4.9.1 General Graphic Printing

4.9.1.1 Process Description

The term "graphic arts" as used here means 4 basic processes of the printing industry: web offset lithography, web letterpress, rotogravure, and flexography. Screen printing and manual and sheet-fed techniques are not included in this discussion.

Printing may be performed on coated or uncoated paper and on other surfaces, as in metal decorating and some fabric coating (see Section 4.2, Surface Coating). The material to receive the printing is called the substrate. The distinction between printing and paper coating, which may employ rotogravure or lithographic methods, is that printing invariably involves the application of ink by a printing press. However, printing and paper coating have these elements in common: application of a relatively high-solvent-content material to the surface of a moving web or film, rapid solvent evaporation by movement of heated air across the wet surface, and solvent-laden air exhausted from the system.

Printing inks vary widely in composition, but all consist of 3 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. The solvent evaporates from the ink into the atmosphere during the drying process.

4.9.1.1.1 Web Offset Lithography -

Lithography, the process used to produce about 75 percent of books and pamphlets and an increasing number of newspapers, is characterized by a planographic image carrier (i. e., the image and nonimage areas are on the same plane). The image area is ink wettable and water repellant, and the nonimage area is chemically repellant to ink. The solution used to dampen the plate may contain 15 to 30 percent isopropanol, if the Dalgren dampening system is used.[8] When the image is applied to a rubber-covered "blanket" cylinder and then transferred onto the substrate, the process is known as "offset" lithography. When a web (i. e., a continuous roll) of paper is employed with the offset process, this is known as web offset printing. Figure 4.9.1-1 illustrates a web offset lithography publication printing line. A web newspaper printing line contains no dryer, because the ink contains very little solvent, and somewhat porous paper is generally used.

Web offset employs "heatset" (i. e., heat drying offset) inks that dry very quickly. For publication work the inks contain about 40 percent solvent, and for newspaper work 5 percent solvent is used. In both cases, the solvents are usually petroleum-derived hydrocarbons. In a publication web offset process, the web is printed on both sides simultaneously and passed through a tunnel or floater dryer at about 200 - 290°C (400 - 500°F) . The dryer may be hot air or direct flame. Approximately 40 percent of the incoming solvent remains in the ink film, and more may be thermally degraded in a direct flame dryer. The web passes over chill rolls before folding and cutting. In newspaper work no dryer is used, and most of the solvent is believed to remain in the ink film on the paper.[11]

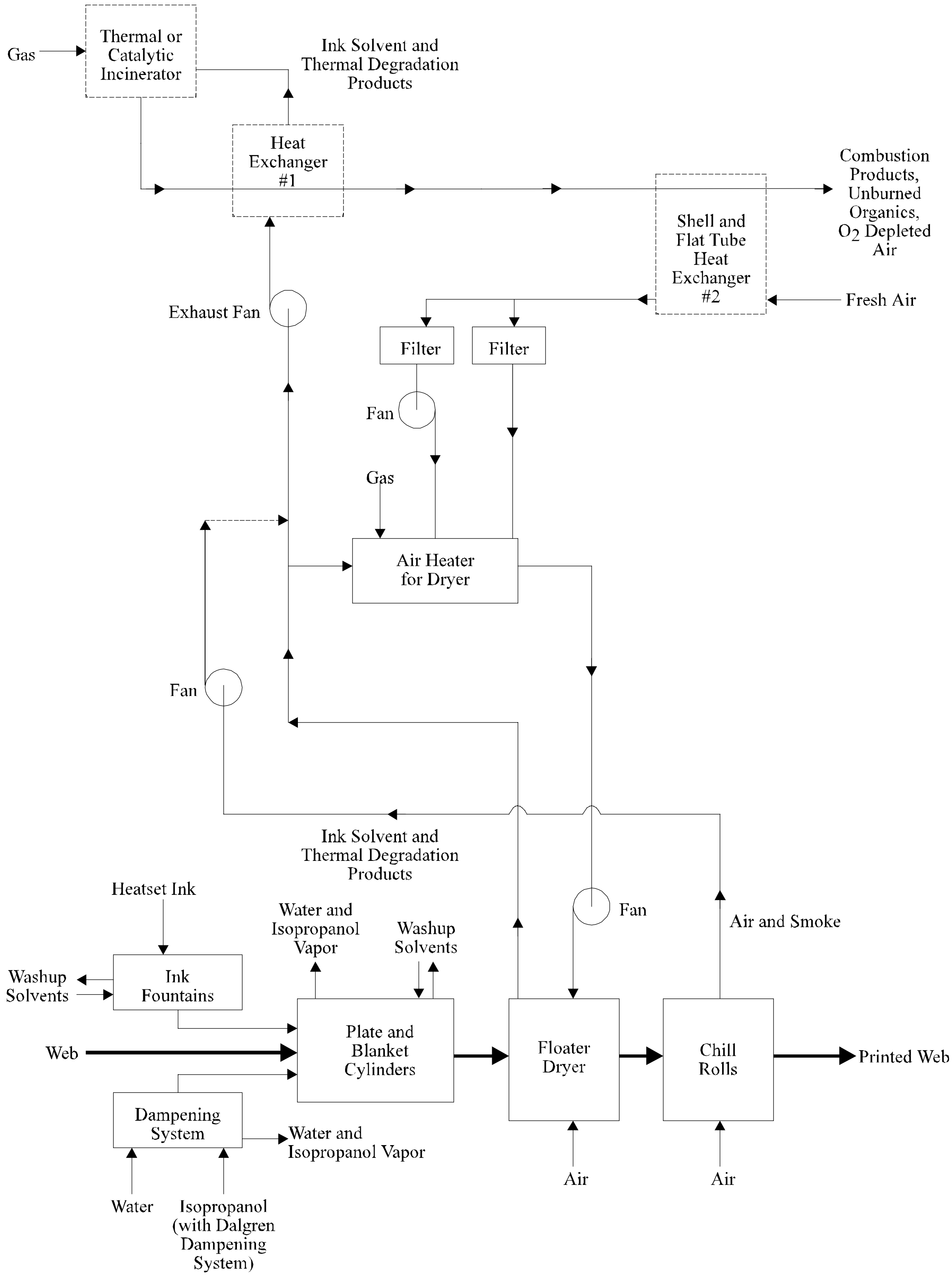

Figure 4.9.1-1. Web offset lithography publication printing line emission points.[11]

4.9.1.1.2 Web Letterpress -

Letterpress is the oldest form of moveable type printing, and it still dominates in periodical and newspaper publishing, although numerous major newspapers are converting to web offset. In letterpress printing, the image area is raised, and the ink is transferred to the paper directly from the image surface. The image carrier may be made of metal or plastic. Only web presses using solventborne inks are discussed here. Letterpress newspaper and sheet-fed printing use oxidative drying inks, not a source of volatile organic emissions. Figure 4.9.1-2 shows 1 unit of a web publication letterpress line.

Publication letterpress printing uses a paper web that is printed on 1 side at a time and dried after each color is applied. The inks employed are heatset, usually of about 40 volume percent solvent. The solvent in high-speed operations is generally a selected petroleum fraction akin to kerosene and fuel oil, with a boiling point of 200 - 370°C (400 - 700°F).[13]

4.9.1.1.3 Rotogravure -

In gravure printing, the image area is engraved, or "intaglio" relative to the surface of the image carrier, which is a copper-plated steel cylinder that is usually also chrome plated to enhance wear resistance. The gravure cylinder rotates in an ink trough or fountain. The ink is picked up in the engraved area, and ink is scraped off the nonimage area with a steel "doctor blade". The image is transferred directly to the web when it is pressed against the cylinder by a rubber covered impression roll, and the product is then dried. Rotary gravure (web fed) systems are known as "rotogravure" presses.

Rotogravure can produce illustrations with excellent color control, and it may be used on coated or uncoated paper, film, foil, and almost every other type of substrate. Its use is concentrated in publications and advertising such as newspaper supplements, magazines, and mail order catalogues; folding cartons and other flexible packaging materials; and specialty products such as wall and floor coverings, decorated household paper products, and vinyl upholstery. Figure 4.9.1-3 illustrates 1 unit of a publication rotogravure press. Multiple units are required for printing multiple colors.

The inks used in rotogravure publication printing contain from 55 to 95 volume percent low boiling solvent (average is 75 volume percent), and they must have low viscosities. Typical gravure solvents include alcohols, aliphatic naphthas, aromatic hydrocarbons, esters, glycol ethers, ketones, and nitroparaffins. Water-base inks are in regular production use in some packaging and specialty applications, such as sugar bags.

Rotogravure is similar to letterpress printing in that the web is printed on one side at a time and must be dried after application of each color. Thus, for 4-color, 2-sided publication printing, 8 presses 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) where nearly all of the solvent is removed.[3] For further information, see Section 4.9.2.

4.9.1.1.4 Flexography -

In flexographic printing, as in letterpress, the image area is above the surface of the plate. The distinction is that flexography uses a rubber image carrier and alcohol-base inks. The process is usually web fed and is employed for medium or long multicolor runs on a variety of substrates, including heavy paper, fiberboard, and metal and plastic foil. The major categories of the flexography market are flexible packaging and laminates, multiwall bags, milk cartons, gift wrap, folding cartons, corrugated paperboard (which is sheet fed), paper cups and plates, labels, tapes, and envelopes. Almost all milk cartons and multiwall bags and half of all flexible packaging are printed by this process.

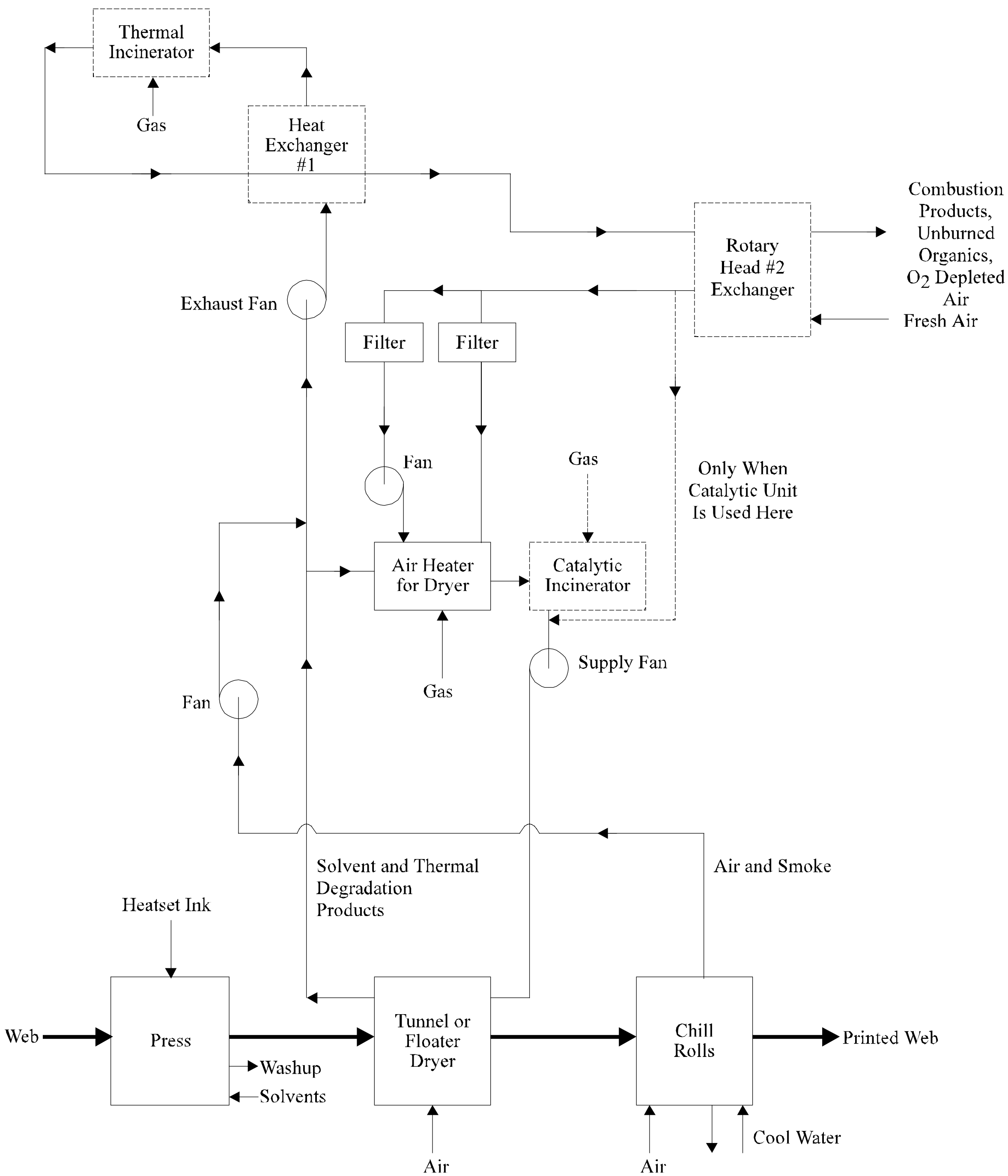

Figure 4.9.1-2. Web letterpress publication printing line emission points.[11]

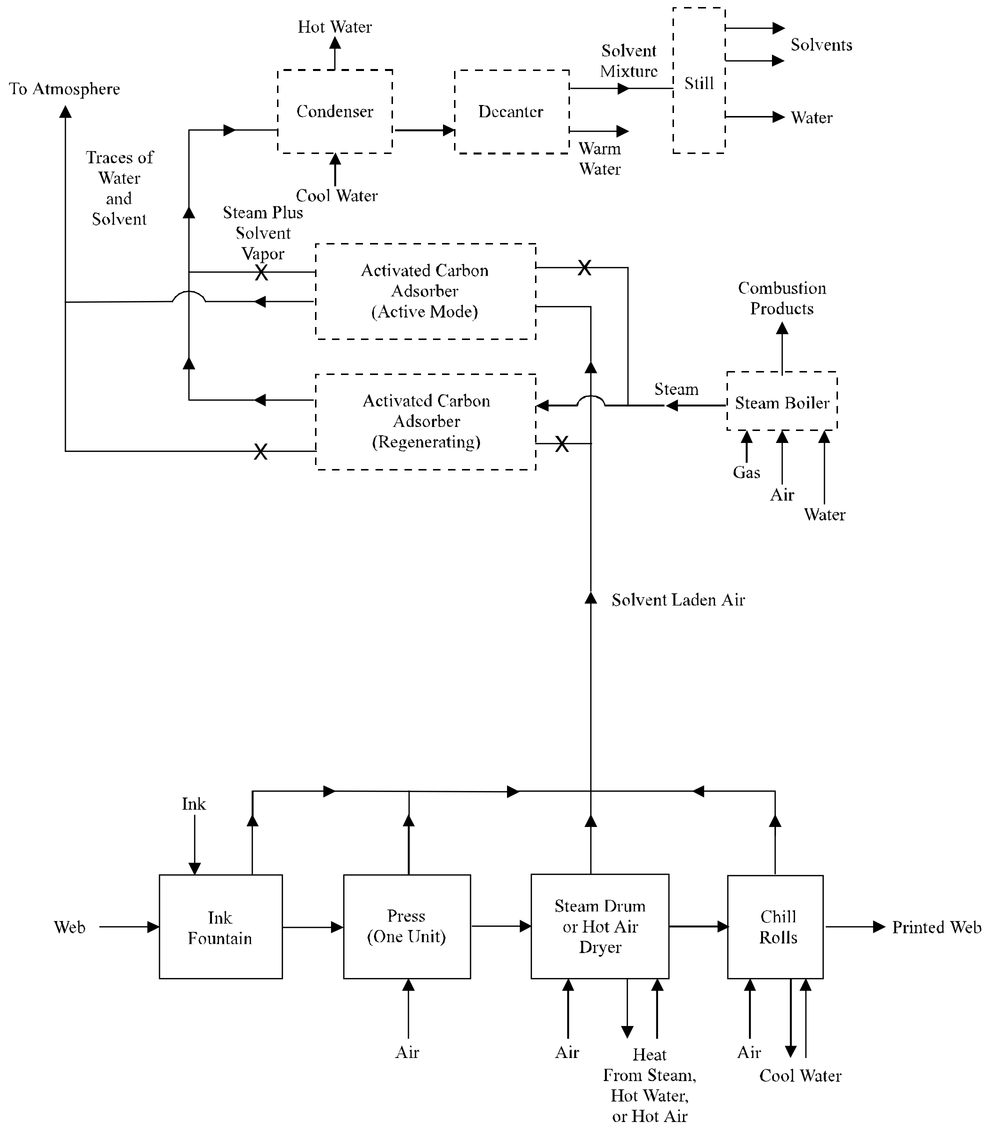

Figure 4.9.1-3. Rotogravure and flexography printing line emission points (chill rolls not used in rotogravure publication printing).[11]

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 they produce no significant emissions. Water-base inks, usually pigmented suspensions in water, are also available for some flexographic operations, such as the printing of multiwall bags.

Solvent-base inks are used primarily in publication printing, as shown in Figure 4.9.1-3. As with rotogravure, flexography publication printing uses very fluid inks of about 75 volume percent 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 glycols, ketones, and ethers. The inks dry by solvent absorption into the web and by evaporation, usually in high velocity steam drum or hot air dryers, at temperatures below 120°C (250°F).[3,13] As in letterpress publishing, the web is printed on only 1 side at a time. The web passes over chill rolls after drying.

4.9.1.2 Emissions And Controls

Significant emissions from printing operations consist primarily of volatile organic solvents. Such emissions vary with printing process, ink formulation and coverage, press size and speed, and operating time. The type of paper (coated or uncoated) has little effect on the quantity of emissions, although low levels of organic emissions are derived from the paper stock during drying.[13] High-volume web-fed presses such as those discussed above are the principal sources of solvent vapors. Total annual emissions from the industry in 1977 were estimated to be 380,000 megagrams (Mg) (418,000 tons). Of this total, lithography emits 28 percent, letterpress 18 percent, gravure 41 percent, and flexography 13 percent.[3]

Most of the solvent contained in the ink and used for dampening and cleanup eventually finds its way into the atmosphere, but some solvent remains with the printed product leaving the plant and is released to the atmosphere later. Overall solvent emissions can be computed from Equation 1 using a material balance concept, except in cases where a direct flame dryer is used and some of the solvent is thermally degraded.

The density of naphtha base solvent at 21°C (70°F) is 0.742 kilogams per liter (kg/L) (6.2 pounds per gallon [lb/gal]).

$$E_{total} = T \qquad (1)$$

where:

E_{total} = total solvent emissions including those from the printed product, kg (lb)
T = total solvent use including solvent contained in ink as used, kg (lb)

The solvent emissions from the dryer and other printline components can be computed from Equation 2. The remaining solvent leaves the plant with the printed product and/or is degraded in the dryer.

$$E = \frac{ISd}{100} \, \frac{(100-P)}{100} \qquad (2)$$

where:

E = solvent emissions from printline, kg (lb)
I = ink use, liters (gallons)
S and P = factors from Table 4.9.1-1.
d = solvent density, kg/L (lb/gal)

Table 4.9.1-1. TYPICAL PARAMETERS FOR COMPUTING SOLVENT EMISSIONS FROM PRINTING LINES[a,b]

Process	Solvent Content Of Ink (Volume %) [S]	Solvent Remaining In Product Plus That Destroyed In Dryer (%) [P][c]	EMISSION FACTOR RATING
Web Offset Lithography			
Publication	40	40 (hot air dryer) 60 (direct flame dryer)	B
Newspaper	5	100	B
Web Letterpress			
Publication	40	40	B
Newspaper	0	NA	NA
Rotogravure	75	2 - 7	C
Flexography	75	2 - 7	C

[a] References 1,14. NA = not applicable.
[b] Values for S and P are typical. Specific values for S and P should be obtained from a source to estimate its emissions.
[c] For certain packaging products, amount of solvent retained is regulated by the Food and Drug Administration (FDA).

4.9.1.2.1 Per Capita Emission Factors -

Although major sources contribute most of the emissions for graphic arts operations, considerable emissions also originate from minor graphic arts applications, including inhouse printing services in general industries. Small sources within the graphic arts industry are numerous and difficult to identify, since many applications are associated with nonprinting industries. Table 4.9.1-2 presents per capita factors for estimating emissions from small graphic arts operations. The factors are entirely nonmethane VOC and should be used for emission estimates over broad geographical areas.

Table 4.9.1-2 (Metric And English Units). PER CAPITA NONMETHANE VOC EMISSION FACTORS FOR SMALL GRAPHIC ARTS APPLICATIONS

EMISSION FACTOR RATING: D

Units	Emission Factor[a]
kg/year/capita	0.4
lb/year/capita	0.8
g/day/capita	1[b]
lb/day/capita	0.003[b]

[a] Reference 15. All nonmethane VOC.
[b] Assumes a 6-day operating week (313 days/yr).

4.9.1.2.2 Web Offset Lithography -

Emission points on web offset lithography publication printing lines include: (1) the ink fountains, (2) the dampening system, (3) the plate and blanket cylinders, (4) the dryer, (5) the chill rolls, and (6) the product (see Figure 4.9.1-1).

Alcohol is emitted from Points 2 and 3. Washup solvents are a small source of emissions from Points 1 and 3. Drying (Point 4) is the major source, because 40 to 60 percent of the ink solvent is removed from the web during this process.

The quantity of web offset emissions may be estimated from Equation 1, or from Equation 2 and the appropriate data from Table 4.9.1-1.

4.9.1.2.3 Web Letterpress -

Emission points on web letterpress publication printing lines are: (1) the press (includes the image carrier and inking mechanism), (2) the dryer, (3) the chill rolls, and (4) the product (see Figure 4.9.1-2).

Web letterpress publication printing produces significant emissions, primarily from the ink solvent, about 60 percent of which is lost in the drying process. Washup solvents are a small source of emissions. The quantity of emissions can be computed as described for web offset.

Letterpress publication printing uses a variety of papers and inks that lead to emission control problems, but losses can be reduced by a thermal or catalytic incinerator, either of which may be coupled with a heat exchanger.

4.9.1.2.4 Rotogravure -

Emissions from rotogravure printing occur at: (1) the ink fountain, (2) the press, (3) the dryer, and (4) the chill rolls (see Figure 4.9.1-3). The dryer is the major emission point, because most of the VOC in the low boiling ink is removed during drying. The quantity of emissions can be computed from Equation 1, or from Equation 2 and the appropriate parameters from Table 4.9.1-1.

Vapor capture systems are necessary to minimize fugitive solvent vapor loss around the ink fountain and at the chill rolls. Fume incinerators and carbon adsorbers are the only devices that have a high efficiency in controlling vapors from rotogravure operations.

Solvent recovery by carbon adsorption systems has been quite successful at a number of large publication rotogravure plants. These presses use a single water-immiscible solvent (toluene) or a simple mixture that can be recovered in approximately the proportions used in the ink. All new publication gravure plants are being designed to include solvent recovery.

Some smaller rotogravure operations, such as those that print and coat packaging materials, use complex solvent mixtures in which many of the solvents are water soluble. Thermal incineration with heat recovery is usually the most feasible control for such operations. With adequate primary and secondary heat recovery, the amount of fuel required to operate both the incinerator and the dryer system can be reduced to less than that normally required to operate the dryer alone.

In addition to thermal and catalytic incinerators, pebble bed incinerators are also available. Pebble bed incinerators combine the functions of a heat exchanger and a combustion device, and can achieve a heat recovery efficiency of 85 percent.

VOC emissions can also be reduced by using low-solvent inks. Waterborne inks, in which the volatile portion contains up to 20 volume percent water soluble organic compounds, are used extensively in rotogravure printing of multiwall bags, corrugated paperboard, and other packaging products, although water absorption into the paper limits the amount of waterborne ink that can be printed on thin stock before the web is seriously weakened.

4.9.1.2.5 Flexography -

Emission points on flexographic printing lines are: (1) the ink fountain, (2) the press, (3) the dryer, and (4) the chill rolls (see Figure 4.9.1-3). The dryer is the major emission point, and emissions can be estimated from Equation 1, or from Equation 2 and the appropriate parameters from Table 4.9.1-1.

Vapor capture systems are necessary to minimize fugitive solvent vapor loss around the ink fountain and at the chill rolls. Fume incinerators are the only devices proven highly efficient in controlling vapors from flexographic operations. VOC emissions can also be reduced by using waterborne inks, which are used extensively in flexographic printing of packaging products.

Table 4.9-3 shows estimated control efficiencies for printing operations.

Table 4.9-3. ESTIMATED CONTROL TECHNOLOGY EFFICIENCIES FOR PRINTING LINES

Method	Application	Reduction in Organic Emissions (%)
Carbon adsorption	Publication rotogravure operations	75[a]
Incineration[b]	Web offset lithography	95[c]
	Web letterpress	95[d]
	Packaging rotogravure printing operations	65[a]
	Flexography printing operations	60[a]
Waterborne inks[e]	Some packaging rotogravure printing operations[f]	65 - 75[a]
	Some flexography packaging printing operations	60[a]

[a] Reference 3. Overall emission reduction efficiency (capture efficiency multiplied by control device efficiency).
[b] Direct flame (thermal) catalytic and pebble bed. Three or more pebble beds in a system have a heat recovery efficiency of 85%.
[c] Reference 12. Efficiency of volatile organic removal — does not consider capture efficiency.
[d] Reference 13. Efficiency of volatile organic removal — does not consider capture efficiency.
[e] Solvent portion consists of 75 volume % water and 25 volume % organic solvent.
[f] With less demanding quality requirements.

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