of capture efficiency determination can be found in the *Guidelines for Determining Capture Efficiency* (EPA, 1995d). The ACT (EPA, 1994a) also provides a detailed discussion on capture efficiencies, particularly in distinguishing between indirect and direct capture efficiencies. Indirect capture efficiency refers to VOC that is first dispersed in the press room air and is subsequently drawn into the dryer (and into a control device). Direct capture efficiency refers to the fraction of VOC (such as that contained in blanket wash) that is carried into the dryer on the substrate. Table 15.4-1 lists the web addresses where electronic versions of these useful documents are available. Federal, state, or local agencies should be able to provide guidance on the specific requirements for estimating and reporting capture efficiency.

VOC content can be determined using EPA Test Method 24. Method 24A is appropriate when determining VOC-content of publication gravure inks and coatings. HAP-content can be determined using EPA Method 311, or in situations where all the HAPs are also VOC, then Method 24 or 24A is appropriate. Copies of these documents are available at http://www.epa.gov/ttn/emc/promgate.html. Material safety data sheets (MSDS) may also be useful in determining VOC- and HAP-content.

EPA Test Methods 25 and 25A can be used to determine control device efficiency. They are also available at http://www.epa.gov/ttn/emc/promgate.html. The ACT (EPA, 1994a) provides guidance regarding when to use Method 25 and when to use Method 25A.

4.1.2 Combustion Sources

Refer to EIIP Volume II, Chapter 2 on calculating emissions from combustion sources.

4.1.3 Facility Totals

The following approaches can be used to calculate total emissions from a facility, based on the printing process used.

TABLE 15.4-1

REFERENCES FOR RETENTION FACTORS AND CAPTURE EFFICIENCIES AVAILABLE ON THE INTERNET

Document	Internet Address
Alternative Control Techniques Document : Offset Lithographic Printing (EPA, 1994a)	http://www.epa.gov/ttnuatw1/print/printpg.html
Guidelines for Determining Capture Efficiency (EPA, 1995d)	http://www.epa.gov/ttncaaa1/t1/meta/m28508.html
Printer's Plain Language Workbook (EPA, 1999f)	http://www.epa.gov/ooaujeag/sectors/pdf/lngwkbk.pdf
Background Information Document (BID) for Final NESHAP for Printing	http://www.epa.gov/ttn/uatw/print/prbid2.pdf
EPA Test Methods 204, 204 a-f	http://www.epa.gov/ttn/emc/promgate.html
Potential to Emit (PTE) Guidance for Specific Source Categories (EPA, 1998b)	http://www.epa.gov/ttn/oarpg/t3/meta/m29616.html

Lithography

Total emissions for a facility can then be calculated by summing the emissions from usage of the various materials as follows:

$$E_{Total} = E_{ink} + E_{fountain\ solutions} + E_{hand\ cleaning\ solutions} + E_{automatic\ blanket\ wash} + E_{coatings/adhesives} + E_{other} \quad (15.4\text{-}3)$$

Where:

E_{total} = Emissions, total, lb
E_{ink} = Emissions, ink, lb
$E_{fountain\ solutions}$ = Emissions, fountain solutions, lb
$E_{cleaning\ solutions}$ = Emission, cleaning solutions, lb
$E_{automatic\ blanket\ wash}$ = Emissions, automatic blanket wash, lb
$E_{coating/adhesives}$ = Emissions, coatings/adhesives, lb
E_{other} = Emissions, other VOC - or HAP containing materials, lb

Flexography, Gravure, and Screen Printing

Total emissions for a facility can then be calculated by summing the emissions from usage of the various materials as follows:

$$E_{Total} = E_{ink} + E_{dilution\ solvent} + E_{cleaning\ solutions} + E_{coatings/adhesives} + E_{other} \quad (15.4\text{-}4)$$

Where:

E_{total}	=	Emissions, total, lb
E_{ink}	=	Emissions, ink, lb
$E_{dilution\ solvent}$	=	Emissions, dilution solvent, lb
$E_{cleaning\ solutions}$	=	Emission, hand cleaning solutions, lb
$E_{coating/adhesives}$	=	Emissions, coatings/adhesives, lb
E_{other}	=	Emissions, other VOC - or HAP containing materials, lb

Letterpress

Total emissions for a facility can then be calculated by summing the emissions from usage of the various materials as follows:

$$E_{Total} = E_{ink} + E_{cleaning\ solutions} + E_{coatings/adhesives} + E_{other} \quad (15.4\text{-}5)$$

Where:

E_{total}	=	Emissions, total, lb
E_{ink}	=	Emissions, ink, lb
$E_{cleaning\ solutions}$	=	Emission, cleaning solutions, lb
$E_{coating}$	=	Emissions, coatings/adhesives, lb
E_{other}	=	Emissions, other VOC - or HAP containing materials, lb

4.1.4 Emissions Calculations When Using EPA Methods 204 and 204a-f

EPA has promulgated Methods 204 and 204a-f to determine site-specific capture efficiencies. A detailed description of each of these test methods is not presented in this document. Instead, readers are referred to the EPA website for a complete methodology for each of these test procedures. Table 15.5-1 lists each of these test methods and its internet address. A complete list

TABLE 15.4-2

EPA TEST METHODS FOR DETERMINING CAPTURE EFFICIENCY

Promulgated Test Method	Internet Address
Method 204-204f Preamble	http://www.epa.gov/ttn/emc/promgate/pre204.pdf
Method 204 - Permanent or Temporary Total Enclosure (TTE) for Determining Capture Efficiency	http://www.epa.gov/ttn/emc/promgate/m-204.pdf
Method 204a - VOCs in Liquid Input Stream	http://www.epa.gov/ttn/emc/promgate/m-204a.pdf
Method 204b - VOCs in Captured Stream	http://www.epa.gov/ttn/emc/promgate/m-204b.pdf
Method 204c - VOCs in Captured Stream (Dilution Technique)	http://www.epa.gov/ttn/emc/promgate/m-204c.pdf
Method 204d - Fugitive VOCs from Temporary Total Enclosure	http://www.epa.gov/ttn/emc/promgate/m-204d.pdf
Method 204e - Fugitive VOCs from Building Enclosure	http://www.epa.gov/ttn/emc/promgate/m-204e.pdf
Method 204f - VOCs in Liquid Input Stream (Distillation)	http://www.epa.gov/ttn/emc/promgate/m-204f.pdf

of all EPA Emissions Measurement Center (EMC) promulgated test methods is available at www.epa.gov/ttn/emc/promgate.html.

4.1.5 EXAMPLE CALCULATIONS

The following pages provide example calculations for each of the printing processes described in this document. Example 15.4-1 provides sample calculations for lithography, 15.4-2 for flexography, 15.4-3 for gravure, 15.4-4 for screen printing, and 15.4-5 for letterpress. These sample calculations can be used for estimating HAP emissions

Example 15.4-1

Part A:
A print shop using a sheetfed lithography process reports the following material usage:

Material	Annual Use	Unit	VOC Content (Percent by weight or lb/gal)	HAP Content (% by VOC weight or lb/gal)
Ink	19,000	lb	35%	0%
Fountain Solution: Concentrate	300	gal	1.85 lb/gal	Ethylene Glycol, 100%
Fountain Solution: Additive	100	gal	4.5 lb/gal	2-Butoxyethanol, 82% Ethylene Glycol, 18%
Automatic Blanket Wash	7,750	gal	0.8 lb/gal	Naphthalene, 0.296 lb/gal 2-Butoxyethanol, 0.144 lb/gal
Cleaning Solution	2,212.5	gal	0.8 lb/gal	Naphthalene, 0.16 lb/gal
Coating: UV	1,530	lb	2%	0%
Coating: Conventional	6,003	lb	35%	0%

No control devices are in place for this particular facility. According to the ACT (EPA, 1994a), it can be assumed that 95 percent of the ink and conventional coating (i.e., varnish) VOC is retained in the substrate. A 50% retention factor is assumed for cleaning solutions, since soiled towels are kept in a closed container and have a vapor pressure of less than 10 mmHg at 20°C. Therefore, the emissions can be calculated as described below.

Ink Emissions

With no control device in place, VOC emissions are calculated using equation 15.4-2.

$$
\begin{aligned}
E_{VOC}\text{ (ink)} &= U * (W/100) * (1 - R/100) \\
&= (19{,}000 \text{ lb/year}) * (35/100) * (1-95/100) \\
&= 332.5 \text{ lb VOC/year from ink usage}
\end{aligned}
$$

Note: In this example, the ink is 0% HAP by weight, therefore, no HAPs are emitted from the ink.

Example 15.4-1 (Continued)

Fountain Solution Emissions

With no control device in place, VOC and HAP emissions are calculated using equation 15.4-2.

E_{VOC} (Concentrate) = U * (W/100) * (1 - R/100)
= (300 gal/year) * (1.85 lb/gal)*(1-0/100)
= 555 lb VOC/year from fountain solution concentrate usage

E_{VOC} (Additive) = U * (W/100) * (1 - R/100)
= (100 gal/year) * (4.5 lb/gal) * (1-0/100)
= 450 lb VOC/year from fountain solution additive usage

E_{VOC} (Total, Fountain Solution) = E_{VOC} (Concentrate) + E_{VOC} (Additive)
= 555 lb VOC/year + 450 lb VOC/year
= 1055 lb VOC/year

E_{HAP} (Concentrate) = U * (W/100) * (1 - R/100)
= (300 gal/year) * (1.85 lb/gal) * (1 - 0/100)
= 555 lb HAP

E_{HAP} (Additive) = U * (W/100) * (1 - R/100)
= (100 gal/year) * 4.50 * ((82+18)/100) * (1-0/100)
= 450 lb HAP

E_{HAP} (Total, Fountain Solution) = E_{HAP} (Concentrate) + E_{HAP} (Additive)
= 555 lb + 450 lb HAP/year
= 1050 lb HAP/year

Cleaning Solution Emissions

With no control device in place, VOC and HAP emissions are calculated using equation 15.4-2.

E_{VOC} (Automatic Blanket Wash) = G * C * (1 - R/100)
= (7,750 lb/year) * (0.8) * (1 - 0/100)
= 6,200 lb VOC/year

Example 15.4-1 (Continued)

E_{VOC} (Cleaning Solutions) = G * C * (1 - R/100)
= (2,212.5) * (0.8) * (1-50/100)
= 885 lb VOC/year

E_{VOC} (Total, Cleaning Solutions) = E_{VOC} (Automatic Blanket Wash) + E_{VOC} (Hand Cleaning Solutions)
= 6,200 lb VOC/year + 885 lb VOC/year
= 7,085 lb VOC/year

E_{HAP} (Automatic Blanket Wash) = G * C * (1 - R/100)
= (7,750) * (0.296 + 0.144) * (1 - 0/100)
= 3,410 lb HAP/year

E_{HAP} (Cleaning Solutions) = G * C * (1 - R/100)
= (2,212.5) * (0.16) * (1-50/100)
= 177 lb HAP/year

E_{HAP} (Total, Cleaning Solution) = E_{HAP} (Automatic Blanket Wash) + E_{HAP} (Hand Cleaning Solutions)
= 3,410 (lb HAP/year) + 177 (lb HAP/year)
= 3,587 lb HAP/year

Coating Emissions

With no control device in place, VOC emissions are calculated using equation 15.4-2.

E_{VOC} (UV Coating) = U * (W/100) * (1 - R/100)
= (1,530 lb/year) * (2/100) * (1-0/100)
= 31 lb VOC/year

E_{VOC} (Conventional Coating) = U * (W/100) * (1 - R/100)
= (6,003 lb/year) * (35/100) * (1-95/100)
= 105 lb VOC/year

E_{VOC} (Total, Coating) = E_{VOC} (UV Coating) + E_{VOC} (Conventional Coating)
= 31 lb VOC/year + 105 lb VOC/year
= 136 lb VOC/year

Example 15.4-1 (Continued)

Note: In this example, the coatings are 0 percent HAP by weight, therefore, no HAPs are emitted.

Facility Totals

Total HAP and VOC emissions for this facility are then calculated using equation 15.4-3.

E_{total} = $E_{ink} + E_{fountain\ solutions} + E_{cleaning\ solutions} + E_{coating}$

E_{VOC} = 332.5 lb VOC/year + 1050 lb VOC/year + 7,085 lb VOC/year + 136 lb VOC/year
= 8,603.5 lb VOC/year

E_{HAP} = 0 lb HAP/year + 1050 lb HAP/year + 3,587 lb HAP/year + 0 lb HAP/year
= 4,637 lb HAP/year

Example 15.4-1 (Continued)

Part B:
A print shop using a heatset web offset lithographic process reports the following material usage:

Material	Annual Use	Unit	VOC Content (Percent by weight or lb/gal)	HAP Content (% by VOC weight or lb/gal)
Ink	100,000	lbs	45%	0%
Fountain Solution: Concentrate	300	gal	1.85 lb/gal	Ethylene Glycol, 1.85 lb/gal
Fountain Solution: Additive	100	gal	4.5 lb/gal	2-Butoxyethanol, 4.5 lb/gal
Automatic Blanket Wash	500	gal	6.48 lb/gal	Xylene, 0.10 lb/gal Cumene, 0.08 lb/gal
Hand Cleaning Solution	1,000	gal	6.73 lb/gal	Naphthalene, 0.16 lb/gal 2-Butoxyethanol, 0.14 lb/gal
Coating: UV	1,500	lb	1%	0%
Coating: Conventional	10,000	lb	40%	0%

An oxidizer with a destruction efficiency of 95% is in place for this particular facility. According to the ACT for Offset Lithography (EPA, 1994a), it can be assumed that 20 percent of the ink and conventional coating (i.e., varnish) VOC is retained in the substrate and the remaining 80% if completely captured in the dryer. A 70% capture efficiency can be used for fountain solutions utilizing alcohol substitutes. In this example, a 40% capture efficiency can be used for automatic blanket washes with composite VOC vapor pressures of less than 10 mmHg at 20°C. A 50% retention factor can be assumed for hand cleaning solutions, since soiled towels are kept in a closed container and have a composite VOC vapor pressure of less than 10 mmHg at 20°C. Therefore, the emissions can be calculated as described below.

Ink Emissions

With a 95% efficient oxidizer in place, VOC emissions are calculated using equation 15.4-1.

E_{VOC} (Ink) = V * (1 - R/100) * (1 - [K/100 * J/100])
V = (100,000 lb/year * (45/100) = 45,000 E_{VOC} (Ink) = 45,000 * (1 - 80/100) * (1 - [95/100 * 100/100])
= 1,800 lb VOC/year from ink usage

Note: In this example, the ink is 0% HAP by weight, therefore, no HAPs are emitted from the ink.

Example 15.4-1 (Continued)

Fountain Solution Emissions

With a 95% efficient oxidizer in place, VOC emissions are calculated using equation 15.4-1.

E_{VOC} (Concentrate)	= V * (1 - R/100) * (1 - [K/100 * J/100])
	V = (300 * 1.85) = 555 lb
E_{VOC} (Concentrate)	= 555 * (1 - 0/100) * (1 - [95/100 * 70/100])
	= 186 lb VOC/year from fountain solution concentrate usage
E_{VOC} (Additive)	= V * (1 - R/100) * (1 - [K/100 * J/100])
	V = (100 * 4.5) = 450 lb
E_{VOC} (Additive)	= 450 * (1 - 0/100) * (1 - [95/100 * 70/100])
	= 151 lb VOC/year from fountain solution concentrate usage
E_{VOC} (Total, Fountain Solution)	= E_{VOC} (Concentrate) + E_{VOC} (Additive)
	= 186 lb/year VOC + 151 lb/year VOC
	= 337 lb HAP/year
E_{HAP} (Concentrate)	= V * (1 - R/100) * (1 - [K/100 * J/100])
	V = (300 * 1.85) = 555 lb
E_{HAP} (Concentrate)	= 555 * (1 - 0/100) * (1 - [95/100 * 70/100])
	= 186 lb HAP/year from fountain solution concentrate usage
E_{HAP} (Additive)	= V * (1 - R/100) * (1 - [K/100 * J/100])
	V = (100 * 4.5) = 450 lb
E_{HAP} (Additive)	= 450 * (1 - 0/100) * (1 - 95/100 * 70/100])
	= 151 lb HAP/year from fountain solution concentrate usage
E_{HAP} (Total Fountain Solution)	= E_{HAP} (Concentrate) + E_{HAP} (Additive)
	= 186 lb/year HAP + 151 lb/year HAP
	= 337 lb HAP/year

Example 15.4-1 (Continued)

Cleaning Solution Emissions

With a 95% efficient oxidizer in place, VOC emissions from the automatic blanket wash are calculated using equation 15.4-1.

E_{VOC} (Automatic Blanket Wash)	=	V * (1 - R/100) * (1 - [K/100 * J/100])
		V = (500 * 6.48) = 3,240 lb
E_{VOC} (Automatic Blanket Wash)	=	3,240 * (1 - 0/100) * (1 - 95/100 * 40/100])
	=	2,009 lb VOC/year from auto blanket wash usage

Since hand washing does not occur while the dryer is running, VOC emissions from the hand wash cleaning solution are calculated using equation 15.4-2.

E_{VOC} (Hand Wash)	=	V * (1 - R/100)
		V = (1,000 * 6.73) = 6,730 lb
E_{VOC} (Hand Wash)	=	6,730 * (1 - 50/100)
	=	3,365 lb VOC/year from hand wash usage
E_{VOC} (Total, Cleaning Solution)	=	E_{VOC} (Auto Blanket Wash) + E_{VOC} (Hand Wash)
	=	2,009 lb/year VOC + 3,365 lb/year VOC
	=	5,374 lb VOC/year
E_{HAP} (Automatic Blanket Wash)	=	V * (1 - R/100) * (1 - [K/100 * J/100])
		= (500 * 0.18) = 90 lb
E_{HAP} (Automatic Blanket Wash)	=	90 * (1 - 0/100) * (1 - [95/100 * 40/100])
	=	56 lb HAP/year from automatic blanket wash usage
E_{HAP} (Hand Wash)	=	V * (1 - R/100)
		V = (1,000 * 0.3) = 300
E_{HAP} (Handwash)	=	300 * (1 - 50/100)
	=	150 lb HAP/year from hand wash usage
E_{HAP} (Total, Cleaning Solution)	=	E_{HAP} (Auto Blanket Wash) + E_{HAP} (Hand)
	=	56 lb/year HAP + 150 lb/year HAP
	=	206 lb HAP/year

Example 15.4-1 (Continued)

Coating Emissions

Since the conventional coating in this example is applied before the dryer ducted to a 95% efficient oxidizer, VOC emissions from the coating are calculated using equation 15.4-1.

E_{VOC} (Conventional Coating) = V * (1 - R/100) * (1 - [K/100 * J/100])
V = (10,000 * 45/100) = 4,500 lb
E_{VOC} (Conventional Coating) = 4,500 * (1 - 80/100) * (1 - [95/100 * 100/100])
= 180 lb VOC/year from conventional coating usage

Since the UV coating in this example is applied after the dryer, VOC emissions from the coating are calculated using equation 15.4-2.

E_{VOC} (UV Coating) = V * (1 - R/100)
V = (1,500 * 1/100) = 15 lb
E_{VOC} (UV Coating) = 15 * (1 - 0/100)
= 15 lb VOC/year from hand wash usage

E_{VOC} (Total, Coating) = E_{VOC} (Conventional Coating) + E_{VOC} (UV Coating)
= 180 lb/year VOC + 15 lb/year VOC
= 195 lb VOC/year

Note: In this example, the coating is 0% HAP by weight, therefore, no HAPs are emitted from the coating.

Facility Totals

Total HAP an d VOC emissions for this facility are then calculated using equation 15.4-3.

E_{total} = E_{ink} + $E_{fountain\ solutions}$ +$E_{cleaning\ solutions}$ + $E_{coating}$

E_{VOC} = 1,800 lb VOC/year + 337 lb VOC /year + 5,374 lb VOC/year + 195 lb VOC/year
= 7,706 lb VOC/year

E_{HAP} = 0 lb HAP/year + 337 lb HAP/year + 206 lb HAP year + 0 lb HAP/year
= 543 lb HAP/year

Example 15.4-2

A flexography printing operation reported using a thermal incinerator with a 95% control device efficiency. The press is in an enclosure that has 70% capture efficiency, based on EPA Method 204 test results. The facility reported following annual material usage, and associated VOC content, based on EPA Method 24 test results:

Material	Annual Use (lb)	VOC Content (by weight)
Ink	30,000	18%
Dilution Solvent	15,000	25%
Cleaning Solution	9,000	40%

The plant engineer calculated this facility's emissions as follows, using equations 15.4-1 through 15.4-3:

E_{VOC} (Ink) = U * (M/100) * (1-R/100) * [1 - (K/100 * J/100)]
= (30,000 lb/year) * (18/100) * (1-0/100) * [1 - (95/100 * 70/100)]
= 1,809 lb VOC/year

E_{VOC} (Dilution Solvent) = G * C * (1-R/100) * [1 - (K/100 * J/100)]
= (15,000 lb/year) * (25/100) * (1-0/100) * [1 - (95/100 * 70/100)]
= 1,256 lb VOC/year

E_{VOC} (Cleaning Solution) = G * C * (1-R/100) * [1 - (K/100 * J/100)]
= (9,000 lb/year) * (40/100) * (1-50/100) * [1 - (95/100 * 70/100)]
= 603 lb VOC/year

E_{VOC} = $E_{ink} + E_{dilution\ solvents} + E_{cleaning\ solutions}$
= 1,809 lb/year + 1,256 lb/year + 603 lb/year
= 3,668 lb/year

Note: Calculation of emissions involving numerous inks, coatings, solvents, and other materials will require separate calculations such as presented here for each of the numerous inks being used with the different formulas at a given facility.

Example 15.4-3

A gravure printing operation reported using a carbon adsorber on its ink press with a 75% overall control efficiency, based on test results from a liquid-liquid mass balance (i.e., K/100 * J/100 * 0.75). The facility reported following annual material usage, and associated VOC content, based on EPA Method 24a test results:

Material	Annual Use	Unit	VOC Content (% by weight or lb/gal)
Ink	75,000	lb	12%
Dilution Solvent	37,500	gal	0.256 lb/gal
Cleaning Solution	22,500	gal	0.44 lb/gal
Coating	45,000	lb	10%

The plant engineer calculated this facility's emissions as follows, using equations 15.4-1 through 15.4-3:

E_{VOC} (Ink) = U * (M/100) * (1-R/100) * [1 - (K/100 * J/100)]
= (75,000 lb/year) * (12/100) * (1 - 0/100) * [1 - (0.75])
= 2,250 lb VOC/year

E_{VOC} (Dilution Solvent) = G * C * (1-R/100) * [1 - (K/100 * J/100)]
= (37,500) * (0.256) * (1-0/100) * [1 - (0.75)]
= 2,400 lb VOC/year

E_{VOC} (Cleaning Solution) = G * C * (1 - R/100)
= (22,500) * (0.44) * (1 - 0/100)
= 9,900 lb VOC/year

E_{VOC} (Coating) = U * (M/100) * (1 - R/100)
= (45,000 lb/year) * (10/100) * (1-0/100)
= 4,500 lb VOC/year

E_{VOC} = $E_{ink} + E_{dilution\ solvents} + E_{cleaning\ solutions} + E_{coating}$
= 2,250 lb/year + 2,400 lb/year + 9,900 lb/year
4,500 lb/year
= 19,050 lb/year

Note: Calculation of emissions involving numerous inks, coatings, solvents, and other materials will require separate calculations such as presented here for each of the numerous inks being used with the different formulas at a given facility.

Example 15.4-4

A screen printing shop reported the following annual material usage:

Material	Annual Use (gal)	VOC Content (lb/gal)	HAP Content (lb/gal)
Ink	2,000	1.5	0
Cleaning Solution	9,375	0.32	Toluene, 0.16
Haze Remover	667	0.48	0
Adhesive	312.5	3	1,1,1-Trichloroethylene, 0.2

The plant engineer calculated this facility's emissions as follows, using equations 15.4-2 and 15.4-3:

E_{VOC} (Ink) = G * (1 - R/100)
= (2,000) * (1.5) * (1 - 0/100)
= 3,000 lb VOC/year

E_{VOC} (Cleaning Solution) = G * C * (1 - R/100)
= (9,375) * (0.32) * (1-0/100)
= 3,000 lb VOC/year

E_{HAP} (Cleaning Solution) = G * C * (1 - R/100)
= (9,375) * (0.16) * (1-0/100)
= 1,500 lb HAP/year

E_{VOC} (Haze Remover) = G * C * (1 - R /100)
= (667) * (0.48) * (1 - 0/100)
= 320 lb VOC/year

E_{VOC} (Adhesive) = G * C * (1 - R/100)
= (312.5) * (3) * (1 - 0/100)
= 937.5 lb VOC/year

E_{HAP} (Adhesive) = G * C * (1 - R/100)
= (312.5) * (0.2) * (1 - 0/100)
= 62.5 lb HAP/year

Example 15.4-4 (Continued)

E_{total} = $E_{ink} + E_{cleaning\ solutions} + E_{coating/adhesive} + E_{0ther}$

E_{VOC} = 3,000 lb VOC/year + 3,000 lb VOC/year + 320 lb VOC/year + 937.5 lb VOC/year
= 7257.5 lb VOC/year

E_{HAP} = 1,500 lb HAP/year + 62.5 lb HAP/year
= 1,562.5 lb HAP/year

Note: Calculation of emissions involving numerous inks, coatings, solvents, and other materials will require separate calculations such as presented here for each of the numerous inks being used with the different formulas at a given facility.

Example 15.4-5

A print shop using a letterpress process reports the following material usage:

Material	Annual Use (lb)	VOC Content (by weight)	HAP Content (by weight)
Ink	92,500	15%	0%
Cleaning Solution: Concentrate	32,500	100%	Toluene 60%
Coating: Conventional	8,500	30%	0%

This facility uses no add-on control devices. It's cleaning solution has a vapor pressure of less than 10 mm Hg at 20°C and rags are kept in a closed container. Therefore, a 50% retention factor can be assumed for cleaning solutions. Letterpress inks and conventional coatings are virtually identical to lithographic inks. Therefore, a 95% retention factor is assumed for this non-heat set press. Emissions are calculated as follows:

Ink Emissions

VOC emissions are calculated using equations 15.4-1.

E_{voc} (Ink) = U * (M/100) * (1 - R/100)
= (92,500 lb/year) * (15/100) * (1-95/100)
= 694 lb/year VOC

Cleaning Solution Emissions

VOC/HAP emissions are calculated using equations 15.4-2.

E_{VOC} (Cleaning Solution) = U * (M/100) * (1 - R/100)
= (32,000 lb/year) * (100/100) * (1-50/100)
= 16,000 lb VOC/year

E_{HAP} (Cleaning Solution) = U * (M/100) * (1 - R/100)
= (32,000 lb/year) * (60/l00) * (1-50/100)
= 9,600 lb HAP/year

Example 15.4-5 (Continued)

Coating Emissions

VOC emissions are calculated using equations 15.4-2.

E_{VOC} (Coating) = U * (M/100) * (1 - R/100)
= (8,500 lb/year) * (30/100) * (1- 95/100)
= 128 lb VOC/year

Facility Totals

Total HAP and VOC emissions for this facility are then calculated using equation 15.4-5.

E_{total} = $E_{ink} + E_{cleaning\ solutions} + E_{coating\ adhesives}$

E_{VOC} = 694 lb VOC/year + 16,000 lb VOC/year + 128 lb VOC/year
= 16,822 lb VOC/year

E_{HAP} = 0 lb HAP/year + 9,600 lb HAP/year + 0 1b HAP/year
= 9,600 lb HAP/year

Note: Calculation of emissions involving numerous inks, coatings, solvents, and other materials will require separate calculations such as presented here for each of the numerous inks being used with the different formulas at a given facility.

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

Where there is a choice of methods, material balance is generally preferred over an emission factor unless the assumptions needed to perform a material balance have a high degree of uncertainty and/or the emission factor is site-specific.

For the printing and graphic arts industry, source testing and emission factors are the alternative methods for estimating VOC and HAP emissions.

5.1 EMISSIONS CALCULATIONS USING EMISSION FACTORS

Emission factors can be used when site-specific monitoring data are unavailable. The EPA maintains AP-42 (EPA, 1995c), a compilation of approved emission factors for criteria pollutants and HAP. Another comprehensive source of available air pollutant emission factors from numerous sources is the FIRE system (EPA, 1999a). Refer to Chapter 1, *Introduction to Point Source Emission Inventory Development*, of this series for a complete discussion of available information sources for locating, developing, and using emission factors as an estimation technique.

The basic equation used to calculate emissions using an emission factor is shown in Equation 15.5-1.

$$E_x = EF_x * AF \qquad (15.5\text{-}1)$$

Where:

E_x = Emissions of pollutant x
EF_x = Emission factor of pollutant x
AF = Activity factor

Example 15.5-1 shows how VOC emissions may be calculated for a printing operation.

Example 15.5-1

A publication gravure printing press uses 45,000 gallons of ink annually. A carbon adsorber with an overall control efficiency of 85 percent is currently in place at the facility. Table 4.9.2-1 from *AP-42* gives us an emission factor of 1.86 lb total VOC/gallon of ink used, including the 85% control efficiency (12.40 lb VOC/gallon was the uncontrolled emission factor presented in this table). The VOC emissions were calculated as follows:

$$E_{VOC} = EF_{VOC} * AF$$
$$= 1.86 \text{ lb/gal} * 45{,}000 \text{ gallons of ink used/year}$$
$$= 83{,}700 \text{ lb VOC/year}$$

6

QUALITY ASSURANCE/QUALITY CONTROL

The consistent use of standardized methods and procedures is essential in the compilation of reliable emission inventories. Quality assurance (QA) and quality control (QC) of an inventory is accomplished through a set of procedures that ensure the quality and reliability of data collection and analysis. These procedures include the use of appropriate emission estimation techniques, applicable and reasonable assumptions, accuracy/logic checks of computer models, checks of calculations, and data reliability checks. Volume VI of this series, *Quality Assurance Procedures*, describes additional QA/QC methods and tools for performing these procedures.

Volume II, Chapter 1, *Introduction to Point Source Emission Inventory Development*, presents recommended standard procedures to follow to ensure that the reported inventory data are complete and accurate. Chapter 1 discusses preparation of a QA plan, development and use of QC checklists, and QA/QC procedures for specific emission estimation methods (e.g., emission factors). If further guidance is needed, federal, state, and local agencies should be able to provide guidance regarding specific reporting requirements.

Another useful document, “Guidelines for Determining Capture Efficiency,” can be found at http://www.epa.gov/ttn/emc/guidlnd.html (EPA, 1995d). This document presents details of the EPA approved test methods for determining capture efficiency, which is critical to determining the effectiveness of VOC emission control systems. The document also provides the data quality objective (DQO) and lower confidence limit (LCL) approaches for validating alternative test methods. The DQO and LCL methods are sets of approval criteria which, when met by the data obtained with any given protocol of process parameter measurement procedures, may be used to determine capture efficiency (CE). EPA Method 204 and 204a-f (EPA, 1997) also document procedures using Permanent Total Enclosures and Temporary Total Enclosures to determine capture efficiency.

6.1 QA/QC FOR USING MATERIAL BALANCE

The material balance method for estimating emissions may use various approaches; the QA/QC considerations will also vary and may be specific to an approach. Generally, the fates of all materials of interest are identified, and then the quantity of material allocated to each fate determined. Identifying these fates, such as material contained in a product or material leaving the process in the wastewater, is usually straightforward. However, estimating the amount of material allocated to each fate may be complicated and is the prime QA/QC consideration in using the material balance approach. Amounts obtained by direct measurement are more accurate and produce emission estimates of higher quality than those obtained by engineering or theoretical calculations. QA/QC of an emissions estimate developed from a material balance approach should include a thorough check of all assumptions and calculations. Also, a reality check of the estimate in the context of the overall process is recommended.

6.2 QA/QC FOR USING EMISSION FACTORS

The use of emission factors is straightforward when the relationship between process data and emissions is direct and relatively uncomplicated. When using emission factors, the user should be aware of the quality indicator associated with the value. Emission factors published within EPA documents and electronic tools have a quality rating applied to them. The lower the quality rating, the more likely that a given emission factor may not be representative of the source type. The reliability and uncertainty of using emission factors as an emission estimation technique are discussed in detail in the QA/QC section of Chapter 1 of this volume.

6.3 QA/QC FOR USING SOURCE TEST DATA

Data collected via source testing must meet quality objectives. Source test data must be reviewed to ensure that the test was conducted under normal operating conditions, or under maximum operating conditions in some states, and that the results were generated according to an acceptable method for each pollutant of interest. Calculation and interpretation of accuracy for source testing methods are described in detail in the *Quality Assurance Handbook for Air Pollution Measurements Systems: Volume III. Stationary Source Specific Methods (Interim Edition)*.

The acceptance criteria, limits, and values for each control parameter associated with manual sampling methods, such as dry gas meter calibration, are summarized in Chapter 1 of this volume. The magnitudes of concentration and emission rate errors caused by a +10 percent error in various types of measurements (e.g., temperature) are also presented in Chapter 1 of this volume.

7

DATA CODING PROCEDURES

This section describes the methods and codes available for characterizing emission sources at graphic arts facilities. Consistent categorization and coding will result in greater uniformity among inventories. In addition, the procedures described here will assist the reader who is preparing data for input to the Aerometric Information Retrieval System (AIRS) or a similar database management system. The use of Source Classification Codes (SCCs) provided in Table 15.7-1 is recommended for describing various printing operations. Refer to the Clearinghouse for Inventories and Emission Factors (CHIEF) website for a complete listing of SCCs for printing and graphic arts facilities.

7.1 SOURCE CLASSIFICATION CODES

SCCs for various components of a printing and graphic art operation are presented in Table 15.7-1. These include the following:

- Lithography;
- Flexography;
- Gravure;
- Letterpress; and
- Screen Printing.

7.2 AIRS CONTROL DEVICE CODES

Control device codes applicable to printing and graphic art operations are presented in Table 15.7-2. These should be used to enter the type of applicable emission control device into the AIRS Facility Subsystem (AFS). The “099" control code may be used for miscellaneous control devices that do not have a unique identification code.

Note: At the time of publication, these control device codes were under review by the EPA. The reader should consult the EPA for the most current list of codes.

TABLE 15.7-1

SOURCE CLASSIFICATION CODES FOR PRINTING PROCESSES

Printing Process	Process Description	SCC	Units
Lithographic: SIC 2752	Lithographic: 2752	4-05-004-01	Tons Ink
	Lithographic: 2752	4-05-004-11	Tons Solvent in Ink
	Lithographic: 2752	4-05-004-12	Gallons Ink
	Lithographic: Isopropyl Alcohol Cleanup	4-05-004-13	Tons Solvent Used
	Flexographic: Propyl Alcohol Cleanup	4-05-004-14	Tons Solvent Consumed
	Offset Lithography: Dampening Solution with Alcohol Substitute	4-05-004-15	Tons of Substitute
	Offset Lithography: Dampening Solution with High Solvent Content	4-05-004-16	Tons of Pure Solvent
	Offset Lithography: Cleaning Solution: Water-based	4-05-004-17	Tons Used
	Offset Lithography: Dampening Solution with Isopropyl Alcohol	4-05-004-18	Tons Alcohol Used
	Offset Lithography: Heatset Ink Mixing	4-05-004-21	Tons Solvent in Ink
	Offset Lithography: Heatset Solvent Storage	4-05-004-22	Tons Solvent Stored
	Offset Lithography: Nonheated Lithographic Inks	4-05-004-31	Tons Ink
	Offset Lithography: Nonheated Lithographic Inks	4-05-004-32	Tons Solvent in Ink
	Offset Lithography: Nonheated Lithographic Inks	4-05-004-33	Gallons Ink
Flexographic: SIC 2759	Printing: Flexographic	4-05-003-01	Tons Ink
	Ink Thinning Solvent (Carbitol)	4-05-003-02	Tons Solvent Added
	Ink Thinning Solvent (Cellosolve)	4-05-003-03	Tons Solvent Added

TABLE 15.7-1

(CONTINUED)

Printing Process	Process Description	SCC	Units
Flexographic: SIC 2759 (Cont'd)	Ink Thinning Solvent (Ethyl Alcohol)	4-05-003-04	Tons Solvent Added
	Ink Thinning Solvent (Isopropyl Alcohol)	4-05-003-05	Tons Solvent Added
	Ink Thinning Solvent (n-Propyl Alcohol)	4-05-003-06	Tons Solvent Added
	Ink Thinning Solvent (Naphtha)	4-05-003-07	Tons Solvent Added
	Printing: Flexographic	4-05-003-11	Tons Solvent in Ink
	Printing: Flexographic	4-05-003-12	Gallons Ink
	Printing: Flexographic: Propyl Alcohol Cleanup	4-05-003-14	Tons Solvent Consumed
	Flexographic: Steam: Water-based	4-05-003-15	Tons Ink
	Flexographic: Steam: Water-based	4-05-003-16	Tons Solvent in Ink
	Flexographic: Steam: Water-based	4-05-003-17	Tons Solvent Stored
	Flexographic: Steam: Water-based in Ink	4-05-003-18	Tons Solvent in Ink
	Flexographic: Steam: Water-based Ink Storage	4-05-003-19	Tons Solvent Stored
Gravure: SIC 2754	Gravure: 2754	4-05-005-01	Tons Ink
	Ink Thinning Solvent: Dimethylformamide	4-05-005-02	Tons Solvent Added
	Ink Thinning Solvent: Ethyl Acetate	4-05-005-03	Tons Solvent Added
	Ink Thinning Solvent: Methyl Ethyl Ketone	4-05-005-06	Tons Solvent Added
	Ink Thinning Solvent: Methyl Isobutyl Ketone	4-05-005-07	Tons Solvent Added
	Ink Thinning Solvent: Toluene	4-05-005-10	Tons Solvent Added
	Gravure: 2754	4-05-005-11	Tons Solvent in Ink
	Gravure: 2754	4-05-005-12	Gallons Ink
	Gravure: 2754	4-05-005-13	Gallons Ink
	Gravure: Cleanup Solvent	4-05-005-14	Tons Solvent Consumed

TABLE 15.7-1

(CONTINUED)

Printing Process	Process Description	SCC	Units
Gravure: SIC 2754 (Cont'd)	Other Not Classified	4-05-005-97	Pounds Liquid Ink Consumed
	Ink Thinning Solvent: Other Not Specified	4-05-005-98	1000 Gallons Solvent
	Ink Thinning Solvent: Other Not Specified	4-05-005-99	Tons Solvent Added
Screen Printing: SIC 2759	Screen Printing	4-05-008-01	Tons Ink
	Cleaning Rags	4-05-008-02	Tons Solvent Used
	Screen Printing	4-05-008-11	Tons Solvent in Ink
	Screen Printing	4-05-008-12	Gallons Ink
Letterpress: SIC 2751	Letter Press	4-05-002-01	Tons Ink
	Ink Thinning Solvent (Kerosene)	4-05-002-02	Tons Solvent Added
	Ink Thinning Solvents (Mineral Solvents)	4-05-002-03	Tons Solvent Added
	Letter Press	4-05-002-11	Tons Solvent in Ink
	Printing: Letter Press	4-05-002-12	Gallons Ink
	Letterpress: Cleaning Solution	4-05-002-15	Tons Solvent Consumed
General Processes	Dryer	4-05-001-01	Tons Solvent in Ink
	Dryer	4-05-001-99	Gallons Ink
	Ink Mixing	4-05-006-01	Tons Solvent in Ink
	Solvent Storage	4-05-007-01	Tons Solvent Stored
	Specify in Comments Field	4-05-888-01	Process Unit-Year
	Specify in Comments Field	4-05-888-02	Process Unit-Year
	Specify in Comments Field	4-05-888-03	Process Unit-Year
	Specify in Comments Field	4-05-888-04	Process Unit-Year
	Specify in Comments Field	4-05-888-05	Process Unit-Year

TABLE 15.7-2

AIRS CONTROL DEVICE CODES FOR GRAPHIC ARTS PROCESSES[a]

Control Device	Code
Catalytic Afterburner	019
Catalytic Afterburner with Heat Exchanger	020
Direct Flame Afterburner	021
Direct Flame Afterburner with Heat Exchanger	022
Vapor Recovery Systems (Including Condensers,Hooding,Other Enclosures)	047
Activated Carbon Adsorption	048
Process Enclosed	054
Miscellaneous Control Device	099

[a]At the time of publication, these control device codes were under review by the EPA. The reader should consult the EPA for the most current list of codes.

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8

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