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Graphic Arts: An AP-42 Update

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GRAPHIC ARTS:

AN AP-42 UPDATE

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INTRODUCTION

As the Table of Contents indicates, this report was written for inclusion in EPA Publication No. AP-42, Compilation of Air Pollutant Emission Factors. A preliminary draft of this section was begun when the draft version of the Control Techniques Guideline (CTG) document on "Graphic Arts" became available in April 1978. This work was performed under Work Assignment No. 7 of EPA Contract No. 68-02-2583. The publication date of the CTG document was subsequently postponed from July to December 1978, so completion of this AP-42 section was likewise delayed and was completed under Work Assignment No. 12 of the contract.

4.9 GRAPHIC ARTS

4.9.1 Process Description

4.9.1.1 General--The term "graphic arts" as used here means four 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 4.2 Industrial 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 the following 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
- Solvent laden air exhausted from the system

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

- 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.

4.9.1.2 Web Offset Lithography--Lithography, the process by which about 75 percent of books and pamphlets and an increasing number of newspapers are now printed, 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, which then transfers the wet inked image 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 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 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.[11] For publication work, the web is printed on both sides simultaneously and passed through a tunnel or floater dryer at about 200-290°C (400-~~500~~ 554°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

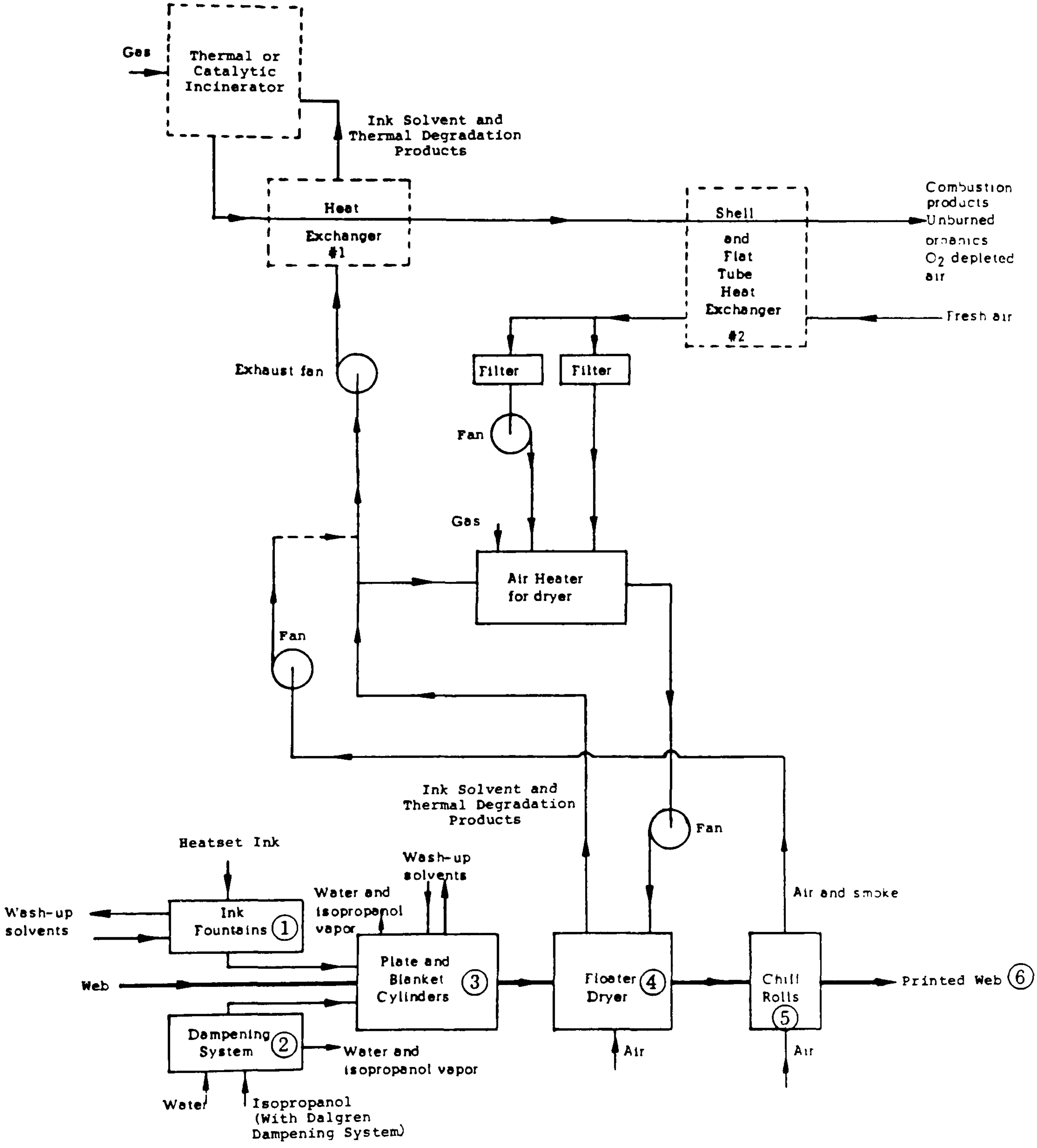

Figure 4.9-1. Web offset lithography publication printing line emission points (dashes show optional control equipment).[11]

thermally degraded in a direct flame dryer. The web passes over chill rolls prior to folding and cutting. For newspaper work, no dryer is used, and most of the solvent is believed to remain in the ink film on the paper.[11]

4.9.1.3 Web Letterpress--Letterpress is the oldest form of printing (limited to movable types) and still predominates in periodical and newspaper publishing, although numerous major newspapers are converting to web offset. In letterpress printing, the image area is raised relative to the nonimage area, 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 solvent-borne inks are discussed here because letterpress newspaper and sheet fed printing use oxidative-drying inks which are not a source of volatile organic emissions. Figure 4.9-2 shows one unit of a web publication letterpress line.

Publication letterpress printing uses a paper web that is printed on one side at a time and dried after each color is applied. The inks employed are heatset and usually contain 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]

4.9.1.4 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,

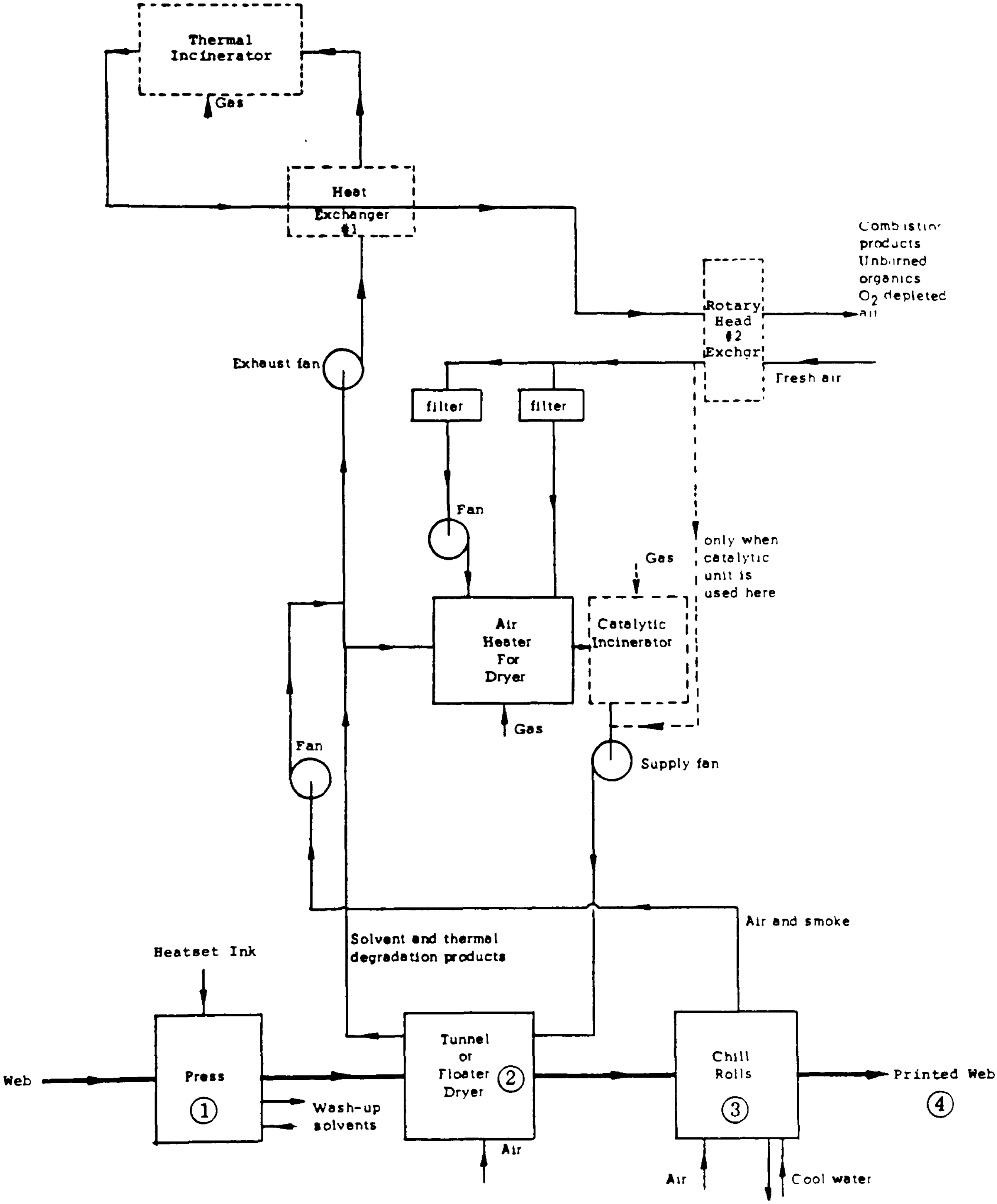

Figure 4.9-2. Web letterpress publication printing line emission points (dashes show optional equipment).[11]

and excess 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. The product is then dried. Rotary gravure systems are known as "rotogravure" presses.

Rotogravure can reproduce 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 (1) publications and advertising such as newspaper supplements, magazines and mail order catalogues; (2) folding cartons and other flexible packaging materials; and (3) specialty products such as wall and floor coverings, decorated household paper products, vinyl upholstery and health products. Figure 4.9-3 illustrates one unit of a publication rotogravure press. Multiple units are required for multiple color printing.

The inks used in rotogravure publication printing contain from 55 to 95 volume percent low boiling solvent, and they must have low viscosities. Typical gravure solvents include alcohols, aliphatic naphthas, aromatic hydrocarbons, esters, glycol-ethers, ketones and nitroparaffins. Water based 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 the application of each color. Thus, for four color, two-sided publication printing, eight presses are employed, with each press including a pass over a

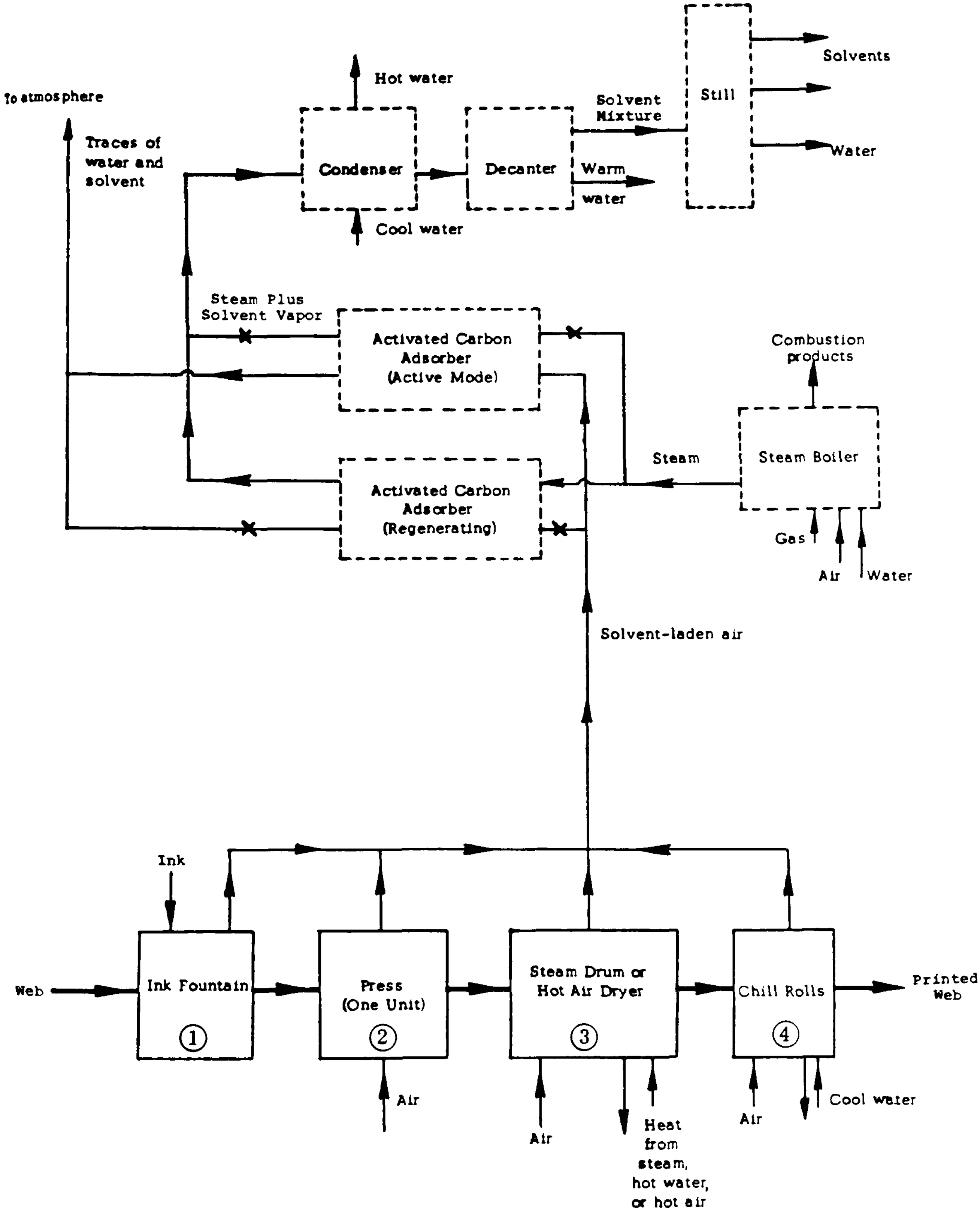

Figure 4.9-3. Rotogravure and flexography printing line emission points (dashes show optional control equipment).[11]

steam drum or through a hot air dryer at 38-93°C (100-200°F), where nearly all of the initial solvent is removed.[3]

4.9.1.5 Flexography--In flexographic printing, as in letterpress, the image area is raised above the surface of the plate. The distinction is that flexography uses a rubber image carrier and alcohol based 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, metal and plastic foil. The major categories of the flexographic 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 flexible packaging are printed by this process.

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 based inks, usually pigmented suspensions in water, are also available for some flexographic operations, such as the printing of multiwall bags.

Solvent-based inks are used primarily in publication printing, as shown in Figure 4.9-3. Like rotogravure, flexography publication printing uses very fluid inks, containing about 75 volume percent organic solvent. The solvent, which must be compatible with rubber, 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] Like letterpress publishing, the web is printed on only one side at a time. The web passes over chill rolls after drying.

4.9.2 Emissions and Controls

4.9.2.1 General--Significant emissions from printing operations consist primarily of volatile organic solvents. Such emissions vary with the 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 in Section 4.9.1 are the principal sources of solvent vapors.

Total annual emissions from the industry in 1976 were estimated to be 340,000 MT (380,000 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 as it leaves 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.

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

where

E_{total} = total solvent emissions including those from the printed product, kg (pounds)

T = total solvent usage including solvent contained in ink, kg (pounds)

The solvent emissions from the dryer and other components that are connected to the main exhaust system can be computed from Equation 2. The remaining solvent leaves the plant with the printed product and/or is degraded in the dryer.

$$E_{dryer} = \frac{SI}{100} \frac{(100 - P)}{100} \quad (2)$$

where

E_{dryer} = solvent emissions from dryer, kg (pounds)

I = ink usage in kg (pounds)

S and P = factors from Table 4.9-1

4.9.2.2 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. Emission point numbers refer to Figure 4.9-1.

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

The quantity of web offset emissions may be estimated from Equation 1 or from Equation 2 and the appropriate parameters from Table 4.9-1.

Table 4.9-1. TYPICAL PARAMETERS FOR COMPUTING SOLVENT EMISSIONS FROM UNCONTROLLED WEB OFFSET LITHOGRAPHY, WEB LETTERPRESS, ROTOGRAVURE AND FLEXOGRAPHY PRINTING LINES[a]

Process	Typical Solvent Content of Ink (percent)	Typical Solvent Remaining in Product and Destroyed in Dryer (percent)	Emission Factor Rating
	S	P	
WEB OFFSET			
Publication	40	40 - hot air dryer 60 - direct flame dryer	A
Newspaper	5	100	B
WEB LETTERPRESS			
Publication	40	40	B
Newspaper	0	(not applicable)	
ROTOGRAVURE	75	2 - 7	C
FLEXOGRAPHY	75	2 - 7	C

[a] References 1 and 14. For certain packaging products, the amount of solvent retained is regulated by the FDA.

4.9.2.3 Web Letterpress--Emission points on web letterpress publication printing lines are: (1) the press (which includes the image carrier and inking mechanism), (2) the dryer, (3) the chill rolls and (4) the product. Emission point numbers refer to Figure 4.9-2.

Web letterpress publication printing produces significant emissions, primarily from the ink solvent, about 60 percent of which is lost from the drying process (point 2). Wash-up solvents are a small source of emissions (point 1). The quantity of emissions can be computed as discussed above for web offset.

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

4.9.2.4 Rotogravure--Emissions from rotogravure printing occur at (1) the ink fountain, (2) the press, (3) the dryer and (4) the chill rolls. Emission point numbers refer to Figure 4.9-3. 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.

Ventilation systems are necessary to minimize solvent loss around the ink fountain and at the chill rolls (points 1 and 4). Fume incinerators and carbon adsorbers are the only devices that have a high efficiency in controlling vapors from rotogravure operations (points 1 to 4).

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 option 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. Water-borne 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 water-borne ink that can be printed on thin stock before the web is seriously weakened.

4.9.2.5 Flexography--Emission points on flexographic printing lines are (1) the ink fountain, (2) the press, (3) the dryer and (4) the chill rolls. Emission point numbers refer to Figure 4.9-3. 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.

Ventilation systems are necessary to minimize solvent loss around the ink fountain and at the chill rolls (points 1 and 4). Fume incinerators are the only devices that have proven highly efficient in controlling vapors from flexographic operations (points 1 to 4). VOC emissions can also be reduced by using water-borne inks, which are used extensively in flexographic printing of packaging products (refer to Section 4.9.2.4).

Table 4.9-2 shows estimated control efficiencies for the printing operations discussed herein.

Table 4.9-2. ESTIMATED CONTROL TECHNOLOGY EFFICIENCIES FOR WEB OFFSET LITHOGRAPHY, WEB LETTERPRESS, ROTOGRAVURE AND FLEXOGRAPHY PRINTING LINES

Emission Technology	Application	Reduction in Organic Emissions (percent)
Carbon adsorption	Publication rotogravure operations	75[d]
Incineration[a]	Web offset lithography	95[e]
	Web letterpress	95[f]
	Packaging rotogravure printing operations	65[d]
	Flexographic printing operations	60[d]
Water-borne inks[b]	Some packaging rotogravure printing operations[c]	65-75[d]
	Some flexographic packaging printing operations	60[d]

[a] Direct flame (thermal) catalytic and pebble bed. Three or more pebble beds in a system have a heat recovery efficiency of 85 percent.

[b] Inks in which the solvent portion consists of 75 volume percent water and 25 volume percent organic solvent.

[c] With less demanding quality requirements.

[d] Reference 3. Overall emission reduction efficiency.

[e] Reference 12. Efficiency of volatile organic removal--does not take into account capture efficiency.

[f] Reference 13. Efficiency of volatile organic removal--does not take into account capture efficiency.

References for Section 4.9

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10. Joseph L. Zborovsky, "Current Status of Web Heatset Emission Control Technology", ibid.

11. R. R. Gadomski, et al., Evaluations of Emission and Control Technologies in the Graphic Arts Industries, Phase I: Final Report, APTD-0597, National Air Pollution Control Administration, Cincinnati, OH, August 1970.

12. R. R. Gadomski, et al., Evaluations of Emissions and Control Technologies in the Graphic Arts Industries, Phase II: Web Offset and Metal Decorating Processess, APTD-1463, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1973.

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14. Communication with Edwin J. Vincent, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 1979.

BACKGROUND DOCUMENT

SECTION 4.9 GRAPHIC ARTS

1.0 INTRODUCTION

The section on Graphic Arts is organized as two separate sections with five subsections each, as follows:

4.9.1 Process Description

- 4.9.1.1 General
- 4.9.1.2 Web Offset Lithography
- 4.9.1.3 Web Letterpress
- 4.9.1.4 Rotogravure
- 4.9.1.5 Flexograpy

4.9.2 Emissions and Controls

- 4.9.1.1 General
- 4.9.1.2 Web Offset Lithography
- 4.9.1.3 Web Letterpress
- 4.9.1.4 Rotogravure
- 4.9.1.5 Flexography

Screen printing and manual techniques are not included due to the lack of available information. Direct lithography, in which the image carrier prints the image directly onto the substrate, is also not included because most lithographic operations are web offset (although most plants classified under commercial lithography operate with sheet fed equipment). Sheet fed gravure is excluded because it is slow and little used. Of the three categories of letterpress printing, only web presses using solvent-borne inks are discussed because

- Letterpress newspaper printing (which is web fed) utilizes oxidant drying inks composed of petroleum oils and carbon black, but little or no volatile solvent

- Letterpress sheet fed printing employs nonsolvent inks that dry in racks by air oxidation at room temperature

Moreover, flexographic newspaper printing, like letterpress newspaper printing, uses oxidative drying inks and emits only ink mist and paper dust, so this form of printing is also omitted from Section 4.9.

2.0 EMISSION FACTORS (Table 4.9-1)

The values for S, solvent content of ink, for web offset and letterpress were taken from Table 35 (pages 123-128) of Reference 11. The information was obtained through mail surveys (421 responses) and field visits (86) to printing establishments. The values for rotogravure and flexography were supplied by Ed Vincent of ESED in a private communication.

Values for P, the solvent remaining with the product or destroyed in the dryer, were taken from Table 35 of Reference 11 for web offset and web letterpress, except for the value for web offset using a direct flame dryer, which was taken from Table 18 (page 113) of Reference 12. The data from Reference 11 were derived from surveys and the data from Reference 12 were derived from source tests. Values for P for rotogravure and flexography were supplied by Ed Vincent of ESED in a private communication.

3.0 CONTROL TECHNOLOGY EFFICIENCIES (Table 4.9-2)

The estimated reductions in organic emissions achievable through the use of control technology that are shown in Table 4.9-2 are taken from pages 3-9 and 3-10 of Reference 3, the CTG document on flexography and rotogravure, with the exceptions of the figures for controlling web offset lithography and web letterpress by incineration, which are from References 12 and 13 (page 400), respectively.

The term "capture efficiency" refers to the efficiency of conveying all solvent emissions to the inlet of the control device. The term "removal efficiency" refers to the efficiency of the control device in removing all emissions that pass through it.

4.0 EMISSION FACTOR RATINGS

The factors are essentially based on the data base for estimating the parameters S and P in Table 4.9-1. The factor for web offset publication printing is rated A because it is based on results of a test program specifically designed to evaluate emissions. The factors for web offset newspaper and web letterpress publication printing are rated B because they are based on a combination of engineering analysis and limited test data. The factors for rotogravure and flexography are rated C because they are based on engineerng analysis and plant visits and may have been derived by averaging data from several plants that varied substantially from each other. The numerical rankings are as follows:

Process	Measured Emissions	Process Data	Engineering Analysis	Total
Web Offset				
Publication	17	9	10	36
Newspaper	9	9	10	28
Web Letterpress				
Publication	9	9	10	28
Rotogravure	0	8	9	17
Flexography	0	8	9	17

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

This document contains the text of AP-42 Section 4.9, Graphic Arts, written in May 1979. The section includes a description of four graphic arts processes (web offset lithography, web letterpress, rotogravure, and flexography), process flow diagrams, and emissions and controls discussions. A method for estimating emissions using theoretically derived equations is also included. A background document which discusses, in some detail, the derivation of emission quantification methodologies follows the Section itself.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
emission factors air pollution control evaporation loss sources graphic arts industry solvent use		

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