VOLUME III: CHAPTER 7

GRAPHIC ARTS

Final Report

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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

This chapter describes the procedures and recommended approaches for estimating emissions from graphic arts. Section 2 of this chapter contains a general description of the graphic arts category and an overview of available emission control technologies. Section 3 of this chapter provides an overview of available emission estimation methods. Section 4 presents the preferred emission estimation method for the graphic arts industry, and Section 5 presents alternative emission estimation techniques. Quality assurance/quality control (QA/QC) issues are discussed in Section 6. Data coding procedures are discussed in Section 7, and Section 8 is the reference section.

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SOURCE CATEGORY DESCRIPTION

The graphic arts industry can be divided by technology into six different printing segments: rotogravure, flexographic, offset lithographic, letterpress, screen, and plateless (xerographic, electrostatic, magnetic, thermal, ink-jet, etc.). The technology (i.e., the type of press equipment) dictates the types of inks and coatings that can be used and defines to a large extent the emissions and the control techniques that are applicable (Environmental Protection Agency [EPA], 1995a).

The printing industry can also be divided by the type of substrate that is used. Among the flexible substrates, paper, foil, and films are used. Paper can be further classified in many ways, including coated versus uncoated. Films include polyethylene and a number of other polymers. Rigid substrates include cardboard, vinyl, and metal cans. A given substrate may be printed upon using different technologies depending on factors such as the end use, quality requirements, quantity, cost, and environmental considerations (EPA, 1995a). Textiles are specifically excluded from the graphic arts operations source category.

A third way to segment the printing industry is by the type of product or end use. In general, the end use falls into the broad categories of publications, packaging, or products. Publication printing includes newspapers, magazines, books, and advertising. Packaging includes paper, plastic and foil bags, wrappers, cardboard cartons, and metal cans. Products include wall and floor covering, greeting cards, and paper towels. Various technologies can be used to print specific items within the broad categories (EPA, 1995a). Table 7.2-1 shows the six major types of printing and the types of products printed by each (EPA, 1995b).

Graphic arts operations are performed on printing presses that are made up of one or more "units." Each unit can print only one color. The substrate in graphic arts operations is either continuous and called a "web," or individual pieces of substrate called "sheets." The pattern that is printed on the substrate is called the "image."

The graphics arts industry includes operations classified by Standard Industrial Classification (SIC) Codes 2752 (Commercial Printing-Lithography), 2754 (Commercial Printing-Gravure), and 2759 (Commercial Printing Not Elsewhere Classified [n.e.c.], which includes letterpress, flexographic, screen, and other commercial printing). Other four-digit codes under major SIC Code 27 cover printing-related industries such as

TABLE 7.2-1

PRODUCTS PRINTED BY EACH GRAPHICS ARTS TECHNOLOGY[a]

Technology	Products
Rotogravure	Packaging, advertising, greeting cards, art books, catalogues, and directories
Flexography	Packaging, advertising newspapers, books, magazines, financial and legal document directories
Offset Lithography	Magazines, catalogues and directories, newspapers, books, stationary, financial and legal documents, advertising, journals, packaging, metal cans
Letterpress	Magazines, catalogues and directories, newspapers, books, stationary, financial and legal documents, advertising, journals, packaging, metal cans
Screen	Signs, electronics, wallpaper, greeting cards, ceramics, decals, banners, plastic bottles
Plateless	Images printed on paper by laser printers, xerographic copiers, fax machines, and ink jets

[a] Source: EPA, 1995a and 1995b.

publishing, book printing, and other printing-related service trades. Because graphic arts operations include not only those whose primary business involves printing, potentially any entities classified under the major SIC Code 27 may perform graphic arts operations. The SIC Codes 26 (Paper and Allied Products), 30 (Rubber and Miscellaneous Plastic Products), 32 (Stone, Clay, and Glass Products), 34 (Fabricated Metal Products), 39 (Miscellaneous Manufacturing Industries), and 86 (Membership Organizations) may also include graphic arts operations. Some of these operations may be inventoried as part of the industrial surface coating source category. Inventory preparers should take care to avoid double counting between these two source categories within an area source inventory. Also, the point source and area source inventory definitions of graphic arts and industrial surface coating should match. This is particularly important when subtracting point source emissions from total estimated emissions in order to get area source emissions. Table 7.2-2 lists the SIC Codes that are likely to have graphic arts operations.

The following six sections discuss the six types of graphic arts operations grouped by printing technology. The importance of the type of printing on a national level, in regard to total emissions, is likely to be a reflection of the product market share and ink sales data presented in Table 7.2-3. The importance of each type of printing on a regional and local level may differ from these national trends.

2.1 (ROTO)GRAVURE PRINTING

Gravure is a printing process in which an image is etched or engraved below the surface of a plate or cylinder. Nearly all gravure printing is done by rotogravure. On the gravure plate or cylinder (roto), the printing image consists of millions of minute cells. Gravure printing requires very fluid inks that flow from the cells to the substrate at high press speeds. Solventborne or waterborne ink systems can be used in gravure printing but these ink systems are not interchangeable. Both the printing cylinders and the drying systems are specific to the solvent system in use. Rotogravure printing is usually performed on a web (EPA, 1995b).

Rotogravure printing can be divided into publication and product/packaging segments. Publication gravure presses in the United States use solventborne (toluene/xylene-based) ink systems exclusively. Because of the expense and complexity of rotogravure cylinder engraving, it is particularly suited to long-run printing jobs. Packaging/product gravure inks include nitrocellulose and water-based inks (EPA, 1995b).

TABLE 7.2-2

SIC CODES THAT MAY INCLUDE GRAPHIC ARTS OPERATIONS[a] (EPA, 1995B)

SIC Code	Industry Description
2652	Set up paperboard boxes
2653	Corrugated and solid fiber boxes
2655	Fiber cans, drums, and similar products
2656	Sanitary food containers
2657	Folding paperboard boxes
2671	Paper coated and laminated, packaging
2672	Paper coated and laminated, n.e.c.
2673	Bags: plastics, laminated, and coated
2674	Bags: uncoated paper and multiwall
2676	Sanitary paper products
2677	Envelopes
2678	Stationary products
2679	Converted paper products, wall coverings, gift wrap, n.e.c.
271x	Newspapers
272x	Periodicals
2731	Book publishing
2732	Book printing
274x	Miscellaneous publishing
2752	Commercial printing, lithographic
2754	Commercial printing, gravure
2759	Commercial printing, n.e.c.
2761	Manifold business forms
2771	Greeting cards
3081	Unsupported plastics, film and sheet

TABLE 7.2-2

(CONTINUED)

SIC Code	Industry Description
3083	Laminated plastics, plate and sheet
3085	Plastic bottles
3089	Plastics, n.e.c.
3221	Glass containers
3411	Metal cans
3412	Metal barrels, drums, and pails
3466	Crowns and closures
3996	Floor coverings
86xx	Membership organizations

[a] n.e.c. = not elsewhere classified.

TABLE 7.2-3

DISTRIBUTION OF PRODUCTS AND INK SALES BY PRINTING TYPE

Type of Printing	Estimated Number of Facilities[a]	Estimated Percentage of Product Market Share[a]	Percentage of Ink Solvent Use[b]
Rotogravure	427	18	22
Flexography	1,587	18	16
Offset Lithography	54,000	47	35
Letterpress	21,000	8	8
Screen	21,000	3	part of remaining 19 percent
Plateless	unknown	3	

[a] Source: EPA, 1995a.
[b] Compiled from: Darnay, 1990; Renson, 1991; and National Association of Printing Ink Manufacturers, 1988.

Gravure ink solvents include alcohols, aliphatic naphtha, aromatic hydrocarbons, esters, glycol ethers, ketones, and nitroparaffins. Gravure water-based inks are in regular production use at some facilities to reduce volatile organic compound (VOC) emissions from the press (EPA, 1993a).

In rotogravure printing, the web is printed on one side at a time and must be dried after the application of each color. Thus, for four-color, two-sided publication printing, eightpasses through the press are employed, each including a pass over a steam drum or through a hot-air dryer at temperatures from ambient up to 120°C (250°F) to remove nearly all of the solvent (EPA, 1993a).

In addition to inks, other materials including adhesives, primers, coatings, and varnishes may be applied with rotogravure cylinders. These materials dry by evaporation as the substrate passes through hot air dryers. Cleaning solutions containing solvents are also used in the rotogravure printing process (EPA, 1995a).

2.2 FLEXOGRAPIC PRINTING

In flexographic printing, the image area is raised from the surface of a plate (like a typewriter) with a rubber (flexible) image carrier. Alcohol-based inks are generally used. The process is usually webfed and used for medium or long multicolor runs on a variety of substrates, including heavy paper, fiberboard, and metal and plastic foil. Almost all milk cartons and multiwall bags, and half of all flexible packaging are printed by this process (EPA, 1993a).

Steam-set inks, employed in the "water flexo" or "steam-set flexo" process, are low-viscosity inks of a paste consistency that are gelled by water or steam. Steam-set inks are used for paper bag printing and produce no significant emissions (EPA, 1993a).

Solvent-based inks are used primarily in publication printing and contain about 75 percent (by volume) organic solvent. The solvent, which must be rubber compatible, may be alcohol or alcohol mixed with an aliphatic hydrocarbon or ester. Typical solvents also include nonaromatic glycols, ketones, and ethers. The inks dry by solvent absorption into the web and by evaporation, usually in high-velocity steam drums or hot-air dryers, at temperatures below 120°C (250°F). Most of the solventborne flexographic inks contain few or no hazardous air pollutants (HAPs). As in rotogravure publishing, the web is printed on only one side at a time. The web passes over chill rolls after drying; no emissions occur from chilling (EPA, 1993a).

When flexography is used to print corrugated board and most paperboard, water-based inks can be used; however, fast-drying inks are required for plastic films and packaging papers so the web can be rewound or processed into the final product at the end of the press. Flexography is becoming popular for printing pressure-sensitive labels, a process in which the ink must dry quickly without penetration. Use of inks that dry by exposure to ultraviolet radiation (producing no emissions) have been used in label printing with much success (EPA, 1995b).

Additional converting operations, which are often done at the flexographic press stations or in-line with the presses, such as film blowing, laminating, coating, adhesive application, and cutting, may result in additional emissions. Cleaning operations also use solvents that contribute to emissions (EPA, 1995b).

2.3 OFFSET LITHOGRAPHIC PRINTING

Lithographic printing is characterized by a planographic printing process (i.e., the image and nonimage areas are on the same plane). The image area is ink-wettable and water- repellent, and the nonimage area is chemically repellent to ink and hydrophilic. The inks used in lithography are either heatset or nonheatset. In offset printing, the graphic image is applied from an ink-covered print plate to a rubber-covered "blanket" cylinder and then transferred onto the substrate, hence the name "offset" lithography (EPA, 1993a). The substrate in offset lithography can be either a web or sheet. A web substrate can be used with either heatset or nonheatset inks; sheets are used with nonheatset inks only. Some offset presses print on both sides of the paper at the same time (called "perfecting"); others print on one side only or two sides sequentially (EPA, 1994a).

An aqueous solution of isopropyl alcohol is commonly used to dampen the nonimage area on the plate and is called the "fountain" or "dampening" solution. The fountain solution in offset lithographic printing has traditionally contained about 15 percent alcohol; at times as high as 30 percent alcohol could be used. Because of environmental pressures, the use of isopropyl alcohol (a VOC) is decreasing. Fountain solutions that contain lower VOCs and/or alcohol substitutes are now in use. The newspaper industry segment of offset lithographic printing predominantly uses alcohol substitutes. Some facilities may use both alcohol and alcohol substitutes; in this case, the alcohol is generally much lower than 15 percent in the fountain solution (EPA, 1994a).

Offset lithographers also use cleaning solutions to clean the press and parts. These cleaning solutions have traditionally been high-solvent-containing (90 to 100 percent) solutions. Some lower- or no-solvent cleaners are becoming available, in which the solvent content is 0 to 30 percent (EPA, 1994a).

2.4 LETTERPRESS PRINTING

Letterpress printing is the oldest form of movable type printing. Letterpress printing uses a relief printing plate (as does flexography) and viscous inks similar to lithographic inks. Various types of letterpress plates are available. These plates differ from flexographic plates in that they have a rigid backing (metal or plastic) and are not "flexible." Both sheetfed and web presses are in use. Web letterpress equipment uses heatset and nonheatset inks. Letterpress printing uses no fountain solutions; the cleaning solvents are similar to those used in lithography. Traditionally, letterpress printing dominated periodical and newspaper publishing; however, the majority of newspapers have converted to nonheatset web offset printing (EPA, 1995a).

Letterpress printing uses a paper web that is printed on both sides, one side at a time, and uses heatset inks, usually of about 40 percent (by volume) solvent. The web is dried after each color is applied. Heatset letterpress ink is similar to heatset lithographic ink. These inks contain resins dissolved in aliphatic hydrocarbons and are dried in hot-air ovens. The inks can be entirely HAP free (EPA, 1993a).

"Moisture set" inks used in some packaging applications contain trimethylene glycol (a HAP). "Water washable" letterpress inks are sometimes used for printing paper and corrugated boxes. These inks contain glycol-based solvents that may contain HAPs (EPA, 1995a).

2.5 SCREEN PRINTING

Screen printing involves forcing ink through a stencil in which the image areas are porous. The screens are generally made of silk, nylon or metal mesh. Screen printing is used for signs, displays, electronics, wallpaper, greeting cards, ceramics, decals, banners, and textiles. Nearly half of the screen printing plants in the United States print on textiles. Ink systems used in screen printing include ultraviolet cure, waterborne, solventborne, and plastisol, with plastisol (polyvinyl chloride) being mainly used in textile printing. Solvent-based ink systems contain aliphatic, aromatic, and oxygenated organic solvents (EPA, 1995a).

Both sheetfed and web presses are used in screen printing. Depending on the substrate printed, the substrate can be dried after each printing station or, for absorbent substrates, after all colors are printed. Solvent- and waterborne inks are dried in hot-air or infrared drying ovens. Dryer gases are partially recycled and partially vented (EPA, 1995a).

2.6 PLATELESS PRINTING

This technology is a relatively new process used primarily for short runs on paper substrates. Plateless printing processes include electronic (e.g., laser printers), electrostatic (e.g., xerographic copiers), magnetic, thermal (e.g., facsimile machines) and ink jet printing. Plateless printing processes are estimated to account for only 3 percent (by value) of printed products. Electrostatic toners and ink jet printer inks may contain HAPs; however the quantities emitted at any location are small (EPA, 1995a).

2.7 POINT SOURCE CONSIDERATIONS

Although 80 percent of graphic arts facilities are estimated to have fewer than 20 employees and less than 10 tons per year (tpy) VOC emissions (Ulconovic, 1991), there are likely to be some point sources and/or point source emissions for this source category in most inventory areas. Forty percent of VOC emissions from graphic arts operations are estimated to be from plants in the 10- to 100-tpy range.

This indicates that the interface between point and area sources, as well as the attainment status of the region, will be especially important for inventories of this source category. A typical scenario is to find a few large graphic arts operations and numerous small graphic arts operations with an equal potential for a significant amount of emissions from both size groups.

Table 7.2-4 presents the available information about the estimated percentage of facilities that are area sources among the various printing processes. These estimates substantiate the assumption that there are a significant number of area source facilities among all types of printing.

Also, many of these small graphic arts operations may be located at facilities whose predominant operation is not printing. This fact is reflected in the SIC Codes for graphic arts operations (Table 7.2-2) that are outside of major SIC Code 27 (Printing and Publishing).

According to Title V permit requirements, if a source qualifies as a major source for one HAP, the facility needs to inventory all HAP sources, regardless of their size. Therefore, data may exist for some small printing operations if they are located in facilities large enough to qualify for Title V permitting. These sources will also be included in a point source inventory.

TABLE 7.2-4

ESTIMATED SMALL BUSINESS DISTRIBUTION OF PRINTING FACILITIES

Type of Printing	Estimated Number of Facilities[a]	Estimated Percentage of Small Businesses
Rotogravure	427	0 for publication; 48 percent of packaging/product printing are small businesses (<500 employees)[b]
Flexography	1,587	Out of 600 responses to an EPA survey of flexographic printing, 98 percent were considered small businesses (<500 employees)[b]
Offset Lithography	54,000	Many[c]
Letterpress	21,000	Unknown
Screen	21,000	Many[d]
Plateless	Unknown	Many[d]

[a] EPA, 1995a.
[b] EPA, 1995b.
[c] EPA, 1994a.
[d] Assumed.

2.8 EMISSION SOURCES

The predominant emissions from graphic arts printing are VOCs contained in the printing inks, fountain solutions, and cleaning solutions. Many of these VOCs are also likely to be HAPs. To a lesser extent, VOCs and HAPs are emitted from binding and laminating operations (EPA, 1995a).

Printing inks vary widely in composition, but all consist of three major components: pigments, which produce the desired colors and are composed of finely divided organic and inorganic materials; binders, the solid components that lock the pigments to the substrate and are composed of organic resins and polymers or, in some inks, oils and rosins; and solvents, which dissolve or disperse the pigments and binders and are usually composed of organic compounds. The binder and solvent make up the "vehicle" part of the ink (EPA, 1993a).

In "heatset" printing processes, the solvent evaporates from the ink into the atmosphere during a drying step. In nonheatset processes, minimal VOCs or HAPs are emitted from inks, although emissions still result from fountain solution (offset lithographic printing only) and cleaning solution use. Ultraviolet inks may be used in graphic arts operations; in this case, there will be no emissions from inks (EPA, 1994a).

Emissions from proofing presses, cleaning operations, ink storage tanks, and ink mixing operations are relatively minor compared to the emissions during the printing process, but they do contribute to overall emissions (EPA, 1995a).

2.9 FACTORS INFLUENCING EMISSIONS

2.9.1 PROCESS OPERATING FACTORS

The type of printing and/or ink (offset heatset, offset nonheatset, gravure, flexographic, etc.) is the most important process operating factor for estimating emissions from graphic arts operations. For similar processes, the next most important process operating factor affecting emissions is the production volume (i.e., amount of material printed [area times length]). The amount of ink used per unit of substrate (i.e., the relative amount of inked versus noninked areas), which is determined by the type of product (newspaper, cereal box, greeting card, etc.), is another important factor. All things being equal, the production volume will be the determining factor in the relative magnitude of emissions. The type of substrate has little effect on the quantity of emissions.

Since printing is not a high-profit-margin production activity, it is in the interest of the printer to minimize the use of raw materials and time needed for each product. Therefore, it would appear that emissions minimization would be an auxiliary goal of the printer to minimize the use of raw materials. A factor that supersedes these goals, however, is customer satisfaction. It is because of the customer's perception of the final product that this source category retains the descriptor of an "art." Consequently, the printer may alter process variables that increase chemical use and, thus, possibly emissions, to achieve an end result that meets the customer's scrutiny. Chemical use may also be increased in the interest of shorter production time and less product waste to increase the profit margin.

One example of this trend in graphic arts operations is in offset lithographic printing, where the use of alcohol, one of the more expensive raw materials, may be used at a higher rate if it appears to be the only way to print a product that pleases the customer. This was shown in the case of a press operator who was found to purchase his own alcohol--at his own expense--to ensure high quality of a printing job when alcohol purchases had been eliminated by the plant management for environmental reasons (EPA, 1994a).

The following process variables relate to specific types of printing or operations common to all types:

Rotogravure

In publication rotogravure printing, the inks contain from 55 to 95 percent (by volume) low-boiling-point solvent (average is 75 percent by volume) with low viscosities (EPA, 1993a). It is important that the ink or other coating dry quickly between each color; therefore, the ink vehicle must be evaporated between stations (EPA, 1995b). Organic solvents (such as toluene, xylene, and ethylbenzene, which are HAPs) and alcohol are mainly used as the volatile portion of the ink, but water-based inks are becoming more popular because of their lower cost and less potential for air pollution. However, a single press is not compatible for use with both systems because water-based inks require more equipment drying capacity and a different cell design.

Although some rotogravure inks contain solvents, additional solvents may be mixed into the ink as well to obtain the desired viscosity. Publication gravure plants recover a large portion of spent solvents from their ink, some of which is reused and some excess that is sold back to the ink suppliers. Some virgin solvent, which has the same composition as the solvent in the inks, is purchased for replenishment purposes, and a small amount is used for cleaning the presses (EPA, 1995a).

Flexography

The ink used in flexography is of low viscosity because the ink must be fluid to print properly. Most flexographic printing (including all flexographic newspaper and corrugated carton printing) is done with waterborne inks, but alcohol or other low-viscosity, volatile liquids are also used as the ink base. Solvents used must be compatible with the rubber or polymeric plates; thus, aromatic solvents are not used. Some of the components of solvent-based flexographic ink include ethyl, methyl, n-propyl, and isopropyl alcohols; glycol ethers; ethylene glycol; aliphatic hydrocarbons; acetates; and esters. Most of the solventborne flexographic inks contain little or no HAPs (EPA, 1995b).

When flexography is used to print corrugated board and most paperboard, water-based inks can be used; however, fast-drying inks are required for plastic films and packaging papers so the web can be rewound or processed into the final product at the end of the press. When printing pressure-sensitive labels, the ink must dry quickly without penetration (EPA, 1995b).

Offset Lithography

The solvents (high-boiling-temperature petroleum oils >400°F) in heatset inks are driven off in a hot air or direct-flame dryer (400-500°F) to set the ink. Nonheatset inks dry by adsorption or oxidation and are not released from the substrate under normal conditions. Approximately 20 to 40 percent of the solvent remains in the substrate with heatset inks; 95 to 100 percent remains in the substrate with nonheatset inks (EPA, 1993a).

Emissions from the fountain solution will depend on whether alcohol or nonalcohol additives are used. The concentration of VOCs in the fountain solution can vary from facility to facility, and from job to job within any one facility (EPA, 1994a).

Solvents used for press cleanup are usually kerosene-type high-boiling-point hydrocarbons, sometimes mixed with detergents (EPA, 1995a). These materials can contain up to 100 percent VOCs but are generally free of HAPs. Low-VOC cleaning solutions are also in use where the VOC content is less than 70 percent, and often less than 30 percent VOCs (EPA, 1994a).

Letterpress

Only web presses using solventborne inks are sources of emissions in this industry. Letterpress newspaper and sheetfed printing use oxidative drying inks and are not a source of emissions. Cleaning solutions are used with all letterpress operations (EPA, 1993a).

Screen Printing

Ink systems used in screen printing include ultraviolet cure, waterborne, solventborne, and plastisol, with plastisol (polyvinyl chloride) being mainly used in textile printing. Solvent-based ink systems contain aliphatic, aromatic, and oxygenated organic solvents (EPA, 1995a).

In-Process Fuel

Fuels such as oil or natural gas are used to operate the dryers used in heatset offset lithography, heatset letterpress, gravure, and alcohol-based flexography. In some cases, recovered solvent may be used as supplemental fuel in the dryer. A boiler may be used to generate steam for steam-/water-based flexography and to regenerate the activated carbon beds used as control devices. The combustion byproducts include particulate matter (PM), particulate matter with diameters less than 10 µg (PM_{10}), sulfur oxides (SO_x), nitrogen oxides (NO_x), VOCs, and carbon dioxide (CO). Recovered solvent may be burned in the dryer (EPA, 1994a).

Storage Tanks

Graphic arts operations may use storage tanks to store inks, solvents, and fuels (oil).

2.9.2 CONTROL TECHNIQUES

Afterburners, both thermal and catalytic, can be used to control VOC emissions from the heatset web offset lithography, rotogravure printing, and flexography. Activated carbon adsorption can be used to control VOC emissions from rotogravure printing and flexography (EPA, 1995a). Condenser filters with and without activated carbon can be used to control VOC emissions from heatset offset lithography (EPA, 1994a). The condensers alone can achieve 90 percent control, while activated carbon increases the control to 95 percent. Total enclosure, with venting of collected VOCs to a control device, is used with rotogravure printing. Pebble-bed incinerators that combine the functions of a heat exchanger and a combustion device also can be used to control VOCs in the graphic arts industry (EPA, 1995a).

Refrigeration of the dampening solution is a process change that can achieve approximately 40 percent reduction of the alcohol emissions (which are VOCs) from offset lithographic printing operations. The use of alcohol substitutes in the dampening solution of offset lithographic printing operations can reduce or eliminate the use of alcohol (EPA, 1994a).

The use of lower-VOC-containing or lower-vapor-pressure cleaning solutions can reduce VOC and HAP emissions from cleaning operations in all types of printing. Storing cleaning rags in closed containers can control some of the fugitive emissions from cleaning (EPA, 1994a). In screen printing, low-VOC- and/or HAP-emitting screen printing cleaning products are available for the removal/reclamation of the stencil from the screen. Process modifications to lower VOC/HAP emissions in screen reclamation are also being used, such as the Screen Printing Association International (SPAI) Workshop Process, high-pressure water blaster, and automatic screen washing system.

In 1978, a control technique guidelines (CTG) document (EPA, 1994a) was published for the control of VOCs from rotogravure and flexographic printing operations (EPA, 1978). New

Source Performance Standards (NSPS) for VOC emissions from publication rotogravure printing were proposed in the Federal Register (FR) October 28, 1980 (45 FR 71538), and promulgated November 8, 1982 (47 FR 50644). NSPS for VOC emissions from rotogravure printing and coating of flexible vinyl were promulgated June 29, 1984 (49 FR 26885). In 1993, a draft CTG document was published for the control of VOC emissions from offset lithographic printing. The draft CTG document was presented as an "Alternative Control Techniques" (ACT) document and announced in June 1994, with modifications, as a result of public comments submitted to EPA in response to the draft CTG (EPA, 1994a).

The following is a chronology of VOC regulations for the graphic arts industry:

- 1978: A CTG document was published for the control of VOCs from rotogravure and flexographic printing operations (EPA, 1978).

- 1982: NSPS for VOC emissions from publication rotogravure were proposed October 28, 1980 (45 FR 71538) and promulgated November 8, 1982 (47 FR 50644).

- 1984: NSPS for VOC emissions from rotogravure printing and coating of flexible vinyl were promulgated June 29, 1984 (49 FR 26885).

- 1994: A draft CTG document was published for the control of VOC emissions from offset lithographic printing in November 1993. The draft CTG was reclassified as an ACT document and announced in June 1994. The ACT information included revisions made in response to public comments to the 1993 draft CTG document (EPA, 1994a).

Although none of these above regulatory efforts were specifically directed towards HAPs, many HAPs of concern in the printing industry are VOCs and, therefore, the same control devices used to limit VOC emissions are also applicable to control of HAPs. A National Emission Standard for Hazardous Air Pollutant (NESHAP) for the printing and publishing industry was proposed in March 1995 (60 FR 13664; 40 CFR Part 63); the background information document for the NESHAP is available (EPA, 1995a).

Table 7.2-5 summaries the national regulations that affect the graphic arts industry. Note that in most cases there is no size cutoff for applicability of the regulation. State regulations may also be in effect that are more stringent than federal regulations. The size cutoffs of these regulations should be noted when preparing an area source inventory; in many cases the state may make the federal rule more stringent by eliminating the size cutoff or facility age exemption that will bring all sources under the regulation or extend the regulations statewide that are primarily targeted for nonattainment areas.

TABLE 7.2-5

NATIONAL REGULATIONS FOR THE GRAPHIC ARTS INDUSTRY

Type of Printing	Type of Regulation	Applicability	Regulated Pollutant	Control Requirement	Control Method(s)
Rotogravure	CTG (1978)[a]	Packaging facilities in nonattainment areas	VOCs	70-80% capture	
				90% destruction	Incineration
				65% overall control	
		Publication facilities in nonattainment areas	VOCs	75-85% capture	
				90% removal	Carbon adsorption
				75% overall control	
		Packaging and publication facilities in nonattainment areas	VOCs	Inks with 25% or less solvent	Material substitution
				Ink with 60% nonvolatile component	Material substitution
	NSPS (1982)[b]	Publication facilities	VOCs	84% overall control	Solvent recovery systems or waterborne inks
	NESHAP (proposed 1995)	Publication facilities that are major sources[c]	HAPs	92% overall control	
		Product and packaging facilities that are major sources[c]	HAPs	95% overall control	
				≤0.2 kg emitted per kg ink solids	
				≤0.04 kg emitted per kg ink solids for presses with a common solvent recovery system	

TABLE 7.2-5

(CONTINUED)

Type of Printing	Type of Regulation	Applicability	Regulated Pollutant	Control Requirement	Control Method(s)
Flexography	CTG (1978)[a]	Packaging facilities in nonattainment areas	VOCs	70-80% capture	
				90% destruction	Incineration
				65% overall control	
		Publication facilities in nonattainment areas	VOCs	75-85% capture	
				90% removal	Carbon adsorption
				75% overall control	
		Packaging and publication facilities in nonattainment areas	VOCs	Inks with 25% or less solvent	Material substitution
				Inks with 60% nonvolatile component	Material substitution
	NESHAP (proposed 1995)	Wide web flexographic facilities that are major sources[c]	HAPs	95% overall control	
				≤0.2 kg emitted per kg ink solids	
				≤0.04 kg emitted per kg ink solids for presses with a common solvent recovery system	

TABLE 7.2-5

(CONTINUED)

Type of Printing	Type of Regulation	Applicability	Regulated Pollutant	Control Requirement	Control Method(s)
Offset Lithography	ACT (1994)[d,e]	Heatset web facilities that emit ≥15 lb per day total emissions	VOCs	95% control of ink emissions	
				Fountain solution VOCs ≤ 1.6% (weight)	
				Fountain solution VOCs ≤ 3% (weight)	Refrigeration
				Fountain solution VOCs ≤ 5% (weight)	Alcohol substitutes
		Nonheatset web facilities that emit ≥15 lb per day total emissions	VOCs	Fountain solution VOCs ≤ 5% (weight)	Alcohol substitutes
		Nonheatset sheet facilities that emit ≥15 lb per day total emissions	VOCs	Fountain solution VOCs ≤ 5% (weight)	
				Fountain solution VOCs ≤ 8.5% (weight)	Refrigeration
				Cleaning solution VOCs ≤ 5% (weight)	Alcohol substitutes
		Newspaper facilities that emit ≥15 lb per day total emissions	VOCs	Fountain solution VOCs ≤ 5% (weight)	Alcohol substitutes
		Cleaning solution at any facilities that emit ≥15 lb per day total emissions	VOCs	VOCs ≤ 30% (weight)	
				Vapor pressure ≤ 10 mm Hg at 20°C	

[a] EPA, 1978.
[b] EPA, 1980.
[c] Emit over 10 tpy of any one HAP or over 25 tpy total of two or more HAPs.
[d] EPA, 1994a.
[e] Recommended for nonattainment areas.

3

OVERVIEW OF AVAILABLE METHODS

3.1 EMISSION ESTIMATION METHODOLOGIES

A number of methodologies are available for estimating emissions from the graphic arts industry. The method used is dependent upon the degree of accuracy required in the estimate, the available data, and the available resources.

This section discusses the methods available for estimating emissions from area sources in the graphic arts industry and identifies the preferred method. A discussion of the data elements needed for each method is also provided. All methods must take into account point source facilities of graphic arts operations and their emissions.

3.2 AVAILABLE METHODOLOGIES

3.2.1 VOLATILE ORGANIC COMPOUNDS

The VOCs released into the air by graphic arts operations are from the evaporation of the VOCs contained in the raw materials such as inks, fountain solution (offset lithographic printing only), and cleaning solutions used in the printing processes. There are three approaches to estimating the amount of VOCs emitted from this source category:

- Facility Survey Method;
- Ink Sales Emission Factor Method; and
- Per Capita Emission Factor Method.

The Facility Survey Method, the preferred method, and Ink Sales Emission Factor Method, the first alternative method, take into account the variations in VOC emissions between each printing type and in the type of emission controls for each type. With the Facility Survey Method, the amount of VOCs recycled can also be addressed. However, for offset lithographic printing processes, the Facility Survey Method requires incorporating assumptions about the amount of VOCs in the inks that are retained in the substrate and not released during printing. The emissions estimate for offset lithographic printing facilities will not be a simple mass balance calculation (because some ink solvent VOCs are retained in the substrate). Therefore, an emissions estimate from facility surveys for offset lithography will be more uncertain than for other than printing processes where all the solvent used is emitted.

The Per Capita Emission Factor Method assumes a correlation between population size and graphic arts emissions, which is probably a very weak assumption. Emissions estimated using the Per Capita Emission Factor Method will not reflect variability between regions and, depending on the emission factor used, may not reflect the distribution of the different types of printing within the region and the controls that are being used.

3.2.2 HAZARDOUS AIR POLLUTANTS

HAP emissions from graphic arts operations can be estimated using two methods:

- Facility Survey Method; or

- Applying speciation profiles to the VOC emission estimate obtained using the Ink Sales Emission Factor or Per Capita Emission Factor Methods.

The Facility Survey Method is the preferred method because it provides the most accurate information on material usage and HAP content. The effect of VOC controls on HAP emissions can also be obtained when using this method.

Speciation profiles can be used with either the Facility Survey or Ink Sales Emission Factor Methods as alternative approaches when a detailed survey is not practical. The least desirable method is the use of speciation profiles with the Per Capita Emission Factor Method.

The speciation profiles will need to be updated frequently as a result of changes in product use that are now occurring to meet new regulations (Titles I, III, and V of the Clean Air Act Amendments) and/or as better quality profiles are available. Local speciation profiles may also be available.

3.3 DATA NEEDS

3.3.1 DATA ELEMENTS

The data elements used to calculate emission estimates for the graphic arts operations will depend on the methodology used for emission estimation. The following data elements are necessary for emissions calculations and should be obtained for each method.

For the Facility Survey Method (from each facility sampled):

- Type of printing (rotogravure, flexography, etc.);
- Primary business;
- Number of employees, and number of employees involved in printing operations;
- Amount of VOC-containing raw materials by type;
- VOC content of each product type (weight percent);
- Percentage of VOCs contained in the material that is emitted during graphic arts operations that is estimated or obtained from source test measurements;
- HAP content of product or solvent by type (weight percent) for all HAPs in the product and estimated amount of HAPs emitted during printing operations;
- Controls used at facility, control efficiency; and
- Amount of VOCs or HAPs recycled.

For the first alternative method, the Ink Sales Emission Factor Method:

- Ink sales for the state, or data from the U.S. Census Bureau;
- Uncontrolled point source emissions for graphic arts operations; and
- Controls in use in the inventory region.

For the second alternative method, the Per Capita Emission Factor Method:

- Population of the inventory area; and
- Per capita emission factor from a national database or local survey.

3.3.2 DOUBLE COUNTING CONSIDERATIONS

Double counting can occur for this source category either because emission sources are counted as both graphic arts and as industrial surface coating area sources, or because point source emissions are not properly subtracted from estimates of total emissions. In either case, a clear definition of what processes and industries are included in the graphic arts and industrial surface coating source categories should be made before data collection for either source category begins. In particular, industries with SIC codes that are *not* in the printing and publishing SIC of 27 should be examined for overlap between the two source categories.

3.3.3 APPLICATION OF CONTROLS

Add-on controls may be used to control ink emissions in the graphic arts industry. Material substitution may also be used to control emissions from all aspects of printing that include the use of water-based inks, reduced alcohol and/or alcohol substitutes in fountain solution, and the use of lower-VOC or low-vapor-pressure cleaning solutions. Rule effectiveness (RE) may be less than 100 percent for add-on controls; RE for material substitution can be assumed to be 100 percent.

Rule penetration will depend on the cutoff size or exemptions for the applicable regulations and can be calculated based on the percentage of sources within the category that are affected by the rule. Because a large number of small sources contribute to total emissions for graphic arts operations, many of the regulations will apply to area sources as well as point sources. In some cases, a lower size cutoff that does not correspond with point versus area distinctions may be specified by the regulation.

3.3.4 SPATIAL ALLOCATION

Spatial allocation may be needed in two possible cases: (1) allocation of state or regional activity to a county level, and (2) allocation of county level emission estimates to a modeling grid cell. In each case, a surrogate for activity should be found that can approximate spatial variation for this category, if specific locations cannot be identified. The preferred method of spatial allocation is to use the facility location collected with other survey information under the preferred method.

Most printing operations occur in or near urban areas to be close to the customers, labor force, or transportation centers. Some national companies locate their large printing plants in suburban or rural areas where land is less expensive. Spatial apportioning can be performed with land use data obtained from county planning departments or population distributions available from the U.S. Census Bureau. Using population to allocate estimated emissions or activity by county or within a grid cell is fairly straightforward and is discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development*. Land use data can be used to generalize building type (i.e., commercial versus residential).

Alternatively, printing facility distributions can be used from *County Business Patterns*[a] (U.S. Bureau of the Census, Department of Commerce) or the local "Yellow Pages" to allocate some segments of the category, such as lithographers. However, these indicators may not be useful for in-house or captive printing operations. The importance of these smaller sources to the total area source inventory will determine the usefulness of the data.

3.3.5 TEMPORAL RESOLUTION

Seasonal Apportioning

There are no dramatic seasonal fluctuations in production in the graphic arts industry; therefore, it can be assumed that emissions are distributed uniformly throughout the year. To determine seasonal emissions, the fraction of the year that corresponds to the season of interest can be multiplied times annual emissions to obtain seasonal emissions.

Daily Resolution

Based on a review of the National Acid Precipitation Assessment Program (NAPAP) data (EPA, 1990), 75 percent of emissions activity occurs on weekdays, 20 percent on Saturdays, and 5 percent on Sunday. For allocation on a hourly basis, 65 percent of activity occurs between 9 a.m. and 6 p.m., with the remaining 35 percent occurring between 7 p.m. and 12 a.m.

3.3.6 PROJECTING EMISSIONS

The following equation should be applied when the base year emissions are calculated by the emission factor method and the emission factor takes into account the control level for the projection year (EPA, 1993b):

[a] See the most recent publication, which can be obtained from the U.S. Bureau of the Census, Department of Commerce, Washington, D.C.

$$EMIS_{PY} = ORATE_{BY} * EMF_{PY} \left[1 - \left(\frac{CE_{PY}}{100} * \frac{RE_{PY}}{100} * \frac{RP_{PY}}{100} \right) \right] * GF \quad (7.3\text{-}1)$$

where:

$EMIS_{PY}$	=	Projection year emissions: ozone season typical weekday (mass of pollutant/day);
$ORATE_{BY}$	=	Base year operating rate (activity level);
EMF_{PY}	=	Projection year (postcontrol) emission factor (mass of pollutant/ production unit);
CE_{PY}	=	Projection year control efficiency (percent);
RE_{PY}	=	Projection year rule effectiveness (percent);
RP_{PY}	=	Projection year rule penetration (percent); and
GF	=	Growth factor (dimensionless).

Current control projection emissions in this case are calculated if the projection year emission factor and RE values represent current regulatory or permit conditions and/or actual conditions when appropriate.

Tools for the development and use of growth factors are discussed in Chapter 1 of this volume. Forecasts of ink or paper sales from the data sources discussed in Section 5 of this chapter can also be used to estimate future growth in the graphic arts.

4

PREFERRED METHODS FOR ESTIMATING EMISSIONS

The preferred method for calculating emissions from graphic arts is the Facility Survey Method. In this method, graphic arts facilities in the inventory area will need to identified. Although initially this is a labor-intensive approach, the results can be used to develop an emission factor specific to the inventory region. Subsequent inventories can use this factor with updated activity data to estimate emissions. If it is not possible to inventory all of the graphic arts facilities in the area, then a representative sample of these graphic arts facilities can be surveyed, and the results can then be scaled up for all facilities in the area. Please refer to Volume I of this series, Chapter 5, *Inventory Development*; Chapter 1 of this volume; and Volume VI of this series, *Quality Assurance Procedures*, for more detailed information about using surveys.

4.1 PLANNING

Identify facilities that would be suitable survey recipients, noting those that are point sources. Facilities engaged in graphic arts may be listed as part of a state or local permitting program. Look for facilities that may have graphic arts facilities as part of another, more significant operation. Title V or other operating permits may include information from such facilities. Facilities can also be identified from the local employment office, professional organizations, and entries in local tax records for printing equipment.

Prepare a survey form or forms that collect the information needed for the inventory. At a minimum, the survey should request:

- Name, location, and contact person of the operation;
- Primary activity and type of graphic arts process(es) used at the facility;
- Amount of inks, fountain solution, and cleaning solution used at the facility. If the amount is expressed in gallons, the density of the materials will be needed as well, in order to calculate emissions in weight units such as pounds or kilograms;
- The VOC or the HAP content of each material, in pounds, or as a weight percentage;

- The amount of material that is recovered and recycled, but not reused within the facility; and

- Control equipment and control efficiency.

During the planning phase, a scaling method should be identified and the survey form should request the information needed to scale up the data collected, such as total employment or production workers. If the survey results are to be converted into an area-specific emission factor, the surrogate activity will also need to be collected. Possible surrogate factors would be per unit, per facility, or per employee factors. If practical, use production workers rather than the total number of employees.

4.2 DISTRIBUTION

Survey distribution will be determined by the budget for the category. Surveys can be distributed by mailing, with initial and follow-up telephone calls. Initial calls may be useful to identify the portion of the survey set that does not have graphic arts processes occurring on their premises. These facilities are an important part of the sample because when the survey is scaled up, if that portion of facilities were to have emissions assigned to them, the emission estimates would be too high. Survey distribution issues are discussed in Chapter 1, *Introduction to Area Source Emission Inventory Development*, under Surveys, in Section 6.

4.3 SURVEY COMPILATION AND SCALING

Use the survey results to either develop an emission factor or an areawide emission estimate. If material amounts were reported in gallons, then the gallons need to be converted to weight units:

$$\begin{matrix}\text{Amount used}\\ \text{in pounds}\end{matrix} = \begin{bmatrix}\text{Amount of}\\ \text{material (gal)}\end{bmatrix} \times \begin{bmatrix}\text{Density factor}\\ \text{(lb/gal)}\end{bmatrix} \qquad (7.4\text{-}1)$$

Note that the amount of VOCs emitted during printing (volatile fraction) is not always equivalent to the measured or estimated VOC content of the raw material (especially for offset lithographic printing), since all the VOCs contained in the raw material may not be emitted during printing. The data used in the alternative Ink Sales Emission Factor Method to determine the VOC emissions by amount of ink used should be used with the Facility Survey Method if the volatile fraction specific to the process is not available. Refer to the Ink Sales Emission Factor Method description and emission factors in Section 5 of this chapter. For example, although nonheatset lithographic inks may contain some VOCs, only 2 percent of the VOCs are emitted during printing.

Use the equation below to estimate uncontrolled total emissions for each pollutant (P) emitted, from each type of graphic arts operation (i). Point source emissions should calculated using the same equation and subtracted from the total emissions calculated using Equation 7.4-2.

$$\begin{matrix}\text{Total}\\\text{Uncontrolled Emissions}_P\\\text{from}\\\text{Graphic Arts}\end{matrix} = \sum\left[\begin{pmatrix}\text{Amount}\\\text{Raw Material}_i\\\text{Used}\end{pmatrix}\begin{pmatrix}\text{Volatile}\\\text{Fraction}_{P,i}\end{pmatrix} - \begin{pmatrix}\text{Amount}\\\text{Recycled}_i\end{pmatrix}\right] \quad (7.4\text{-}2)$$

An area source emission factor can be developed by calculating the area source emissions and dividing the area source emissions by the area source activity rate:

$$\begin{matrix}\text{Graphic Arts}\\\text{Emission}\\\text{Factor}_{P,i}\end{matrix} = \left[\begin{pmatrix}\text{Total}\\\text{Uncontrolled}\\\text{Emissions}_{P,i}\end{pmatrix} - \begin{pmatrix}\text{Uncontrolled}\\\text{Point Source}\\\text{Emissions}_{P,i}\end{pmatrix}\right] \div \begin{matrix}\text{Area Source}\\\text{Activity}\\\text{Rate}_i\end{matrix} \quad (7.4\text{-}3)$$

When the emission factor is used, control efficiency (CE), rule penetration (RP), and rule effectiveness (RE) need to be included as part of the emissions calculation. Please refer to Section 4.2 in Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development* for more information about developing these factors.

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5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

The alternative methods for calculating emissions from the graphic arts source category are the Ink Sales Emission Factor Method and the Per Capita Emission Factor Method. This section provides an outline for estimating emissions from either ink sales or population data. The procedures follow below.

5.1 INK SALES EMISSION FACTOR METHOD

In the Ink Sales Emission Factor Method, total uncontrolled emissions from all graphic arts operations sources are estimated using national or state ink sales data. This method's advantages are:

- Inks are common to all printers and not used by any other source except printers;
- The VOC content of the inks is fairly consistent and can be estimated on the average; and
- The printing processes are technically consistent within each printing type (i.e., emissions per unit of ink will be approximately the same from one facility to another) for ink with the same VOC content used in the same type of printing process.

If the amount of printing ink that is recycled is expected to be significant in the inventory area, the emission estimate needs to be adjusted accordingly. Use information collected from the point source inventory to determine the rate of recycling at graphic arts facilities.

Uncontrolled point source emissions for each printing type are subtracted from the total uncontrolled emissions calculated using this method to obtain uncontrolled area source emissions. If the uncontrolled point source emissions from graphic arts operations are not available or cannot be estimated, then the Facility Survey Method or the other alternative method should be used.

The total area source emissions from graphic arts operations are estimated from the sum of emissions estimated for each of the six types of printing. If local information on ink sales is available, it should be used for this method. If local information is not available, the following approach should be used to estimate ink sales in the inventory area:

First, obtain apportioned ink sales by the following steps:

- Obtain the amount of inks produced, in pounds, in the United States for the inventory year, from the Census Bureau's *Census of Manufactures,* Industry Series for SIC Code 289, Miscellaneous Chemical Products.[a]

- Apportion the nationwide ink amount produced for the inventory year to the state level by the ratio between state and national employment in printing and publishing (SIC Code 27). The Census Bureau's report, *Statistics for Industry Groups and Industries*, can provide this information.[a] The equation to use is:

$$\text{Total Ink Sales for State} = \left[\text{Total Ink Sales for US}\right] \frac{\left[\text{Printing Employment in State}\right]}{\left[\text{Printing Employment in US}\right]} \qquad (7.5\text{-}1)$$

Next, correct the apportioned ink sales amount for point sources in the state. To do this, identify point sources (from the point source inventory) that have graphic arts processes at their facilities. The Aerometric Information Retrieval System (AIRS) Facility Subsystem (AFS) Source Classification Codes (SCCs) in Table 7.5-1 can be used to identify the applicable graphic arts emissions from the point source inventory. For these facilities, the following additional information should be collected:

- Facility location (county or inventory area);

- Amount of ink used by the facility (amount purchased minus amount recycled);

- SIC Code for the facility's primary operation; and

[a] See the most recent publication, which can be obtained from the U.S. Bureau of the Census, Department of Commerce, Washington, D.C.

TABLE 7.5-1

AFS SOURCE CLASSIFICATION CODES FOR GRAPHIC ARTS

Point Source Description	Process Description	SCC	Units
Offset Lithography - All Processes	Dampening Solution with Isopropyl Alcohol	4-05-004-13	Tons Alcohol Used
	Dampening Solution with Alcohol Substitute	4-05-004-15	Tons Substitute Used
	Cleaning Solution - High Solvent Content	4-05-004-16	Tons Pure Solvent Used
	Cleaning Solution - Water-Based	4-05-004-17	Tons Used
Heatset Offset Lithography	Heatset Lithographic Inks	4-05-004-11	Tons Solvent in Ink
	Heatset Lithographic Inks	4-05-004-12	Gallons Ink
	Heatset Lithographic Inks	4-05-004-01	Tons Ink
	Heatset Ink Mixing	4-05-004-21	Tons Solvent in Ink
	Heatset Solvent Storage	4-05-004-22	Tons Solvent Stored
Nonheatset Offset Lithography	Nonheatset Lithographic Inks	4-05-004-31	Tons Ink
	Nonheatset Lithographic Inks	4-05-004-32	Tons Solvent in Ink
	Nonheatset Lithographic Inks	4-05-004-33	Gallons Ink
Letterpress - All Processes	Letterpress Cleaning Solution	4-05-002-15	Tons Solvent Consumed

TABLE 7.5-1

(CONTINUED)

Point Source Description	Process Description	SCC	Units
Heatset Letterpress	Heatset Letterpress Ink	4-05-002-01	Tons Ink
	Heatset Letterpress Ink	4-05-002-11	Tons Solvent in Ink
	Heatset Letterpress Ink	4-05-002-12	Gallons Ink
	Ink Mixing	4-05-006-01	Tons Solvent in Ink
	Storage	4-05-007-01	Tons Solvent Stored
Gravure Printing	Gravure Ink	4-05-005-01	Tons Ink
	Gravure Ink	4-05-005-11	Tons Solvent in Ink
	Gravure Ink - High Solvent Content	4-05-005-13	Gallons Ink
	Gravure Ink - Water-Based	4-05-005-12	Gallons Ink
	Ink Mixing	4-05-006-01	Tons Solvent In Ink
	Solvent Storage	4-05-007-01	Tons Solvent Stored
	Gravure Cleanup Solvent	4-05-005-14	Tons Solvent Consumed
Flexographic Alcohol-Based Inks	Flexographic Ink Use - Alcohol-Based	4-05-003-01	Tons Ink
	Flexographic Ink Use - Alcohol-Based	4-05-003-11	Tons Solvent in Ink
	Flexographic Ink Use - Alcohol-Based	4-05-003-13	Gallons Ink

TABLE 7.5-1

(CONTINUED)

Point Source Description	Process Description	SCC	Units
Flexographic Alcohol-Based Inks (Continued)	Flexographic Ink Use - Alcohol-Based	4-05-003-12	Gallons Ink
	Flexographic-Alcohol Cleanup	4-05-003-14	Tons Solvent Consumed
	Ink Mixing	4-05-003-01	Tons Solvent in Ink
	Solvent Storage	4-05-007-01	Tons Solvent Stored
Flexographic Steam/ Water-Based Ink	Flexographic Ink Use - Steam/Water-Based	4-05-003-15	Tons Ink
	Flexographic Ink Use - Steam/Water-Based	4-05-003-16	Tons Solvent in Ink
	Flexographic Ink Use - Steam/ Water-Based	4-05-003-17	Tons Solvent Stored
	Steam/Water-Based Ink Mixing	4-05-003-18	Tons Solvent Stored
	Steam/Water-Based Ink Storage	4-05-003-19	Tons Solvent Stored
Miscellaneous	Cleaning Rags	4-05-008-01	Tons Solvent Used

- Facility's employment, if the SIC Code is 27, and if it is available.

Subtract the amount of ink (do not include fountain solutions or cleaning solutions) used by all point source facilities in the state from the total amount of ink allocated to the state:

- Determine the number of employees at printing and publishing point source facilities (SIC Code 27) in the state and subtract those employees from the state total. The remaining employee numbers will be used to apportion the area source ink sales numbers.

- If the numbers of employees at the printing and publishing point source facilities is not available from the facilities' permits, point source inventory information, or local employment data, then the employment can be derived from the U.S Bureau of the Census report, *County Business Patterns*.

  When employment in *County Business Patterns* is presented as a number of facilities that have employment within a range of values, the total number of employees for all the facilities listed in each range can be estimated using the midpoint of the indicated size range. See Example 7.5-1 for more details.

The remaining amount of ink can be assumed to be responsible for area source emissions. This ink should be apportioned from the state level to the inventory area, using the non-point-source employment in facilities with SIC Codes of 27.

Apportion the statewide ink sales data for each type of printing to the inventory region by the ratio of the printing employment in the inventory region for each printing type (t) to the state printing employment, as follows:

$$\begin{array}{c}\text{Total Ink}\\ \text{Sales for}\\ \text{Inventory Region}\end{array} = \left[\begin{array}{c}\text{Total Ink}\\ \text{Sales for}\\ \text{State}\end{array}\right] \frac{\left[\begin{array}{c}\text{Printing}\\ \text{Employment}\\ \text{in Inventory}\\ \text{Region}\end{array}\right]}{\left[\begin{array}{c}\text{Printing}\\ \text{Employment}\\ \text{in State}\end{array}\right]} \qquad (7.5\text{-}2)$$

- Apportion the inventory region ink sales to each type of printing, using the estimated percentage product market share of ink sales for each type of printing in Table 7.2-3.

Example 7.5-1:

If an inventory for the region contains five graphic arts point sources, and the top five graphic arts facilities, by total employment, in the *County Business Patterns* for the region are distributed as follows: three facilities in the 100 to 149 employees per facility size range and two facilities in the 50 to 99 employee per facility size range, then the total number of employees for point sources can be calculated using the midpoint of the employee size ranges, as in the equation below:

$$\text{Total Employees at Point Sources} = \left[3\,\frac{(100 + 149)}{2} + 2\,\frac{(50 + 99)}{2} \right] = 3(124.5) + 2(74.5) = 523$$

Assume that point sources correspond to the facilities with the highest number of employees. Start with the facilities with the largest number of employees and sum the number of employees at the largest facilities for as many facilities as there are point source graphic arts facilities in the county for the desired SIC.

- Uncontrolled emission factors for ink, fountain solution, and cleaning solution, in terms of pounds of VOCs emitted per pound of ink used, are in Table 7.5-2. The equation to calculate uncontrolled emissions for a single printing type (t) is:

(7.5-3)

$$\text{Uncontrolled VOC Emissions} = \left[\begin{array}{c} \text{Area Source} \\ \text{Ink}_t \text{ Sales} \\ \text{in the} \\ \text{Inventory Region} \end{array} \right] \times \left[\left(\begin{array}{c} \text{Ink Emission} \\ \text{Factor}_t \end{array} \right) + \left(\begin{array}{c} \text{Fountain} \\ \text{Solution} \\ \text{Emission} \\ \text{Factor}_t \end{array} \right) + \left(\begin{array}{c} \text{Cleaning} \\ \text{Solution} \\ \text{Emission} \\ \text{Factor}_t \end{array} \right) \right]$$

See Table 7.2-5 in this chapter for a summary of national rules for the graphic arts industry. Other types of controls and control efficiencies will vary from area to area and more stringent controls may be required, which will need to be identified from local rules or, if necessary, through a survey of a small cross section of area source graphic arts facilities. Please refer to Section 4.2 in Chapter 1 of this volume, *Introduction to Area Source Emission Inventory Development* for more information about developing these factors. Alternatively, no controls could be applied to the area source emission estimates, which will result in the most conservative estimate.

TABLE 7.5-2

COMPONENT VOC EMISSION FACTORS FOR GRAPHIC ARTS OPERATIONS

Type of Printing	Component Emission Factors (Pounds of VOC Emitted per Pound of Ink Used)		
	Ink	**Fountain Solution**	**Cleaning Solution**
Rotogravure	0.70[a]	NA[b]	0.03[a]
Flexography	0.60[a]	NA	0.04[a]
Offset Lithography			
Heatset	0.32[c]	0.90[c]	0.03[c]
Nonheatset Web	0.02[c]	0.53[c]	0.03[c]
Nonheatset Sheet	0.02[c]	1.25[c]	1.10[c]
Newspaper	0.02[c]	0.07[c]	0.07[c]
Letterpress	0.24[d]	NA	[e]
Screen	[f]	NA	[f]
Planographic	[f]	NA	[f]

[a] Bay Area SIP (engineering judgement).
[b] NA = not applicable.
[c] EPA, 1994a.
[d] EPA, 1993a.
[e] Unknown at this time; use the emission factor for newspaper offset lithography if no other information is available.
[f] Unknown at this time. The Facility Survey Method should be used for these sources until information is available if they are expected to be significant area source emissions.

- Calculate controlled area source emissions for each printing type (t) for the inventory region with the following equation:

(7.5-4)

$$\begin{matrix}\text{Controlled}\\ \text{Area Source}\\ \text{Emissions}_t\end{matrix} = \left[\begin{matrix}\text{Area Source}\\ \text{Ink}_t\text{ Sales}\\ \text{in the Inventory Region}\end{matrix}\right] \times \left\{\left(\begin{matrix}\text{Ink Emission}\\ \text{Factor}_t\end{matrix}\right) \times \left[1 - \left(\frac{CE_1}{100} \times \frac{RE_1}{100} \times \frac{RP_1}{100}\right)\right]\right\}$$

$$+ \left\{\left(\begin{matrix}\text{Fountain Solution}\\ \text{Emission Factor}_t\end{matrix}\right) \times \left[1 - \left(\frac{CE_{FS}}{100} \times \frac{RE_{FS}}{100} \times \frac{RP_{FS}}{100}\right)\right]\right\}$$

$$+ \left\{\left(\begin{matrix}\text{Cleaning Solution}\\ \text{Emission Factor}_t\end{matrix}\right) \times \left[1 - \left(\frac{CE_{CS}}{100} \times \frac{RE_{CS}}{100} \times \frac{RP_{CS}}{100}\right)\right]\right\}$$

where:

$(CE_{I,FS,CS})$ = Control efficiency (percent) for each material used: ink (I), fountain solution (FS), and cleaning solution (CS);

$(RE_{I,FS,CS})$ = Rule effectiveness (percent); and

$(RP_{I,FS,CS})$ = Rule penetration (percent).

- Calculate the total area source controlled VOC emissions from graphic arts operations in the inventory region by summing the controlled VOC emissions for each type of printing (t):

$$\begin{matrix}\text{Total Controlled}\\ \text{Area Source}\\ \text{VOC Emissions in}\\ \text{Inventory Region}\end{matrix} = \sum \left[\begin{matrix}\text{Total Controlled}\\ \text{VOC Emissions}_t\text{ in the}\\ \text{Inventory Region}\end{matrix}\right] \qquad (7.5\text{-}5)$$

5.2 PER CAPITA EMISSION FACTOR METHOD

This method calculates graphic arts emissions from the inventory area population. The correlation between population and graphic arts activity is not strong and emissions calculated using this method will not reflect local variability in activity, controls, or types of printing taking place.

- Obtain the population of the inventory region from federal, state, or local census data for the current inventory year and the most recent year for which emission estimates derived from survey data are available.

- Estimate the total VOC emissions from graphic arts facilities with less than 100 tons per year VOC emissions, as in the equation below:

$$\begin{matrix}\text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Facilities with} \\ \text{<100 tpy Emissions} \\ \text{(tons)}\end{matrix} = \left[\begin{matrix}\text{Population of} \\ \text{Inventory} \\ \text{Region}\end{matrix}\right]\left[\begin{matrix}0.00065 \\ \text{(tons VOC per capita)}\end{matrix}\right] \qquad (7.5\text{-}6)$$

Note: The factor 0.00065 tons VOC per capita is equivalent to 1.3 pounds per person per year (EPA, 1991). This factor was derived for facilities with emissions that are less than 10 tpy, and is independent of the number of facilities with emissions greater than 100 tpy in the inventory area.

- Subtract the emissions from point sources in the inventory region (as defined by the region) with emissions less than 100 tons per year using data from the point source inventory as in the equation below:

$$\begin{matrix}\text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Area Sources}\end{matrix} = \left[\begin{matrix}\text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Facilities with} \\ \text{<100 tpy Emissions}\end{matrix}\right] - \left[\begin{matrix}\text{Total Uncontrolled} \\ \text{Emissions from} \\ \text{Graphic Arts} \\ \text{Point Sources with} \\ \text{<100 tpy Emissions}\end{matrix}\right] \qquad (7.5\text{-}7)$$

- If information about CE, RE, and RP is available, then the following equation should be used:

$$\begin{matrix}\text{Total Controlled}\\ \text{Emissions from}\\ \text{Area Sources}\end{matrix} = \left[\begin{matrix}\text{Total Uncontrolled}\\ \text{Emissions from}\\ \text{Graphic Arts}\\ \text{Area Sources}\end{matrix}\right] \left[1 - \left(\frac{CE}{100} \times \frac{RE}{100} \times \frac{RP}{100}\right)\right] \qquad (7.5\text{-}8)$$

If control information is not available, then the more conservative uncontrolled estimate should be used.

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QUALITY ASSURANCE/ QUALITY CONTROL (QA/QC)

Data handling for all of the methods do not involve any category-specific issues; refer to the discussion of data handling QA/QC in Volume VI for more information. When using the Facility Survey Method, the survey planning, sample design, and data handling should be planned and documented in the inventory QA/QC plan. Refer to the discussion of survey planning and survey QA/QC in Chapter 1 of this volume.

6.1 EMISSION ESTIMATE QUALITY INDICATORS

The preferred method gives higher quality estimates than the alternative methods, but requires significantly more effort. The level of effort for the Facility Survey Method requires from 100 to 800 hours depending on the size of the inventory region, the number of graphic arts operation facilities, and the level of detail in the survey. The level of effort for the Ink Sales Emission Factor Method requires between 100 and 200 hours depending on the size of the inventory region, the number of graphic arts operation facilities, and the ease in obtaining the appropriate ink sales data. The level of effort required to calculate emissions using the Per Capita Emission Factor Method ranges from 8 to 40 hours.

6.1.1 DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

The DARS scores for each method are summarized in Tables 7.6-1, 7.6-2, and 7.6-3. A range of scores is given for the preferred and first alternative method because the implementation of these methods can vary. All scores assume that good QA/QC measures are performed and that no significant deviations from the prescribed methods have been made. If these assumptions are not met, new DARS scores should be developed according to the guidance in Appendix F of EIIP Volume VI, *Quality Assurance Procedures*.

The preferred method gives a higher DARS score than the alternative methods, with the Facility Survey Method scoring higher than the Ink Sales Emission Factor Method that in turn scored higher than the Per Capita Emission Factor Method. The alternative methods have scores of 0.5 and 0.31, and the preferred method has a score ranging from 0.56 to 0.76. The relatively high score for the Ink Sales Method assumes that ink sales data are available. This method will have a lower score if the data cannot be obtained directly, and national data must be apportioned.

6.1.2 SOURCES OF UNCERTAINTY

Some of the uncertainty of the emissions estimates based on the Facility Survey Method can be quantified using standard statistical methods. A relative and qualitative assessment can be made for other methods. The Facility Survey Method will be the least uncertain, since (in theory) the local mix of process types and sizes will be accounted for. Emissions from printing types in which most of the ink evaporates from the substrate can be estimated by mass balance with a high degree of certainty. The uncertainty in the emissions estimate is highest for material when an estimate of the amount of VOCs retained in the substrate is needed and is comparable in magnitude to that emitted (for heatset offset lithographic printing only). However, the scaling of the survey results will need to be planned with care. The surrogate(s) should reflect the printing activity for each facility including the nonpublishing and printing industries that use graphic arts processes.

The Ink Sales Emission Factor Method's advantage is that the ink sales data and the information used for the apportioning method are readily available and inexpensive. However, the use of surrogate apportioning factors to apportion the national ink usage to the inventory area and national percentages to allocate ink usage to the different types of printing introduces uncertainty. Because the estimated emissions of each type of material used in printing is not expected to vary widely from facility to facility, and because the type of printing is usually known with a high degree of certainty, the emission factors used in the Ink Sales Emission Factor Method will have the same certainty as that used in the Facility Survey Method.

The Per Capita Emission Factor Method will have the highest degree of uncertainty, since a true relationship between population and printing has not been established. Since the per capita emission factor was developed from national data, as the spatial scale is reduced from the national level, the uncertainty of the emissions estimated is greatly increased. Also, because of variation in emissions among the types of printing, population data will likely not reflect the local distribution of printing type, and consequently, emissions.

TABLE 7.6-1

FACILITY SURVEY METHOD DARS SCORES

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.5	0.8 - 0.9	0.4 - 0.45
Source Specificity	0.8 - 0.9	0.5 - 0.8	0.4 - 0.72
Spatial	0.9	0.9 - 1.0	0.81 - 0.90
Temporal	0.8 - 1.0	0.8 - 1.0	0.64 - 1.0
Composite Scores	0.83 - 0.90	0.75 - 0.85	0.56 - 0.76

TABLE 7.6-2

INK SALES EMISSION FACTOR METHOD DARS SCORES

Attribute	Scores		
	Factor	Activity	Emissions
Measurement	0.4 - 0.5	0.6	0.24 - 0.30
Source Specificity	0.8 - 0.9	0.8 - 0.9	0.64 - 0.81
Spatial	0.7 - 0.6	0.7 - 0.6	0.49 - 0.36
Temporal	0.7 - 0.6	0.9	0.63 - 0.54
Composite Scores	0.65	0.75	0.5 - 0.49

TABLE 7.6-3

PER CAPITA METHOD DARS SCORES

Attribute	Scores		
	Factor	**Activity**	**Emissions**
Measurement	0.4	0.8	0.32
Source Specificity	0.5	0.4	0.2
Spatial	0.3	1.0	0.27
Temporal	0.5	1.0	0.45
Composite Scores	0.43	0.75	0.31

7

DATA CODING PROCEDURES

This section describes the codes available to characterize the graphic arts emission estimates. Consistent categorization and coding will result in greater uniformity between inventories. Inventory planning for data collection calculations and inventory presentation should take the data formats presented in this section into account. Available codes and process definitions may impose constraints or requirements on the preparation of emission estimates for this category.

7.1 PROCESS AND CONTROL CODES

The source category process codes for the graphic arts operations are shown in Table 7.7-1. These codes are derived from the EPA's AIRS Area and Mobile Source (AMS) source category codes (EPA, 1994b).

The control device codes shown in Table 7.7-2 may be used in AMS to record the level of control used for this source in the inventory region. Federal, state, and local regulations can be used as guides to estimate the type of control used and the level of efficiency that can be achieved. Be careful to apply only the regulations that specifically include area sources. If a regulation is applicable only to point sources, it should not be assumed that similar controls exist at area sources without a survey. The equations that utilize the control efficiency to calculate area source emissions for the inventory region are discussed in Chapter 1 of this volume.

Other control devices may be used in the graphic arts industry. The "099" code can be used for miscellaneous control devices that do not have a unique control device identification code. The "999" code can be used for a combination of control devices where only the overall control efficiency is known.

TABLE 7.7-1

AIRS AMS CODES FOR THE GRAPHIC ARTS

Category Description	Process Description	AMS Code	Units
Graphics Arts: All Processes	Total: All Solvent Types	24-25-000-000	Tons VOCs Emitted

TABLE 7.7-2

AIRS CONTROL DEVICE CODES

Control Device	Code
Catalytic Afterburner	019
Catalytic Afterburner with Heat Exchanger	020
Direct Flame Afterburner	021
Direct Flame Afterburner with Heat Exchanger	022
Activated Carbon Adsorption	048
Vapor Recovery System	047
Process Change	046
Process Enclosed	054
Miscellaneous Control Device	099
Combined Control Devices	999

8

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