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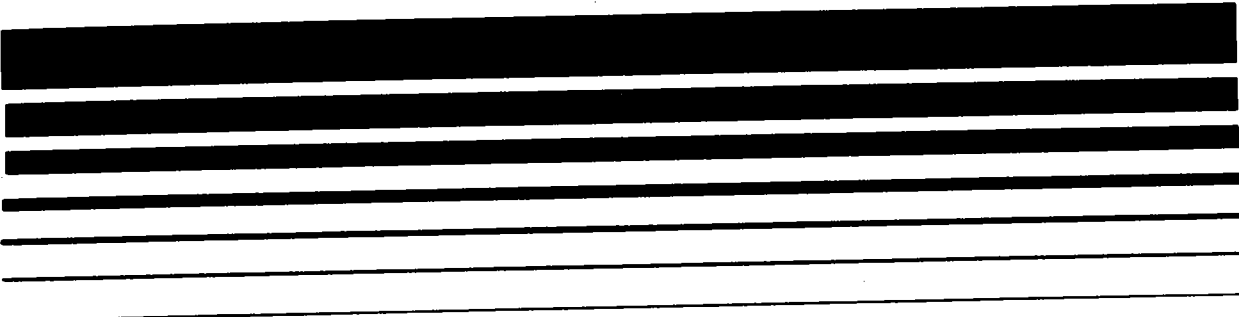
Air



Guideline Series

Control of Volatile Organic Compound Emissions from Offset Lithographic Printing

DRAFT



CTG

CONTROL OF VOLATILE ORGANIC COMPOUND EMISSIONS
FROM OFFSET LITHOGRAPHIC PRINTING

DRAFT

EMISSION STANDARDS DIVISION
CHEMICALS AND PETROLEUM BRANCH

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR QUALITY PLANNING AND STANDARDS
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NOTE

The EPA estimates that State and local regulations developed pursuant to this draft CTG would affect about 34,500 facilities and reduce volatile organic compound emissions by about 468,000 tons per year at a cost of about \$110,000,000 per year (assuming no savings from reduction of alcohol used in fountain solution). Further information on costs and controls is presented in the draft CTG document. The EPA requests comments from the public on all aspects of the draft CTG including the recommendations for reasonably available control technology (RACT) and the estimated cost of control.

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1.0 INTRODUCTION

The 1990 Clean Air Act (CAA) Amendments require that State implementation plans (SIP's) for ozone nonattainment areas be revised. The revisions will require the implementation of reasonably available control technology (RACT) for control of volatile organic compound (VOC) emissions from sources for which the U. S. Environmental Protection Agency (EPA) has already published control techniques guidelines (CTG's) or for which EPA will publish a CTG between the date of enactment of the Amendments and the date an area achieves attainment status.

Section 172(c)(1) of the 1990 CAA Amendments requires nonattainment area SIP's to provide, at a minimum, for "such reductions in emissions from existing sources in the area as may be obtained through the adoption, at a minimum, of reasonably available control technology...." The EPA defines RACT as presumptively: "The lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility" (44 FR 53761, September 17, 1979). The EPA has elaborated in subsequent Federal Register notices on how States and the EPA should apply the RACT requirements (see 51 FR 43814, December 4, 1989 and 53 FR 45103, November 8, 1988).

The CTG's are intended to provide State and local air pollution authorities with an information base for proceeding with their own analyses of RACT to meet statutory requirements. The CTG's review current knowledge and data concerning the technology and costs of various emission control techniques.

Each CTG contains a "presumptive norm" for RACT for a specific source category, based on the EPA's evaluation of the capabilities and problems general to that category. Where applicable, the EPA recommends that States adopt requirements consistent with the presumptive norm. However, the presumptive norm is only a recommendation. States may choose to develop their own RACT requirements on a case-by-case basis, considering the economic and technical circumstances of an individual source. Note that no laws or regulations preclude States from requiring more control than recommended as the presumptive norm for RACT. A particular State, for example, may need a more stringent level of control to meet the ozone standard or to reduce emissions of a specific toxic air pollutant.

This CTG is 1 of at least 11 that the EPA is required to publish within 3 years of enactment of the Amendments. It addresses RACT for control of VOC emissions from offset lithographic printing. This document is currently in draft form and is being distributed for public comment. The EPA solicits comments on all aspects of this draft CTG including the controls recommended as RACT and the estimated cost and cost-effectiveness of these controls per facility (Chapter 6) and on a nationwide basis (Appendix E). Public comments will be reviewed and incorporated as judged appropriate before the EPA finalizes the CTG.

2.0 SUMMARY

2.1 INTRODUCTION

Offset lithographic printing has a broad range of applications, including books, magazines, periodicals, labels and wrappers, catalogs and directories, financial and legal documents, business forms, advertising materials, newspapers, newspaper inserts, charts and maps, calendars, tickets and coupons, greeting cards, and stamps.

None of the above applications are exclusive to offset printing; other modes of printing in the graphic arts industry can produce items such as those mentioned above. However, the newspaper industry uses offset lithography predominantly, with over 70 percent of all newspapers in the United States printed by this method.

2.2 PROCESS DESCRIPTION

Lithography is a planographic method of printing; that is, the printing and nonprinting areas are essentially in the same plane on the surface of a thin metal "lithographic" plate. The distinction between the areas is maintained chemically: when the lithographic plate is made, the image area is rendered water repellent, and the nonimage area is rendered water receptive.

In offset lithographic printing, ink is transferred from the lithographic plate to a rubber-covered "intermediate," or "blanket," cylinder and then to the substrate. Transfer of the ink from the lithographic plate to the blanket cylinder, rather than directly to the substrate, is the offset characteristic of this type of printing.

A printing press is made up of a number of printing units, from 1 to 12. Figure 2-1 is a schematic of an offset

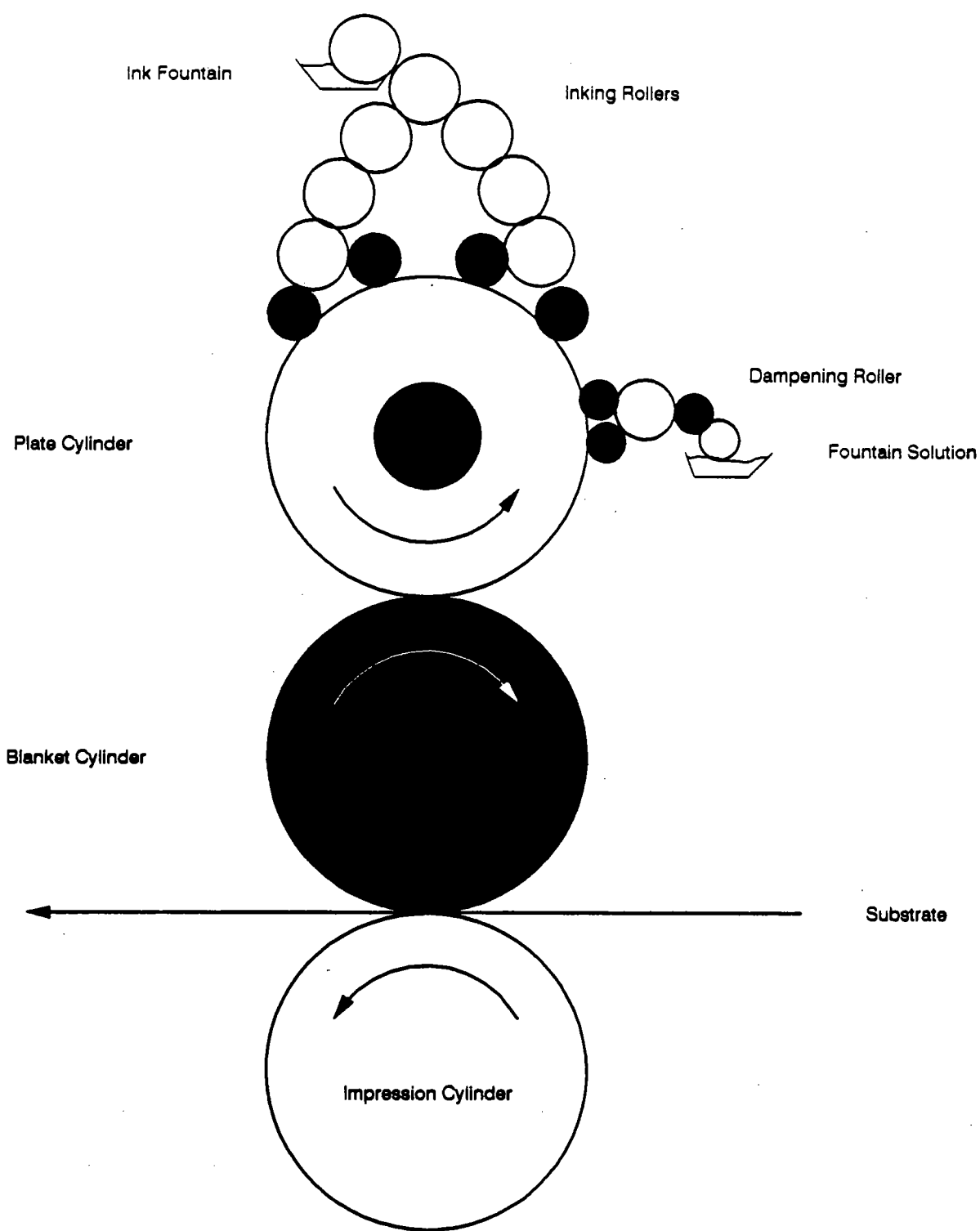


Figure 2-1. Schematic of a printing unit.

lithographic printing unit. Printing units are available that print both sides of the substrate at the same time (a process known as perfecting), as well as only one side (known as nonperfecting).

Offset lithographic printing is also characterized by the form in which the material to be printed on (the substrate) is fed to the press. In sheet-fed printing, individual sheets of paper or metal are fed to the press. In web printing, continuous rolls of paper are fed to the press and the paper is cut to size after it is printed.

Lithographic inks are composed of pigments, vehicles, binders, and other additives. The pigments provide the desired color and are composed of organic and inorganic materials. Lithographic inks may be heatset, where heat is required to set the ink, or non-heatset, where the inks are set by absorption into the substrate, by oxidation, or by other non-heatset methods. Heatset inks may contain up to 45 percent VOC's. Non-heatset inks have higher boiling points than heatset inks and are less pasty. They usually contain below 35 percent VOC's. Most non-heatset inks used in sheet-fed printing are below 25 percent VOC.

A "fountain solution" is applied to the lithographic plate to render the nonimage areas unreceptive to ink. Since printing inks are oil-based, the fountain solution is water-based. The fountain solution contains small quantities of gum arabic or synthetic resins, acids and buffer salts to maintain the pH of the solution, and a wetting agent or "dampening aid" to enhance the spreadability of the fountain solution across the print plate. The role of the dampening aid is to reduce the surface tension of water as well as increase viscosity.

Isopropyl alcohol (IPA), a VOC, has been used as the dampening aid since the 1950's. The concentration of alcohol in the fountain solution can range from 0 to 35 percent (by volume) or higher, with the concentration in most presses falling between 15 and 20 percent.

Cleaning solutions are used to remove excess printing inks, oils, and paper components from press equipment. The solutions are petroleum-based solvents, often mixed with detergent and/or water. The cleaning compound may be a single solvent, such as kerosene, or a combination of solvents. Cleaning solutions are used to wash the blankets, the rollers, and the outside of the presses. A general purpose cleaner may not work well for every job.

2.3 MODEL PLANTS

Model plants were developed to evaluate the potential ranges in VOC emissions from the different types of offset lithographic printing and the different processes involved in producing a printed product. Model plants for the following four types of printing were used to represent the industry: (1) heatset web, (2) non-heatset web (non-newspaper), (3) non-heatset sheet-fed, and (4) newspaper non-heatset web. The model plants ranged in size from small to large, and comprised from 1 to 10 presses and from 1 to 120 individual units. These model plants were developed to represent a range of sizes and emission potentials, and are not meant to characterize the printing industry. State and local agencies are advised to use actual plant data whenever possible.

In practice, any of the four types of model plants described above can be combined under one roof to form one facility made up of different printing processes or "sub-facilities." For instance, a company may have a medium-size sheet-fed operation and a small heatset web press. However, the possible number of combinations of two-, three-, and four-model sub-facilities in one facility is too large for the purposes of this discussion; therefore, State and local agencies are advised to treat each sub-facility as a separate unit in terms of strategies for VOC emission control.

2.4 EMISSION CONTROL STRATEGIES

There are three sources of VOC emissions from offset lithographic printing: (1) exhaust from the hot air dryers used to set heatset inks, (2) dampening aids used in fountain solution, and (3) cleaning solutions.

Mechanisms to control VOC emissions from lithographic printing presses can be categorized as:

- Add-on controls;
- Process modifications; or
- Material reformulation or substitution.

2.4.1 Add-On Controls

Add-on control devices can be grouped into two broad categories: combustion control devices (destructive) and recovery devices (nondestructive). Combustion control devices are designed to destroy VOC's in the vent stream prior to atmospheric discharge; recovery devices limit VOC emissions by recovering material for reuse.

The heatset web offset lithographic printing industry employs three basic add-on control devices: (1) thermal incinerators, (2) catalytic incinerators, and (3) condenser filter systems. According to several vendors, the field is dominated by incineration, with catalytic incineration being slightly more popular. Incineration can achieve approximately 98 percent VOC removal.

The condenser filter systems currently in use have been designed specifically for the heatset web offset printing industry. Solvents recovered from condenser filter systems can be burned in the dryers or boilers as supplemental fuel. Condenser filter systems can achieve as high as 97 percent VOC removal efficiency, although about 90 percent is typical. With the addition of activated carbon canisters on the outlet of the filter exhaust, 95 percent removal can be readily achieved.

2.4.2 Process Modification

Process modifications are changes in operational methods or equipment resulting in improved VOC control. The modifications may involve retrofitting existing equipment or replacing older equipment with new technology to accommodate the process change.

Cooling a fountain solution that contains IPA is one process modification that reduces the evaporation of IPA and, hence, VOC emissions from the fountain. Refrigerated

circulators are available that cool the fountain solution to a pre-set temperature, usually from 55 to 60°F. This also gives operators better control of ink emulsification and hot weather scumming, and stabilizes the ink/water balance by minimizing alcohol evaporation. Refrigeration of fountain solution trays has been shown to reduce alcohol consumption by as much as 44 percent.

Another process change is a new device that has been introduced to the printing industry that reduces the use of dampening aids in the fountain solution. The device magnetizes the fountain water and reduces its surface tension so that less alcohol is needed. Over 200 units are reported to be in use in the United States. Preliminary data show that alcohol consumption can be greatly reduced with this device, although a small amount of alcohol may be needed for startup. Despite the early success of this device, current use in the industry is limited, with some facilities reporting no reduction in the need for alcohol.

2.4.3 Material Reformulation or Substitution

Material reformulation includes the use of nonalcohol additives in the fountain solution dampening system and lower VOC cleaning solutions.

2.4.3.1 Fountain Solution. A large portion of the VOC emissions from the model plants was due to the IPA used in the fountain solution. Nonalcohol additives (or alcohol substitutes) have been developed in recent years to replace or minimize the amount of alcohol used in a fountain solution. Nonalcohol additives are made up of glycol (such as ethylene or propylene glycol, glycol ethers, or proprietary compounds) that are chemically similar to alcohol, with the same surface tension reducing ability but a more complex structure. Nonalcohol additives have a higher boiling point and a lower volatility than traditional dampening aids. The additives are incorporated in small quantities (from 2 to 4 ounces to 1 gallon of water) to produce a final fountain solution that is less than 3 percent VOC. Some of the additives have

recently been classified as hazardous air pollutants (HAP's) by the EPA in the CAA Amendments of 1990.

Depending on the printing process variables, difficulties have been reported in totally replacing alcohol with alcohol substitutes. Some printers assert that they cannot function without some alcohol in their fountain solution; however, the National Association of Printers and Lithographers (NAPL) and other printers believe that a commitment by management could result in lower alcohol use rates. The newspaper industry has successfully used nonalcohol additives.

2.4.3.2 Cleaning Solutions. A few cleaning solutions are available with a lower VOC content than traditional cleaning compounds, which are often 100 percent VOC. However, some lower VOC cleaning products contain HAP's. The VOC content of the lower VOC products without HAP's ranges from 0 to 30 percent. Lower VOC cleaning products that do not contain HAP's are carried by only a few vendors at this time. These products contain organic compounds that are not VOC's.

2.5 MODEL PLANT VOLATILE ORGANIC COMPOUND EMISSION ESTIMATES

2.5.1 Volatile Organic Compound Emissions From Inks

Ink use for the model plants was estimated from ink usage rates derived from surveys and other sources of information on the industry. The estimated average ink use for the model plants ranged from 1 to 14 tons per year (tpy) for non-heatset sheet-fed facilities, from 77 to 618 tpy for non-heatset and heatset web facilities (non-newspaper), and 10 to 2,155 tpy for newspaper facilities (non-heatset web).

The VOC emissions from ink use for the model plants were determined from the amount of ink used, the average amount of VOC in the ink, and the amount of VOC retained on the substrate. For heatset model plants, the VOC content of the ink was estimated at 40 percent VOC. Using a substrate retention factor of 20 percent VOC for heatset ink, the corresponding VOC emissions from the heatset model plants due to ink use ranged from 25 to almost 200 tpy.

For the non-heatset model plants, the substrate retention factor of VOC was estimated at 0.95, since the inks are

designed to dry by absorption or oxidation and not by evaporation of the ink oils. With an estimated VOC content of 30 percent for non-heatset web inks (non-newspaper), the estimated VOC emissions from the non-heatset web model plants from ink use ranged from less than 1 to 11 tpy. For non-heatset sheet-fed model plants, using an estimated VOC content of 25 percent in the ink, the VOC emissions from ink use were estimated to range from 0.02 to 0.25 tpy. Ink use rates for newspaper model plants were estimated based on information provided by industry and range from 10 to almost 2,200 tpy. The VOC emissions from ink use were calculated from ink use rates, a 10 percent VOC content for news inks, and a 0.95 VOC retention factor by the substrate. Estimated emissions ranged from 0.10 ton to 11 tpy.

2.5.2 Volatile Organic Compound Emissions from Fountain Solution

Isopropyl alcohol is assumed to be completely volatilized within the fountain solution delivery system because of the heat and work of the system on the solution. Volatile organic compound emissions from IPA use, therefore, are equal to the amount of alcohol used.

The estimated use of IPA for the model plants was based on alcohol-to-ink ratios obtained from an industry survey. The estimated use rate in the model plants ranged from 1 to almost 600 tons of alcohol per year, according to the size and type of facility. This use rate was estimated to correspond to a baseline alcohol concentration in the fountain of 17 percent (by volume) in heatset web and non-heatset sheet model plants, and 10 percent alcohol in non-heatset web model plants.

Use of nonalcohol additives for the model plants representing newspaper facilities also was estimated using information obtained from an industry survey. The estimated use of nonalcohol additives in the newspaper model plants ranged from almost 1 tpy for the smallest model plant to 151 tpy for the largest facility. The nonalcohol additives were estimated to be 10 percent VOC; therefore, VOC emissions

estimates for the newspaper facilities ranged from 0.1 to approximately 15 tpy, from the smallest facility to the largest, respectively.

2.5.3 Volatile Organic Compound Emissions from Cleaning Solutions

Estimated cleaning solution use for the model plants was based on rates estimated from industry surveys. Because cleaning compounds used for offset lithographic printing are approximately 100 percent VOC, the VOC emissions associated with use of cleaning compounds for the model plants are equal to the amount of cleaners used. The estimated cleaning solution usage for the model plants and, consequently, VOC emissions from cleaning solutions ranged from 1 to 55 tpy, depending on the size and type of facility.

2.5.4 Reduction of Volatile Organic Emissions from Heatset Inks

Controlled levels of VOC emissions from inks were calculated based on application of four types of add-on controls: (1) thermal incinerators, (2) catalytic incinerators, (3) condenser filters with activated carbon, and (4) condenser filters without carbon. A 98-percent efficiency was used for incinerators, 95 percent was used for condenser filters with carbon, and 90 percent was used for condenser filters without carbon. Estimated controlled VOC emissions for the model plants ranged from 1 to 20 tpy, depending on the size of the facility and type of control device.

2.5.5 Reduction of Volatile Organic Compound Emissions from Fountain Solution

Controlled VOC emissions from the model plants were estimated for fountain solution with alcohol levels at 10, 5, 3, and 0 percent (by volume), as compared with 17 or 10 percent alcohol in the baseline (uncontrolled), depending on the type of facility. The estimated VOC emissions at the reduced levels of alcohol were proportional to the amount of alcohol remaining in the fountain solution. The controlled VOC emissions calculated for the model plants using magnetism in the fountain solution corresponded to 0 and 3 percent

alcohol, where the higher level represented the use of alcohol for startup.

Emission reductions with refrigeration of the fountain were also estimated for the model plants with alcohol concentrations of 17, 8.5, 5, and 3 percent (by volume). Estimates of controlled VOC emissions for alcohol reduction and/or refrigeration ranged from a low of zero emissions for total elimination of alcohol to a high of approximately 311 tpy for the largest heatset web model plant operating with 17 percent alcohol and refrigeration of the fountain.

The reduction in VOC emissions with the use of alcohol substitutes was estimated for the model plants that did not use nonalcohol additives in the baseline (all non-newspaper model plants). Because of the low volatility of the alcohol substitutes, refrigeration was not considered in conjunction with alcohol substitutes, since cooling does not contribute to additional control. The estimated after-control emissions for the model plants (non-newspaper) with the use of alcohol substitutes ranged from 20 pounds per year to approximately 6 tpy, depending on the type and size of the facility.

2.5.6 Reduction of Volatile Organic Compound Emissions from Cleaning Solutions

Some lower VOC cleaning compounds (nonhazardous) are available with VOC contents ranging from 0 to 30 percent (by weight), as used. Controlled VOC emissions with the use of lower VOC cleaning compounds in the model plants were estimated to range from less than 0.5 to over 16 tpy, depending on the baseline level of cleaning solution use.

2.6 COSTS OF VOLATILE ORGANIC COMPOUND CONTROL TECHNIQUES

2.6.1 Costs of Add-On Controls for Volatile Organic Compound Emissions from Heatset Inks

Design assumptions, costing equations, and price quotes for removing VOC's emitted from heatset inks and contained in dryer exhaust streams, were obtained from vendors with extensive experience with the industry. Capital and annual costs were estimated for the addition of thermal incinerators,

catalytic incinerators, and condenser filters to the heatset model plants.

The cost analyses used for thermal and catalytic incinerators followed the methodology outlined in the OAQPS Control Cost Manual.¹ Equipment cost correlations were based on data provided by the various vendors. Annual costs for the add-on controls include operating and maintenance costs, as well as annualized capital charges. With condenser filters, solvent recovery credits were included because the condensed VOC can be used as fuel.

The cost analyses for the model plants show that the annual costs of adding incinerators range from approximately \$75,000 to \$351,000 per year for 24 to 194 tons of VOC removed, for small to large model plants, respectively. Thermal incinerators are slightly more costly (approximately 10 percent) than catalytic for the same VOC reduction potential. The use of condenser filters with carbon was estimated for the model plants to cost approximately \$69,000 to \$290,000 for small to large facilities, respectively, for 23 to 188 tons of VOC removed. Condenser filters without carbon have lower costs in general (but lower VOC reduction potentials), ranging from approximately \$50,000 to \$230,000 for 22 to 178 tons of VOC removed, for small to large plants, respectively.

2.6.2 Costs of Reducing Volatile Organic Compound Emissions from Fountain Solution

2.6.2.1 Material Reduction or Substitution. Reducing the use of alcohol in the fountain solution results in a savings of \$920 per ton of alcohol not used. Nonalcohol fountain additives, or alcohol substitutes, although more expensive than alcohol (\$1.55 per pound), save money because they are used in lower quantities.

Reducing alcohol or switching to substitutes may not be an easy transition for some printers. An industry-wide concern is the potential for lost production and the retraining time that may be necessary. The process change may

also result in paper and material waste, especially during the transition.

Such "changeover costs" will likely differ for each facility, depending on the type of mechanical equipment currently in place. Sheet-fed presses may be the most difficult to change because of the high variability and number of products printed, each of which requires press resetting. Although these changeover costs are recognized, it is believed that such costs will decrease substantially after printers become accustomed to the new regime. Material cost savings eventually may outweigh initial costs.

The estimated potential savings of alcohol reduction or substitution in the fountain solution for the model plants ranged from approximately \$500 to almost \$13,000 per year, depending on the size and type of the facility and the level of alcohol reduction.

2.6.2.2 Refrigeration of the Fountain. Refrigerated circulators cool the fountain solution to a preset temperature, usually from 55 to 60°F, thus reducing the amount of alcohol needed to maintain the same concentration of alcohol in the fountain. For the model plants in the baseline, where 17 percent alcohol is used in the fountain, the estimated cost of using refrigeration to control VOC emissions ranged from an expenditure of approximately \$80,000 per year to a savings of almost \$232,000 per year, depending on the size and type of facility.

Because sheet-fed presses are very small sources of fountain emissions, the cost of applying refrigerated circulators to these plants is extremely high, with net costs ranging from \$12,000 to \$80,000 per year for small to large plants, respectively. Refrigerated circulators were not applied to newspaper model plants, because nonalcohol additives are used in newspaper facilities and refrigeration does not help because nonalcohol additives have a much lower evaporation rate as compared with even cold alcohol.

2.6.2.3 Magnetizing the Fountain Solution. Adding magnetism to the fountain solution may reduce the alcohol

needed in the fountain. The magnets' costs are low (approximately \$350 each), with insignificant installation costs.

Most printing facilities will show a net savings with the successful use of a magnet because of the savings in alcohol. The estimated cost of adding magnets to the fountain solution system in the model plants ranged from approximately \$200 to almost \$8,000 per year, depending on the size and type of facility. This cost may be reduced by the decrease in alcohol use; the magnitude of the savings depends on the alcohol concentration before and after the magnets are applied (see Section 2.6.2.1 above).

2.6.3 Costs of Reducing Volatile Organic Compound Emissions from Cleaning Solutions

Lower VOC cleaning compounds that do not contain HAP's are priced slightly higher than traditional offset lithographic cleaning compounds. The incremental costs of using these lower VOC (without HAP's) cleaning solutions in the model plants were estimated to range from approximately \$550 to \$24,000 per year, depending on the size and type of model plant.

2.7 REASONABLY AVAILABLE CONTROL TECHNOLOGY FOR CONTROL OF VOLATILE ORGANIC COMPOUND EMISSIONS FROM OFFSET LITHOGRAPHIC PRINTING

Recommendations for controlling VOC emissions from heatset inks, fountain solution, and cleaning solution used in offset lithographic printing are discussed below.

2.7.1 Heatset Inks

The recommended level of control for VOC emissions from dryer exhaust is a 90-percent reduction in VOC's.

2.7.2 Fountain Solution

2.7.2.1 Heatset Web Printing. The recommended level of control for VOC emissions from fountain solution is equivalent to 1.6 percent alcohol (by volume) in the fountain; it may be achieved by actually reducing to 1.6 percent or less (by volume). It also may be achieved with 3 percent alcohol or less (by volume) if the fountain solution is refrigerated to

below 60°F. Higher levels of control can be achieved by using alcohol substitutes or less alcohol in the fountain.

2.7.2.2 Sheet-fed Printing. The recommended level of control of fountain solution emissions in sheet-fed facilities is equivalent to 5 percent alcohol (by volume) in the fountain. It may be achieved by actually reducing alcohol to 5 percent or less (by volume). It also may be achieved by refrigerating a fountain solution that contains 8.5 percent alcohol. Higher levels of control can be achieved by using alcohol substitutes or less alcohol.

2.7.2.3 Non-heatset Web. The recommended level of control for VOC emissions from non-heatset web facilities is the use of nonalcohol additives or alcohol substitutes (less than 3.0 percent additive by volume in the final solution).

2.7.3 Cleaning Solutions

The recommended control of VOC emissions from cleaning solutions is the use of cleaners with less than 30 percent (by weight) VOC, as used.

2.8 ENVIRONMENTAL IMPACTS OF REASONABLY AVAILABLE CONTROL TECHNOLOGY

Controlling VOC emissions from offset lithographic printing presses will significantly reduce the amount of air pollution introduced into the environment.

Controlling VOC's in the dryer exhaust by incineration was estimated to increase air emissions of nitrogen oxides (NO_x) at an estimated rate of 0.1 to 2.8 tons of NO_x per year for the model plants, with high NO_x emissions associated with thermal as opposed to catalytic incineration. Using condenser filters to control dryer VOC exhaust will reduce the amount of fuel consumed during printing because the collected solvents can be used as fuel for the dryers. If reduced demand for fuel is translated into a conservation of energy resources, the air pollution associated with fuel production will be reduced. Some additional energy is required to operate the additional fans and controls for the add-on controls, as well as for refrigerated circulator systems. This may result in minor additional environmental impacts.

Catalysts and carbon used in add-on controls in heatset printing will result in a small (insignificant) increase in solid waste because of periodic disposal requirements. Use of condenser filters may increase the load to water treatment facilities (to a small extent) because of the inability to completely separate out ink oils.

2.9 CONCLUSIONS

On the basis of the model plant analyses, the main source of VOC emissions in offset lithographic printing facilities appears to be alcohol used in fountain solution. Uncontrolled exhaust from heatset ink drying is the second largest source of emissions (in heatset facilities only). The VOC emissions from cleaning solutions generally are less than those from inks or fountain solution, and are estimated to range from 3.0 to 50 percent of the total VOC emissions from any one facility.

2.10 REFERENCE

1. U. S. Environmental Protection Agency. OAQPS Control Cost Manual. Office of Air Quality Planning and Standards. Research Triangle Park, NC. Publication No. EPA-450/3-90-006. January 1990.

3.0 INDUSTRY PROFILE AND MODEL PLANTS

3.1 OVERVIEW OF THE PRINTING INDUSTRY

The printing industry, sometimes called the graphic arts industry, is included under the major industrial category Printing, Publishing, and Allied Industries (Standard Industrial Classification [SIC] 27),¹ which includes all commercial, publishing, and newspaper printing.

In terms of employment, the printing industry is the sixth largest manufacturing industry in the United States. In 1986, the industry provided over 500,000 jobs, with a combined payroll exceeding \$11 billion. Between 1976 and 1986, the average employment growth rate for the printing industry was 79 percent; the manufacturing industry's growth as a whole during that period was only 8 percent.²

The printing industry is largely made up of small businesses. In 1986, it comprised 30,564 businesses, with over 90 percent of commercial printing establishments employing fewer than 50 people, and over 65 percent employing fewer than 10.²

Printing ranks as one of the top 10 manufacturing industries in 37 States. California, New York, Illinois, Pennsylvania, and Ohio account for 38 percent of the industry's employment and 41 percent of its annual payroll. In Illinois, printing is the largest manufacturing industry, and it continues to grow despite Illinois' declining manufacturing sector.² On a regional basis, 57 percent of the printing industry is concentrated in the North Central (Illinois, Indiana, Michigan, Ohio, Wisconsin), North Atlantic

(New Jersey, New York, Pennsylvania), and Pacific (Alaska, California, Hawaii, Oregon, Washington) regions.²

Printing processes include letterpress, flexography, rotogravure, screen, and offset lithography. In March, April, and May of 1990, offset lithographic printing made up approximately 64 percent of the SIC 27 category, based on number of employees.³

3.2 OFFSET LITHOGRAPHIC PROCESS AND APPLICATIONS

Unlike other printing processes, which use raised or recessed surfaces to print the image, lithography is a planographic method of printing; that is, the printing and nonprinting areas are in the same plane on the surface of a thin metal "lithographic" plate. The distinction between the areas is maintained chemically. When the lithographic plate is made, the image area is rendered oil receptive and water repellent, and the nonimage area is rendered water receptive. A fountain containing water-based solution is used to dampen the lithographic plate in the water receptive areas.

During printing, ink is transferred first from the ink reservoir, or fountain, to ink rollers, and then onto the lithographic plate. The ink is transferred from the lithographic plate to a rubber-covered blanket cylinder. The blanket cylinder then prints the ink image onto the substrate. Transfer of ink from the lithographic plate to the intermediate blanket cylinder, rather than directly to the substrate, is the offset characteristic of lithographic printing.

Offset lithographic printing can be done using two generic types of ink: heatset inks, which are dried by heat, or non-heatset inks, which are not heated. In the heatset ink printing process, the printed substrate passes through a heated dryer to solidify (set) the printing inks by evaporating the ink oils. In the non-heatset ink process, the inks dry by absorption into the substrate, by oxidation, or by other non-heat processes.⁴ Inks are discussed in further detail in Section 3.5.

Two types of systems to feed the substrate to the print rolls may be used: (1) web, where paper is fed to the press in a continuous roll and the product is cut to size after the web is printed; and (2) sheet-fed, where individual sheets of paper or metal are fed to the printing press.

Offset lithographic printing presses are any of three types: heatset web, non-heatset web (newspaper and non-newspaper), or non-heatset sheet-fed.⁵ Presses are discussed in detail in Section 3.3.

The lithographic process is used for a broad range of printing applications, including books, magazines, periodicals, labels and wrappers, catalogs and directories, financial and legal documents, business forms, advertising brochures, newspapers, newspaper inserts, charts and maps, calendars, tickets and coupons, greeting cards, and stamps.

One type, heatset web, is employed mostly for printing publications such as magazines, catalogs, and books, and for various commercial jobs (e.g., calendars).⁶ Non-heatset web, on the other hand, is generally used to print newspapers, business forms, and miscellaneous commercial items such as newspaper inserts and multicolored catalogs. Non-heatset sheet-fed presses are typically employed for most types of commercial printing, such as paper packaging boxes (cereal, etc.), greeting cards, and metal decorating.⁶ The most commonly used substrates are paper, paperboard, metal, supported foil, and film.⁷

Newspapers are predominantly produced by the non-heatset web offset lithographic process. Over 70 percent of the newspapers printed in 1987 were offset, with the remainder being produced by the letterpress printing process.⁸ Many newspapers are planning to convert from letterpress to offset lithography in the future.⁸

Preliminary figures indicate that daily newspapers were published in 1,516 cities Nationwide in 1989 (1,626 daily newspapers and 847 Sunday papers), with a total combined circulation of close to 62 million. Eighty-four percent of

daily newspapers have circulations of under 50,000.⁹ California, Texas, Pennsylvania, and Ohio have the highest number of daily newspapers.¹⁰ Figure 3-1 shows the distribution of daily newspapers in 1988 by circulation rate.⁹ Circulation rate can be used as a rough estimate of facility size. The population of weekly newspapers is in excess of 7,000 papers for over 3,100 presses.

3.3 CHARACTERISTICS OF OFFSET LITHOGRAPHIC PRINTING PRESSES

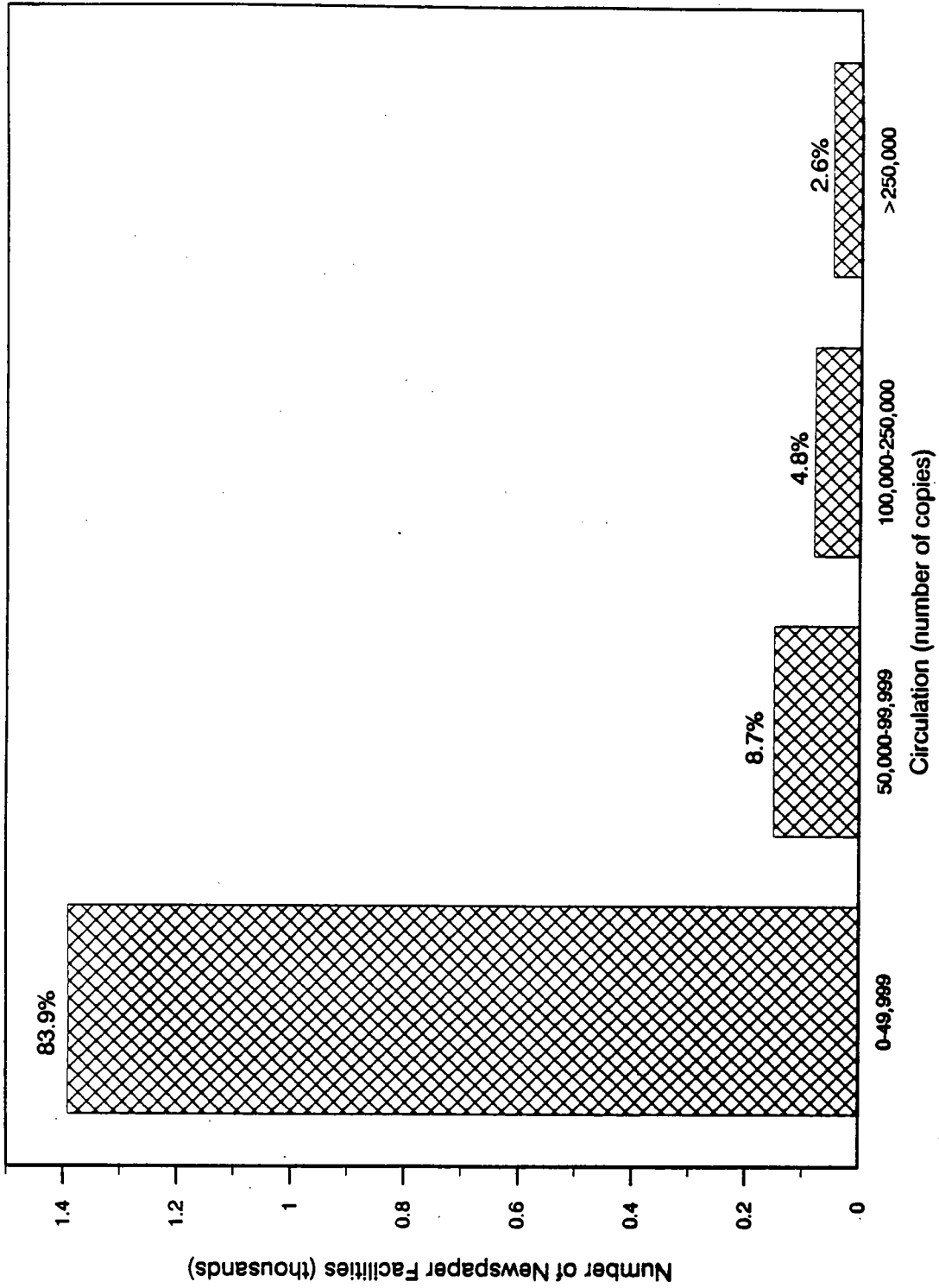
This section provides an overview of the types and sizes of offset presses used in commercial lithographic printing, synthesized from surveys conducted by two affiliates of the Printing Industries of America, Incorporated: the Web Offset Association (WOA) and the Non-Heatset Web Section (NHWS). The WOA surveyed 552 companies operating heatset web presses; NHWS surveyed approximately 702 companies operating non-heatset web presses. The surveys represent approximately 80 percent of all offset lithographic web presses currently in operation.

3.3.1 Types of Presses

3.3.1.1 Web Presses. Web offset printing presses are available in three designs: in-line presses, common-impression-cylinder (CIC) presses, and blanket-to-blanket presses. The designs differ mostly in the configuration of the printing unit. Each unit can print a different color on the substrate.

Printing on one side of the substrate is called "non-perfecting;" printing on both sides is called "perfecting." Non-perfecting presses have only one blanket per unit. Perfecting presses usually have two blankets per unit, although a single-blanket unit can be used to print on the reverse side by flipping the substrate over.

In-line presses can print only one side of the web and are used mainly for printing business forms. An in-line press printing unit (Figure 3-2) consists of the inking system, fountain dampening system, plate cylinder, blanket cylinder, and impression cylinder.¹¹



NOTE: Daily = 31% morning only and 67% evening only.

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Figure 3-1. Circulation of daily newspapers in 1988. 9

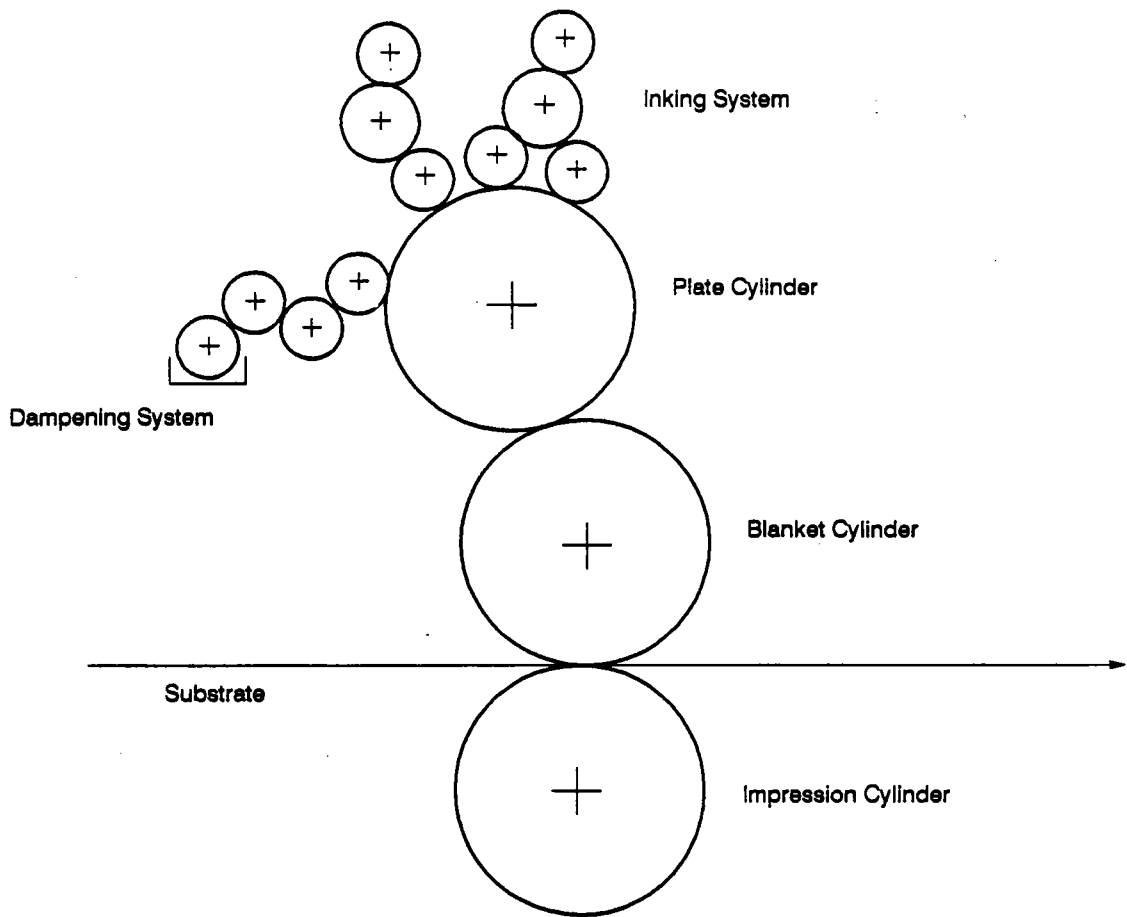


Figure 3-2. An in-line printing unit (single blanket).

Common-impression-cylinder presses, also known as satellite presses, may consist of one or two printing units, each with one large impression cylinder and up to five printing units arranged radially around the cylinder (Figure 3-3). A printing couple assembly includes the inking system, dampening system, plate cylinder, blanket cylinder, and impression cylinder. Each printing unit applies one color to the web; therefore, a CIC press with a single printing couple containing five printing units is capable of sequentially printing up to five colors on one side of the web. A CIC press operates at higher speeds than most presses.¹¹

Blanket-to-blanket presses are the most common type of offset lithographic web press. They can have 1 to 12 printing units, each with two printing couples stacked on top of each other (horizontal configuration) or side by side (vertical configuration). (Configuration refers to the direction the substrate travels [see Figure 3-4].) The printing couples lack the impression cylinders found on CIC and in-line presses. Instead, the web is threaded between the blanket cylinders of the two printing couples, with each blanket cylinder acting as the other's impression cylinder. The blanket-to-blanket press is therefore a perfecting press, where the blanket cylinders of each printing unit can print simultaneously on each side of the web. Each printing unit applies the same color to both sides of the web.¹¹

Figure 3-5 shows the distribution of printing plants by number of heatset web presses operated by WOA members.¹² Approximately 28 percent of the companies surveyed operate only one heatset web press, 63 percent operate between two and six presses, and 9 percent operate more than six.¹²

Figure 3-6 shows the distribution of plants by the number of non-heatset web presses operated by NHWS members.¹³ The majority of NHWS member companies surveyed (61 percent) operate only one non-heatset web press, approximately

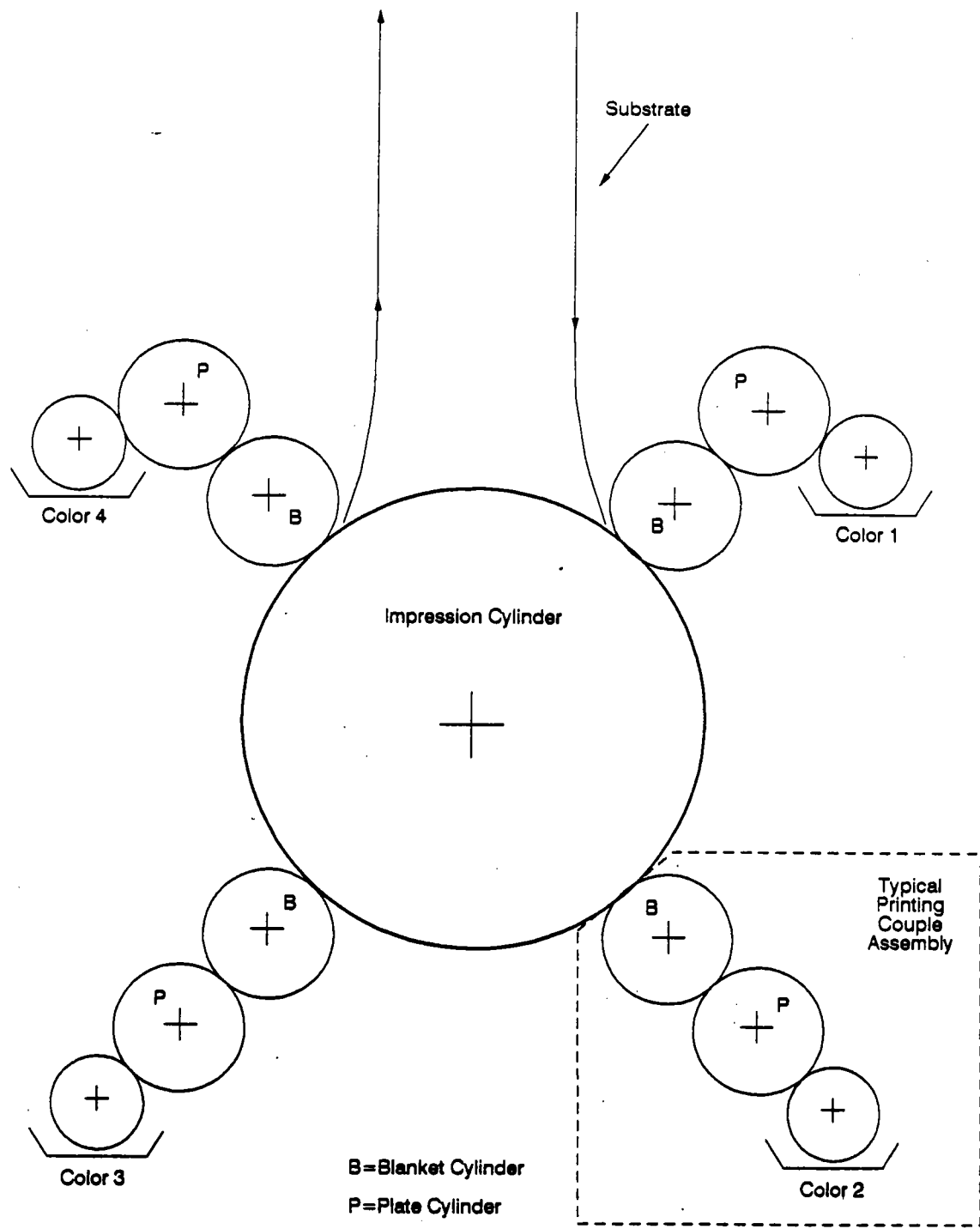
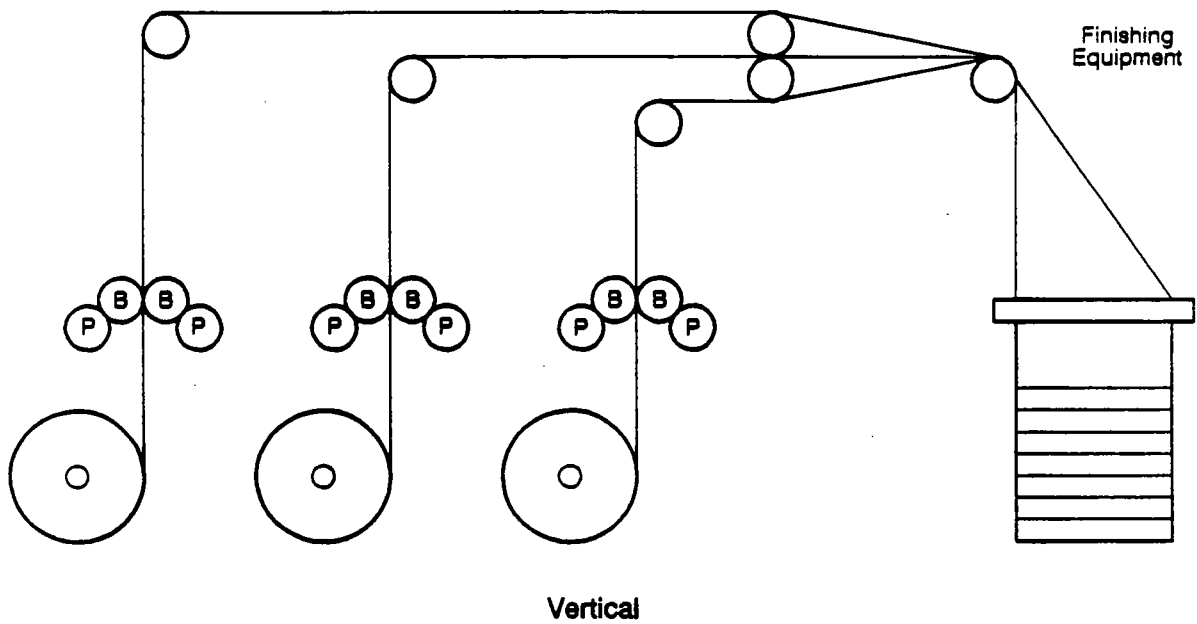
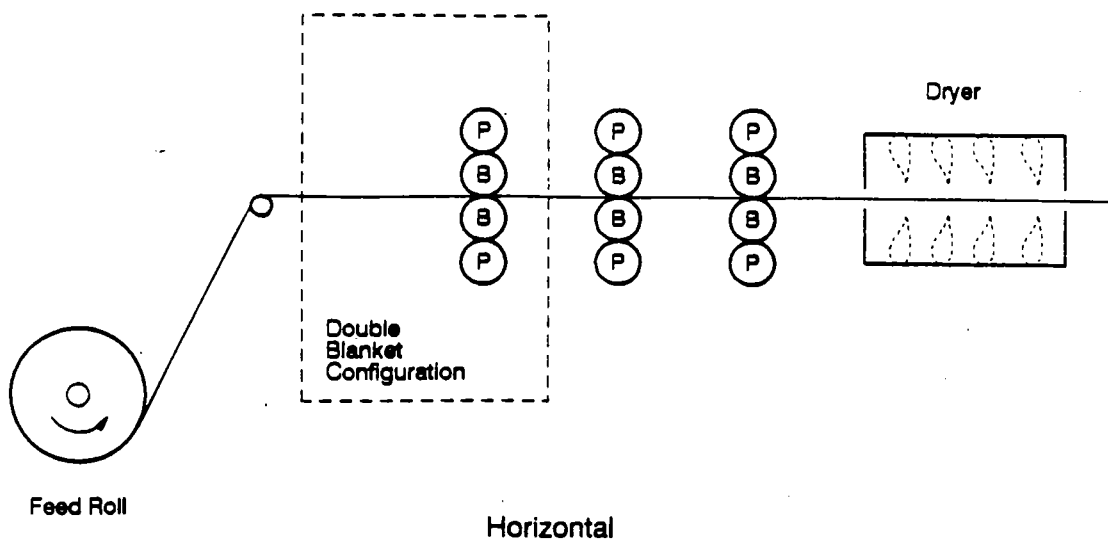


Figure 3-3. Schematic diagram of a lithographic common-impression-cylinder press.



B = Blanket Cylinder
 P = Plate Cylinder

Figure 3-4. Horizontal and vertical blanket-to-blanket web offset presses.

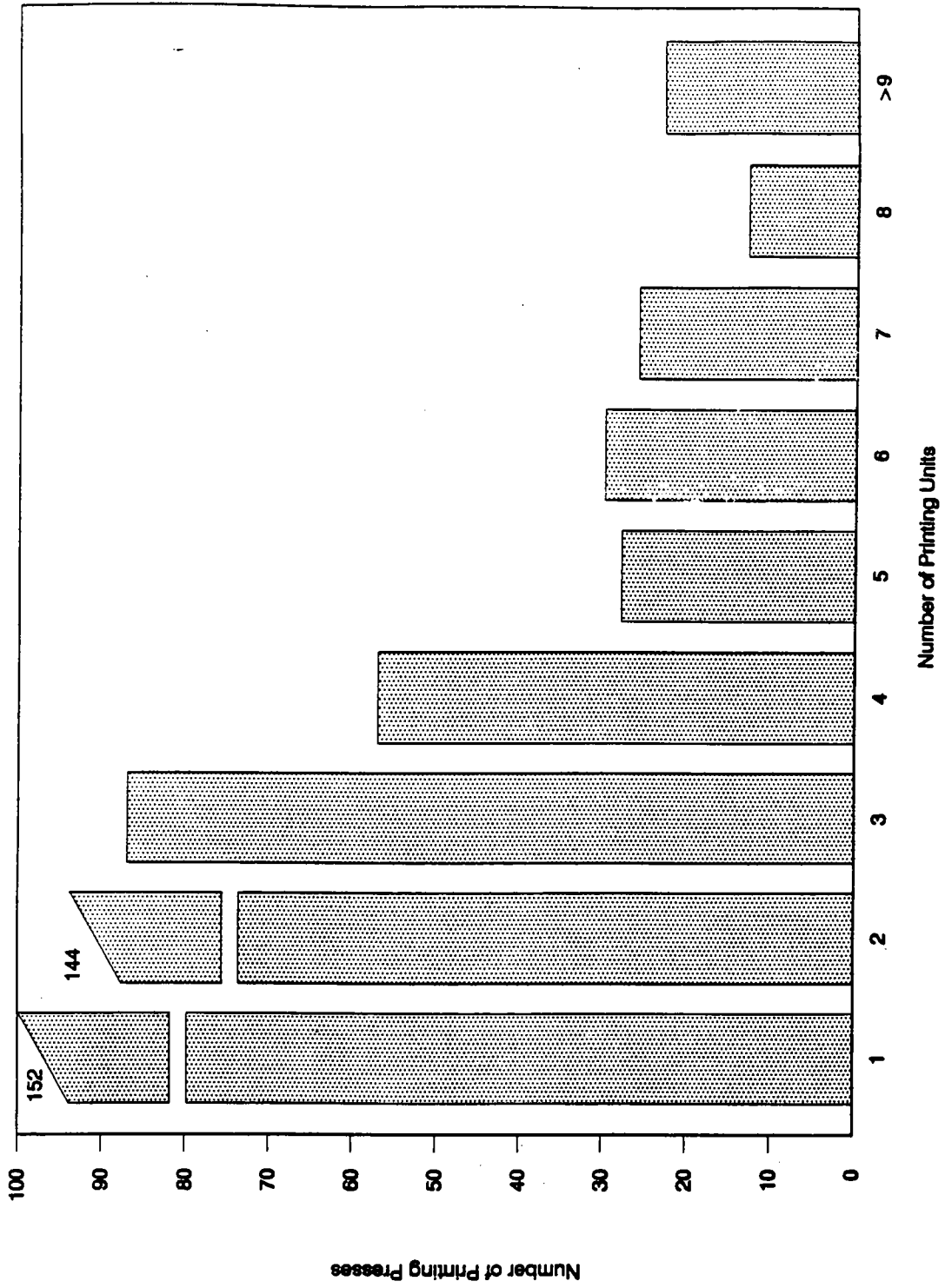


Figure 3-5. Distribution of plants by number of heatset presses. 12

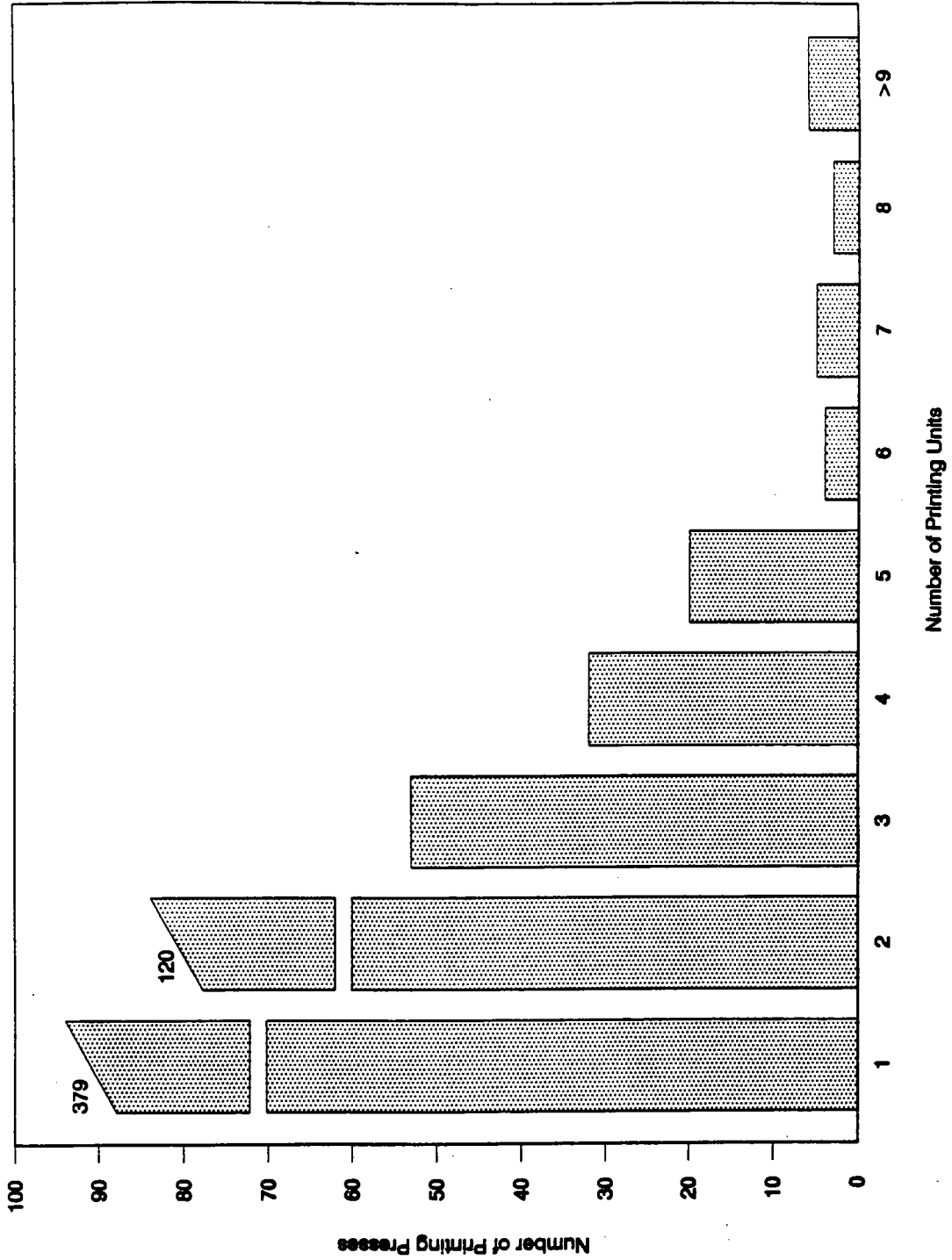


Figure 3-6. Distribution of plants by number of non-heatset presses. 13

37 percent operate between two and six presses, and only 2 percent operate more than six.¹³

3.3.1.2 Sheet-Fed Presses. Sheet-fed presses differ from web presses in the method of substrate delivery, the inking system design, and in the cylinder arrangement of the printing unit. Sheet-fed presses require additional cylinders to move the sheets through the press. The cylinder gaps contain clamping devices that hold the plate and blanket on their respective cylinder bodies. On a web press, the gap on the plate cylinder represents a non-printing area where the web is cut in the finishing process and is approximately 1/8 of an inch (in.) wide. This gap is smaller on sheet-fed presses, so that more surface area is available on the cylinders for printing an image. Sheet-fed presses always use a hard impression cylinder, which is not possible with blanket-to-blanket web offset presses.¹¹ Generally, sheet-fed presses, because they are non-heatset, do not have dryers or chill rolls, but may use infrared heat to accelerate ink setting.

3.3.2 Press Size and Number of Units

Offset lithographic presses are characterized by press size and the number of printing units on a press. Press size is described as the maximum length and width of paper (substrate) that can be printed on the press.

The width of the plate and blanket cylinders determines the maximum width of a substrate that can be printed on a particular press. The printing industry refers to this as the "across-the-cylinder" dimension. The across-the-cylinder dimension is flexible on both sheet-fed and web presses; that is, different substrate widths can be printed (up to the maximum press capacity).

The circumference of the blanket cylinder determines the maximum length of a substrate that can be printed on a particular press. The printing industry refers to this as the "around-the-cylinder" dimension. The around-the-cylinder dimension is fixed on web presses but can be varied on

sheet-fed presses. A web press size of 22 5/16 x 38 in., for example, can print 22 5/16-in. wide paper with lengths varying up to 38 inches. A sheet-fed press size of 17 1/2 x 22 1/2 in. can print substrates as small as 8 1/2 in. wide and 11 in. long and can be varied up to the maximum design size.¹⁴ The most common press width for heatset and non-heatset presses is 22 inches.

Figures 3-7 and 3-8 show the distribution of presses by press width for heatset and non-heatset processes, respectively.^{12,13}

The number of printing units on a press determines the number of colors that can be printed on the substrate. Five perfecting double blanket printing units, or couples, are most common on web offset lithographic presses for heatset processes and four non-perfecting, single blanket units are most common for non-heatset processes.^{12,13}

Figures 3-9 and 3-10 show the distribution of presses by the number of printing units per press for heatset and non-heatset presses, respectively.^{12,13}

3.4 COMPONENTS OF STANDARD OFFSET LITHOGRAPHIC PRESSES

The individual components of standard offset lithographic presses are described in the following subsections.

3.4.1 Infeed Section

The mechanics of the infeed sections of web and sheet-fed presses differ substantially.

3.4.1.1 Web Presses. The infeed section of a web press provides for mounting, aligning, and unwinding of the rolls of paper (web) to be run through the press. The infeed extends from the stand that holds the roll to the first printing unit. The infeed controls the speed, tension, and lateral position of the web as it moves from the roll stand to the first printing unit. A poorly set up paper roll or an improper infeed setting can adversely affect all other sections of the press.¹¹

Presses may have single- or double-roll stands; a double-roll stand can feed two webs to the press at once. An

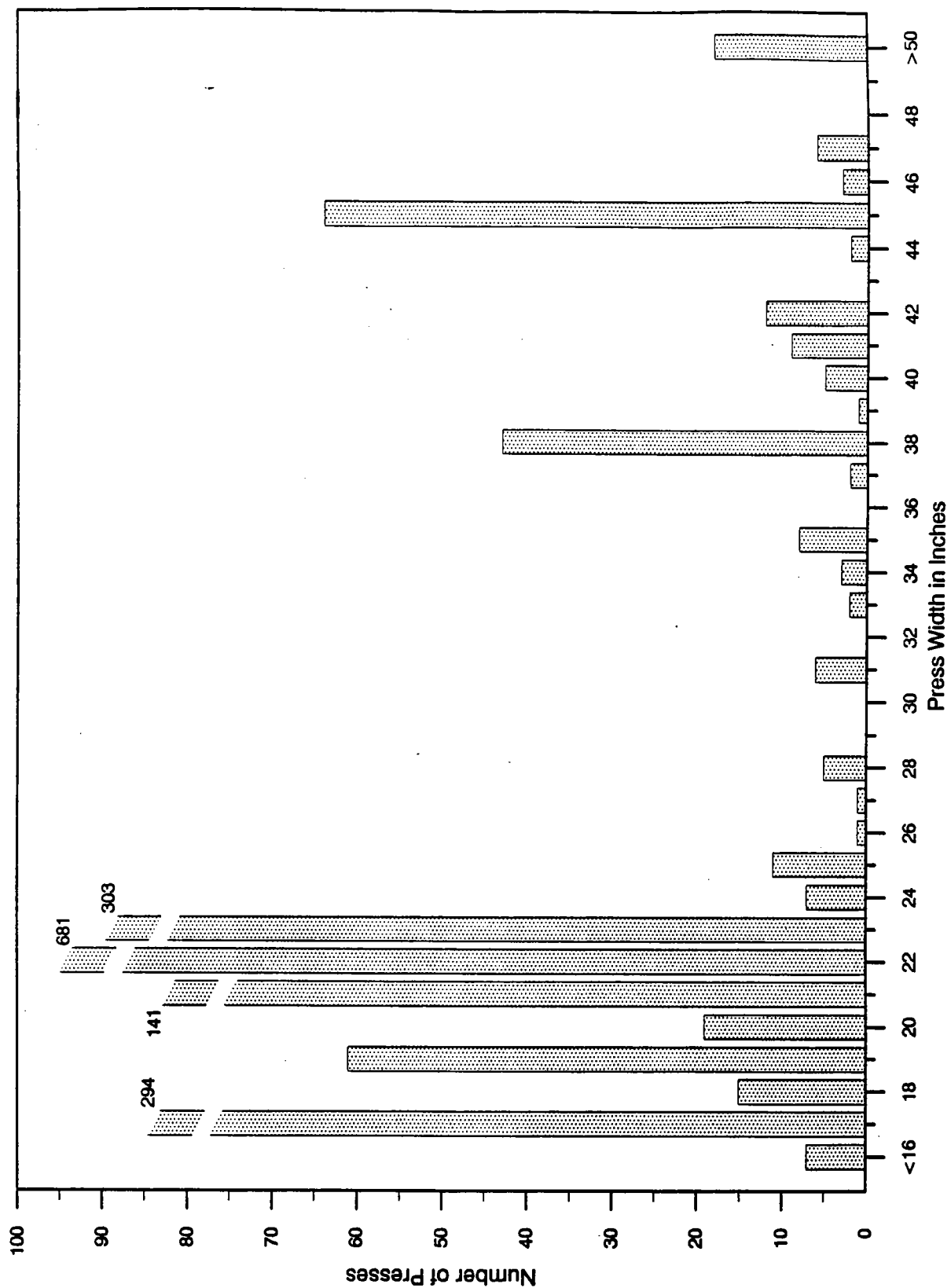
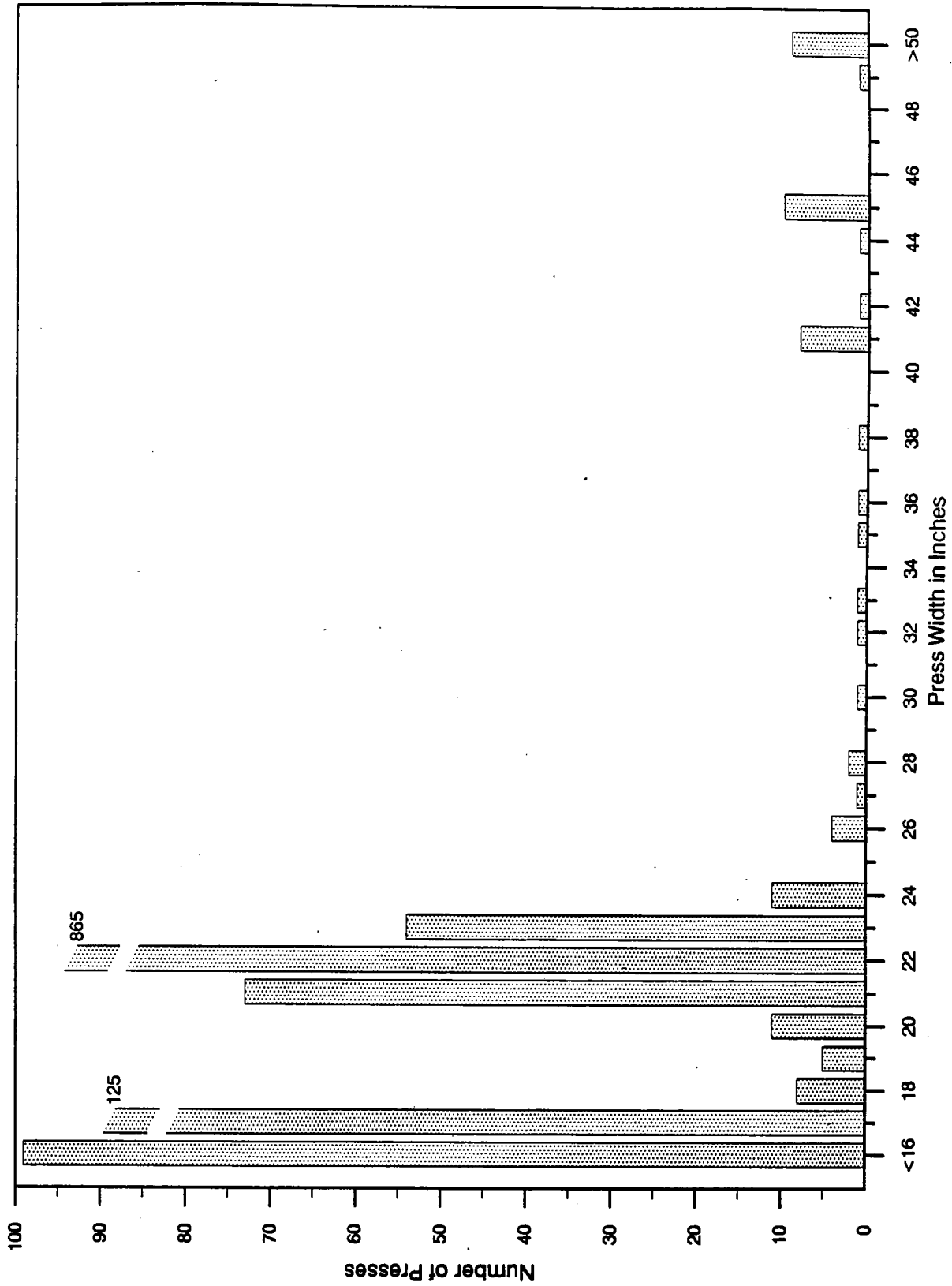
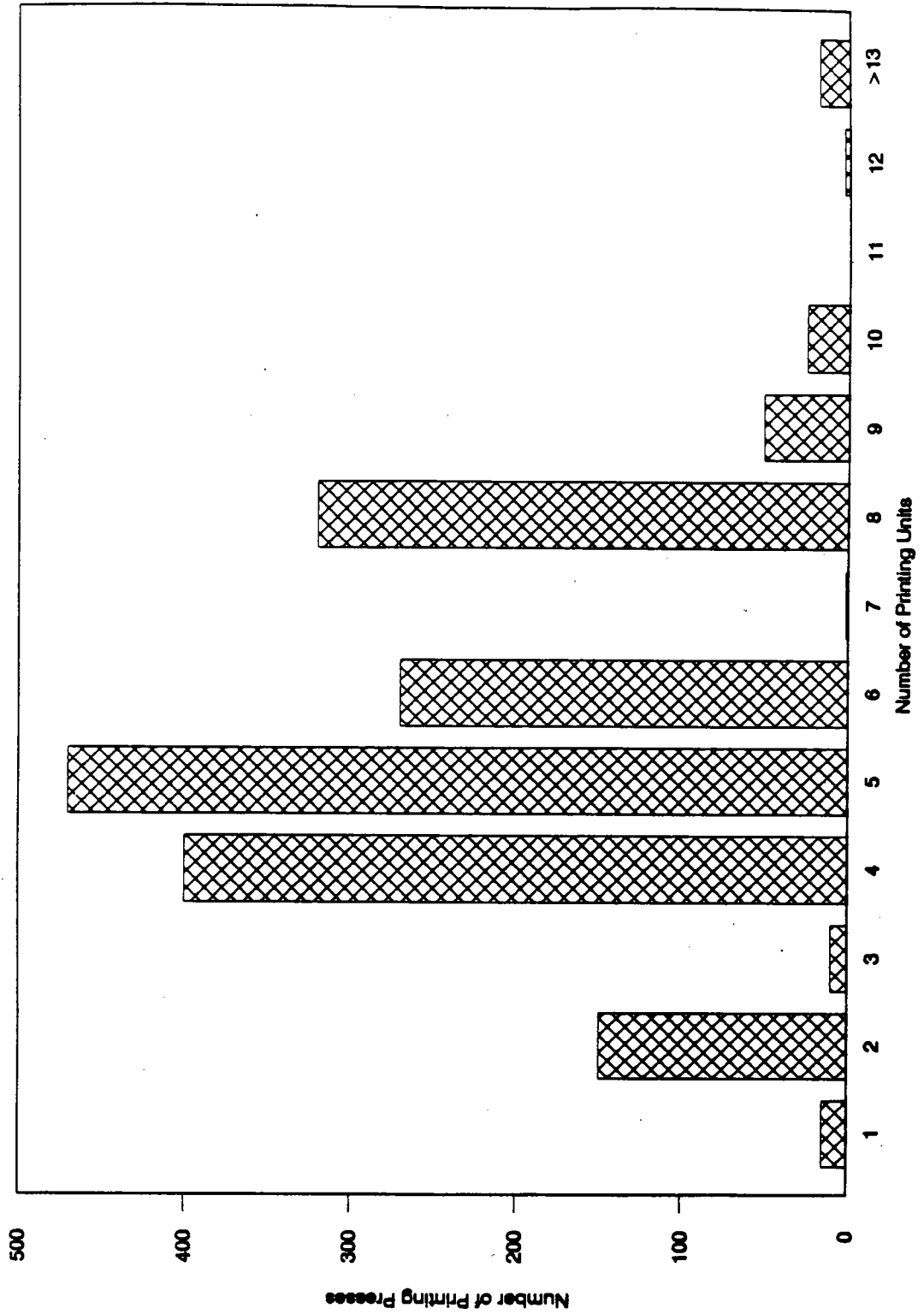


Figure 3-7. Distribution of heatset presses by size.12



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Figure 3-8. Distribution of non-heatset presses by size.13



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Figure 3-9. Distribution of heatset presses by number of printing units.12

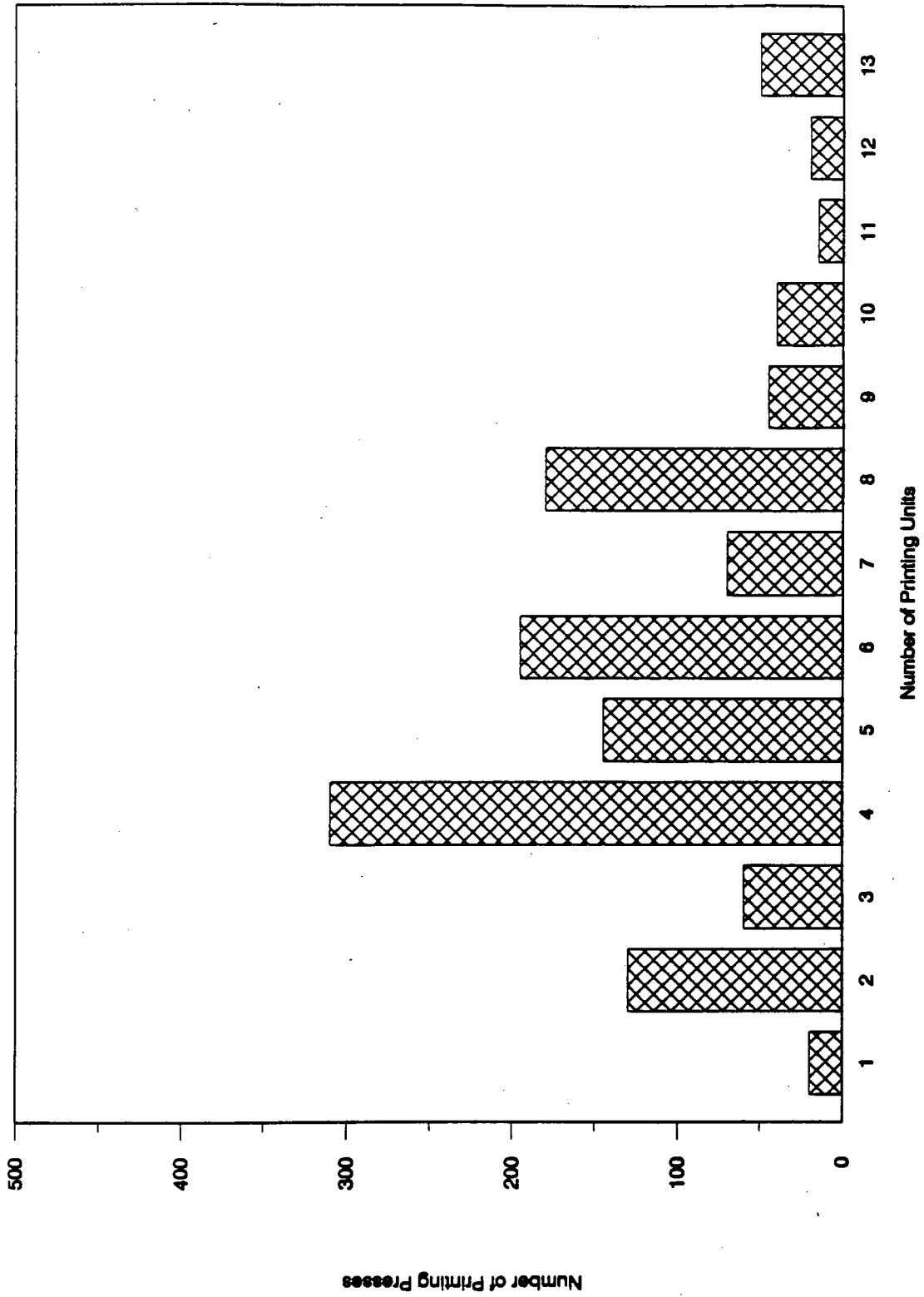


Figure 3-10. Distribution of non-heatset presses by number of printing units. 13

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auxiliary stand to hold additional rolls (usually two) is often added to increase the number of webs that can be run simultaneously. The roll stand can be positioned in line with the press, to the side of the press, or underneath the pressroom floor.

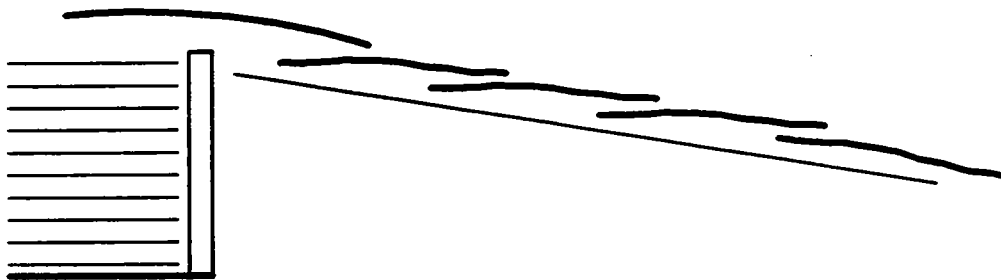
On the roll stand, the paper roll is usually turned by a shaft inserted through its core. The roll is held on the shaft in an exact side-to-side position, either by "chucks," which clamp the roll in place, or by mechanical expansion of the shaft itself. A brake on the roll shaft controls the infeed tension. Older roll stands have a simple friction brakeshoe; newer ones are equipped with electromechanical, hydraulic, pneumatic, or magnetic brakes. Controls on the roll stand position the web laterally before it enters the first printing unit. Photoelectric or electronic sensors read changes in the position of the web and activate devices that restore the web to its proper lateral position.¹¹

3.4.1.2 Sheet-Fed Presses. The infeed section on a sheet-fed press can be either a successive-sheet feeding system or a stream feeding system (Figure 3-11). The successive-sheet system delivers each sheet to the printing unit separately. The subsequent sheet is not moved until the preceding sheet has cleared the advancing mechanisms. The stream feeding system overlaps the sheets as they are delivered to the printing unit. The advantage of this system over successive-sheet infeed is more precise sheet registration and control, since the sheet overlap tends to stabilize the following sheets and the distance between the feeder and registration devices is very short (several inches).¹⁴

Sheets can be fed to either of these systems from either a pile or roll of paper. A pile feeder contains individual sheets of paper stacked on a platform. The platform automatically raises the sheets to the infeed section for a continuous supply of sheets. Roll feeders use a rolled supply



Successive-Sheet Feeding



Stream Feeding

Figure 3-11. Successive-sheet and stream feeding in sheet-fed presses.

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of paper that is cut to size before delivery to the infeed section.¹⁴

3.4.2 Printing Units

Each press is made up of from 1 to 12 printing units. Each printing unit has a complex arrangement of rollers for transferring ink from the ink fountain and fountain solution from the dampening system to the plate cylinder. When the plate cylinder rotates, the lithographic plate usually first contacts the dampening system rollers, which distribute the fountain solution. The fountain solution adheres only to the nonimage area of the plate. The lithographic plate then comes into contact with the inking system rollers, which distribute the ink onto the image area of the plate.

Next, the ink on the lithographic plate is transferred to the rubber-covered blanket cylinder, which, in turn, prints the image on the web. The arrangement in Figure 3-12 is commonly called blanket-to-blanket because each blanket cylinder presses the web against the other cylinder and simultaneously prints both sides of the web (perfecting). In printing units that print only one side of the web (non-perfecting), one blanket cylinder and all associated equipment are replaced with an impression cylinder.

3.4.3 Inking Systems

Figure 3-13 represents a typical inking system for an offset lithographic printing unit. The performance requirements for inking systems are very stringent. The system: (1) "works" the ink from a gel-like consistency to a semiliquid state, (2) distributes an even thin film of ink around all of the form rollers, (3) deposits a uniformly thin film of ink on the image area, (4) picks up fountain solution from the lithographic plate and emulsifies some of it into the ink, and (5) picks up loose particles of foreign matter from the lithographic plate and holds them in suspension until the entire system is cleaned.¹⁴

The inking system contains four major components: the ink fountain, the ductor (transfer roller), and two series of

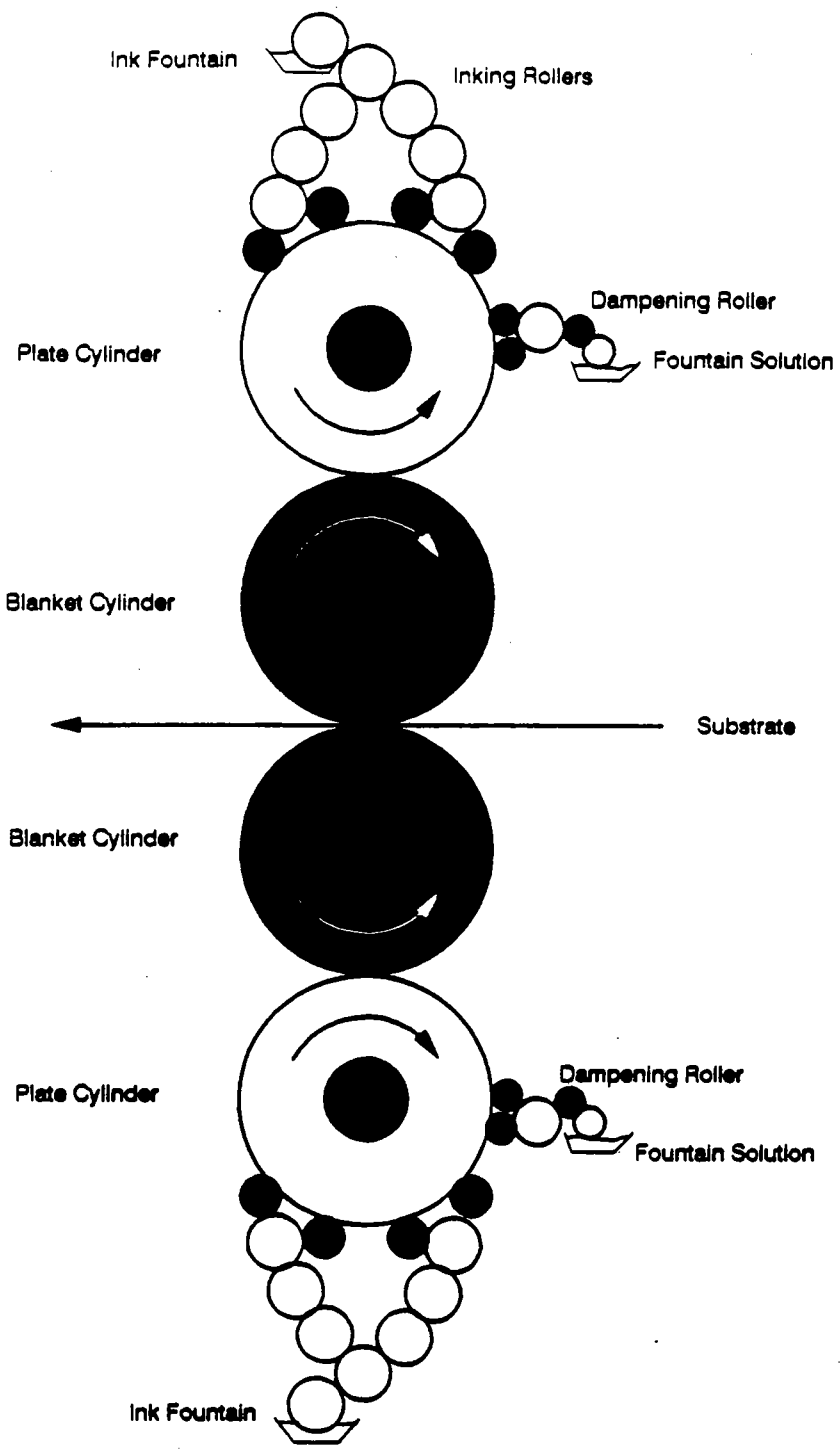


Figure 3-12. Schematic diagram of blanket-to-blanket printing.

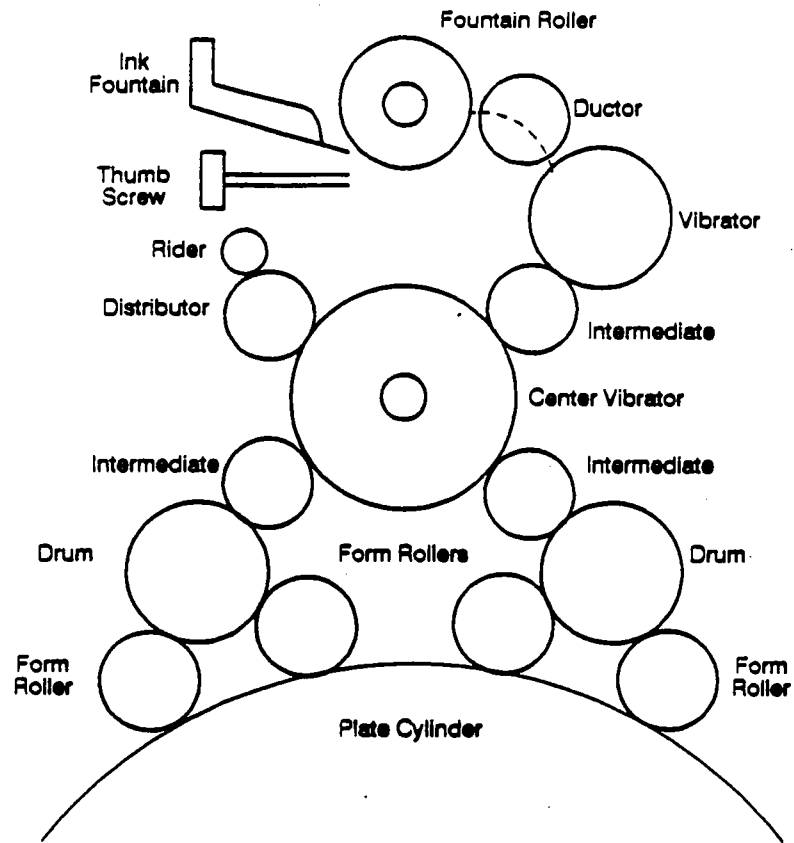


Figure 3-13. Schematic of a typical inking system.

rollers called the roller train and the form rollers. The ink fountain contains the ink supply and a fountain roller that intermittently distributes the ink onto the ductor.

In a conventional inking system, the ink supply travels through the bottom of the ink fountain over a flexible steel strip called the fountain blade. A small adjustable gap between the fountain blade and fountain roller determines the amount of ink that is distributed to the system.

In an inking system called the anilox system, the fountain roller has an engraved pattern of cells that holds the ink. A continuous supply of ink is distributed to a shorter series of rollers or directly to an ink form roller. The anilox system provides a smooth, efficient distribution of ink to the plate cylinder.

In the injector inking system, the ink is pumped onto the roller by a solenoid-controlled pump.⁴ Control of the pump speed can take place away from the presses in a "quiet room." Ink is placed on the roller in a glob and is then rolled into a thin film. The anilox and injector inking systems are used primarily in newspaper printing.¹¹

The second series of rollers in a conventional system distributes the ink between the fountain roller and the form rollers, and is designed to work the ink by imparting energy and motion. Including a sufficient number of intermediate rollers between the fountain roller and the form rollers is critical to the proper performance of the inking system, because the number of times the ink film is split during transfer from roller to roller is a factor in working or conditioning the ink.

Another design feature is the lateral oscillation of various rollers (vibrators or drums). This lateral motion, occurring simultaneously with the normal rotational motion, helps work the ink because the combined motions induce shear and help reduce "ridging" of the ink through increased lateral distribution. Rotational distribution is accomplished by using drums and rollers of differing diameters. Feeding and

working the ink ensures that the form rollers receive a constant and properly distributed supply of conditioned ink for each impression the printing unit makes.¹⁴

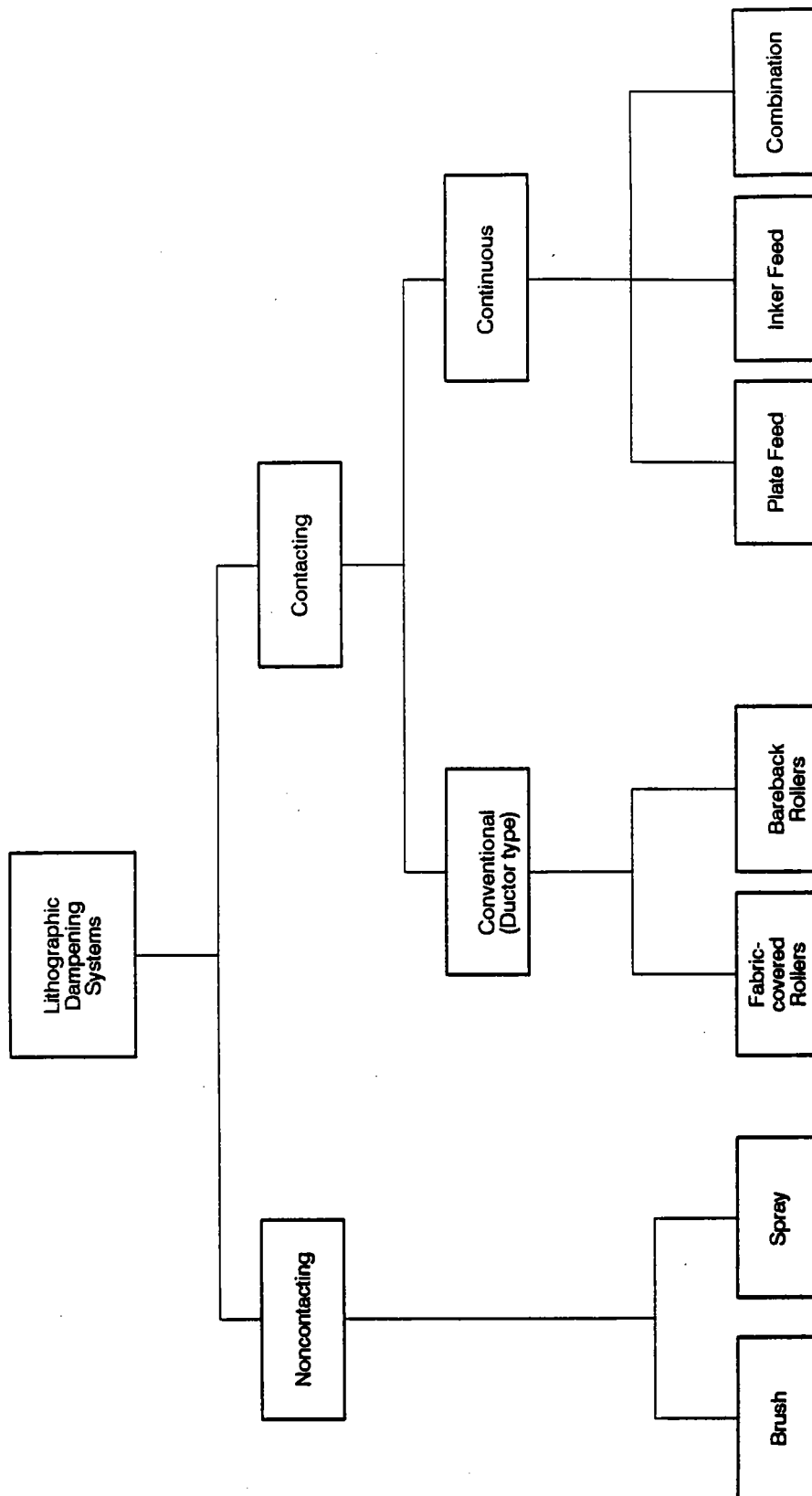
3.4.4 Dampening Systems

A well made lithographic plate on a properly operated press prints a strong, sharp image and retains perfectly clean nonimage areas for extremely long runs. Ink receptive properties of the image areas are difficult to destroy when the plate is properly made, but the water receptive properties of the nonimage areas can be destroyed within seconds if the dampening rollers do not contact the printing plate. To maintain these properties, the image areas must be wetted with ink and the nonimage areas must be continually wetted with fountain solution.¹⁴

Fountain solution is delivered to the plate cylinder by a system of rollers similar to the inking system, which applies the fountain solution to the plate cylinder. Figure 3-12 shows a generic configuration of the fountain solution rollers within the printing unit. There are many variations in fountain solution delivery (dampening) systems. Figure 3-14 shows a classification system for various dampener types.¹⁵

The major differentiation in dampening systems is between contacting and noncontacting systems. In the noncontacting system, brushes or spray bars are used to transfer the fountain solution from the fountain reservoir to the plate cylinder, so that no equipment contacts the plate cylinder. Figure 3-15 shows a schematic of a brush dampening system.

In a contacting system, rollers are used to transfer the fountain solution to the plate cylinder. In the conventional contacting type, there is a gap between the pan where the fountain solution is fed and the rollers; the gap is bridged by a free-standing pivoting roller. The rollers that contact the plate cylinder can be covered with fabric or left bare. Figure 3-16 shows a conventional contacting dampening system. In a continuous contacting system, all rollers are contiguous. Some systems feed fountain solution onto the plate cylinder



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Figure 3-14. MacPhee Dampening Classification system. 15

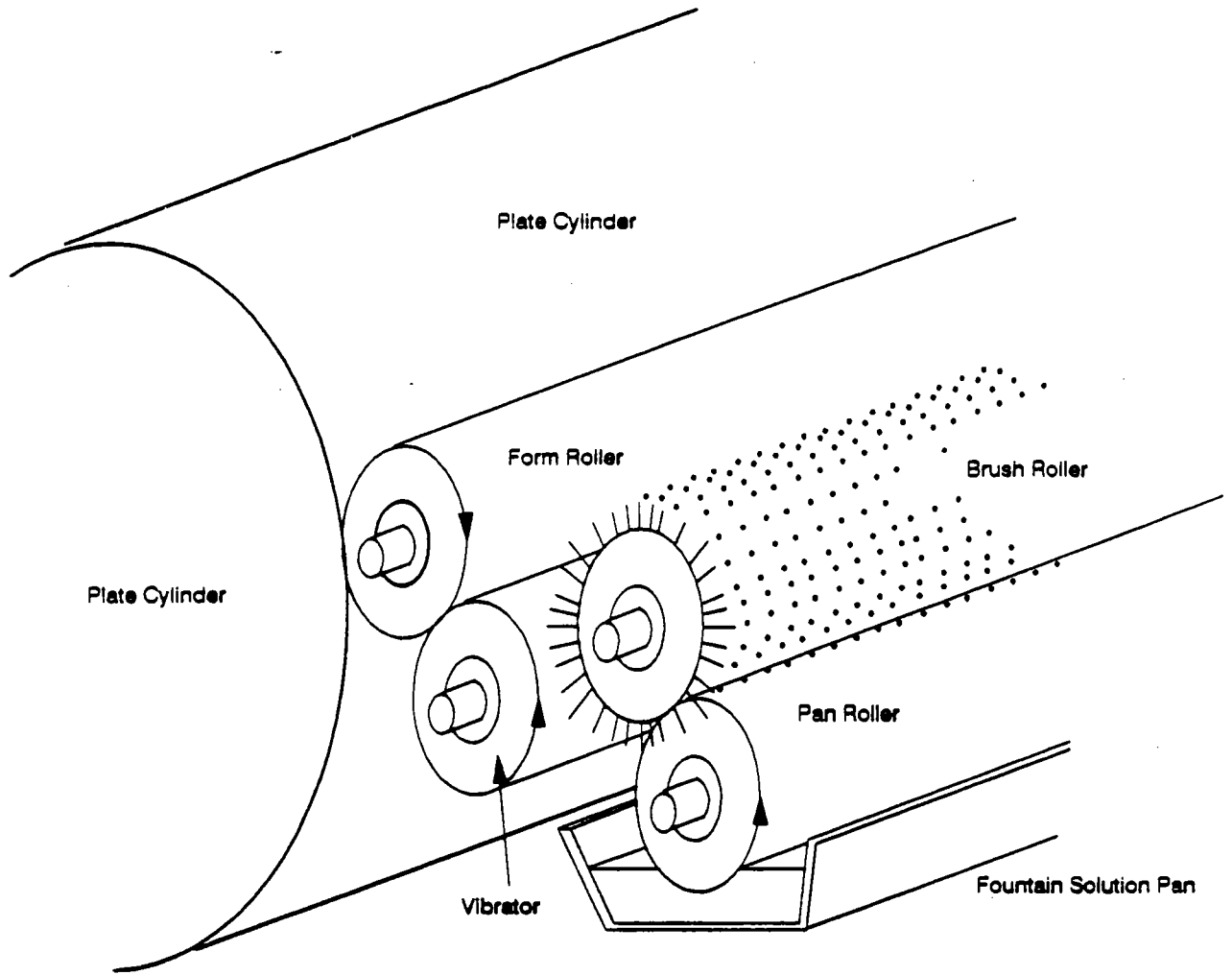


Figure 3-15. Schematic of a brush dampening system.

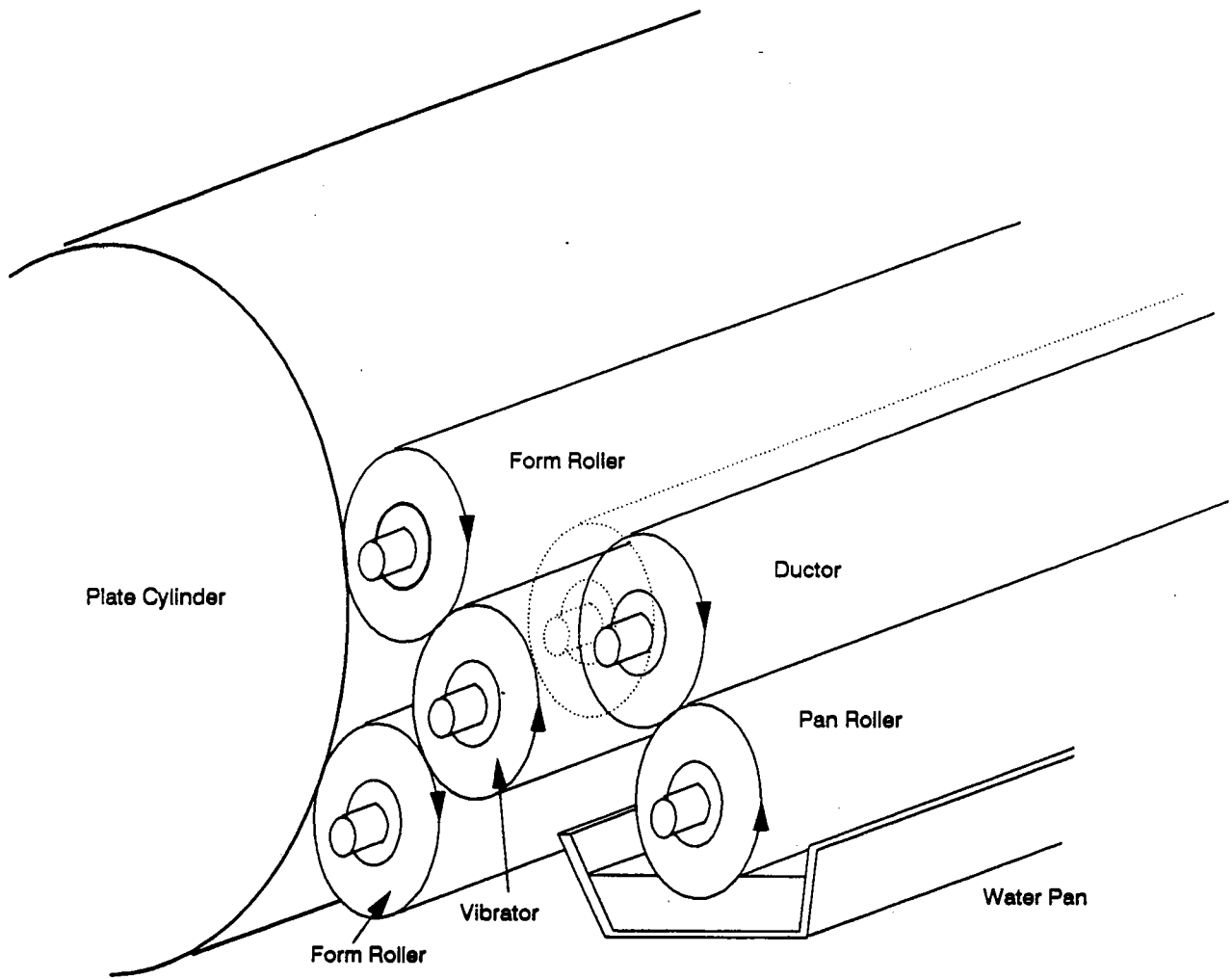


Figure 3-16. Schematic of a conventional contacting dampening system.

before the ink rollers (plate feed), some feed onto the ink rollers, which, in turn, contact the plate cylinder (inker feed), and some combine both of these methods. Figure 3-17 shows the arrangement of rollers in a continuous contacting dampening system. The speed of the fountain roller controls the amount of solution that is fed into the system.

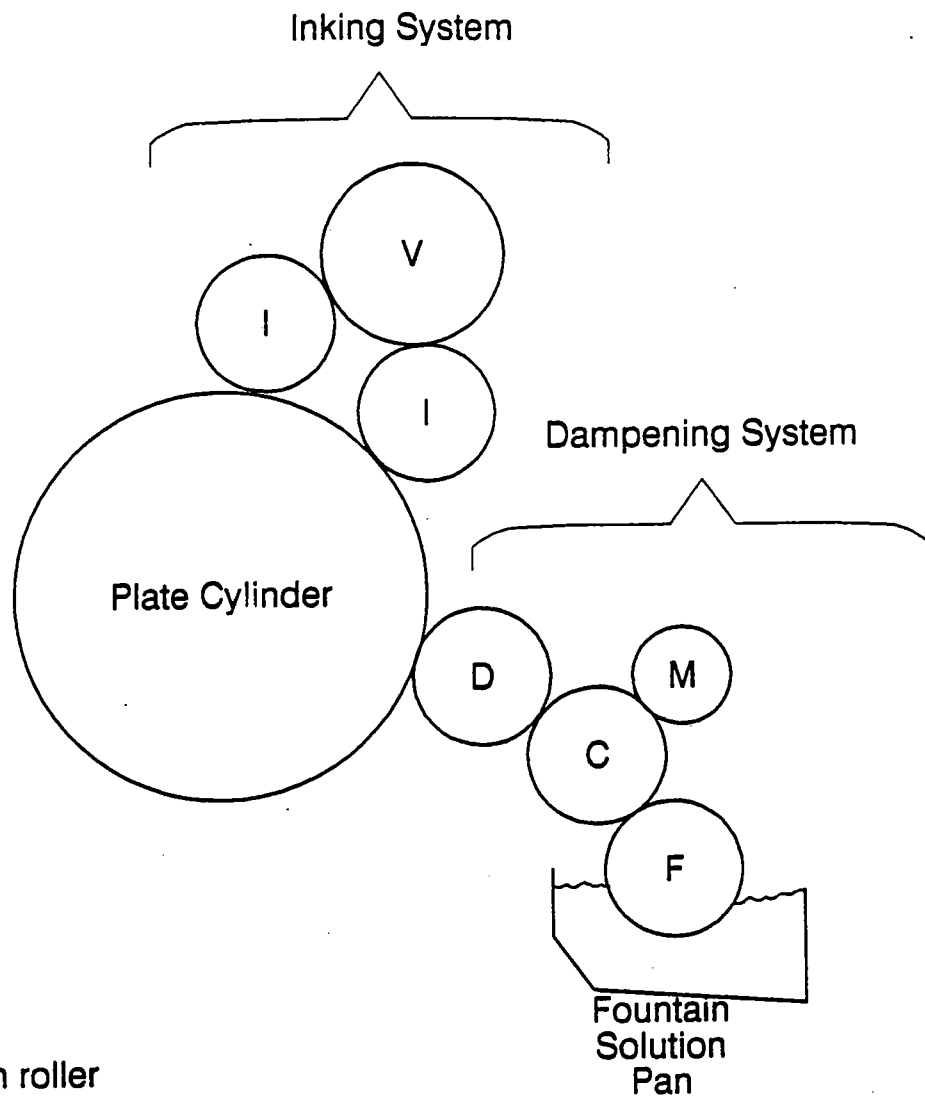
Centralized fountain solution circulation systems allow printers to service all fountains from a centralized location, which reduces the likelihood of variation in print quality between the printing units on a press. Additionally, circulation systems use filters that remove solids from the fountain solution, which can reduce press downtime for cleaning and increase print quality.

Circulation systems are frequently equipped with a unit to control alcohol additions to the solution. A hydrometric float measures the specific gravity of the solution and triggers alcohol additions when appropriate. Figure 3-18 shows a circulating fountain system. Noncontact delivery systems were the first to use centralized circulating systems, since the lack of roller and plate cylinder contact reduces the likelihood of "feedback," (i.e., ink returning to contaminate the fountain reservoir). However, contact systems also have had success with centralized circulating systems.¹⁵ Circulation systems are useful in maintaining a more consistent fountain solution mix, but, as a drawback, do not allow for different fountain solution mixtures to be used on different printing units of the press.

3.4.5 Dryers and Chill Rolls

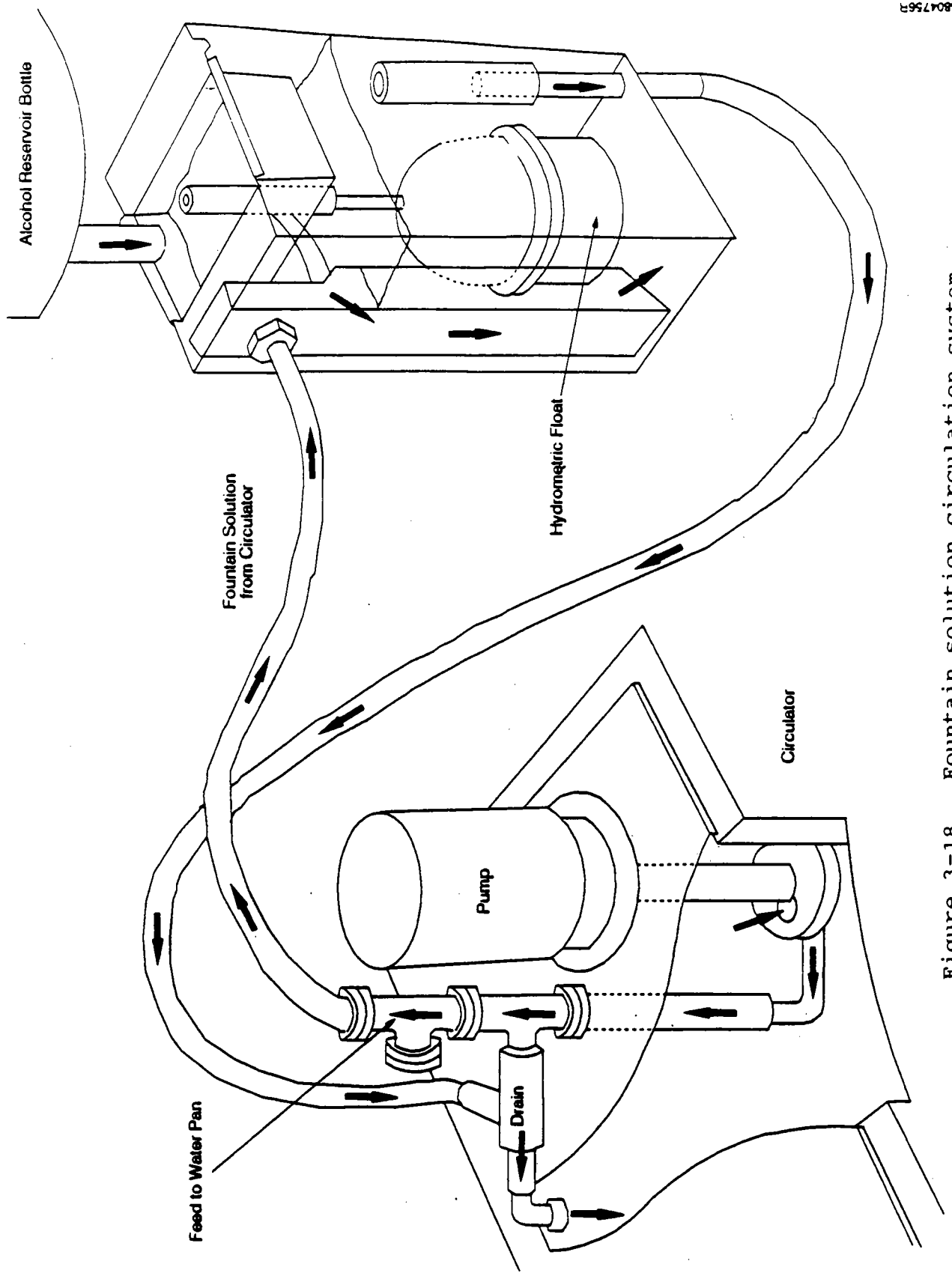
Heatset inks require drying and chilling. Evaporation of the ink solvent in the dryer radically increases the ink's viscosity and leaves pigment particles embedded in semisoft binding resins. Cooling the binding resins with chill rolls solidifies, or dries, the inks.¹¹

The printed web enters the dryer after leaving the last printing unit. Evaporation time for the ink solvent in a dryer, which may have air temperatures as high as 600°F,



- F = fountain roller
- M = metering roller
- C = chrome transfer roller
- D = dampening form roller
- I = ink form roller
- V = vibrator

Figure 3-17. Continuous contacting dampening system.



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Figure 3-18. Fountain solution circulation system.

averages about 0.7 second. High velocity hot air nozzles blow high pressure hot air at both sides of the web, as shown in Figure 3-19. Exhaust ducts recirculate controlled portions of the heated exhaust air. The heated air and solvent vapor are recirculated through a combustion chamber, oxidizing some of the ink oil.¹¹ Figure 3-20 is a detailed drawing of a high velocity hot air dryer showing the air supply system and paper pathway.

When the web leaves the dryer, its surface temperature is between 220 and 330°F. The chill rolls cool the web to a maximum of about 90°F.¹¹ The chill roll section is an assembly of driven steel drums with chilled water circulating through them. The hot web from the dryer passes over these rolls to set the ink. Most chill roll sections have three rollers; some have only two, others may have more. Figure 3-21 shows a chill stand unit.¹¹

3.4.6 Folders and Sheetters

In web presses, the cooled printed web can be prepared for shipment by rerolling the web. More often, however, the press prints several pages on the web at one time, and thus has a folder, or a sheeter, or both. The folder receives the printed web, cuts it, and folds it into an assembly of pages in the correct sequence (signature). Several signatures, each from different press runs, may be assembled in the bindery to create a book or magazine. Modern folders can produce a wide array of folded signatures.

A sheeter receives the printed web, cuts it into large sheets, and stacks the sheets for transport to the next processing step or to the customer. Figure 3-22 shows the progress of printed paper from the dryer, bypassing a folder, moving through a sheeter and onto the delivery.

Although the printed material from the press may be a finished product after folding or sheeting, additional processing is likely. Most heatset web plants also have a bindery section, which is separate from the pressroom.

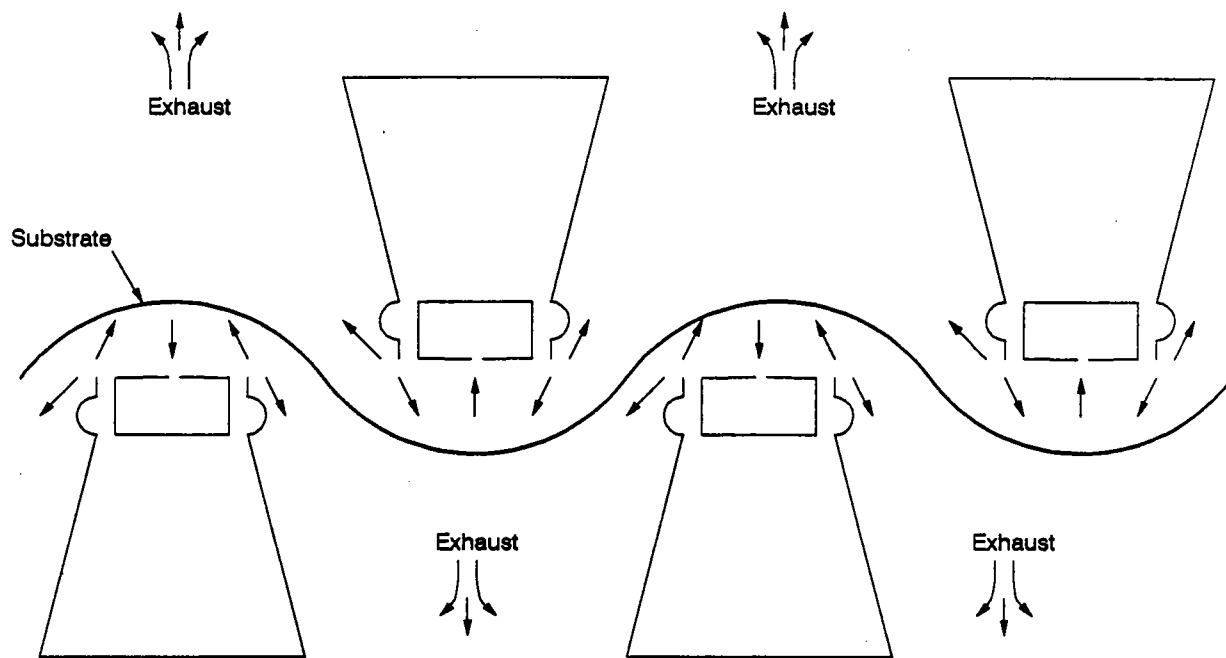
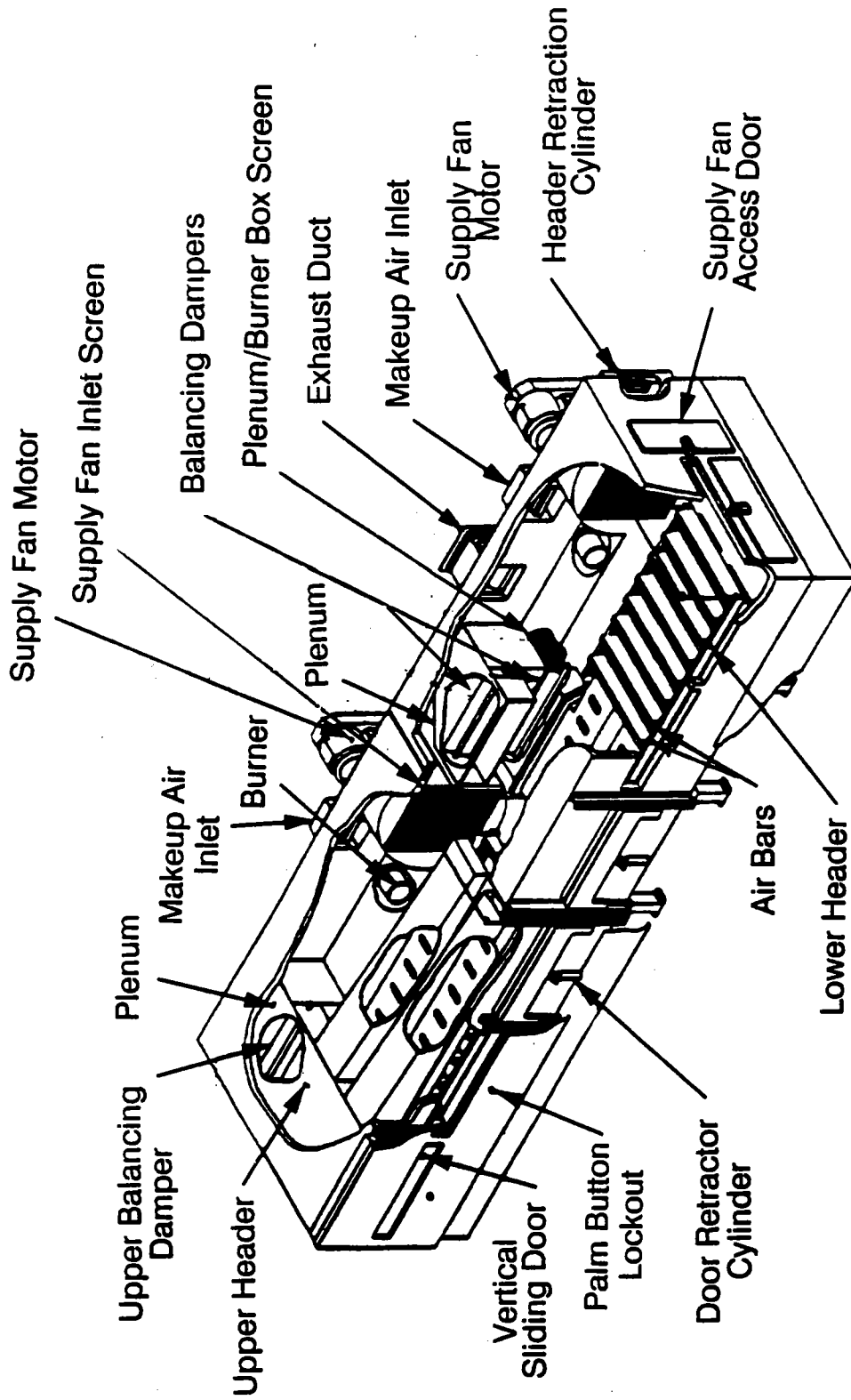


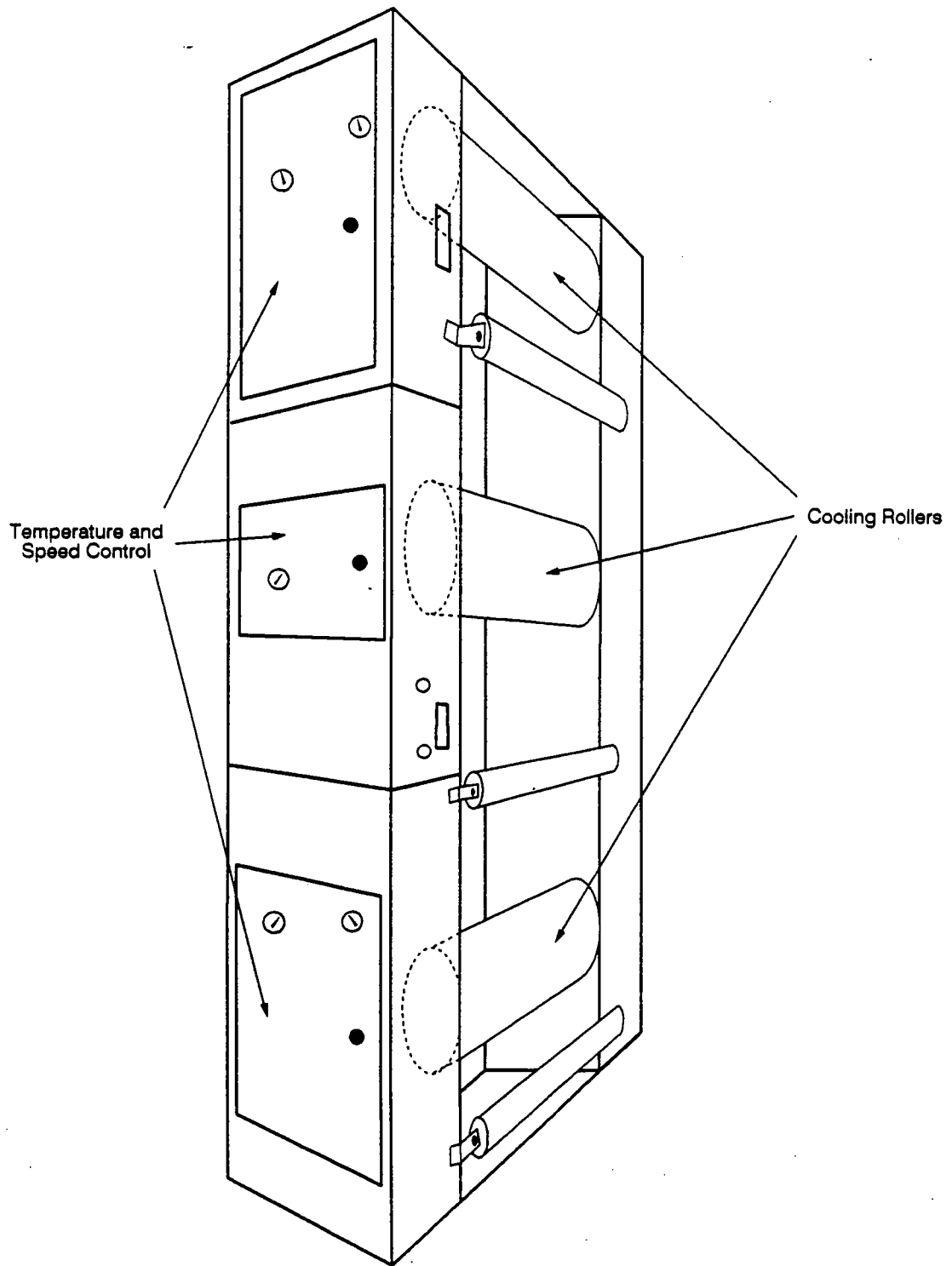
Figure 3-19. High-velocity hot air nozzles.



Courtesy of TEC Systems

TEC Phazer Drying System

Figure 3-20. High velocity hot air dryer.



Temperature and
Speed Control

Cooling Rollers

Figure 3-21. A chill stand.11

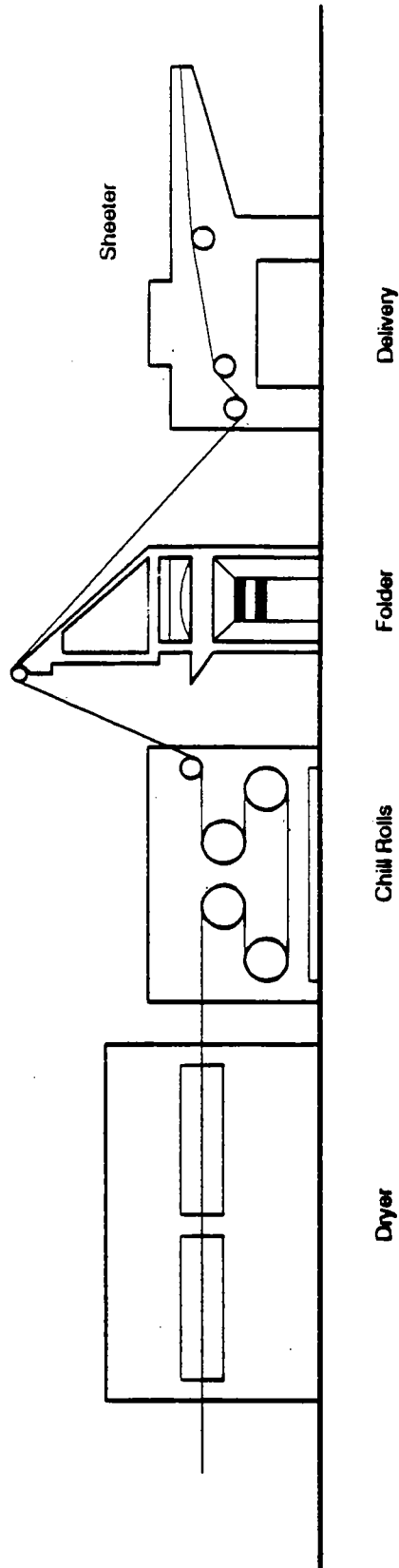


Figure 3-22. Progress of printed paper from dryer to delivery.

3.5 INKS, FOUNTAIN SOLUTION, AND CLEANING SOLUTIONS

3.5.1 Inks

Lithographic inks are stronger in color than inks in other printing processes. They are composed of pigments, vehicles, binders, and other additives. The pigments provide the desired color and contain organic and inorganic materials; they must be water insoluble so the inks will not bleed in the presence of the fountain solution. The vehicle is a solvent that carries the pigment and binders, and is usually composed of organic materials. Binders form a continuous film which fixes the pigment to the substrate; they are composed of organic resins and polymers, or oils and resins. Additives include waxes, lubricants, and driers.

3.5.1.1 Heatset Inks. Heatset ink vehicles are used in heatset web offset lithographic printing. The major components of the heatset ink vehicles are petroleum oils, hard soluble resins, drying oil varnishes, and plasticizers.⁷ Heatset ink vehicles rely on heat-induced evaporation to dry. The web passes through a dryer, reaches a temperature of 200 to 300°F, and then is cooled on chill rolls to a temperature of approximately 90°F.⁴

Heatset web inks may contain up to 40 to 45 percent VOC's.¹⁶ Ten to 15 years ago, 45 percent was the standard; today, the VOC content can be as low as 30 to 35 percent (as measured by EPA Method 24),^{17,18} although 30 percent is reported to be difficult to formulate.⁶

For heatset inks, the ink oil is critical in controlling viscosity and tackiness of the ink, and can be reduced only so far without adversely affecting the perceived quality of the final product. Narrow-cut petroleum fractions with boiling ranges between 450 and 600°F are characteristic of the oils used in heatset inks.¹¹ Research is being conducted by some of the larger ink companies on lowering the temperature at which the inks will set. At lower temperatures, less of the oil will volatilize and more will remain in the ink film on the substrate.¹⁸

3.5.1.2 Non-heatset Inks. Non-heatset inks have lower vapor pressures than heatset inks and are not as pasty or viscous. They contain below 35 percent VOC's (as measured by EPA Method 24 and ink formula mass balance).^{16,18} Some non-heatset sheet-fed inks are 20 to 25 percent VOC's (unknown measurement method).¹⁹

The majority of sheet-fed, non-heatset inks in current use are quickset inks. Fifteen to 20 years ago, sheet-fed inks required 4 to 8 hours to set after printing. In an effort to reduce drying time, quickset inks were developed. Quickset inks contain a film former and set by absorption. They are set to the touch within 1 to 2 minutes; however, they should be allowed to set for at least 1 hour before printing on the second side of the substrate.²⁰ Some of the ink oil absorbs and causes precipitation of resin-rich film former and color. A complex ink may contain 12 to 17 components. The VOC content of quickset inks is 12 to 15 percent.²¹

Soybean oil inks, although in use for several years, have recently become more popular in some newspaper inks for a number of reasons. Their main advantage is that the 15- to 25-percent petroleum oil fraction of conventional inks is reduced to between 5 and 8 percent, thereby removing 65 to 85 percent of petroleum based oils.²² Soybean oil has a much lower vapor pressure than petroleum oil, reducing the amount of oil that can evaporate. Additionally, soybeans are attractive because they are a natural product, a renewable resource, and totally independent of petroleum supplies.²³ Soybean oil inks have worked successfully in sheet-fed printing and newspaper printing, but their application in heatset processes is currently limited.^{20,22} Since many soy inks are more costly, they will not likely replace black inks in the near future, although color soy inks may be more competitive.

Oxidation is the major drying mechanism used for sheet-fed non-heatset inks. Oxygen is absorbed from the ambient air, causing the ink to harden. Sheet-fed inks that

dry by oxidation take approximately 2 to 8 hours to completely dry after printing.¹⁴ These inks reportedly have VOC contents around 5 to 10 percent (measurement method unknown).⁶ Specialty inks for use with sheet-fed plastics or foil have a reported VOC content of 5 percent (measurement method unknown). A low VOC content is necessary to prevent the product from becoming greasy.¹⁹

3.5.1.3 Newspaper Inks. Newspaper inks are non-heatset inks that dry by absorption. In addition to newspapers, business forms and directories are printed with newspaper inks.¹¹ The four general categories of newspaper inks are regular, low-rub, no-rub, and color inks. Fifty percent of the newspapers in the industry currently use low-rub inks.

Regular newspaper inks are composed of 15 to 20 percent carbon black pigment, petroleum oils to wet the pigment, and high molecular weight petroleum oil. Low-rub and no-rub inks contain around 12 percent carbon black. For no-rub inks, the carbon black content is reduced by increasing the resin concentration. In addition, the petroleum oil component is lightened. Color inks contain 18 to 20 percent pigment. They are similar to no-rub inks in their use of resins and lighter weight petroleum oils.²⁴

3.5.1.4 Other Inks. Inks that rely on other ink-drying mechanisms, such as radiation curing, electron beams, and thermocatalyzation, are more expensive than traditional inks and cannot be used on all substrates.

Radiation-cured inks are used in both sheet-fed and web offset lithographic printing. The inks dry by the application of ultraviolet, or other radiation. Radiation-curing inks are highly reactive and usually contain proprietary cross-linking chemical compounds.⁷ These inks differ from conventional inks in their binding properties and lack of drying agents. Ultraviolet inks use acrylic prepolymers and monomers, and initiators as binding compounds. They produce a high-quality gloss finish, which makes them a good replacement for conventional inks, although more costly.²⁵

Thermal-curing inks are also reactive inks, using special proprietary cross-linking catalysts. These inks are used in web printing and contain few or no solvents. Thermal-curing inks dry by polymerization when heat is applied, as differentiated from heatset inks, which dry by evaporation when heat is applied.⁷

3.5.2 Fountain Solution

Fountain solution is applied to the lithographic plate to render the nonimage areas unreceptive to ink. Since printing inks are oil based, the fountain solution is water based. The fountain solution contains a wetting agent, acids and buffer salts to maintain the pH of the solution, small quantities of gum arabic or synthetic resins, and a dampening aid to enhance the spreadability of the fountain solution across the lithographic plate. Fountain solutions are acidic if gum arabic is used, neutral if synthetic resins and buffers are used, or alkaline, as in the newspaper industry.

The role of the dampening aid is to reduce the surface tension of the water, as well as increase viscosity. Isopropyl alcohol has been used as the dampening aid since the 1950's.¹¹ The concentration of alcohol in the fountain solution can range from 0 to 35 percent alcohol (by volume) or higher, with most presses falling in the 15 to 20 percent range.²⁶ The industry is divided on the issue of how much alcohol is necessary to operate an offset press. The NAPL has stated that alcohol use has become somewhat of a crutch to printers because it permits all types of work to be run, even under adverse conditions.²⁶

In the past, the concentration of the additives in the fountain solution has been controlled by pH measurements. The newspaper industry has started a trend in the offset industry toward increased use of electrical conductivity as a monitor of fountain solution mixtures.¹⁵ Conductivity has been found to be a more sensitive and reliable measure of concentration than pH, especially with neutral solutions.¹⁵

Nonalcohol dampening aids that replace or minimize the amount of alcohol used in fountain solutions have been developed in recent years. These alcohol replacements or substitutes are made up of glycol, such as ethylene glycol, glycol ethers or cellosolve ethers, or proprietary compounds, and are chemically similar to alcohol. They have the same surface-tension-reducing ability but are more complex in structure and have higher boiling points.

Nonalcohol products can combine all the fountain additives into one solution (onestep) that is mixed with water to produce the fountain solution, or a nonalcohol dampening aid can be added to a conventional mix of fountain additives in concentrated form and then combined with water in a two-step process. This latter procedure is used on sheet-fed presses.²⁷ The nonalcohol substitutes and/or fountain concentrate is added in small quantities (2 to 4 ounces to 1 gallon of water).

Although alcohol substitutes range from 0 to 100 percent VOC, the small quantities used result in a final solution that is less than 3 percent (by weight) VOC, regardless of VOC content of the substitute. Motivation for alcohol replacement was originally based on lowering the alcohol fumes in the pressroom to comply with Occupational Safety and Health Administration regulations,²⁸ as well as to offset the high cost of petroleum-dependent IPA.²⁷

Depending on the choice of dampening system, difficulties have been reported in totally replacing alcohol with alcohol substitutes,²⁹ although many of the newer dampening systems operate best when the alcohol concentration is reduced to the 5 to 15 percent range.³⁰ The NAPL, along with many printers, says that it takes a "firm management commitment"²⁶ to lower or replace IPA in the fountain. The major suppliers of alcohol substitutes to the printing industry have reported a more than 200 percent increase in sales since 1985.²⁷ Since some of the fountain solution must be taken up into the ink to maintain the proper ink/water balance on the lithographic plate, ink

manufacturers also have had to reformulate some of their inks to accommodate alcohol substitutes.^{31,32}

3.5.3 Cleaning Solutions

Cleaning solutions are used to wash the blankets, the rollers, and the exterior surfaces of the press to remove excess printing inks, oils, and paper pieces (pilings). The solutions are petroleum-based solvents, often mixed with detergent and/or water. The cleaning compound may be a single solvent, such as kerosene, or a combination of solvents.³³ Blanket cleaning is required at least once or twice per shift, between jobs, and as needed to improve print quality, depending on the type of printing.

Approximately two-thirds of the cleaning solution is used as a blanket wash and one-third to clean the rollers and the presses.³⁴ A general purpose cleaner may not work well for every job.²⁴ Although newspaper presses can use the same cleaner for blankets and rollers, other printers may use two or more different cleaners sequentially to clean a specific area.³³ The more viscous the ink, as in heatset and sheet-fed printing, the more difficulty will be encountered with cleaning.

Blankets and rollers may be cleaned automatically or manually when the presses are shut down. Excess fluid from roller washes is collected in trays below the rollers. Cleaning compounds may be dispensed from general storage drums to smaller containers or squirt bottles that are kept near the presses. Manual cleaning can be performed by applying a small amount of cleaning solution to a rag that is later disposed of. Although a large portion of the cleaning solution is retained by the rags if kept in an airtight container, the VOC's still very likely will evaporate at a later time when the rags are cleaned.

Automatic cleaning systems can be used to apply blanket washes. Automatic systems allow presses to run continuously without cleaning interruptions. Washing is initiated either periodically or as triggered by paper splices.²⁴ Since the

solution is metered, less cleaning solution may be used with automatic cleaning systems.³⁵ The majority of the industry, however, uses manual cleaning methods, since automatic cleaning requires a large capital investment.³⁵

Some cleaning solutions have been developed that contain solvents with high flash points to avoid a hazardous ignitable (less than 140°F) classification;²⁴ however, these cleaners contain the same amount of VOC as measured by EPA methodology. Water-miscible cleaning compounds have been developed that, when diluted with water, produce a lower VOC concentration than traditional cleaning compounds.³³ Citrus-based cleaners with lower VOC's (less than 3.5 pounds of VOC per gallon) are now sold by some companies and are being developed by others.^{36,37}

There is some industry dissatisfaction with the lower-VOC cleaning products currently on the market.²⁴ The water-miscible compounds are reported to cause metal parts to rust or promote tears in the paper when the water-soaked paper sticks to the blanket.⁴ The water-miscible products may not work well with ultraviolet or thermally-catalyzed inks. Vendors of water-miscible cleaning compounds, however, claim improved cleaning qualities with their products.³³

3.6 MODEL PLANTS

To evaluate the potential ranges of VOC emissions from different types and different materials of offset lithographic printing, model plants were developed using information from the following sources:

- Responses to the 1990 Section 114 printing questionnaire sent out under the Offset Lithographic Printing Control Techniques Guideline (CTG) project.³⁸
- A study done by the NAPL and discussed in a special report on alcohol use by the industry.²⁶
- Trip reports of site visits conducted during 1990 as part of the Offset Lithographic Printing CTG project.^{39,40,41}

- Graphic Arts Monthly, August 1990 article entitled, "The GAM 101 Official Ranking."⁴²
- The American Newspaper Publishers Association, Washington, DC, (1989 data).⁴³
- Telephone conversations with members of the sheet-fed offset lithographic printing industry.^{44,45,46}
- Directory of Heatset Web Offset Printers and Heatset Web Offset Press Installations (March 1990).¹²
- Directory of Non-heatset Web Offset Printers and Non-heatset Web Offset Press Installations (March 1990).¹³
- 75 voluntary responses to questionnaires by sheet-fed printers of the NAPL.³⁸

Tables 3-1 and 3-2 present model plants for the four types of printing discussed above: heatset web, non-heatset web (non-newspaper), non-heatset sheet-fed, and newspaper (non-heatset web). The model plants were chosen to represent a range in emission potential and are not meant to characterize the printing industry.

The model plants are characterized by number of presses and number of units per press, total number of units, press width, and operating hours. For newspaper facilities, circulation rate was used to further characterize plant sizes. Operating hours for the model facilities were estimated at an average of 3,000 hours per year, based on operation of the presses for 16 hours per day, 5 days per week, 52 weeks per year, with about 25 percent of the time being "make-ready time" in which no significant VOC emissions occur.⁴⁷ Actual operating hours can vary from 1,500 to 6,000 hours per year, depending on the facility and type of printing presses.³⁸

The non-heatset model plants represent presses that use inks that dry by absorption or oxidation. Inks cured by ultraviolet light, electron beam, or thermally-catalyzed inks were not included as model presses because no VOC's are expected to be emitted from the ink. However, the analyses

TABLE 3-1. OFFSET LITHOGRAPHIC PRINTING MODEL PLANTS

Model Plant Code	Size	Number of Presses	Number of Units/Press	Total Units	Press Width (in.)	Annual Hours of Operation
<u>HEATSET WEB MODEL PLANTS^a</u>						
A-I	Very Small	1	1-6	1-6	38	3,000
A-II	Small	1-2	6-8	6-16	38	3,000
A-III	Medium	2-4	6-8	12-32	38	3,000
A-IV	Large	4-6	8	32-48	38	3,000
<u>NON-HEATSET WEB MODEL PLANTS^b</u>						
B-I	Very Small	1	4-6	4-6	38	3,000
B-II	Small	1-2	6-8	6-16	38	3,000
B-III	Medium	2-4	6-8	12-32	38	3,000
B-IV	Large	4-6	8	32-48	38	3,000
<u>NON-HEATSET SHEET MODEL PLANTS^b</u>						
C-I	Very Small	1-2	1-2	1-4	38	3,000
C-II	Small	2-4	1-2	2-8	38	3,000
C-III	Medium	4-6	2-4	8-24	38	3,000
C-IV	Large	6-8	4-6	24-48	38	3,000

^a Double Blanket.

^b Single Blanket.

TABLE 3-2. OFFSET LITHOGRAPHIC NEWSPAPER (NON-HEATSET WEB) MODEL PLANTS

Model Plant Code	Size	Circulation	Number of Presses	Number of Units/Press	Total Units	Press Width (in.)	Annual Hours of Operation
D-I	Very Small	25,000	1	6	6	27½	3,000
D-II	Small	25-50,000	1	8-10	8-10	27½	3,000
D-III	Medium	50-100,000	1-2	9-12	9-24	55	3,000
D-IV	Medium Large	100-250,000	2-4	9-12	18-48	55	3,000
D-V	Large	250-500,000	4-8	10-12	40-96	55	3,000
D-VI	Extra Large	>500,000	10	10-12	100-120	55	3,000

Note--The units are double-blanket.

below pertaining to fountain solution and cleaning solution apply to presses using these as well as other types of inks.

The model plants described here might be found in any combination within a single facility. For instance, a printing company may have a medium-size sheet-fed operation corresponding to Model Plant C-III and a small heatset web press, corresponding to Model Plant A-I.³⁹ Because the number of combinations of two-, three-, and four-model sub-facilities in one facility is too large for the purposes of this discussion, State and local agencies can treat each sub-facility as a separate unit. Total emissions for the entire facility can be determined by adding the emissions from each sub-facility. Since add-on controls are only used with heatset presses, there probably will be no economies of scale in combining heatset with non-heatset printing. Costs of emissions controls, therefore, will be additive.

3.6.1 Estimated Raw Material Use

Annual use of printing inks, fountain solution dampeners, and cleaning solutions for the model plants is shown in Tables 3-3 and 3-4. The estimates were based on the following sources:

- Responses to the 1990 Section 114 printing questionnaire sent out under the Offset Lithographic Printing CTG project.³⁸
- A study done by the NAPL and discussed in a special report entitled: "What's Being Done to Stall an EPA Crackdown on Alcohol in Dampeners."²⁶
- 75 voluntary responses to questionnaires by sheet-fed printers of the NAPL.³⁸
- The American Newspaper Publishers Association, Washington, DC, based on 1989 data.⁴³

The method used to estimate raw materials use for the model plants, along with emissions of VOC's from use of raw materials, is discussed in more detail in Chapter 5.0.

A nominal 38-in. press width was used for model plants in Groups A, B, and C. For narrower presses, less ink, fountain

TABLE 3-3. OFFSET LITHOGRAPHIC PRINTING MODEL PLANTS - ANNUAL PRODUCT USE

Model Plant Code	Size	Total Units	Ink (Tons)	Fountain Solution Alcohol (Tons)	Cleaning Solution (Tons)
<u>HEATSET WEB MODEL PLANTS^a</u>					
A-I	Very Small	1-6	15-93	14-83	0.4-3
A-II	Small	6-16	92-247	83-222	3-8
A-III	Medium	12-32	185-494	167-445	6-16
A-IV	Large	32-48	494-742	445-667	16-24
<u>NON-HEATSET WEB MODEL PLANTS^b</u>					
B-I	Very Small	4-6	62-93	33-50	2-3
B-II	Small	6-16	92-247	49-131	3-8
B-III	Medium	12-32	185-494	98-261	6-16
B-IV	Large	32-48	494-742	261-393	16-24
<u>NON-HEATSET SHEET MODEL PLANTS^b</u>					
C-I	Very Small	1-4	0.4-2	0.5-2	0.5-2
C-II	Small	2-8	1-3	1-4	1-4
C-III	Medium	8-24	3-9	4-11	4-12
C-IV	Large	24-48	9-18	11-23	12-24

^a Double Blanket.

^b Single Blanket.

TABLE 3-4. NEWSPAPER (NON-HEATSET WEB) MODEL PLANTS - ANNUAL PRODUCT USE

Model Plant Code	Size	Total Units	Ink (Tons)	Fountain Solution Additive (Tons)	Cleaning Solution (Tons)
D-I	Very Small	6	2-19	0.1-1	3
D-II	Small	8-10	15-82	1-6	4-5
D-III	Medium	9-24	67-209	5-15	4-12
D-IV	Medium Large	18-48	125-829	9-58	9-24
D-V	Large	40-96	529-1647	37-115	20-48
D-VI	Extra Large	100-120	1072-3239	75-227	50-59

Note---The units are double-blanket.

solution, and cleaning solution use can be expected; for wider presses, more can be expected. Use rates of printing supplies also can vary from job to job, depending largely on paper type, degree of ink coverage, water quality, ink/water balance, dampening system, and, to a lesser extent, season of the year and geographic location.³⁵ If possible, State and local agencies should use actual plant records to establish raw material use and to estimate emissions.

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4.0 EMISSION CONTROL TECHNIQUES

4.1 INTRODUCTION

This chapter describes techniques for controlling VOC emissions from offset lithographic printing presses. There are three principle sources of VOC emissions from lithographic printing presses: heatset printing inks, which use hydrocarbon liquids as carriers that are partially driven off in dryers; the fountain solution, where VOC's such as IPA may be used to reduce the surface tension of water; and cleaning solutions, which are predominately VOC's.

Techniques to control VOC emissions from lithographic printing presses can be categorized as add-on controls, process modifications, or material reformulation or substitution.

In the following sections, the conditions affecting VOC removal for each method are examined, and the applicability of each method is evaluated.

4.2 ADD-ON CONTROLS

Add-on control devices can be grouped into two broad categories: combustion devices (destructive) and recovery devices (nondestructive). Combustion devices are designed to destroy VOC's in the vent stream prior to atmospheric discharge. Recovery devices limit VOC emissions by recovering VOC-containing material for other uses.

Add-on controls have been installed at a number of heatset lithographic printing facilities. Equipment vendors indicate that add-on controls have only been installed on heatset processes¹⁻⁹ because heat is used to set the ink, and the dryer on a heatset press discharges a waste with a relatively high concentration of VOC's. Frequently, several

dryer exhausts pass through a manifold to a single control device. (In non-heatset printing, most of the VOC's in ink are retained by the substrate.)^{10,11}

The offset lithographic printing industry employs three basic add-on control devices: thermal incinerators, catalytic incinerators, and condenser filter systems. According to several vendors,^{1,2,3} the most prevalent control devices are incinerators, both thermal and catalytic.

4.2.1 Thermal Incinerators

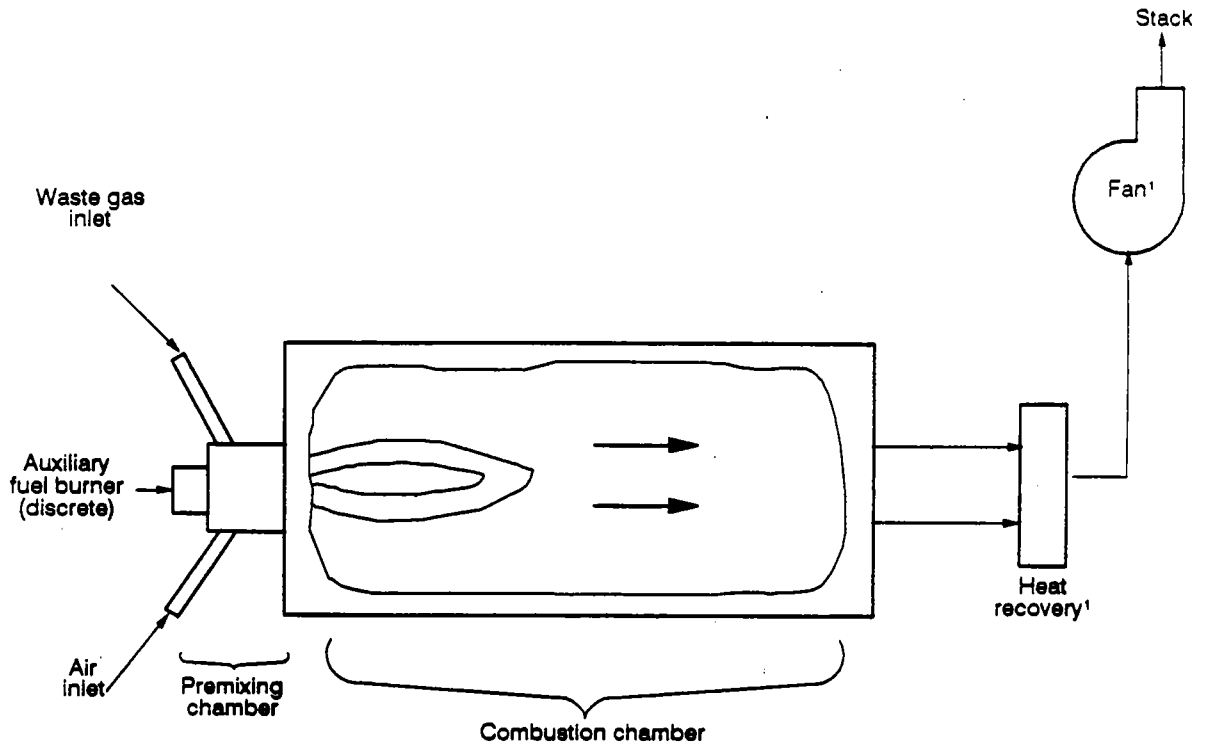
4.2.1.1 Thermal Incineration Process Description.

Thermal incinerators are used extensively in the printing industry to burn VOC's emitted by heatset press dryers. As with any combustion process, the combustion efficiency of the thermal incineration process is influenced by residence time, mixing, and temperature. An efficient thermal incinerator system provides:

- A chamber temperature high enough to enable the oxidation reaction to proceed rapidly to completion;
- Enough turbulence to obtain good mixing between the hot combustion products from the burner, combustion air, and VOC; and,
- Sufficient residence time (approximately 0.75 sec) at the chosen temperature (1,400°F or greater)¹² for the oxidation reaction to reach completion.

Improper design or operation of an incinerator can result in incomplete combustion and, consequently, VOC emissions. Several incinerator designs are available, all of which achieve the same VOC destruction efficiency.

A thermal incinerator is usually a refractory-lined chamber containing a burner (or set of burners). As shown in Figure 4-1, dual-fuel burners and inlets for the offgas and combustion air discharge into a premixing chamber to thoroughly mix the hot products from the burners with the process vent streams. The mixture of hot reacting gases then passes into the main combustion chamber. This chamber is sized to allow the mixture enough time at the elevated temperature for the oxidation reaction to reach completion



¹ Optional

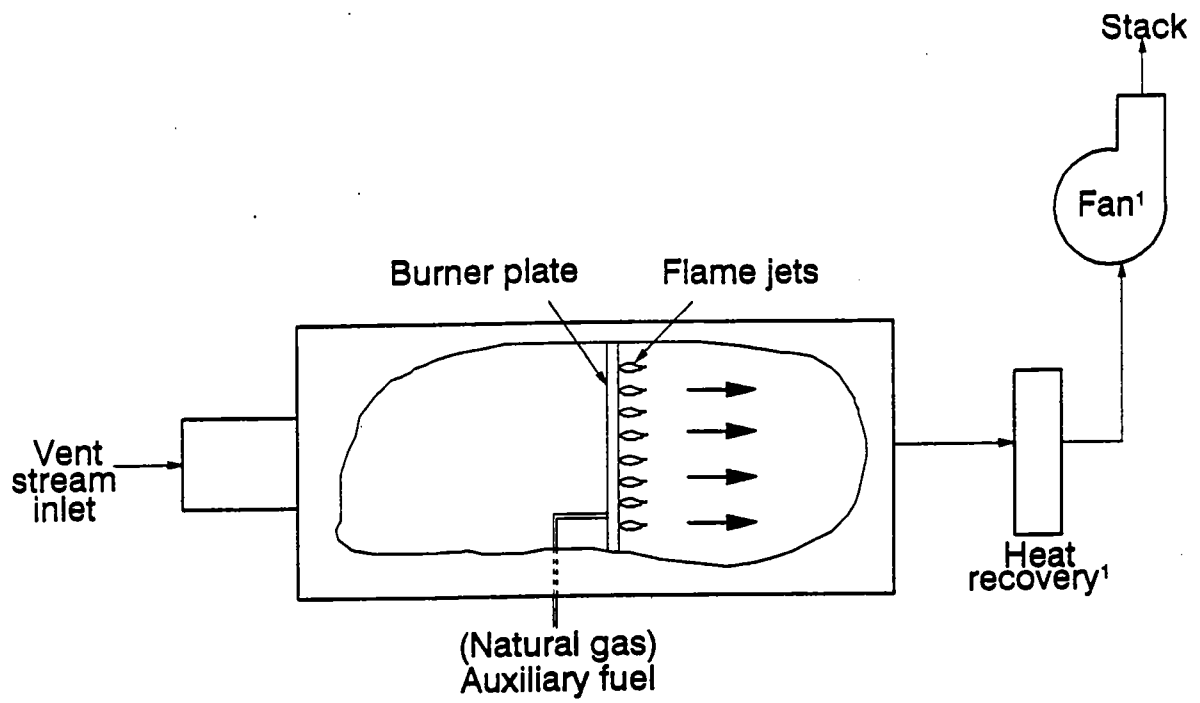
Figure 4-1. Discrete burner, thermal incinerator.

(residence times of 0.75 to 1.0 sec are common).¹² Energy can then be recovered from the hot flue gases in a heat recovery section. Preheating combustion air or plant space heating air is a common mode of energy recovery. (Insurance regulations require that if the waste stream is preheated, the VOC concentration in that stream must be maintained below 25 to 50 percent of the lower explosive limit to avoid explosion hazards.)

Thermal incinerators designed specifically for VOC incineration with natural gas as the auxiliary fuel may also use a grid-type (distributed) gas burner,¹³ as shown in Figure 4-2. The tiny gas flame jets on the grid surface ignite the vapors as they pass through the grid. The grid acts as a baffle for mixing the gases entering the chamber. This arrangement ensures burning of all vapors at lower chamber temperature and uses less fuel, so the system can use a shorter reaction chamber while maintaining high efficiency.¹³

Other parameters affecting incinerator performance are the heating value of the dryer exhaust stream, the stream's water content, and the amount of excess combustion air (the amount of air above the stoichiometric air needed for reaction). The heating value is a measure of the heat released by combustion of the VOC in the dryer exhaust. Combustion of a dryer exhaust stream with a low heating value may require burning auxiliary fuel to maintain the desired combustion temperature. Auxiliary fuel requirements can be lessened or eliminated by using recuperative heat exchangers to preheat combustion air.

A thermal incinerator handling combined dryer exhaust streams with varying heating values and moisture contents requires careful adjustment to maintain proper chamber temperatures and operating efficiency. Because water requires a great deal of heat to vaporize, entrained water droplets can increase auxiliary fuel requirements to provide the additional energy needed to vaporize the water and raise it to the combustion chamber temperature.



¹ Optional

Figure 4-2. Distributed burner, thermal incinerator.

Combustion devices are always operated with some quantity of excess air to ensure a sufficient supply of oxygen. The amount of excess air used varies with the fuel and burner type but should be kept as low as possible. Using too much excess air wastes fuel because the additional air must be heated to the combustion chamber temperature. Large amounts of excess air also increase flue gas volume and may increase the size and cost of the system. Prepackaged, single-unit thermal incinerators are available to control streams with flow rates in the range of 500 standard cubic feet per minute (scfm) to about 50,000 scfm.

4.2.1.2 Thermal Incinerator Efficiency. All VOC's are combustible, with combustion efficiency limited only by cost. Hazardous waste incinerators are required to achieve 99.99 percent efficiency for the principle organic constituents present in the hazardous waste. Test results show that thermal incinerators can achieve 98 percent destruction efficiency for most VOC compounds at combustion chamber temperatures ranging from 1,300 to 2,370°F and residence times of 0.5 to 1.5 seconds.¹⁴ These data reveal significant variations in destruction efficiency for C₁ to C₅ alkanes and olefins, aromatics (benzene, toluene, and xylene), oxygenated compounds (methyl ethyl ketone and IPA), chlorinated organics (vinyl chloride), and nitrogen-containing species (acrylonitrile and ethylamines) at chamber temperatures below 1,400°F.

The above information, used in conjunction with kinetics calculations, indicates that the combustion chamber parameters for achieving at least a 98-percent VOC destruction efficiency are a combustion temperature of at least 1,400°F and a residence time of 0.75 sec (based on residence in the chamber volume at combustion temperature). A thermal incinerator designed to produce these conditions in the combustion chamber should be capable of high destruction efficiency for almost any nonhalogenated VOC.

At temperatures over 1,400°F, oxidation reaction rates are much faster than the gas diffusion mixing rate. As a

result, the combustion reaction is in danger of being hampered merely because sufficient oxygen molecules are not in proximity to the organic. To ensure that this does not occur, mixing must be enhanced via vanes or other physical methods. This helps the oxidation reaction reach completion.

On the basis of studies of thermal incinerator efficiency, it has been concluded that 98 percent VOC destruction (or a 20 part-per-million-by-volume [ppmv] VOC exit concentration) is achievable by all new incinerators.¹⁴ The 98-percent efficiency estimate is predicated on thermal incinerators operated at 1,400°F or higher with 0.75 sec residence time.

4.2.1.3 Applicability of Thermal Incinerators. In terms of technical feasibility, thermal incinerators are applicable as a control device for all heatset web offset lithographic printing presses. They can be used for dryer exhaust streams containing any type of VOC and any VOC concentration, and they can be designed to handle fluctuation in flow rates. Thermal incinerators are currently used in a number of printing facilities.

4.2.2 Catalytic Incinerators

4.2.2.1 Catalytic Incineration Process Description. Catalytic incineration, or oxidation, is another major combustion technique used for VOC emission control. Catalysts cause the oxidizing reaction to proceed at a lower temperature than is required with thermal oxidation. Combustion catalysts include platinum, platinum alloys, copper oxide, chromium, and cobalt and mixed oxide catalysts.¹² The catalytic material is deposited in thin layers on inert substrates to provide for maximum surface area between the catalyst and the VOC stream.

A catalytic oxidation unit is shown in Figure 4-3. The waste gas is introduced into a mixing chamber, where it is heated to above 600°F by contact with the hot combustion products from auxiliary burners. The heated mixture is then passed through the catalyst bed. Oxygen and VOC's migrate to the catalyst surface by gas diffusion and are adsorbed in the

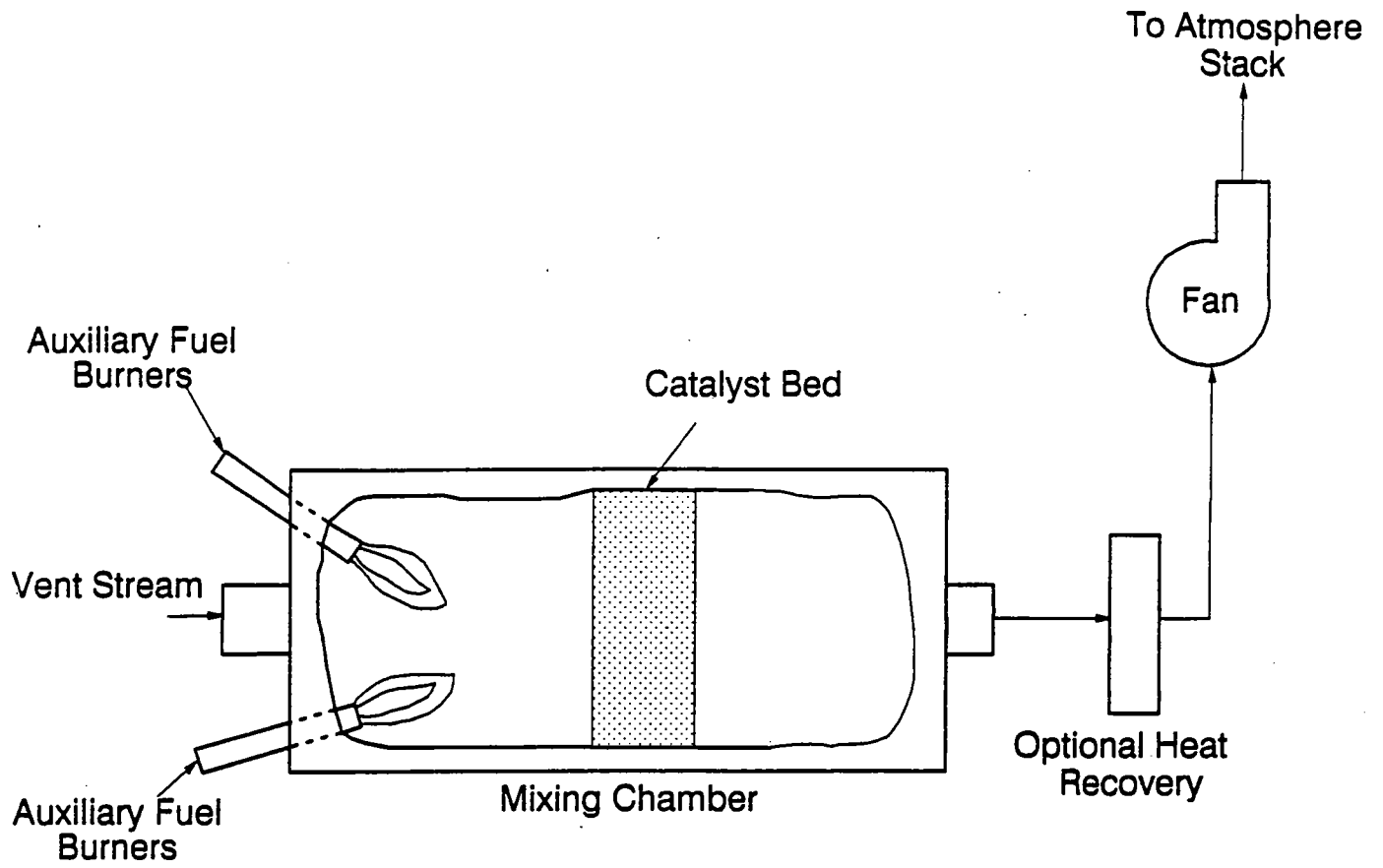


Figure 4-3. Catalytic incinerator.

pores of the catalyst. The oxidation reaction takes place at these active sites. Reaction products are desorbed from the active sites and transferred by diffusion back into the waste gas.¹⁵ The combusted gas may then be passed through a waste heat recovery device before exhausting into the atmosphere. Catalytic incinerators employed in the lithographic printing industry are typically operated at 600 to 700°F.¹⁶ If the heating value of the waste gas stream is high enough, and a heat exchanger is used to preheat the inlet gas, a catalytic incinerator can maintain its operating temperature without the need for burning supplemental fuels.

4.2.2.2 Catalytic Incinerator Characteristics. The operating temperatures of combustion catalysts usually range from 600 to 1,200°F. Low temperatures may slow down and possibly stop the oxidation reaction. High temperatures (greater than 1,200°F) may result in shortened catalyst life and possibly deterioration of the catalyst. Thermal aging is caused by high temperatures damaging the active metal, sintering, or crystallizing the surface area. This results in a permanent loss of surface area. To prevent deactivation of the catalyst, a maximum bed temperature of 1,200°F should not be exceeded.

Masking occurs when there is a loss of active sites due to a buildup of dust, carbons, or resins, which plug the catalyst pores. This process is reversible to some extent; the catalysts can be cleaned periodically with a caustic solution to restore some of the activity.⁶ Any accumulation of particulate matter, condensed VOC's, or polymerized hydrocarbons on the catalyst could block the active sites and, therefore, reduce effectiveness.

Catalyst poisoning occurs when an active site is taken up by contaminants such as phosphorous, lead, silicone, sulphur, bromine, fluorine, or chlorine in the waste stream. Catalysts can also be deactivated by compounds containing sulfur, bismuth, phosphorous, arsenic, antimony, mercury, lead, zinc, tin, or halogens.¹⁷ If the catalyst is exposed to any of

these compounds, VOC's will pass through unreacted or only be partially oxidized, forming compounds such as aldehydes, ketones, and organic acids.

Several articles have been published concerning problems with phosphorous poisoning of catalytic incinerators from fountain solution etch chemicals from offset lithographic printing presses.^{16,18} In catalytic incineration, periodic replacement of the catalyst at intervals of 2 to 5 years can be anticipated because of thermal aging, masking, and poisoning processes.⁶ In some applications, a service life of only 3 to 6 months has been reported for precious metal catalysts because of poisoning.¹⁶

Problems with catalyst poisoning have led to the development of a reportedly "poison-resistant" catalyst for use in offset lithographic printing facilities¹⁶ that is more tolerant of phosphorous and halogens than are traditional catalysts. Alternately, some systems are designed with sacrificial beds of inexpensive catalysts upstream from the precious metal catalyst to trap the poisoning phosphorous and silicone.⁶

4.2.2.3 Catalytic Incinerator Efficiency. Catalytic incinerator efficiency depends on the "space velocity" (the gas flow per bulk volume of the catalyst bed, time^{-1}), operating temperature, oxygen concentration, and waste gas VOC composition and concentration. A catalytic unit operating at about 840°F with a catalyst bed volume of 0.5 to 2 cubic feet per 16.8 standard cubic feet per sec (scf/sec) vent stream passing through the device can achieve 95 percent VOC destruction efficiency. In some cases, catalytic incinerators have been reported to achieve efficiencies of 98 percent or greater.⁶ These higher efficiencies are usually obtained by increasing the catalyst bed volume-to-vent stream flow ratio.

4.2.2.4 Applicability of Catalytic Incinerators. Because of the sensitivity of a catalytic incinerator to VOC inlet stream flow conditions, the applicability of catalytic units for control of VOC from some offset lithographic

printing operations is limited, although many catalytic units have operated successfully on offset lithographic dryer exhausts.

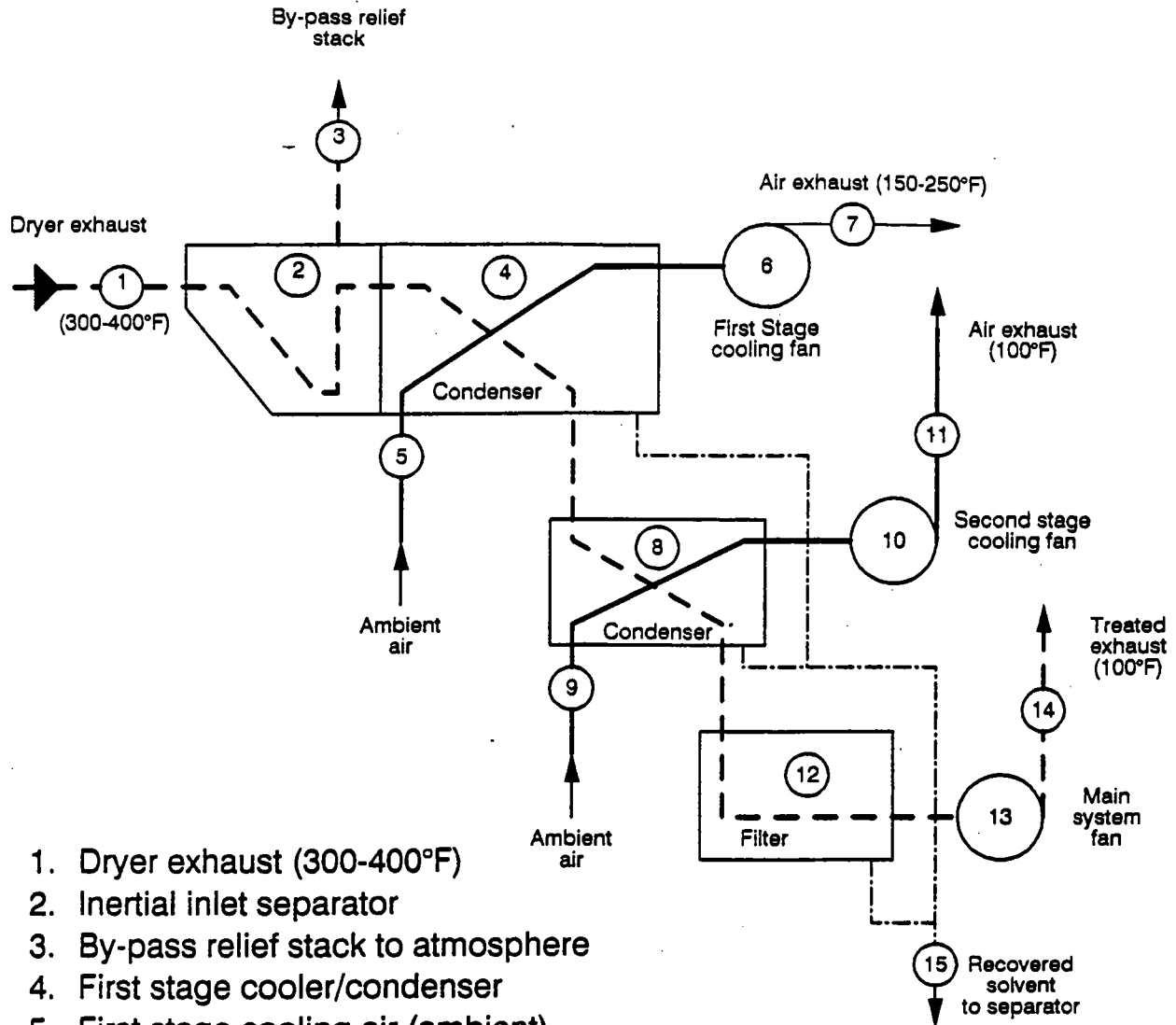
4.2.3 Condenser Filter Systems

4.2.3.1 Condenser Filter Process Description. Condenser filter systems condense solvents from the hot air dryer exhaust by cooling the exhaust gases with ambient air and multistage heat exchangers. Condensation occurs when one component of a saturated vapor mixture undergoes a phase change from gas to liquid. The heat removed from the vapor phase should be sufficient to lower the vapor-phase temperature to below its dew point temperature (the temperature at which condensation occurs first).

Condenser filter systems have been designed specifically for the heatset web offset printing industry. Condenser filters are nondestructive control devices that recover oils and solvents from the dryer exhaust gas. These devices employ surface condensation and microfiltration to remove solvents, as shown in Figure 4-4.¹⁹

In a condenser filter system, the dryer exhaust is drawn from the dryer discharge stack into the first stage of the condenser filter. A combination of velocity reduction, directional change, and mesh screen separation causes solids (wastes, resins, paper, etc.) to drop out. The dryer exhaust, minus the solids, continues to flow through the first stage condenser inlet. The first and second stage condensers are indirect plate-to-plate heat exchangers of counterflow design. Hot solvent-laden exhaust fumes flow from top to bottom, with cooler ambient air flowing from bottom to top, induced by cooling fans. The clean condenser cooling air is returned to the atmosphere or is recovered for reuse, that is, heating plant make-up air.

Solvents condensed in the first- and second-stage condensers are collected and drained from the system. The remaining airborne droplets of solvent are collected by high-efficiency, self-draining, microfiber air filters. These filters, called "candles," are elongated mesh bags capable of



1. Dryer exhaust (300-400°F)
2. Inertial inlet separator
3. By-pass relief stack to atmosphere
4. First stage cooler/condenser
5. First stage cooling air (ambient)
6. First stage cooling air fan
7. First stage hot air exhaust (150-250°F) for reuse
8. Second stage cooler/condenser
9. Second stage cooling air (ambient)
10. Second stage cooling air fan
11. Second stage air exhaust (100°F max) to atmosphere
12. Third-stage filter section
13. Main fan
14. Treated effluent exhaust (100°F max) to atmosphere
15. Oil solvent to separator for recovery

Figure 4-4. Condenser filter system.

handling flows of 500 cubic feet per minute (cfm) each.

A slightly different design employs a prefilter, one single-stage condenser, a filter media, and a mist eliminator.²⁰ The prefilter removes large particles. The main filter media is automatically advanced by a differential static pressure controller to maintain low system pressure drops and optimum performance efficiency. The mist eliminator traps and collects aerosol droplets of remaining solvent. Solvents recovered from condenser filter systems are typically burned in the dryers or boilers as supplemental fuel.

4.2.3.2 Condenser Filters with Carbon. A condenser filter system sold by at least one vendor uses adsorption, along with condensation and filtration, to remove VOC's from dryer exhausts. Although only a few facilities are using the device at this time, the concept has been shown to be technically feasible for the offset lithographic printing industry.

An activated carbon bed added directly downstream from a condenser filter adsorbs any VOC's that remain in the condenser filter exhaust stream and significantly improves the VOC removal efficiency. Because of the high temperatures of dryer exhaust (350°F), carbon adsorption alone would not be a suitable control strategy, since adsorption efficiency decreases with increasing temperature. However, after the condenser filter lowers the exhaust temperature to approximately 100°F, adsorption systems can remove additional VOC's.

Activated carbon, however, has a finite adsorption capacity. When the carbon is saturated, no further organic removal is possible. At this point, the organic compounds must be removed from the bed before adsorption can continue. This removal process is called desorption, or regeneration. Most gases can be desorbed from the carbon by heating them to a sufficiently high temperature, usually via steam or hot air.

Low-pressure steam is the recommended heat source for carbon regeneration in condenser filter systems although hot air also can be used. The steam-laden vapors from

regeneration are then sent to a condenser, and the condensate passes to a decanter, where the VOC and water layers are separated. The VOC's recovered from the decanter can be burned as fuel. Depending on its quality, the water layer can either be discharged to a wastewater treatment facility or recycled to provide process steam. Vendors to the printing industry have found that ink oils are not very soluble, so the concentration of organics in the condensate water should be low.²¹ The regeneration process may be repeated many times, but eventually the carbon must be replaced.

The life span of the activated carbon depends on the nature of the pollutants being controlled. Vendors to the offset lithographic printing industry predict a 5-year carbon life,²¹ after which the carbon must be disposed of and replaced.

Often, a two-bed system is employed, where one bed is always on-line while the other is being regenerated, especially for 24-hour operations. Parallel beds are not necessary if the exhaust flow is not continuous and operating hours do not exceed the time to saturation. In the offset lithographic printing industry, beds can typically be regenerated at night when press lines are down. Adsorption systems are designed to handle the maximum number of hours of continuous press operation before saturation occurs.

4.2.3.3 Condenser Filter Efficiency. The VOC removal efficiency of a condenser depends on the type of vapor stream entering the condenser, condenser operating parameters, and whether or not a carbon unit is used in the condenser exhaust. Condenser filter systems have been evaluated in several States. These units can reportedly achieve as high as 97 percent VOC removal efficiency, although about 90 percent is typical for units without carbon.²⁰ Carbon units can guarantee 95 percent efficiencies.²²

The advantage of condenser filter systems over combustion systems is that the recovered solvent can be reused. Normally, the solvent can be burned in the dryer or a boiler

as fuel, with a 3-to-1 ratio of recovered solvent to natural gas.²⁰ Operating and maintenance costs are offset by potential fuel savings. Cost issues are discussed in more detail in Chapter 6.0.

4.3 PROCESS MODIFICATION

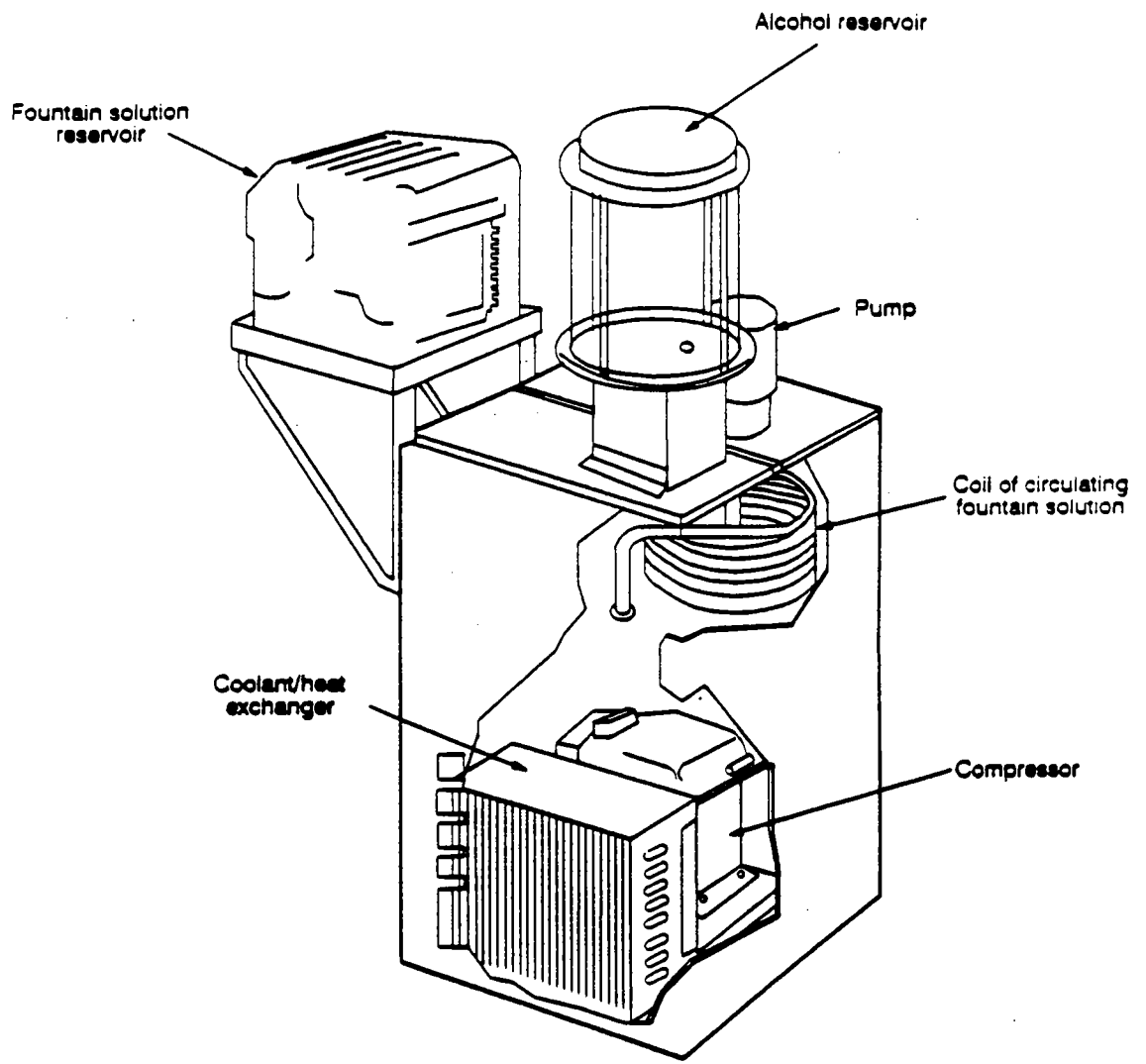
Process modifications are changes in operating methods or equipment that result in improved VOC control. The modifications may involve retrofitting existing equipment or replacing older equipment with new technology to accommodate the process change.

4.3.1 Refrigerated Fountain Solution Systems

4.3.1.1 Process Description. Fountain solutions used in offset lithography are composed primarily of water, but also may contain an etchant (phosphoric acid), gum arabic, and a dampening aid to reduce the surface tension of water. Most often the dampening aid is IPA, which is a VOC. To improve printing quality, many presses are fitted with refrigerated circulators, which cool fountain solutions to a preset temperature, usually from 55 to 60°F, giving operators better control over ink/water emulsification and hot weather scumming, and stabilize the ink/water balance by minimizing alcohol evaporation. Cooling also reduces VOC emissions from the fountain solutions.

One refrigerated circulator can handle six to eight 38-in. fountain solution trays.²³ The units can be equipped with stainless steel filters to remove contaminants. Figure 4-5 shows a refrigeration fountain solution unit.

4.3.1.2 Efficiency of Refrigerated Circulators. Refrigeration of fountain solution trays has been shown to reduce alcohol consumption by as much as 44 percent.²⁴ The temperature of the fountain solution can be reduced from room temperature to as low as 40°F. Theoretical calculations show that the evaporation rate of IPA is decreased by 49 percent when temperatures are reduced from 80 to 60°F (see Appendix B).



Courtesy of Baldwin Technologies

Figure 4-5. Refrigerated fountain solution circulators.

4.3.1.3 Applicability. Refrigerated units are technically feasible options for reducing VOC emissions from offset lithographic printing presses that use alcohol and are currently used at a number of lithographic printing facilities. They can be designed to handle any flow rate as well as fluctuations in flow. Older presses can be retrofitted with refrigerated units. Refrigerated units can be easily installed on centralized circulating systems.

4.3.2 Water Conditioning Devices

A new device that reportedly reduces the amount of dampening aid in the fountain solution has been recently introduced to the printing industry. The device magnetizes the fountain water and reduces its surface tension so that the need for alcohol or an alcohol substitute reportedly is greatly reduced.²⁵ Although there has been limited use within the industry over 200 printing units in the United States are reportedly using this method successfully.²⁶ One facility confirmed the successful use of the device on all presses just 2 months into a trial period.²⁷ However, preliminary use of the devices has shown that more alcohol may be necessary for startup of the presses.^{27,28}

Although some facilities have had excellent results with magnetic devices, there is controversy about the effectiveness within the industry.²⁹ Despite the early success, current use in the industry is limited with some facilities reporting no reduction in the need for alcohol with the use of magnets. Third party testing also has provided conflicting results, with some tests showing reduced surface tension and others showing no change in surface tension.

4.4 MATERIAL REFORMULATION OR SUBSTITUTION

Material reformulation includes such techniques as reducing the amount of alcohol in the fountain, using alcohol substitutes in the fountain solution, and using lower VOC cleaning solutions.

4.4.1 Fountain Solution

A large amount of VOC emissions from offset lithographic presses occur from the alcohol used in the fountain solution. The role of the fountain solution is to dampen the water receptive nonimage areas of the lithographic plate. Although fountain solution is mostly water, alcohol is used in the solution to reduce the surface tension of the water and increase the wetting ability of the fountain solution. As stated previously, IPA has been used by offset lithographic printers since the 1950's. The concentration of alcohol in the fountain solution can range from 0 to 35 percent, with an estimated average at about 17 percent.³⁰

4.4.1.1 Reduction in Alcohol. The NAPL has correlated continuous dampening systems and acid-based fountain solutions with higher than average alcohol consumption rates.³⁰ Brush or spray dampening equipment sometimes is associated with lower alcohol use, possibly due to the ability of the brush or spray to reduce the surface tension of water.³⁰ A survey of suppliers of dampening equipment that included both continuous and conventional dampening on web and sheet-fed units indicated that the equipment, regardless of type, could be used with very little alcohol (5 percent) or even none at all.³¹⁻³⁵

4.4.1.2 Nonalcohol Additives. Nonalcohol fountain solution additives, or alcohol substitutes, lower the amount of VOC's in the final fountain mixture, as well as the amount emitted from the presses.

Alcohol substitutes are mixed at a ratio of 3 to 4 ounces of substitute (specific gravity approximately equal to 1) to 1 gallon of water (128 ounces) for a final concentration that is less than 3 percent (by weight) alcohol substitute. The VOC content of the substitutes can range from 0 to 100 percent, with two-step substitutes corresponding to the higher end of the range and one-step substitutes corresponding to the lower end, at 10 percent VOC or less.³⁶

Because the additives have a lower evaporation rate than alcohol (approximately one-fourth), and because of the lower mixing ratio of the additive with water (1 gallon of alcohol substitute can replace up to 16 gallons of alcohol), the overall emissions of VOC's from the fountain solution are lowered (see Chapter 5.0).

4.4.1.3 Applicability of VOC Reduction in Fountain Solution. Alcohol reduction or replacement may impact members of the offset lithographic printing industry differently because of the subtleties associated with printing on different substrates for each individual product. A common complaint from printers is the decline of product quality with low alcohol rates--a criticism that is difficult to substantiate or refute. Although some printers assert that they cannot function without some alcohol in their fountain solution,³⁰ the NAPL and other printers believe that with a commitment by management, alcohol use rates can be lowered. The advantage that some printers find with alcohol is that it is more "forgiving" than alcohol substitutes; problems with print quality are more quickly eliminated when alcohol use is not restricted.³⁰

Suppliers of nonalcohol fountain solution additives state that they have seen an increased demand for their products in recent years in all areas of offset lithographic printing,³⁷ although sheet-fed printers have had some difficulty adapting to reduced alcohol levels or nonalcohol substitutes.^{38,39} The slower press speeds and intermittent printing associated with sheet-fed printing have made effective dampening difficult with reduced alcohol levels and nonalcohol fountain solutions. The use of alcohol substitutes in sheet-fed printing, however, has increased in the last few years, as it has with other offset lithographic printing methods.³⁸ Successful alcohol substitution may require a transition period in which as much as 10 percent alcohol is used.^{39,40}

It is believed that pressmen will eventually find a solution to their problems with alcohol substitutes if the use

of alcohol is restricted.^{30,41} The newspaper industry has been successful in converting to nonalcohol dampening solutions.⁴²

4.4.2 Cleaning Solutions

In an EPA survey of offset lithographic printers, no facility reported using lower VOC cleaning products exclusively. Facilities that were visited and are using other lower VOC products and controls to reduce VOC emissions are not using lower VOC cleaning products as well.^{41,43,44} A rule in the South Coast Air Quality Management District in California (Rule 1130) required that offset lithographic printing cleaning products contain approximately 30 percent VOC or less (2.5 pounds per gallon), although printers report cleaning difficulties with these products.⁴⁵

Cleaning solutions are available from a few vendors with a lower VOC content than traditional cleaning compounds, which are often 100 percent VOC.⁴⁶ Of the lower VOC cleaning products, only a few contain materials that are not included on the EPA's list of HAP's in the CAA Amendments of 1990, and they are carried by only a few vendors at this time. The VOC content of the non-HAP's lower VOC products ranges from 0 to 30 percent.^{47,48,49} These products contain organic compounds with relatively lower volatility.

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5.0 EMISSION ESTIMATION TECHNIQUES

This chapter discusses VOC emissions and potential emission reductions with the use of the control technologies described in Chapter 4.0, applied to the model plants presented in Chapter 3.0.

Sources of VOC emissions from offset lithographic printing operations are the inks (heatset), fountain solution, and cleaning solutions used as raw materials in the printing process. Emissions of VOC's from each type of material are discussed separately below. Calculations to support the information presented in this chapter are found in Appendix B.

5.1 PRINTING INKS

5.1.1 Ink Use

Estimated ink use rates for the model plants were derived from information from industry surveys.^{1,2} For heatset and non-heatset web model plants, the ink use rate was estimated to be 10.3 pounds per unit-hour (lb/unit hour);¹ for non-heatset sheet model plants, a rate of 0.25 lb/unit hour was used.¹ The average ink use for model plants in Groups A, B, and C was calculated using the following equation:

$$\begin{array}{l} \text{ink use} \\ \text{(lb)} \end{array} = \begin{array}{l} \text{ink use rate} \\ \text{(lb/unit hour)} \end{array} \times \text{number of units} \times \begin{array}{l} 3,000 \text{ hour} \\ \end{array} \quad (1)$$

The total operating hours estimate for the model plants (3,000 hour) was based on operation of the presses for 16 hours per day, 5 days per week, 52 weeks per year, where approximately 25 percent of this time is "make ready time" during which no significant VOC emissions occur.³

The ink use rate used for the newspaper model plants (Group D) was the average annual ink use corresponding to

facility size (from industry data).² For model plants in Groups A, B, and C, an average ink use was calculated for the range of units (single blanket) in each size category. Average annual ink use for the model plants is shown in Table 5-1.

5.1.2 Baseline (Uncontrolled) Volatile Organic Compound Emissions from Inks

Baseline emissions of VOC's from inks for the model plants were calculated from the amount of ink used, the percent VOC in the ink, and the estimated percent VOC from the ink retained by the print and substrate, according to the following equation:

$$\text{VOC emissions from inks} = \text{weight of ink used} \times \frac{\text{weight percent VOC in the ink}}{100} \times \frac{(100 - \text{percent VOC retained by the paper})}{100} \quad (2)$$

A representative percentage of printing ink VOC was selected for each model plant type, based entirely on a survey of the industry by the National Association of Printing Ink Manufacturers.⁴ The survey data are anecdotal in that, as far as can be determined, they are not based entirely on EPA methods. In the absence of analytical values, the industry data have been used.

A 40-percent (by weight) VOC in the ink was used to represent a range of 25 to 45 percent VOC reported for heatset inks.⁴ A VOC content of 30 percent was used for non-heatset web ink to represent a range of 0 to 45 percent VOC reported for these inks.⁴

For non-heatset sheet-fed model plants, a VOC content of 25 percent was used to represent the range of 5 to 35 VOC by weight reported for sheet-fed inks.⁴ A 10-percent VOC content is used for newspaper ink (non-heatset web) to represent the range of 0 to 45 percent VOC reported for newspaper inks.⁴

For heatset inks, the amount of VOC retained by the substrate was estimated at 20 percent.^{4,5,6} The retention of

TABLE 5-1. MODEL PLANT PRODUCT USE AND BASELINE (UNCONTROLLED) VOLATILE ORGANIC COMPOUND EMISSIONS (AVERAGE TONS PER YEAR)

Model Plant Code ^a	Model Plant Size	Total Number of Units	Total Number of Employee	Ink		Fountain Solution Additive ^c		Cleaning Solution		Total VOC Emissions
				Use	VOC Emissions ^b	Use	VOC Emissions ^b	Use	VOC Emissions ^b	
A-I	Very Small	4 - 6	1 - 9	77	25	70	70	2	2	97
A-II	Small	6 - 16	10 - 19	170	54	153	153	5	5	213
A-III	Medium	12 - 32	20 - 99	340	109	306	306	11	11	426
A-IV	Large	32 - 48	>100	618	198	556	556	20	20	774
B-I	Very Small	4 - 6	1 - 9	77	1	41	41	2	2	44
B-II	Small	6 - 16	10 - 19	170	3	90	90	5	5	98
B-III	Medium	12 - 32	20 - 99	340	6	180	180	11	11	197
B-IV	Large	32 - 48	>100	618	11	327	327	20	20	358
C-I	Very Small	1 - 4	1 - 4	1	0.02	1	1	1	1	2
C-II	Small	2 - 8	5 - 19	2	0.04	2	2	2	2	4
C-III	Medium	8 - 24	20 - 50	6	0.11	8	8	8	8	16
C-IV	Large	24 - 48	>50	14	0.25	17	17	17	17	34
D-I	Very Small	6	1 - 6	10	0.1	0.7	0.1	2	2	2
D-II	Small	8 - 10	7 - 13	48	0.2	3	0.3	5	5	6
D-III	Medium	9 - 24	13 - 65	138	0.7	10	1.0	8	8	10
D-IV	Medium Large	18 - 48	49 - 130	477	2.4	33	3.3	16	16	22
D-V	Large	40 - 96	110 - 355	1088	5.4	76	7.6	34	34	47
D-VI	Very Large	100 - 120	370 - 444	2155	10.8	151	15.1	55	55	81

^aModel plants in Group A are heatset web, double blanket. Model plants in Group B are non-heatset web (non-newsprint), single blanket. Model plants in Group C are non-heatset sheet-fed, single blanket. Model plants in Group D are newspaper (non-heatset web), double blanket.

^bSee text regarding the source of these values.

^cIn model plant Groups A, B, and C, the additive is isopropyl alcohol. In model plant Group D, a nonalcohol additive that has a lower volatility than isopropyl alcohol is used.

VOC by the substrate is assumed to be 95 percent for model plants that use non-heatset inks.^{4,5,6} In heatset printing, VOC's from the ink are emitted from the hot air dryer exhaust. Because VOC's are retained by the substrate, VOC emissions within the facility limits are much lower from non-heatset inks than from heatset inks. Non-heatset sheet-fed model plants have the lowest VOC emissions because of the lower ink-use rate and the smaller number of units per facility. Table 5-1 shows estimated baseline VOC emissions for the model plants, derived from the above parameters and equations.

5.1.3 Reduction of Volatile Organic Compound Emissions from Ink

Volatile organic compound emissions from the ink in heatset printing operations can be controlled by add-on devices that destroy or collect the VOC released from the dryer. Chapter 4.0 describes four technologies available to the lithographic printing industry for controlling VOC's from inks: thermal incinerators, catalytic incinerators, condenser filters, and condenser filters with carbon. The control efficiency for thermal and catalytic incinerators was estimated at 95 to 100 percent, with 98 percent control a reasonable estimate of performance.^{7,8,9,10} Control efficiency was estimated at 90 percent for condenser filters^{11,12} and at 95 percent for condenser filters with carbon.¹³ Controlled levels of VOC emissions from inks were calculated according to the following equation, using an estimated control efficiency (CE) for each add-on control device:

$$\begin{array}{l} \text{controlled} \\ \text{VOC emissions} \\ \text{from inks} \end{array} = \begin{array}{l} \text{baseline} \\ \text{(uncontrolled)} \\ \text{VOC emissions} \\ \text{from inks} \end{array} \times \frac{100 - \text{CE}}{100} \quad (3)$$

Table 5-2 shows controlled versus baseline VOC emissions from inks in heatset model plants, using the four possible add-on control devices. The controlled emissions figures in Table 5-2 were calculated using a 98-percent control

TABLE 5-2. CONTROLLED VERSUS BASELINE (UNCONTROLLED) VOLATILE ORGANIC COMPOUND EMISSIONS FROM INKS IN HEATSET MODEL PLANTS

Model Plant Code	Model Plant Size	Baseline VOC Emissions (tpy)	Controlled VOC Emissions					
			Thermal Incineration		Catalytic Incineration		Catalytic Incineration	
			Emissions (tpy)	Reductions (tpy)	Percent Reduction	Emissions (tpy)	Reductions (tpy)	Percent Reduction
A-I	Very Small	25	1	24	98	1	24	98
A-II	Small	54	1	53	98	1	53	98
A-III	Medium	109	2	107	98	2	107	98
A-IV	Large	198	4	194	98	4	194	98

Model Plant Code	Model Plant Size	Baseline VOC Emissions	Controlled VOC Emissions					
			Condenser Filter with Carbon		Condenser Filter		Condenser Filter	
			Emissions (tpy)	Reductions (tpy)	Percent Reduction	Emissions (tpy)	Reductions (tpy)	Percent Reduction
A-I	Very Small	25	2	23	95	3	22	90
A-II	Small	54	3	51	95	5	49	90
A-III	Medium	109	6	103	95	11	98	90
A-IV	Large	198	10	188	95	20	178	90

Note--Model plant code refers to model plants described in more detail in Table 5-1.

efficiency for thermal and catalytic incinerators, a 95-percent efficiency for condenser filters with carbon, and a 90-percent efficiency for condenser filters.

5.2 FOUNTAIN SOLUTIONS

5.2.1 Isopropyl Alcohol and Nonalcohol Additive Use

Isopropyl alcohol is added to offset lithographic fountain solution to decrease the surface tension of the water used to wet the nonimage areas of the lithographic plate. Some offset facilities and most of the newspaper industry use nonalcohol additives (containing VOC's) to reduce water surface tension. Additives are discussed in more detail in Chapters 3.0 and 4.0.

The IPA use rates for model plants in Groups A and C were estimated from alcohol-to-ink ratios obtained from an industry survey.¹⁴ For heatset web model plants, a ratio of 0.9 pounds of alcohol per pound of ink was used. For sheet-fed model plants, a ratio of 1.25 pounds of alcohol per pound of ink was used. For non-heatset web model plants, the IPA use rate of 0.53 pounds of alcohol per pound of ink was estimated from an industry survey¹⁴ and discussions with industry representatives.¹⁵ The use of alcohol in the model plants presented in Table 5-1 was based on these ratios.

The use of nonalcohol additives for the model plants representing newspaper facilities (Group D) was estimated using a ratio of 0.07 pounds of additives per pound of ink. This ratio was obtained from a survey of the industry.¹ The nonalcohol additives have a lower evaporation rate than alcohol; therefore, less is needed to produce the same effect in the fountain solution delivery system. The estimated annual amount of nonalcohol additive used in the fountain solution for various sized newspaper model plants is shown in Table 5-1.

5.2.2 Baseline (Uncontrolled) Volatile Organic Compound Emissions from Fountain Solution

The VOC's in the fountain solution are assumed to be completely volatilized within the fountain solution delivery

system because of the heat and work of the system on the solution;¹⁶ no unused alcohol is disposed of. Volatile organic compound emissions from IPA use, therefore, are calculated using the following equation:

$$\begin{array}{l} \text{VOC emissions} \\ \text{from fountain} \\ \text{solution} \\ \text{alcohol} \end{array} = \begin{array}{l} \text{fountain solution} \\ \text{alcohol use} \end{array} \quad (4)$$

Equation (4) was used to calculate fountain solution VOC emissions in the baseline for all of the model plants in Groups A, B, and C in Table 5-1.

One-step nonalcohol additives or alcohol substitutes are estimated to contain from 0 to 100 percent VOC (by weight) in their concentrated form, based on information received from printers and vendors.^{15,17} Volatile organic compound emissions from nonalcohol substitutes were calculated according to the following equation:

$$\begin{array}{l} \text{VOC emissions} \\ \text{from substitute} \end{array} = \begin{array}{l} \text{weight of} \\ \text{substitute} \end{array} \times \frac{\begin{array}{l} \text{percent VOC in} \\ \text{concentrate} \end{array}}{100} \quad (5)$$

Table 5-1 shows baseline VOC emissions from the model plants in Group D (newspaper model plants), calculated using Equation (5), and an estimate of 10 percent VOC in the nonalcohol additive.

5.2.3 Reduction of Alcohol in Fountain Solutions

One method for controlling VOC emissions from the fountain solution is to reduce the concentration of alcohol in the fountain. The average alcohol content of fountain solution currently used by industry is reported to be 17 percent by volume.¹⁴ Table 5-3 shows VOC emissions and reductions from baseline associated with lowering fountain solution alcohol levels to 10 percent, 5 percent, and 3 percent for model plants in Groups A, B, and C.

Volatile organic compound emissions associated with reducing fountain solution alcohol for model plants in

TABLE 5-3. ESTIMATES OF BASELINE VOLATILE ORGANIC COMPOUND EMISSIONS FROM FOUNTAIN SOLUTION AND THE REDUCTIONS ASSOCIATED WITH A VARIETY OF CONTROL ALTERNATIVES (CONTINUED)

Model Plant Code ^a	Baseline ^b VOC Emissions (tpy)	17% IPA and Refrigeration			10% IPA			10% IPA and Refrigeration		
		Emissions (tpy)	Reductions (tpy)	Percent Reduced	Emissions (tpy)	Reductions (tpy)	Percent Reduced	Emissions (tpy)	Reductions (tpy)	Percent Reduced
A-I	70	39	31	44	41	29	41	23	47	67
A-II	153	86	67	44	90	63	41	50	103	67
A-III	306	171	135	44	180	126	41	101	205	67
A-IV	556	311	245	44	327	229	41	183	373	67
B-I	41	NAC	NA	NA	NA	NA	NA	23	18	44
B-II	90	NA	NA	NA	NA	NA	NA	50	40	44
B-III	180	NA	NA	NA	NA	NA	NA	101	79	44
B-IV	327	NA	NA	NA	NA	NA	NA	183	144	44
C-I	1.2	0.7	0.5	44	0.7	0.5	41	0.4	0.8	67
C-II	2.3	1.3	1.0	44	1.4	0.9	41	0.8	1.5	67
C-III	7.5	4.2	3.3	44	4.4	3.1	41	2.5	5.0	67
C-IV	16.9	9.5	7.4	44	9.9	7.0	41	5.6	11.3	67
D-I	0.1	NAC	NA	NA	NA	NA	NA	NA	NA	NA
D-II	0.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
D-III	1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
D-IV	3.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
D-V	7.6	NA	NA	NA	NA	NA	NA	NA	NA	NA
D-VI	15.1	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 5-3. ESTIMATES OF BASELINE VOLATILE ORGANIC COMPOUND EMISSIONS FROM FOUNTAIN SOLUTION AND THE REDUCTIONS ASSOCIATED WITH A VARIETY OF CONTROL ALTERNATIVES (CONTINUED)

Model Plant Code ^a	5% IPA				5% IPA and Refrigeration				3% IPA	
	Emissions (tpy)	Reductions (tpy)	Percent Reduced	Emissions (tpy)	Reductions (tpy)	Percent Reduced	Emissions (tpy)	Reductions (tpy)	Percent Reduced	Emissions (tpy)
A-I	21	49	71	12	58	84	13	57	82	82
A-II	45	108	71	25	128	84	27	126	82	82
A-III	90	216	71	50	256	84	54	252	82	82
A-IV	163	393	71	92	465	84	98	458	82	82
B-I	21	20	50	11	30	72	12	29	70	70
B-II	45	45	50	25	65	72	27	63	70	70
B-III	90	90	50	50	130	72	54	126	70	70
B-IV	164	163	50	92	235	72	98	229	70	70
C-I	0.4	0.8	71	0.2	1.0	84	0.2	1.0	82	82
C-II	0.7	1.6	71	0.4	1.9	84	0.4	1.9	82	82
C-III	2.2	5.3	71	1.2	6.3	84	1.3	6.2	82	82
C-IV	5.0	11.9	71	2.8	14.1	84	3.0	13.9	82	82
D-I	NA	NA	NA	NA ^c	NA	NA	NA	NA	NA	NA
D-II	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D-III	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D-IV	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D-V	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D-VI	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

TABLE 5-3. ESTIMATES OF BASELINE VOLATILE ORGANIC COMPOUND EMISSIONS FROM FOUNTAIN SOLUTION AND THE REDUCTIONS ASSOCIATED WITH A VARIETY OF CONTROL ALTERNATIVES (CONCLUDED)

Model Plant Code	3% IPA and Refrigeration				Alcohol Substitutes				No. VOC	
	Emissions (tpy)	Reductions (tpy)	Percent Reduced	Emissions (tpy)	Reductions (tpy)	Percent Reduced	Emissions (tpy)	Reductions (tpy)	Reductions (tpy)	Percent Reduced
A-I	7	63	90	1	69	99	0	70	100	
A-II	15	138	90	2	151	99	0	153	100	
A-III	30	276	90	3	303	99	0	306	100	
A-IV	55	501	90	6	550	99	0	556	100	
B-I	7	34	83	0.4	40	99	0	41	100	
B-II	15	75	83	0.9	89	99	0	90	100	
B-III	31	149	83	1.8	178	99	0	180	100	
B-IV	56	271	83	3.3	324	99	0	327	100	
C-I	0.1	1.1	90	0.01	1.19	99	0	1.2	100	
C-II	0.2	2.1	90	0.02	2.28	99	0	2.3	100	
C-III	0.7	6.8	90	0.10	7.4	99	0	7.5	100	
C-IV	1.7	15.2	90	0.20	16.7	99	0	16.9	100	
D-I	NA	NA	NA	NA	NA	NA	0	0.1	100	
D-II	NA	NA	NA	NA	NA	NA	0	0.3	100	
D-III	NA	NA	NA	NA	NA	NA	0	1.0	100	
D-IV	NA	NA	NA	NA	NA	NA	0	3.3	100	
D-V	NA	NA	NA	NA	NA	NA	0	7.6	100	
D-VI	NA	NA	NA	NA	NA	NA	0	15.1	100	

a Represents model plants described in Table 5-1 in more detail.
 b Assumes fountain water includes 17% IPA, by volume for heatset web and sheet-fed model plants; 10% IPA, by volume, is assumed for the non-heatset web (non-newsprint) model plants.
 c NA = not applicable.

Groups A, B, and C were calculated using the following equation:

$$\begin{array}{l} \text{VOC emissions} \\ \text{from fountain} \\ \text{solution at} \\ \text{lower alcohol} \\ \text{levels} \end{array} = \begin{array}{l} \text{VOC emissions} \\ \text{at baseline} \\ \text{concentration} \end{array} \times \frac{\text{lower \% alcohol}}{\text{baseline \% alcohol}} \quad (6)$$

For example, for model plants in Groups A and C in Table 5-3, reduction of fountain solution alcohol to 10 percent was calculated using baseline emissions from Equation (4) above, and a factor of 10 over 17, corresponding to a reduced alcohol level of 10 percent and an alcohol concentration of 17 percent in the baseline.

5.2.4 Refrigerated Fountain Solution Systems

Evaporation of alcohol from fountain solution can be reduced by cooling the fountain solution with a refrigerated circulator. Because the evaporation of alcohol is slowed, less alcohol is needed in the fountain solution to maintain the desired concentration, which in turn reduces the amount of alcohol used by the facility and VOC emissions from the fountain solution.

Refrigeration systems are designed to reduce the temperature of the fountain solution from approximately 80 to below 60°F. For pure IPA, this temperature decrease theoretically results in a 50-percent reduction in evaporation (see Appendix B). One vendor of refrigerated fountain solution systems found that refrigeration of the fountain reduced the alcohol consumed by the press by 44 percent.¹⁸ Equation (7) was used to estimate VOC emissions from refrigerated fountain solution systems containing alcohol, using 44 percent as an approximate reduction in VOC emissions:

$$\begin{array}{l} \text{VOC emissions} \\ \text{from a} \\ \text{refrigerated} \\ \text{fountain} \end{array} = \begin{array}{l} \text{VOC emissions} \\ \text{from an} \\ \text{unrefrigerated} \\ \text{fountain} \end{array} \times (1 - 0.44) \quad (7)$$

The VOC emissions and reductions for model plants in Groups A, B, and C associated with refrigeration of fountain solutions at 17, 10, 5, and 3 percent alcohol, as appropriate, are shown in Table 5-3.

5.2.5 Use of Alcohol Substitutes

Volatile organic compound emissions also can be reduced by using a nonalcohol additive, or alcohol substitute, as discussed above for the newspaper industry. The concentrated alcohol substitute is diluted with water at a ratio of approximately 2 to 4 ounces of concentrate to 1 gallon of water. One pound of alcohol substitute replaces approximately 10 pounds of alcohol in the fountain solution.^{14,19-26}

The amount of alcohol substitute (by weight) needed to replace fountain solution alcohol can be calculated with the equation below:

$$\begin{array}{l} \text{weight of} \\ \text{alcohol} \\ \text{substitute} \end{array} = \frac{\text{weight of alcohol used}}{10} \quad (8)$$

The method for calculating VOC emissions with the use of alcohol substitutes is presented in Equation (5). The VOC emissions resulting from the use of substitutes and the associated reductions for the model plants are presented in Table 5-3.

5.2.6 Magnetizing the Fountain Solution

A novel water conditioning device that uses magnetism to reduce the surface tension of fountain water is described in Chapter 4.0. Although potentially magnetism could totally remove the need for alcohol or alcohol substitutes, some printers maintain that alcohol is still needed in the fountain, especially during startup.²⁷⁻³⁰

For the purposes of estimating emissions from the model plants, VOC emissions with the use of a magnet are assumed to be either zero or to reflect the use of 3 percent alcohol for

start-up. Using Equation (6), VOC emissions with the use of a magnet are:

$$\begin{array}{l} \text{VOC emissions} \\ \text{with magnetism of} \\ \text{fountain solution} = \\ \text{(at 3\% alcohol)} \end{array} = \begin{array}{l} \text{VOC emissions} \\ \text{at baseline} \\ \text{concentrations} \end{array} \times \frac{3\% \text{ alcohol}}{\text{baseline \% alcohol}} \quad (6)$$

or

$$\begin{array}{l} \text{VOC emissions} \\ \text{with magnetism of} \\ \text{fountain solution} \\ \text{(no alcohol)} \end{array} = 0 \quad (9)$$

depending on the use of alcohol. Table 5-3 shows VOC emissions and reductions for model plants in Groups A, B, and C with either 3 percent or no VOC, and for model plants in Group D with no VOC.

5.3 CLEANING SOLUTIONS

5.3.1 Volatile Organic Compound Emissions from Cleaning Solutions

Cleaning solution use in the model plants was based on an estimated rate of 0.04 gallons per unit hour (0.33 pounds per unit hour).¹ Cleaning compounds used for offset lithographic printing are approximately 100 percent VOC.¹ The VOC emissions associated with use of cleaning compounds for the model plants were calculated according to the following equation:

$$\begin{array}{l} \text{VOC emissions} \\ \text{from cleaning} \\ \text{solutions} \end{array} = \begin{array}{l} \text{weight of} \\ \text{cleaning} \\ \text{solution} \end{array} \times \frac{\text{percent} \\ \text{VOC}}{100} \quad (10)$$

If the cleaner is all VOC, the emissions are equal to the amount of cleaning solution used. The baseline emissions for the model plants (shown in Table 5-1) presume that the cleaners are all VOC.

5.3.2 Reduction of Volatile Organic Compound Emissions from Cleaning Solutions

Lower VOC cleaning compounds are available that have VOC contents ranging from 0 to 30 percent (by weight), as used (see Chapter 4.0). Emissions and reductions from baseline emissions with the use of cleaning products with 30 percent VOC were calculated using Equation (10). Table 5-4 shows the VOC emissions and reductions associated with lower VOC cleaning products for the model plants.

TABLE 5-4. VOLATILE ORGANIC COMPOUND EMISSIONS AND REDUCTIONS
 ASSOCIATED WITH LOWER VOC CLEANING PRODUCTS
 (tons per year)

Model Plant Code ^a	Baseline VOC Emissions ^b	VOC Emissions with Lower VOC Cleaners ^c	VOC Reduction
A-I	2.5	0.7	1.8
A-II	5.5	1.6	3.9
A-III	11.0	3.3	7.7
A-IV	19.9	6.0	13.9
B-I	2.5	0.7	1.8
B-II	5.5	1.6	3.9
B-III	11.0	3.3	7.7
B-IV	19.9	6.0	13.9
C-I	1.0	0.3	0.7
C-II	2.0	0.6	1.4
C-III	8.0	2.4	5.6
C-IV	17.0	5.1	11.9
D-I	1.5	0.4	1.1
D-II	4.5	1.3	3.2
D-III	8.2	2.5	5.7
D-IV	16.4	4.9	11.5
D-V	33.9	10.2	23.7
D-VI	54.8	16.4	38.4

^aRefers to model plants described in more detail in Table 5-1.

^bBaseline VOC content is 100 percent.

^c70 percent reduction from the baseline.

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6.0 IMPACT ANALYSIS OF VOLATILE ORGANIC COMPOUND EMISSIONS CONTROL TECHNIQUES AND SELECTION OF REASONABLY AVAILABLE CONTROL TECHNOLOGY

This chapter addresses the cost and environmental impacts of the VOC control methods described in Chapter 4.0. Sections 6.1, 6.2, and 6.3 discuss the costs of controlling VOC emissions from inks, fountain solution, and cleaning solution, respectively. Section 6.4 describes the potential environmental impacts of the various control strategies. Section 6.5 is a summary of RACT recommended for offset lithographic printing.

6.1 COSTS OF ADD-ON CONTROLS FOR EMISSIONS FROM INKS

This section presents the methodology and results of the procedures used to develop costs for controlling VOC's emitted from ink in heatset printing facilities by using add-on control devices. Design assumptions, costing equations, and prices for removing VOC's from dryer exhaust streams using thermal incinerators, catalytic incinerators, and condenser filter systems can be found in Appendix C.

6.1.1 General Cost Considerations

All costs are provided in first quarter 1990 dollars. When necessary, equipment costs were updated using Chemical Engineering magazine cost indices. Labor rates and utility prices were obtained from recent publications from the U. S. Department of Labor and the U. S. Department of Energy.^{1,2}

Table 6-1 presents general design specifications and emission control efficiencies for thermal and catalytic incinerators and condenser filter systems, as applied to the model plants described in Chapter 3.0.

TABLE 6-1. GENERAL DESIGN SPECIFICATIONS FOR ADD-ON CONTROL DEVICES

Item	Specifications		
	Thermal Incinerator	Catalytic Incinerator	Condenser Filter System
Emission Control Efficiency (percent reduction)	98	98	90-95
Minimum capacity/size	500 scfm ^a	2,000 scfm ^b	3,000 scfm
Maximum capacity/size	50,000 scfm	50,000 scfm	10,000 scfm
Operating Temperature	1,600°F ^c	900°F	100°F
Equipment Life	10 yrs	10 yrs	10 yrs
Ductwork Length Required	300 ft	300 ft	300 ft
Heat Recovery Option	yes ^d	yes ^d	no ^e
Solvent Recovery Possible	no	no	yes
Annual Operating Hours	3,000	3,000	3,000

^aFor capital costs. A minimum flow rate of 50 scfm was used for determining operating costs.

^bFor capital costs. A minimum flow rate of 200 scfm was used for determining operating costs.

^cThis temperature was chosen to represent a typical incinerator; any temperature above 1,400°F is possible.

^dHeat recovery options of 0%, 35%, 50%, and 70% are evaluated with the least-cost option being selected for each model plant stream.

^eAnnual operating costs of these devices are not reduced by application of heat recovery. However, dryer intake air and plant make-up air can be preheated, resulting in plant-wide fuel savings.

"Minimum capacity" pertains to the smallest unit commercially available; "maximum capacity" represents the largest unit available. Multiple devices are necessary for flows exceeding the maximum control device capacity. Conversely, installing the minimum size indicated here may result in some devices being oversized.

Equipment life was based on vendor records (as documented in Chapter 4.0). In practice, control equipment can be located in the pressroom, outside the building, or on the building roof. A ductwork requirement of 300 ft was imposed to recognize that some facilities may not be able to install large skid-mounted devices in an existing pressroom. An additional fan was included to overcome pressure loss through the additional ductwork.

Cost credits from recovery and reuse of solvents from the use of condenser filters place an economic value on the solvents recovered from the heatset dryer exhaust. Typically, the recovered solvent is assigned a dollar value equivalent to the amount of natural gas saved when the solvent is burned in the dryer or boiler along with natural gas.

An estimate of 3,000 annual operating hours was used in calculating direct annual costs such as labor costs, and for utility consumption and hourly emission rates.

6.1.2 Thermal Incinerator Cost Methodology

A thermal incinerator system consists of the following equipment: combustion chamber, instrumentation, recuperative heat exchanger (optional), blower, ductwork, and a secondary fan. The OAQPS Control Cost Manual³ contains a detailed discussion of incinerator control system design. Control system elements and design assumptions specific to offset lithography dryer exhaust streams are discussed below. General design specifications for thermal incinerators are shown in Table 6-1.

The VOC concentrations in the model plant dryer exhaust streams range from approximately 600 ppmv to 800 ppmv for the model plants in Group A. The dryer exhaust streams will support combustion without auxiliary combustion air.

The heat content values of the model plant dryer exhaust streams are less than 10 British thermal units per standard cubic foot (Btu/scf), well below 25 percent of the lower explosive limit. Twenty-five percent is considered the maximum safe concentration (without extensive safety instrumentation) to avoid premature ignition or an explosion.

Four different heat recovery scenarios were evaluated in the cost estimation procedure: The cost algorithm includes systems with 0 percent, 35 percent, 50 percent, and 70 percent heat recovery. The optimum heat exchange is calculated by an economic optimization routine, where the tradeoff between the capital cost of the equipment and the direct operating cost (primarily fuel) of the system determines the optimum level of energy recovery. The routine provided the lowest total annual cost, the logical choice for a control device. Total capital and annual costs are based on the most cost-effective configuration.

The cost analysis follows the methodology outlined in the OAOPS Control Cost Manual.³ Equipment cost correlations were based on data provided by various vendors. Each correlation is valid for incinerators in the 500 to 50,000 scfm range.³ For flow rates above 50,000 scfm, multiple incinerators were assumed.

Equipment costs for thermal incinerators are a function of total volumetric throughput (Q_{tot}), expressed in scfm. The cost of the 300 ft of ductwork (not included in equipment cost) was derived from literature data.⁴ It was assumed to be a 24-in. diameter duct with two elbows per 100 ft (see Appendix C).

Collection fan costs were developed using a method from the literature.⁵ The duct and fan costs were added to the total equipment cost. A percentage of the purchased equipment cost was used to estimate the cost of installation.

Table 6-2 lists the initial cost factors used for calculating direct and indirect installation and purchased

TABLE 6-2. CAPITAL COST FACTORS FOR ADD-ON CONTROL DEVICES

	Condenser Filters	
	3000 scfm	10,000 scfm
	Thermal and Catalytic Incinerators	
<u>Direct Costs</u>		
Equipment Cost ^a	As estimated, A	170,000 = A
Instrumentation	0.10 A	0.056 A
Sales taxes	0.03 A	0.060 A
Freight	0.05 A	0.006 A
Purchased equipment cost	<u>B = 1.18 A</u>	<u>B = 1.122 A</u>
	92,000 = A	
	0.035 A	
	0.062 A	
	0.011 A	
	<u>B = 1.108 A</u>	
<u>Direct Installation Costs</u>		
Foundations & supports	0.08 B	0.15 B
Handling & erection	0.14 B	0.01 B
Electrical	0.04 B	0.05 B
Piping	0.02 B	0.05 B
Insulation for ductwork	0.01 B	
Painting ^b	<u>0.01 B</u>	<u>0.01 B</u>
Direct installation cost	0.30 B	0.27 B
Total Direct Cost	1.30 B	1.27 B
<u>Indirect Installation Costs</u>		
Engineering	0.10 B	0.03 B
Construction and field expenses	0.05 B	0.01 B
Contractor fees	0.10 B	0.03 B
Start-up	0.02 B	0.03 B
Performance test	0.01 B	0.12 B
Contingencies	<u>0.03 B</u>	<u>0.02 B</u>
Total Indirect Cost	0.31 B	0.24 B

^aDuctwork and fan costs not included.

^bPainting costs assumed same as for incinerators.

equipment costs for thermal incinerators.³ The annual costs are presented in Table 6-3. Both operating and maintenance labor requirements were assumed to be 0.5 hours each per 8-hour shift. Supervisory costs were estimated at 15 percent of the operating labor cost. The maintenance rates were assumed to be 10 percent higher than the operating rates. Capital recovery, a part of the annual cost, was based on a 10-percent interest rate and a 10-year life for the equipment. Taxes, insurance, and administrative costs were assumed to be 4 percent of the total capital investment.³ Overhead costs were estimated at 60 percent of operation and maintenance.

The costs of installing thermal incinerators in the model plants are discussed in Section 6.1.5.

6.1.3 Catalytic Incinerator Cost Methodology

A catalytic incineration system consists of the incinerator with its preheat and catalyst chamber, instrumentation, recuperative heat exchanger (optional), blower, collection fan, and ductwork. The OAQPS Control Cost Manual³ contains further discussion of catalytic incinerator control system design. General catalytic incinerator design specifications are shown in Table 6-1.

The cost analysis follows the methodology outlined in the OAQPS Control Cost Manual.³ Equipment costs for fixed-bed catalytic incinerators are given as a function of Q_{tot} , in scfm. The cost of the system was calculated for four levels of heat recovery (0 to 70 percent). Details can be found in Appendix C.

The selection of the optimum level of heat recovery was the same as that used for thermal incinerators (i.e., the lowest total annual cost alternative).

The duct, fan, and installation costs were calculated as previously described for thermal incinerators. Table 6-2 lists the values of direct and indirect installation factors for catalytic incinerators. The costs parameters are those described for thermal incinerators. Catalyst life was assumed

TABLE 6-3. ANNUAL COST ASSUMPTIONS FOR ADD-ON CONTROL DEVICES

	Thermal Incineration	Catalytic Incineration	Condenser Filter System (Carbon) ^a
Annual Hours of Operation	3,000	3,000	3,000
Operating Labor Rate (\$/hr)	15.64	15.64	15.64
Operating Labor Required (hrs/8-hr shift)	0.5	0.5	0.5 (1.0)
Supervisor Cost (% of Operating Labor)	15	15	15
Maintenance Labor Rate (\$/hr)	17.21	17.21	17.21
Maintenance Labor Required (hrs/8-hr shift)	0.5	0.5	0.3 (0.8)
Catalyst/Carbon Cost	---	\$650/ft ³	\$2/lb
Annual Maintenance Material	100% of Maint. Labor	100% of Maint. Labor	\$1,900 for 3,000 scfm system, \$4,500 for 10,000 scfm system
Utilities			
Electricity (\$/1000 kWh)	61.0	61.0	61.0
Natural Gas (\$/106 Btu)	3.30	3.30	3.30
Recovery Credits ^b (\$/gallon of recovered solvents)	N/A	N/A	0.68
Overhead (% of Operation and Maintenance)	60	60	60
Administrative Charges	2% TCIC	2% TCIC	2% TCIC
Property Taxes	1% TCIC	1% TCIC	1% TCIC
Insurance	1% TCIC	1% TCIC	1% TCIC
System Capital Recovery Factor	0.1628	0.1628	0.1628
Catalyst/Carbon Capital Recovery Factor	---	0.4021	0.2638

^aCondenser filter with carbon costs are shown in parentheses when different than "without carbon" costs.

^bRecovery credits assume that recovered solvents are burned in the dryer (i.e., same value as No. 2 heating oil).

TCIC = total capital investment.

to be 2 years. The assumptions used to calculate the annual costs are presented in Table 6-3.

The costs of installing catalytic incinerators in the model plants are discussed in Section 6.1.5.

6.1.4 Condenser Filter Cost Methodology

Condenser filter systems first condense VOC from the air stream and then filter out the resulting liquid using microfiltration. The general design specifications for condenser filters are presented in Table 6-1. The cost analysis uses equipment costs and cost factors provided by vendors.^{6,7} Installation factors are presented in Table 6-2. Credit was allowed for the recovered solvent because the condensed VOC's can be used as fuel for the dryer or boiler.

Assumptions on which annual costs were calculated are presented in Table 6-3. Electrical costs, based on vendor estimates, were \$1.60 per year per scfm for flows less than 10,000 scfm, and \$2.00 per year per scfm for flows of 10,000 scfm or greater.

The costs of installing condenser filters in the model plants are discussed in Section 6.1.5.

6.1.5 Comparison of Add-On Control System Costs

This section discusses the capital costs and annualized costs of each of the control systems if installed on the four heatset model plants.

For a specific control system, capital and annualized costs vary with dryer exhaust heat content and, therefore, exhaust VOC content. The dryer exhaust flows are assumed to deliver 250°F air to the control device.

Table 6-4 presents the results of the cost analysis. Additional stream information is presented in Appendix C. The cost analyses for the model plants show that the annual costs of adding incinerators range from approximately \$70,000 to \$351,000 per year for 24 to 194 tons of VOC removed, for small to large model plants, respectively. Thermal incinerators are slightly more costly (approximately 10 percent) than catalytic for the same VOC reduction potential. The cost of using

TABLE 6-4. COST RESULTS FOR MODEL PLANTS WITH ADD-ON CONTROL SYSTEMS

Model Plant Code	Control Device	Baseline			Annual Cost (\$/Yr)	Total Emissions Reduction (tons)
		Annual Ink VOC Emissions (tons)	Capital Cost (\$)	Annual Cost (\$/Yr)		
A-I	Thermal Incinerator	24.7	174,123	75,933	24.2	
A-I	Catalytic Incinerator	24.7	221,821	75,211	24.2	
A-I	Condenser Filter with Carbon	24.7	229,316	69,309	23.5	
A-I	Condenser Filter	24.7	196,289	50,396	22.2	
A-II	Thermal Incinerator	54.4	368,733	161,596	53.3	
A-II	Catalytic Incinerator	54.4	392,137	139,642	53.3	
A-II	Condenser Filter with Carbon	54.4	383,877	119,247	51.7	
A-II	Condenser Filter	54.4	327,036	93,185	49.0	
A-III	Thermal Incinerator	108.8	568,469	273,206	106.6	
A-III	Catalytic Incinerator	108.8	519,887	209,478	106.6	
A-III	Condenser Filter with Carbon	108.8	735,968	206,322	103.3	
A-III	Condenser Filter	108.8	622,287	164,493	97.9	
A-IV	Thermal Incinerator	197.8	632,737	351,125	193.8	
A-IV	Catalytic Incinerator	197.8	931,492	321,253	193.8	
A-IV	Condenser Filter with Carbon	197.8	1,085,771	290,184	187.9	
A-IV	Condenser Filter	197.8	915,249	229,895	178.0	

Note--Model plant code refers to model plants described in more detail in Chapter 3.0.

condenser filters with carbon was estimated for the model plants at approximately \$69,000 to \$290,000 for small to large facilities, respectively, for 23 to 188 tons of VOC removed. Condenser filters without carbon have lower costs in general (but lower VOC reduction potentials), ranging from approximately \$50,000 to \$230,000 for 22 to 178 tons of VOC removed, for small to large plants, respectively.

6.2 COSTS OF CONTROL OF EMISSIONS FROM FOUNTAIN SOLUTION

6.2.1 Material Reduction or Substitution Costs

Since alcohol in the fountain is a panacea for many printing ills, there is little incentive for printers to minimize use (see discussion in Chapter 4.0). The term "material reduction" is used to indicate that the control scheme would limit the use of alcohol to a preestablished maximum level. Reducing the use of alcohol in the fountain solution results in a savings of \$920⁸⁻¹² per ton of alcohol not used. Fountain additives, or alcohol substitutes, although more expensive than alcohol (\$1.55 per pound),¹³⁻¹⁹ save money because they are used in smaller quantities.

Reducing alcohol use or switching to substitutes may not be an easy transition for some printers. There is an industry-wide concern about the potential for lost production and the retraining time that may be necessary.²⁰ The process change will result in paper and material waste, especially during the transition.

Such changeover costs will likely differ for each facility, depending on the type of mechanical equipment currently in place.²¹ Sheet-fed presses may be the most difficult to change because of the high variability and number of products printed, each of which requires press resetting.²²

Though these changeover costs are recognized, based on the variety of solvent levels and substitute usage now achieved across the industry, it is reasonable to conclude that such costs would decrease substantially after printers become accustomed to the new regime. Material cost savings

eventually may outweigh initial costs. Changeover costs would include lost production if the facility normally operates on a 24-hour per day schedule. Because the model plant analysis was based on a 16-hour day, lost production was not included.

Table 6-5 shows the VOC reductions and estimated savings for control of fountain alcohol.

6.2.2. Costs From the Use of Refrigerated Circulators

Refrigerated circulators reduce VOC emissions from fountain solution by cooling the solution. This reduces the evaporation rate from the fountain, thereby requiring less alcohol than unrefrigerated fountains. The costs of the refrigerated circulator is offset by savings in alcohol consumption. Refrigerated circulators are discussed in more detail in Chapter 4.0.

The following cost analyses use equipment cost data and estimated operating costs provided by a vendor based on extensive experience with the industry.²³ The cost factors for determining both direct and indirect annual costs for refrigerated circulators are shown in Table 6-6. Example calculations can be found in Appendix C.

Table 6-7 shows the costs of applying refrigerated circulators to model plants in Groups A, B, and C. Because sheet-fed presses are very small sources of fountain emissions, the cost effectiveness of applying refrigerated circulators to Group C plants is extremely high.

Group D (newspaper) plants are not candidates for refrigerated circulators because they already use fountain additives without alcohol. Refrigeration does not help in this case, because the fountain additives have a much lower evaporation rate than even the cold alcohol.

6.2.3 Costs From the Use of Magnets

Applying magnetism to the fountain solution reportedly reduces the VOC needed in the fountain solution. Magnets currently in use cost approximately \$350 per fountain solution tank. Installation costs are insignificant, and include two hose clamps to place the magnet in the fountain solution feed line.²⁴ The service life of the magnet should equal the life

TABLE 6-5. ANNUAL SAVINGS AND VOC REDUCTIONS ASSOCIATED WITH FOUNTAIN SOLUTION MATERIAL SUBSTITUTION OR REDUCTION FOR THE MODEL PLANTS

Model Plant Codes ^a	NO. VOC		ALCOHOL SUBSTITUTES ONLY				3 PERCENT ALCOHOL		5 PERCENT ALCOHOL		10 PERCENT ALCOHOL	
	Annual Savings ^b (\$)	VOC Reductions (tpy)	Annual Savings ^b (\$)	VOC Reductions (tpy)	Annual Savings ^b (\$)	VOC Reductions (tpy)	Annual Savings ^b (\$)	VOC Reductions (tpy)	Annual Savings ^b (\$)	VOC Reductions (tpy)	Annual Savings ^b (\$)	VOC Reductions (tpy)
A-I	63,963	70	42,410	69	52,675	57	45,150	49	26,338	29	57,943	63
A-II	140,719	153	93,303	151	115,886	126	99,331	108	57,943	63	115,886	126
A-III	281,437	306	186,605	303	231,772	252	198,662	216	115,886	126	210,702	229
A-IV	511,704	556	339,282	550	421,403	458	361,203	393	210,702	229	210,702	229
B-I	37,720	41	25,010	40	26,680	29	18,400	20	-	-	-	-
B-II	82,800	90	54,900	89	57,960	63	41,400	45	-	-	-	-
B-III	185,600	180	109,800	178	115,920	126	82,800	90	-	-	-	-
B-IV	300,840	327	199,470	324	210,680	229	149,960	163	-	-	-	-
C-I	1,104	1.2	732	1.1	909	1	779	0.9	455	0.5	871	0.9
C-II	2,116	2.3	1,403	2.2	1,743	2	1,494	1.6	871	0.9	2,841	3
C-III	6,900	7.5	4,575	7.5	5,682	6	4,871	5	2,841	3	6,402	7
C-IV	15,548	16.9	10,309	17.0	12,804	14	10,975	12	6,402	7	6,402	7
D-I	600	.07	- ^c	-	-	-	-	-	-	-	-	-
D-II	3,000	0.3	-	-	-	-	-	-	-	-	-	-
D-III	8,640	1.0	-	-	-	-	-	-	-	-	-	-
D-IV	30,000	3.3	-	-	-	-	-	-	-	-	-	-
D-V	68,400	7.6	-	-	-	-	-	-	-	-	-	-
D-VI	135,600	15.5	-	-	-	-	-	-	-	-	-	-

^aRefers to model plants described in more detail in Chapter 3.0.

^bsavings due to reduction in alcohol from a baseline of 17 percent alcohol for model plants in Groups A and C, and 10 percent for model plants in Group B. No change-over costs are included.

^cNewspaper model plants use non-alcohol additives in the baseline; therefore, the "no VOC" option is the only option that reflects a higher level of control.

TABLE 6-6. COST DATA FOR REFRIGERATED CIRCULATORS

Direct Costs^a

Purchased Equipment Costs	25,640	
Installation	<u>500</u>	
Total Capital Investment (TCI)	26,140	= A

Direct Annual Costs^b

Electricity	4.94 Kw for Model Plant A-I 8.05 Kw for all others
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Indirect Annual Costs

Administrative Charges	.02 A
Property Taxes	.01 A
Insurance	.01 A
Capital Recovery	.1628 A

<u>Total Annual Cost</u>	Direct Annual Costs + Indirect Annual Costs
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^aIt was assumed that two circulators would be needed per press, for up to eight units per press, with no limitation on the width of the units. The cost data are presented in cost (in 1990 dollars) per circulator.

^bIt was assumed that no maintenance, labor, or other annual costs would result from the addition of refrigerated circulators. Uncontrolled facilities use either manual methods of alcohol addition or unrefrigerated circulators. With the manual techniques, it was assumed that elimination of the manual labor to add alcohol would often more than offset the labor required to operate an automated circulating system. The annual costs associated with unrefrigerated systems were assumed to be similar to those of refrigerated systems, the refrigerant is replaced infrequently and the other hardware is identical for the two systems.

TABLE 6-7. COST ANALYSIS FOR THE MODEL PLANTS WITH REFRIGERATED CIRCULATORS

Model Plant Code ^a	Capital Cost (\$)	Total Annual Costs (\$/yr)	Baseline ^b		Material Savings (\$/yr)
			VOC Emissions (tpy)	VOC Reductions (tpy)	
A-I	52,280	12,410	70	31	28,144
A-II	104,560	27,097	153	67	61,916
A-III	209,120	54,195	306	135	123,832
A-IV	313,680	81,292	556	245	225,150
B-I	52,280	12,410	41	18	16,560
B-II	104,560	27,097	90	40	36,800
B-III	209,120	54,195	180	79	72,680
B-IV	313,680	81,292	327	144	132,480
C-I	52,280	12,410	1.2	0.5	497
C-II	156,840	37,231	2.3	1.0	911
C-III	261,400	62,052	7.5	3.3	3,036
C-IV	365,960	86,873	16.9	7.4	6,808

^aRefers to model plants described in more detail in Chapter 3.0.

^bBaseline refers to 17 percent alcohol use for model plants in Groups A and C, and 10 percent for model plants in Group B.

of the press.²⁵ A printing facility will show a net savings with the use of a magnet if there is sufficient reduction in alcohol use. The costs to equip the model plants with magnets, shown in Table 6-8, use a capital recovery factor of 0.163 (based on 10 percent interest rate and a 10-year service life) and estimated indirect annual costs of 4 percent of the total capital investment.³ The savings, of course, depend on the amount of VOC reduction achieved after installation of the magnets. To determine the potential costs or savings, the magnet costs from Table 6-8 can be reduced by the material savings (Table 6-3) from lower alcohol consumption. Example calculations can be found in Appendix C.

6.3 COSTS OF CONTROL OF EMISSIONS FROM CLEANING SOLUTIONS

Lower VOC cleaning compounds that are also not HAP's cost slightly more than traditional offset lithographic cleaning compounds--approximately 91 cents per pound^{13,26,27} compared with approximately 69 cents per pound for traditional cleaning compounds.²⁸ Table 6-9 shows the incremental costs associated with the use of lower VOC cleaning compounds in the model plants. Example calculations can be found in Appendix C.

6.4 ENVIRONMENTAL IMPACTS OF CONTROL TECHNIQUES

The environmental impacts associated with applying VOC control technology to offset lithographic printing facilities are analyzed in this section. The controls are specific to the four industry segments (heatset, non-heatset web, non-heatset sheet, and newspaper), as well as to the specific sources of emissions (inks, fountain solution, and cleaning solutions).

This analysis of environmental impacts considers effects on air and water quality, production of solid waste, and energy consumption. The types of environmental impacts associated with the control strategies described in Chapter 4.0 are identified with estimates of the impacts resulting from applying these controls to the model plants.

TABLE 6-8. COSTS ASSOCIATED WITH THE USE OF MAGNETS FOR REDUCTION OF VOLATILE ORGANIC COMPOUND EMISSIONS FROM THE FOUNTAIN SOLUTION IN THE MODEL PLANTS

Model Plant Code ^a	Number of Units	Total Capital Investment	Annualized Equipment Costs ^b	Total Annual Costs ^c
A-I	5	\$1,750	\$285	\$355
A-II	11	\$3,850	\$627	\$781
A-III	22	\$7,700	\$1,253	\$1,561
A-IV	40	\$14,000	\$2,279	\$2,839
B-I	5	\$1,750	\$285	\$355
B-II	11	\$3,850	\$627	\$781
B-III	22	\$7,700	\$1,253	\$1,561
B-IV	40	\$14,000	\$2,279	\$2,839
C-I	3	\$1,050	\$171	\$213
C-II	5	\$1,750	\$285	\$355
C-III	16	\$5,600	\$911	\$1,135
C-IV	36	\$12,600	\$2,051	\$2,555
D-I	6	\$2,100	\$342	\$426
D-II	9	\$3,150	\$513	\$639
D-III	17	\$5,950	\$968	\$1,206
D-IV	33	\$11,550	\$1,880	\$2,342
D-V	68	\$23,800	\$3,873	\$4,825
D-VI	110	\$38,500	\$6,266	\$7,806

^aRefers to model plants described in more detail in Chapter 3.0.

^bCalculated using a 0.163 capital recovery factor.

^cThe sum of annualized equipment costs and indirect costs (taxes, insurance, and administration charges) calculated as 4 percent of the total capital investment.

TABLE 6-9. COST ANALYSIS FOR THE USE OF LOWER VOLATILE ORGANIC COMPOUND CLEANING SOLUTIONS^a IN THE MODEL PLANTS

Model Plant Code ^b	Controlled VOC Emissions ^d					Annual Incremental Cost of Lower VOC Cleaners (\$)
	Baseline ^c VOC Emissions (tpy)	Emissions (tpy)	Reductions (tpy)	Percent Reduced	Annual Incremental Cost of Lower VOC Cleaners (\$)	
A-I	2.5	0.7	1.8	70	1,092	
A-II	5.5	1.6	3.9	70	2,400	
A-III	11.0	3.3	7.7	70	4,795	
A-IV	19.9	6.0	13.9	70	8,718	
B-I	2.5	0.7	1.8	70	1,092	
B-II	5.5	1.6	3.9	70	2,400	
B-III	11.0	3.3	7.7	70	4,795	
B-IV	19.9	6.0	13.9	70	8,718	
C-I	1.0	0.3	0.7	70	440	
C-II	2.0	0.6	1.4	70	881	
C-III	8.0	2.4	5.6	70	3,522	
C-IV	17.0	5.1	11.9	70	7,485	
D-I	1.5	0.4	1.1	70	660	
D-II	4.5	1.3	3.2	70	1,981	
D-III	8.2	2.5	5.7	70	3,610	
D-IV	16.4	4.9	11.5	70	7,221	
D-V	33.9	10.2	23.7	70	14,926	
D-VI	54.8	16.4	38.4	70	24,128	

^aThese lower volatile cleaners do not contain any HAP's.

^bRefers to model plants described in more detail in Chapter 3.0.

^cBaseline VOC content is 100 percent; no credit was given for recovery on cleaning rags.

^dEstimated VOC content of lower VOC cleaning compounds is 30 percent.

6.4.1 Air Quality Impacts

6.4.1.1 Air Impacts from Add-On Controls. The control devices discussed in this report (thermal incinerators, catalytic incinerators, and condenser filters) can reduce VOC emissions by 90 percent or more.

The combustion products of incinerators will include trace quantities of "secondary" air pollutants, which form as a result of incomplete combustion, as well as NO_x, carbon monoxide (CO), sulfur dioxide (SO₂) if the fuel contains sulfur, and particulate matter (PM), with the most significant secondary pollutant being NO_x. If the incinerators are improperly operated or poorly maintained, these contaminants may increase.

The principal factors affecting the rate of NO_x formation are the amount of excess air available, the peak flame temperature, the length of time that the combustion gases are at peak temperature, the cooling rate of the combustion products, and the nitrogen content of the compounds being burned.²⁹ Nitrogen oxide emissions from incinerators are generally low.

Condenser filters have no direct NO_x formation potential. Condenser filters recover solvent that may be reused or burned as fuel; therefore, a small decrease in the pollution caused by fuel production occurs. Condenser filters with carbon adsorption units require steam or hot air to remove or strip the VOC's off the bed. This results in some increased boiler demand with attendant emission increases. No emissions were attributed directly to this technology. Energy requirements are discussed in Section 6.4.4.

Estimates of uncontrolled and controlled VOC emissions from inks and of NO_x generated with add-on control devices for the model plants in Group A are presented in Table 6-10. Controlled emissions were calculated assuming a 98-percent VOC destruction efficiency for thermal and catalytic incinerators, a 90-percent VOC removal efficiency for condenser filters, and a 95-percent VOC removal efficiency for condenser filters with carbon adsorption units (see Chapter 4.0).

TABLE 6-10. AIR AND ENERGY IMPACTS FOR MODEL PLANTS WITH ADD-ON CONTROL DEVICES

Model Plant Code	Control Device	AIR IMPACTS			ENERGY IMPACTS: INCREMENTAL INCREASES OVER BASELINE		
		Uncontrolled VOC Emissions (tpy)	Controlled VOC Emissions (tpy)	NO _x Emissions ^a (tpy)	Mbtu of Natural gas/yr ^b	1000 kW-hr/yr ^c	Thousand Pounds of Steam/yr ^d
A-I	Thermal incinerator	24.7	0.5	0.4	6,686	52.4	---
A-I	Catalytic incinerator	24.7	0.5	0.1	2,842	33.0	---
A-I	Condenser filter with carbon	24.7	1.2	---	(930)	52.5	172
A-I	Condenser filter	24.7	2.5	---	(881)	52.5	---
A-II	Thermal incinerator	54.4	1.1	1.0	17,083	112.3	---
A-II	Catalytic incinerator	54.4	1.1	0.3	9,648	59.0	---
A-II	Condenser filter with carbon	54.4	2.7	---	(2053)	327.9	381
A-II	Condenser filter	54.4	5.4	---	(1946)	327.9	---
A-III	Thermal incinerator	108.8	2.2	1.9	34,166	224.7	---
A-III	Catalytic incinerator	108.8	2.2	0.5	19,295	117.7	---
A-III	Condenser filter with carbon	108.8	5.4	---	(4107)	655.7	762
A-III	Condenser filter	108.8	10.9	---	(3891)	655.7	---
A-IV	Thermal incinerator	197.8	4.0	2.8	49,596	336.9	---
A-IV	Catalytic incinerator	197.8	4.0	0.8	27,552	177.1	---
A-IV	Condenser filter with carbon	197.8	9.9	---	(7466)	983.6	1,384
A-IV	Condenser filter	197.8	19.8	---	(7073)	983.6	---

^aBased on 100 lb NO_x/10⁶ scf natural gas for thermal incinerators, 50 lb NO_x/10⁶ scf for catalytic incinerators, nitrogen sources in air and fuel only, and 3,000 hours of operation annually.

^bNumbers in parentheses represent savings or the energy value of recovered solvent.

Note, however, that condenser filters with carbon adsorption beds require steam for regeneration of the carbon bed. Steam may be available on site. Production of steam requires increased boiler fuel consumption and attendant secondary emissions are not quantified here.

^cFor incinerators, electricity use was based on pressure drops through the system. For condenser/filters, electricity demand was correlated to flow rate at 26.23 kW-hr/yr per scfm.

^dSteam factor = 3.5 lb steam/lb carbon.

6.4.1.2 Air Impacts from Fountain Solution Controls.

Uncontrolled and controlled VOC emissions from the fountain solution in the model plants are shown in Table 5-3 of Chapter 5.0.

Uncontrolled VOC emissions for model plants in Groups A and C were based on an average of 17 percent (by volume) alcohol content in the fountain solution, and 10 percent (by volume) for model plants in Group B. Volatile organic compound emissions range from 0.5 to 556 tpy. Emissions from newspaper model plants (Group D) are low due to nonalcohol additives used in the fountain solution. Nonalcohol additives are both less volatile and used in very small quantities, resulting in much lower VOC emissions than when alcohol is used.

Fountain solution VOC controls include:

- (1) refrigeration of those solutions that contain alcohol,
- (2) lowering the solution's alcohol concentration, or
- (3) using alcohol substitutes. Controlled VOC emissions from the fountain solution for facilities that use alcohol in the baseline range from 0 to 55 tpy, depending on the type and size of the plant, the concentration of VOC's in the fountain solution, and the temperature of the solution. Refrigeration reduces the evaporation rate of alcohol by at least 44 percent (see Chapter 4.0). There are no VOC emissions, of course, if the VOC in the fountain solution is totally eliminated.

Some alcohol replacements currently in use, such as ethylene glycols, are considered hazardous air pollutants.

6.4.1.3 Air Impacts from Cleaning Solution Controls.

Control of VOC's is achieved by lowering their concentration in the cleaning solution. Estimated VOC emissions from cleaning solutions are presented in Table 5-4 of Chapter 5.0. Baseline uncontrolled emissions from organic cleaners range from 1.2 tpy to 54.8 tpy. Controlled emissions from the use of cleaners that are only 30 percent VOC range from 0.4 tpy to 16.4 tpy. Some of the lower VOC cleaning compounds contain hazardous air pollutants, so prudence must be exercised in selecting the appropriate cleaners.

6.4.2 Water Quality Impacts

6.4.2.1 Water Impacts from Add-On Controls.

Incinerators have no wastewater discharge, hence no water impact. Condenser filters have a negative water impact, since both water and VOC condense. The solvent/water mixture collected from condenser filters drains to an oil/water separator, where the VOC's are decanted off. Although ink solvents reportedly have low solubility in water,³⁰ some will remain in the water fraction as it moves to a wastewater treatment plant. The water impact is believed to be negligible, in most cases.

Carbon adsorption units also present a potential wastewater problem. Low-pressure steam is the most common carbon regenerating method. The steam carries VOC from the adsorber. When cooled, the condensate contains both solvents and water. Assuming the solvents are not very soluble in water, an oil/water separator can be used to remove the majority of the solvents. In some cases, the oil can be burned in the dryer or used to make steam. The water can be either discharged or reused for steam.

6.4.2.2 Water Impacts from Fountain Solution Controls.

Contamination of the fountain solution by ink and paper lint results in the need to periodically flush out reservoirs. The frequency of fountain solution disposal can be reduced by filtration techniques that remove emulsified ink droplets and other contaminants from the fountain solution.^{31,32}

6.4.2.3 Water Impacts from Cleaning Solution Controls.

There are no water quality impacts expected from the control of VOC emissions from cleaning solutions.

6.4.3 Solid Waste Production

This section presents the solid waste production impacts associated with add-on technologies to control VOC's emissions from inks. No solid waste impacts are expected to be associated with changes made to fountain solution or cleaning solution use made to control VOC's.

The use of catalytic incinerators will result in periodic disposal of spent catalyst. The frequency of disposal varies greatly, depending on the characteristics of the waste stream. The mechanisms of catalyst deactivation are discussed in Chapter 4.0. Periodic replacement of the catalyst at intervals of 2 to 5 years can be anticipated because of the gradual loss of activity that results from thermal aging and chemical poisoning processes.³³

The use of carbon adsorption systems also will result in periodic disposal of spent carbon, as the carbon's working capacity diminishes with age. As with catalysts, carbon life is a function of the environment to which it is exposed; therefore, disposal rates will vary from facility to facility. Spent carbon can sometimes be reactivated or returned to the vendor. The facility decides the most economical pathway for its situation.

6.4.4 Energy Impacts

Table 6-10 shows the energy impacts of add-on controls in heatset facilities. The use of incineration to control VOC emissions from dryer exhaust streams requires fuel and electricity. A fuel, typically natural gas, is needed to support combustion. Electricity is required to operate the fans, blowers, and instrumentation that may be necessary to ensure gas transport through the system. Fuel and energy usage requirements for incinerators are discussed in more detail in Sections 6.1.2 and 6.1.3.

Condenser filters require electricity to operate the fans and dampers that direct the gas flows through the system. Recovered solvents are reported to have a fuel value similar to that of No. 2 fuel oil (19,950 Btu/scf). Systems with carbon adsorption require frequent regeneration with steam or air. Steam requirements are presented in Table 6-10 above. Impacts from the production of this additional steam are expected to be small. A plant may have process steam available; otherwise, a "tea kettle" steam generator can be built and fueled with the VOC that is condensed.³⁴

Energy requirements for refrigerated circulators are shown in Table 6-11 for the model plants in Groups A, B, and C. Energy requirements for the circulators range from approximately 30,000 to 208,000 kW/hour, depending on facility size.

6.4.5 Summary

Controlling VOC emissions from offset lithographic printing will significantly reduce the amount of air pollutants introduced into the environment. Controlling VOC's in the dryer exhaust by incineration in the heatset model plants is estimated to increase NO_x emissions by an estimated 0.1 to 2.8 tpy (on the average).

Using condenser filters to reduce VOC's from ink dryer exhaust eliminates NO_x emissions and reduces the amount of fuel that must be purchased because the solvents can be used as fuel. Air pollution associated with fuel production will be reduced if the decreased demand translates to conservation of energy resources. Some additional energy is required to operate the additional fans and controls of the add-on controls and the refrigerated circulator systems. This may result in minor additional environmental impacts.

Condenser filters may increase the load to water treatment facilities (imperceptively) because of the inability to completely separate ink oil from the water.

Periodic disposal of the catalysts and carbon used in add-on controls to the dryer exhaust will result in a small (insignificant) increase in solid waste.

6.5 SELECTION OF REASONABLY AVAILABLE CONTROL TECHNOLOGY

This section provides State and local regulatory authorities with guidance on the selection of RACT for VOC emissions from offset lithographic printing operations. Background on the regulatory authority and goals for establishment of RACT is discussed in Section 6.5.1. Recommendations for controlling VOC emissions from heatset inks, fountain solutions, and cleaning solutions used in offset lithographic printing are listed in Sections 6.5.2 through 6.5.4.

TABLE 6-11. ENERGY REQUIREMENTS FOR MODEL PLANTS WITH
FOUNTAIN SOLUTION REFRIGERATED
CIRCULATORS

Model Plant Codes	Energy Requirements (1,000 kW-hr)
A-I	29.6
A-II	96.6
A-III	193.2
A-IV	289.8
B-I	29.6
B-II	96.6
B-III	193.2
B-IV	289.8
C-I	29.6
C-II	88.9
C-III	148.2
C-IV	207.5

Note--Model plants in Group D (newspaper) do not use alcohol;
therefore, refrigerated circulators are ineffective for
VOC control.

6.5.1 Background

The Clean Air Act Amendments of 1990 mandate that State Implementation Plans (SIP's) for certain ozone nonattainment areas be revised to require the implementation of RACT to limit volatile organic compound (VOC) emissions from sources for which EPA has already published a CTG or for which it will publish a CTG between the date the amendments are enacted and the date an area achieves attainment status.

Section 172(c)(1) requires that nonattainment area SIP's provide for the adoption of RACT for existing sources. As a starting point for ensuring that these SIP's provide for the required emissions reduction, the EPA has defined RACT as "...the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. Reasonably available control technology for a particular industry is determined on a case-by-case basis, considering the technological and economic circumstances of the individual source category." The EPA has elaborated in subsequent notices on how RACT requirements should be applied.

The CTG documents are intended to provide State and local air pollution authorities with an information base for proceeding with their own analysis of RACT to meet statutory requirements. Each CTG document contains a recommended "presumptive norm" for RACT for a particular source category, based on the EPA's current evaluation of capabilities and problems general to the source category. However, the "presumptive norm" is only a recommendation. Where applicable, the EPA recommends that regulatory authorities adopt requirements consistent with the presumptive norm level, but authorities may choose to develop their own RACT requirements on a case-by-case basis, considering the economic and technical circumstances of the individual source category.

6.5.2 Heatset Inks

The recommended level of control for VOC emissions in the dryer exhaust from heatset inks is 90 percent. This may be achieved by the use of incinerators, or condenser filters with or without carbon.

6.5.3 Fountain Solution

6.5.3.1 Heatset Web Printing. The recommended level of control for VOC emissions from fountain solution is equivalent to a 1.6 percent alcohol (by volume) solution. It may be achieved by actually reducing the alcohol level in the fountain to 1.6 percent or less (by volume). It also may be achieved with 3 percent alcohol or less (by volume) if the fountain solution is refrigerated to below 60°F. Lower levels of emissions can be achieved by using alcohol substitutes or less alcohol in the fountain.

6.5.3.2 Sheet-fed Printing. The recommended level of control for fountain solution emissions in sheet-fed facilities is equivalent to a 5-percent alcohol (by volume) solution. It may be achieved by actually reducing the alcohol level in the fountain to 5 percent or less (by volume) or by using 8.5 percent alcohol or less (by volume) if the fountain solution is also refrigerated to below 60°F. Higher levels of control can be achieved using alcohol substitutes or less alcohol in the fountain.

6.5.3.3 Non-heatset Web Printing. The recommended level of control for VOC emissions from non-heatset web facilities reflects the use of alcohol substitutes in the fountain (less than 3.0 percent VOC by volume in the final solution) in the quantities recommended by the manufacturer. Higher levels of control can be achieved when less substitute is used in the fountain.

6.5.4 Cleaning Solution

The recommended control of VOC emissions from cleaning solutions is the use of cleaners with less than 30 percent VOC (by weight), as used, that do not contain any hazardous air pollutants.

6.5.5 Request for Comment

The EPA solicits comments on all aspects of this draft CTG, including the controls recommended as RACT and the estimated cost and cost-effectiveness of these controls per facility (Chapter 6) and on a nationwide basis (Appendix E).

6.6 REFERENCES

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7.0 FACTORS TO CONSIDER WHEN IMPLEMENTING REASONABLY AVAILABLE CONTROL TECHNOLOGY

7.1 INTRODUCTION

This chapter presents information on factors that air quality management agencies should consider when developing an enforceable rule limiting VOC emissions from offset lithographic printing operations. Information is provided on important definitions, rule applicability, the standards format, emissions testing, equipment standards, monitoring, and reporting/recordkeeping.

Where several options exist for implementing a certain aspect of the rule, each option is discussed, along with its advantages and disadvantages relative to other options. For each aspect of the rule, one option is usually identified as the preferred option. This guidance is for instructional purposes only and, as such, is not binding. In some cases, there may be other equally valid options. The State or other implementing agency can exercise its prerogative to consider other options, provided they meet the objectives prescribed in this chapter.

Appendix D contains an example rule that incorporates the guidance provided in this document. The example rule provides an organizational framework and sample regulatory language specifically tailored for offset lithographic printing operations. The example rule is not intended to be binding. When developing its own rule, the State or other implementing agency should consider all the information presented in this document along with information about the specific sources to which the rule will apply. The rule should address all the factors listed in this chapter to ensure that the rule is

enforceable and has reasonable provisions for demonstrating compliance.

7.2 DEFINITIONS

The offset lithographic printing rule should accurately describe the types of sources that will be affected and use clearly defined terms to describe the industry and the applicable control methods. This section offers guidance to agencies in selecting terms that may need to be clarified when used in a regulatory context. Example definitions of pertinent terms are presented here so that the implementing agency may refer to them when drafting its regulation.

Incinerators are defined and discussed in Sections 4.2.1 and 4.2.2. Condenser filters are defined and discussed in Section 4.2.3. A description of refrigerated circulators is given in Section 4.3.1.1.

Definitions of the terms used in this chapter are given below. It may be helpful to include these definitions in the rule. It also may be useful to define terms pertaining to equipment used in monitoring and recording emissions, such as "continuous recorder" and "flow indicator."

Alcohol substitutes. Nonalcohol additives that contain VOC's and are used in the fountain solution. Some additives are used to reduce the surface tension of water; others (especially in the newspaper industry) are added to prevent piling (ink build-up).

Batch. A supply of fountain solution that is prepared and used without alteration until completely used or removed from the printing press.

Cleaning solution. Liquids used to remove ink and debris from the operating surfaces of the printing press and its parts.

Dampening System. Equipment used to deliver the fountain solution to the lithographic plate.

Fountain Solution. A mixture of water, nonvolatile printing chemicals, and an additive (liquid) that reduces the surface tension of the water so that it spreads easily across the printing plate surface. The fountain solution wets the

nonimage areas so that the ink is maintained within the image areas. Isopropyl alcohol, a VOC, is the most common additive used to reduce the surface tension of the fountain solution.

Heat-set. Any operation where heat is required to evaporate ink oil from the printing ink. Hot air dryers are used to deliver the heat.

Lithography. A printing process in which the image and nonimage areas are chemically differentiated; the image area is oil receptive and the nonimage area is water receptive. This method differs from other printing methods, in which the image is a raised or recessed surface.

Non-Heatset. Any operation where the printing inks are set without the use of heat. For the purposes of this rule, ultraviolet-cured or electron beam-cured inks are considered non-heatset.

Offset. A printing process that transfers the ink film from the lithographic plate to an intermediary surface (blanket), which, in turn, transfers the ink film to the printing substrate.

Press. A printing production assembly composed of one or many units to produce a printed sheet or web.

Sheet-fed. A printing operation where individual sheets of substrate are fed to the press sequentially.

Unit. The smallest complete component of a printing press.

Web. A continuous roll of paper used as the printing substrate.

7.3 APPLICABILITY

As discussed in Chapter 3.0, the offset lithography industry can be divided into four types of printing: heatset web, non-heatset web (non-newspaper), non-heatset sheet-fed, and newspaper (non-heatset web). Because some printing facilities consist of more than one type of printing, it is helpful to define the specific source or "affected facility" that will be regulated. Printing operations having combinations of two or more different types of printing presses may be broken down into sub-facilities. A

sub-facility may be defined as "one or more printing operation(s) of the same type."

One possible definition of an affected facility is "one or more sub-facilities involved in similar offset lithographic printing processes." Other types of printing, such as flexographic, rotogravure, or letterpress, may be present on the property as well. The information contained in this document, however, focuses on offset lithographic printing only.

Another possible definition of an affected facility is "an individual printing press with its own individual dryer exhaust controls (if heatset) or the combination of two or more presses and the common dryer exhaust, or fountain solution and cleaning solution delivery systems that they share." Obviously, if different RACT requirements are required for different types or sizes of offset lithographic printing operations, then the presses used in the different processes should be considered separately when applying requirements.

Note that this RACT implementation guidance would apply only to sources described in this document. The implementing agency also may wish to include this rule with other sources that it deems appropriate--for example, other types of printing in the graphic arts industry.

7.4 FORMAT OF THE STANDARDS

Several formats are available for RACT regulations covering this source category. Because emissions from dryer exhaust and applicable control devices can be measured, an emission standard, rather than an equipment standard, is recommended. Possible emission standard formats include: (1) a mass emission rate limit, (2) a concentration limit, or (3) a percent-reduction level. Emissions from fountain and cleaning solutions are difficult to collect for measurement; therefore, equipment (material) standards are used for these sources.

Of the three types of emission standard formats, percent reduction is generally preferred for add-on control devices

because it best represents the performance capabilities of the device(s) that will be used to comply with the regulation. The other two formats (mass emission rate and concentration limit) are not preferred because they could cause greater control than is required by the rule at some sources and less control than is required at others. For example, under a mass emission rate or concentration format, the required control efficiency is greater for streams with higher emission rates or higher exhaust stream concentrations. Further, the required control level for exhaust streams with a low mass emission rate or concentration would not reflect the capabilities of RACT.

A weight-percent-reduction standard applied to incinerators and condenser filters is usually feasible because emission rates can be measured readily from the control device inlet and outlet. As discussed in Chapter 4.0 of this document, all new incinerators can achieve at least 98 percent (by weight) reduction in total organics concentration (minus methane and ethane), provided that the total organic (minus methane and ethane) of the dryer exhaust stream is greater than approximately 2,000 ppmv. For exhaust streams with organics concentrations below approximately 2,000 ppmv, a 98 percent (by weight) reduction may be difficult to achieve; however, an incinerator outlet concentration of 20 ppmv is achievable.

For condenser filters, a 90- to 95-percent (by weight) reduction of total organics is achievable. A minimum outlet concentration of 20 ppmv may be achievable by some types of condenser filters. A recommended standard would be a weight-percent reduction (depending on which device is selected as the basis for RACT) in total organic compounds (minus methane and ethane) or reduction to a concentration of total organic compounds (minus methane and ethane), whichever is less stringent.

For VOC control from the fountain solution and cleaning solution, the recommended equipment standard is a maximum concentration of VOC in the final solution. For fountain

solutions with alcohol, the standard can be either a volume- or weight-percent reduction because the alcohol is usually IPA, which has a known density. For alcohol substitutes in the fountain solution, the preferred option is a weight-percent of VOC, as the compounds that contribute to VOC emissions have slightly different specific gravities.

If refrigeration of the fountain solution is chosen as a method for lowering VOC emissions, the temperature of the fountain solution would be measured to demonstrate a specified temperature.

7.5 EMISSIONS TESTING

When the owner or operator of any affected facility conducts either an initial or subsequent emissions test, it is recommended that the facility be running at a representative full operating condition and flow rate. Emissions testing should include an initial test when the equipment is installed and operating, to demonstrate compliance with the specified requirements.

The EPA Method 25 (Appendix A of 40 CFR 60) is recommended as the best available procedure for determining emissions from heatset dryer exhaust. However, the minimum detectable concentration for this method is 50 parts per million (ppm) as carbon. Given that low concentrations of VOC's sometimes are found in dryer exhaust from offset lithographic presses and high removal efficiencies are achievable by add-on controls, the EPA Method 25 may not be suitable for determining compliance with a weight-percent reduction standard in all situations. Note that the EPA Method 25 specifies a minimum probe and filter temperature of 265°F. To prevent condensation, the probe and filter should be heated to the gas stream temperature, typically closer to 350°F.

The EPA Method 25A (Appendix A of 40 CFR 60) uses a flame ionization detector (FID), which has the ability to measure lower concentrations. However, this technique is not usually recommended for incinerators, as incomplete combustion may result in the formation of aldehydes, ketones, and partially

oxidized organic species, which interferes with the accuracy of FID measurement. For thermal and catalytic incinerators, EPA Method 25 is recommended, except in cases where the allowable outlet VOC concentration of the control device is less than 50 ppmv as carbon, in which case EPA Method 25A shall be used.

The EPA Reference Method 1 or 1A is recommended for selecting the sample site. To determine reduction efficiency, it is recommended that the control device sampling sites be located prior to the inlet of the control device (following the dryer) and at the outlet of the control device. The EPA Methods 2, 2A, 2C, or 2D are recommended for determining the volumetric flow rate, and the EPA Method 3 is recommended for determining the air dilution correction, based on 3 percent oxygen in the emission sample.

7.6 EQUIPMENT STANDARDS

Equipment standards should specify the VOC concentration of the fountain solution (as either a weight or volume percent) and the procedure for determining compliance with the standard.

7.6.1 Fountain Solution

A sample of the fountain solution in each tray (for manual systems) or tank (for circulation systems) can be taken to determine the IPA content of the fountain solution. The method recommended for detecting and quantifying alcohol in fountain solutions is a modification of the EPA Method 415.1 (under development), where a gas chromatograph is used for direct identification of IPA. This method works best for a fresh batch of fountain solution, before use in the press.

It may be difficult to accurately detect the IPA content of the fountain solution after the fountain solution has been used in the press, because it contains suspended particles of ink and paper. In this case, the alcohol content of the fountain solution sample can be determined with a refractometer or hydrometer that has been calibrated against the EPA Method 415.1 measurement of the fresh fountain solution. Since the suspended ink and paper debris may raise

the refractometer or hydrometer reading, a measurement up to 10 percent over the reading for a fresh solution will be allowed to demonstrate compliance.

If alcohol substitutes or nonalcohol additives are used, the VOC concentration of the fountain can be solution determined from the vendor's analysis of VOC's in the concentrate, and facility records of the mixing ratio of the concentrate with water. The use of alcohol substitutes by the facility should be established whether or not alcohol is used, since some facilities may combine alcohol and alcohol substitutes.

7.6.2 Refrigeration Equipment

A thermometer or other temperature detection device capable of reading to 0.5°F can be used to ensure that the fountain solution is at or below the temperature required by the rule. Temperatures as low as 55°F have been required in some areas.

7.6.3 Cleaning Solution

A sample of the cleaning solution, as used, can be taken to determine that its VOC content is at or below the desired amount. The EPA Method 415.1 can be used to detect and quantify VOC's for solutions with high water content. The modification will relax the detection limits for use in the offset lithographic printing industry.

7.7 MONITORING

7.7.1 Control Devices

Add-on control devices must be maintained and operated properly to comply with the suggested emission limit. Two possible monitoring methods are available: continuous emission monitoring and continuous control device measurement. Continuous inlet and outlet monitoring is preferred because it will give a continuous, direct measurement of actual emissions. However, no continuous monitoring method to measure total organics has been demonstrated for add-on controls in the printing industry. This is because each of the many diverse types of compounds in the dryer exhaust streams would have to be identified separately and the

concentration of each determined. Continuous monitoring of all the individual compounds would be too expensive to be practical.

In continuous control device measurement, certain parameters, such as temperature and flow rate, can reflect the level of control device efficiency. It has been shown, for example, that lower temperatures can cause significant decreases in combustion control device efficiency, while higher temperatures may cause decreases in condenser filter efficiency. Because temperature monitors with strip charts are relatively inexpensive and easy to operate, it is recommended that the owner or operator of an affected facility install, calibrate, maintain, and operate a temperature monitoring device in accordance with the manufacturer's specifications. The monitoring temperature can be set according to the operation of the device during compliance testing.

For heatset printing, 100 percent capture is achievable for emissions from the dryer. To ensure 100 percent capture, the pressure in the dryer is kept slightly lower than the press room pressure when the press is operating. Dryer pressure can be readily monitored and documented using a variety of tests that qualitatively measure air flow direction.

7.7.2 Fountain Solution Alcohol Concentration

A refractometer or hydrometer can be used to determine on a regular basis the concentration of a fluid, such as alcohol, in water. Refractometers rely on the differences in refractive index (reflection of light) between water and other liquids; hydrometers rely on the difference in specific gravity. These devices are available for use on a frequent basis in fountain solution at printing facilities. The readouts are optical or digital. Standard solutions may be used to calibrate the devices. Alternatively, the devices may be standardized against measurements taken with the EPA Method 415.1. Both devices should be equipped with temperature corrections.

Conductivity meters also are used to monitor the relative concentration of the fountain solution. Conductivity meters need to be referenced to the conductivity of the incoming water because conductivity varies for each area, season of the year, and, possibly, time of day. Conductivity is a good quality assurance mechanism, as paper and ink fragments in the fountain contribute to conductivity. However, for this very reason, conductivity would not be as accurate a measure of VOC concentration as a readout from a refractometer or hydrometer.

7.7.3 Fountain Solution Additive Concentration

The nonalcohol additive or alcohol substitute concentration in the fountain solution can be monitored with a conductivity meter, as described above for fountain solution alcohol, or a pH meter, if a one-step additive is used. A pH meter is less sensitive than a conductivity meter because it is the pH of the chemical additives in the one-step solution that actually is being monitored rather than the VOC's. It is possible that a refractometer or hydrometer could be used with nonalcohol additives if there is a measurable difference in refractive index or density between the substitute and water.

If the facility can demonstrate that the use of alcohol substitutes or nonalcohol additives consistently produces a fountain solution that contains less than 3 percent VOC, the States may waive the monitoring requirement or extend the monitoring time period, on a case-by-case basis, after consistent use has been established. A reasonable time period to establish the baseline is 6 months.

7.7.4 Fountain Solution Temperature

Continuous temperature monitoring of the fountain tray is possible with temperature probes installed in the fountain tray below the surface of the solution. The probes can be attached to continuous recording devices such as strip charts, recorders, or computers. Manual reading of a temperature probe can be effective if the manual reading intervals are frequent enough to observe temperature drift.

7.7.5 Cleaning Solution Concentration

No easily applied method of cleaning solution VOC monitoring has been identified, either for continuous cleaning solution application or for batch processes. For aqueous cleaning solutions, a refractometer, hydrometer, or conductivity meter may be used, although these applications have not been noted in the industry. For automated cleaning operations, flow meters for water and for cleaning solution concentrate can be calibrated against equipment standard samples (see Section 7.6.3) to achieve the required VOC limit. For the manual preparation and application of cleaning solutions, careful recordkeeping is the only alternative to the use of refractometers, hydrometers, or conductivity meters, with frequent correlations to equipment standard samples.

7.8 REPORTING/RECORDKEEPING

Each facility subject to RACT requirements should keep records of certain key parameters that would indicate compliance. First, the facility should identify the control method or equipment standard selected to meet the RACT requirements. Next, the results of any performance and equipment standard testing (discussed in Sections 7.5 and 7.6) should be recorded. Furthermore, the facility should record all parameters listed in Section 7.7 on a routine basis to indicate continued compliance with the RACT emission limit. Any exceedances of the monitored parameters should also be recorded, along with any corrective actions taken.

The air quality management agency can decide which of the recorded data should be reported and what the reporting frequency should be.

7.9 POTENTIAL TO EMIT VOLATILE ORGANIC COMPOUNDS

Some air quality management agencies may need to determine the potential to emit VOC's from a printing operation for regulatory purposes. The following sections describe the procedures that may be used to estimate VOC emissions from each of the three types of materials used in printing process. The potential emissions for the entire

facility are equal to the sum of the potential emissions from each type of material used by the facility.

7.9.1 Ink

7.9.1.1 Heatset Ink. The annual potential emissions from the use of heatset ink is equal to the amount of ink used per year multiplied times the VOC content of the ink, minus 20 percent of this total VOC to account for retention of VOC by the substrate. The VOC content of the ink should be determined by the EPA Method 24. In lieu of using this estimate of 20 percent VOC retention, test data can be used to establish the exact amount of VOC's retained in the substrate for this type of ink.

7.9.1.2 Non-heatset Ink. The annual potential emissions from the use of non-heatset ink is equal to the amount of ink used per year multiplied times the VOC content of the ink, and minus 95 percent of this total VOC to account for retention of VOC by the substrate. The VOC content of the ink should be determined by the EPA Method 24. In lieu of using this estimate of 95 percent VOC retention, test data can be used to establish the exact amount of VOC's retained in the substrate for this type of ink.

7.9.2 Fountain Solution

7.9.2.1 Alcohol. In facilities where alcohol is used in the fountain solution, the annual potential to emit VOC's is equal to the amount of alcohol used per year, since alcohol is a VOC. In most cases, the alcohol will be isopropyl alcohol.

7.9.2.2 Nonalcohol Additive or Alcohol Substitute. For facilities where a nonalcohol additive or alcohol substitute is used in the fountain solution, the potential to emit VOC's is equal to the amount of additive or substitute used per year multiplied by the VOC content of the additive or substitute, as determined by the EPA Method 24.

7.9.3 Cleaning Solution

The potential to emit VOC's from the use of cleaning solution is equal to the amount of cleaning solution used during the year multiplied by the VOC content of the cleaning solution, as determined by the EPA Method 24.

APPENDIX A

CONTACTS

APPENDIX A

CONTACTS

The following is a list of suppliers, equipment vendors, trade organizations, and government representatives who may provide additional information on issues concerning offset lithographic printing.

A.1 SUPPLIERS

ACME Printing Ink Company
Allara, Mr. Bob
Coordinator, Environmental Affairs
1419 West Carroll Street
Chicago, Illinois 60607

Borden Industrial and Packaging
Products
King, Mr. Don
Coordinator, Environmental Affairs
Post Office Box 15947
Cincinnati, Ohio 45215

Cal Ink
Damianakes, Mr. Chuck
Coordinator, Environmental
Affairs
404 Fourth Street
Berkeley, California 94710

Cal Ink
Nickoley, Ms. Loren D.
Environmental Manager
1404 Fourth Street
Berkeley, California 94710

Capitol Ink
Bien, Mr. George
Technical Coordinator
806 Channing Place, NE
Washington, D. C. 20018

Flint Ink Corporation
Administrative Assistant of
Environmental Affairs
Kuligowski, Ms. Cindy
Post Office Box 8609
Ann Arbor, Michigan 48107

Flint Ink Company
Miller, Mr. Al
13055 East Temple Avenue
City of Industry, California 91746-1479

Handschy Industries, Incorporated
Lakie, Mr. Chuck
120 25th Avenue
Bellwood, Illinois 60104

International Blending Corporation
Blackley, Mr. Paul
8090 Ranchers Road
Minneapolis, Minnesota 55432

Midland Color Group
Wawak, Mr. Frank
Coordinator, Environmental Affairs
101 Morse Avenue
Elk Grove Village, Illinois 60007

Polychrome Corporation
Oser, Mr. Mark
137 Alexander Street
Yonkers, New York 10702

Printers Service
Gerson, Mr. David
Coordinator, Environmental Affairs
26 Blanchard Street
Newark, New Jersey 07105

Printex Products
Wahtling, Mr. Ron
5686 Dressler Road, NW
Suite 140
North Canton, Ohio 44720

Printex Products Corporation
Hoppe, Ms. Debbie
Post Office Box 1479
Rochester, New York 14603-1515

Quality Control Litho Products
Lynch, Mr. Roy
280 North Ott Street
Corona, California 91720

RBP Chemical Corporation
Singstock, Mr. Jay
150 South 118th Street
Milwaukee, Wisconsin 53214

RBP Chemical Corporation
Koontz, Mr. Wayne and
Zaloon, Mr. Jeff
150 South 118th Street
Milwaukee, Wisconsin 53214

Rosos Research Laboratories,
Incorporated
Roso, Ms. Agi
President
990 North Shore Drive
Lake Bluff, Illinois 60044

Rycoline Products, Incorporated
Whitehead, Mr. Jim
5540 Northwest Highway
Chicago, Illinois 60630

Sun Chem Corporation,
General Printing Inks (GPI)
Zborovsky, Mr. Joe
Coordinator, Environmental Affairs
631 Central Avenue
Carlstadt, New Jersey 07072

Universal Printing
Notti, Mr. Peter
Laboratory Manager
13621 Alondra Boulevard
Sante Fe Springs, California 90670

Varn Products Company, Incorporated
Ryan, Mr. Dennis
175 Route 208
Oakland, New Jersey 07463

A.2 EQUIPMENT VENDORS

Akiyama, Incorporated
Bernetich, Mr. Joe
224 Lackawanna Avenue
Post Office Box 2086
West Paterson, New Jersey 07424

Allied Signal Incorporated
Holt, Mr. Bill
Post Office Box 580970
Tulsa, Oklahoma 74158

American Environmental
International, Incorporated
Tandon, Mr. J. S.
111 Pfingsten Road
Deerfield, Illinois 60015

Anguil Environmental System,
Incorporated
Anguil, Mr. Jeff
4927 North Lydell Avenue
Milwaukee, Wisconsin 53217

Baldwin Technology Corporation
MacPhee, Mr. John
1281 East Main Street
Stamford, Connecticut 06902-3577

C. A. Enterprises Limited
Martin, Mr. Paul
4400 West 93rd Street
Prairie Village, Kansas 66207

Engelhard Corporation
Burns, Mr. Ken
Catalysts and Chemicals Division
Menlo Park, CN 28
Edison, New Jersey 08818

Epic Products
Dahlgren, Mr. Harvey
Post Office Box 560907
Dallas, Texas 75356

Heidelberg
Desando, Mr. Charlie
73-45 Woodhaven Boulevard
Glendale, New York 11385

Komeri Printing
Songer, Mr. Bill
5520 Meadowbrook Industrial Circle
Rolling Meadows, Illinois 60008

MMT Environmental Services, Incorporated
Friedrich, Mr. Hank
4643 North Chatsworth Street
St. Paul, Minnesota 55126

Rockwell Graphics
Nierrro, Mr. Ted
700 Oakmont Lane
Westmont, Illinois 60559-5546

TEC Systems

W. R. Grace and Company
Carman, Dr. Richard A.
Senior Research Associate
830 Prosper Road
Post Office Box 30
De Pere, Wisconsin 54115-0030

Thermo Electron Wisconsin, Incorporated
Mundich, Mr. Timothy
820 Hyland Avenue
Post Office Box 7001
Kaukauna, Wisconsin 54130

A.3 TRADE ORGANIZATIONS

American Newspaper Publishers
Association
Cunningham, Mr. Wilson
Box 17407 Dulles Airport
Washington, D.C. 20041

Graphic Arts Technical Foundation
Gadomski, Mr. R. R.
4615 Forbes Avenue
Pittsburgh, Pennsylvania 15213-3796

Graphic Arts Technical Foundation
Jones, Mr. Gary
4615 Forbes Avenue
Pittsburgh, Pennsylvania 15213

Graphic Arts Technical Foundation
Schaeffer, Dr. William
4615 Forbes Avenue
Pittsburgh, Pennsylvania 15213-3796

Manufacturers of Emission
Controls Associations
Connor, Mr. Ray
1707 L Street, NW
Suite 570
Washington, D.C. 20036

National Association of Printers
and Lithographers
Cox, Mr. Keeler
Research and Educational Foundation
780 Palisade Avenue
Teaneck, New Jersey 07666

National Association of Printers
and Lithographers
Paperozzi, Mr. Andy
Research and Educational Foundation
780 Palisade Avenue
Teaneck, New Jersey 07666

National Association of
Printing Ink Manufacturers
Volpe, Mr. Paul F.
47 Halstead Avenue
Harrison, New York 10528

National Printing Equipment and
Supply Association, Incorporated
Nuzzaco, Mr. Mark J.
1899 Preston White Drive
Reston, Virginia 22091

Printing Industries of America,
Incorporated
Non-Heatset Web Section
Basore, Mr. Thomas B.
Executive Director
100 Daingerfield Road
Alexandria, Virginia 22314

Printing Industries of America,
Incorporated
Cooper, Mr. Benjamin Y.
Senior Vice-President
100 Daingerfield Road
Alexandria, Virginia 22314

Printing Industries of America,
Incorporated
Purcell, Mr. Tom
1730 North Lynn Street
Arlington, Virginia 22209

Printing Industries of America,
Incorporated
Director of Environmental Concerns
Web Offset Association
1730 North Lynn Street
Arlington, Virginia 22209

A.4 GOVERNMENT REPRESENTATIVES

Bay Area Air Quality Management
District
Schauseleerger, Ms. Christine
939 Ellis Street
San Francisco, California 94109

Georgia Department of Natural
Resources
Collum, Mr. Robert or Mr. Jeff Carter
Air Pollution Branch
205 Butler Street, S. E., Room 1162
Atlanta, Georgia 30334

Maryland Department of the Environment
Waheed, Mr. Husain or Mr. Carl York
Air Management Administration
2500 Broening Highway
Baltimore, Maryland 21224

New York Division of Air Quality
Dalton, Ms. Kathy
50 Wolf Road
Albany, New York 12233

Puget Sound Air Pollution
Control Agency
Corbin, Ms. Margaret
200 West Mercer Street, Room 205
Seattle, Washington 98119-3958

South Coast Air Quality Management
District Board
El Sherif, Mr. Monstafa
9150 Flair Drive
El Monte, California 91731

Tennessee Department of Health and
Environment
Patten, Mr. John
701 Broadway, 4th Floor Custom
Nashville, Tennessee 37219-5403

U. S. Environmental Protection Agency
Office of Air Quality Planning
and Standards (MD-13)
Vatavuk, Mr. William
Standards Development Branch
Research Triangle Park, NC 27711

APPENDIX B
EMISSION ESTIMATION

APPENDIX B
EMISSION ESTIMATION

Sample calculations for the emission estimation techniques used in Chapter 5.0 are shown in Sections B.1.0 through B.5.0. Section B.6.0 contains background information and analyses to support estimation of the decrease in alcohol evaporation from the fountain due to decrease in fountain solution temperature.

B.1.0 ESTIMATION OF RAW MATERIAL USE IN THE MODEL PLANTS

Raw materials used in offset lithographic printing are ink, fountain solution alcohol, and cleaning solution. Use of raw materials for model plants in Groups A, B, and C, was estimated from industry surveys, and is shown below:

Raw Material	Process	Use Rate
Ink	Web	10.3 pounds per unit hour
	Sheet	0.25 pounds per unit hour
Isopropyl Alcohol	Heatset Web	0.9 pounds per pound of ink
	Non-heatset Web (non-newspaper)	0.53 pounds per pound of ink
	Non-Heatset Sheet	1.25 pounds per pound of ink
Cleaning Solution	All	0.33 pounds per unit hour

For heatset web, each unit is a double blanket unit; for non-heatset web and sheet, each unit is a single blanket unit. For newspaper model plants (Group D), ink use rates were provided by the industry. The use of non-alcohol additives at 0.07 pounds of additive per pound of ink, was estimated from industry surveys. The cleaning solution use rate was estimated, as above, for model plants in Groups A, B, and C.

The total number of units for each model plant is shown in Table 5-1 in Chapter 5.0. Using an estimate of 3,000 annual hours of operation, along with an average number of units for each model plant, annual raw material use for each model plant was estimated and is also shown in Table 5-1.

The following sections describe step-by-step calculations for determining annual raw material use. Model Plant A-III, which represents a medium-size heatset web facility, is used as an example. Calculations for the other model plants are similar to the calculations shown here for Model Plant A-III.

B.1.1 Ink Use Calculation

Equation (B-1) below is used to calculate annual ink use.

$$\begin{array}{rcl} \text{ink use rate} & \times & \text{number of units} \times 3000 \text{ hr} = \text{ink use} & \text{(B-1)} \\ (\text{lb/unit hr}) & & & (\text{lb}) \end{array}$$

For Model Plant A-III, an average of 22 units was used in the calculations to represent the range of units for this size plant. Substituting 22 units into Equation (B-1), and using 10.3 lb per unit hour as the ink use rate, gives the following result:

$$10.3 \times 22 \times 3000 = 679,800 \text{ pounds} = 340 \text{ tons of ink used}$$

B.1.2 Isopropyl Alcohol Use Calculation

Equation (B-2) is used to calculate annual IPA use for Model Plant A-III, using a weight ratio of IPA to ink of 0.9 (pounds or tons of IPA per pound or ton of ink).

$$\begin{array}{rcl} 340 \text{ tons ink} & \times & 0.9 \text{ tons IPA per ton ink} & \text{(B-2)} \\ & = & 306 \text{ tons IPA used} & \end{array}$$

For the model plants in Group A and C, it was assumed that the use of alcohol corresponded to an alcohol concentration of 17 percent (by volume) IPA in the fountain; for model plants in Group B, the alcohol concentration was assumed to be 10 percent (by volume). The average alcohol concentrations were not determined from theoretical calculations; their usefulness is shown below (Section B.4.1) in calculating emission reductions.

B.1.3 Cleaning Solution Use Calculation

An equation similar to Equation (B-1) is used to calculate annual cleaning solution use for the model plants, using the cleaning solution use rate (0.33 pounds of cleaning solution per unit hour), the number of units in the model plant (22), and 3,000 annual operating hours. The calculation for Model Plant A-III is shown in Equation (B-3).

$$\begin{aligned} 0.33 \times 22 \times 3000 &= 21,780 \text{ pounds} && \text{(B-3)} \\ &= 11 \text{ tons cleaning solution} \end{aligned}$$

B.2.0 CALCULATION OF VOLATILE ORGANIC COMPOUND EMISSIONS IN THE MODEL PLANTS

Annual VOC emissions for the model plants were calculated from the amount of raw material used, amount of VOC contained in the raw material, and knowledge of the printing process. The results of these calculations are shown in Table 5-1.

B.2.1 Calculation of Volatile Organic Compound Emissions From Ink

The average amount of VOC's from inks that were used to estimate emissions from the model plants due to ink are shown below. State and local agencies are advised to use actual facility data on ink VOC if possible, when determined by EPA Method 24.

<u>Type of Ink</u>	<u>Average Amount of VOC</u>
Heatset Ink	40 percent VOC
Non-heatset Web Ink (non-newspaper)	30 percent VOC
Non-heatset Sheet-fed Ink	25 percent VOC
News Ink	10 percent VOC

For heatset inks, it was estimated that 20 percent of the VOC's from ink were retained by the substrate. For non-heatset inks, substrate retention of the VOC's from inks was

estimated to be 95 percent. Equation (B-4) below was used to calculate the VOC emissions from ink.

$$\text{weight of ink used} \times \frac{\text{weight percent VOC in the ink}}{100} \times \frac{(100 - \text{percent VOC retained by the paper})}{100} = \text{VOC emissions from ink} \quad (\text{B-4})$$

An example calculation for VOC emissions due to ink is shown in Equation (B-5) below using Equation (B-4) for Model Plant A-III with an annual ink use (340 tons) calculated in Section B.1.1 above, 40 percent VOC in the ink (heatset), and 20 percent retained by the substrate (80 percent emitted).

$$340 \text{ tons ink} \times 0.40 \times 0.80 = 109 \text{ tons VOC from ink emitted} \quad (\text{B-5})$$

B.2.2 Calculation of Volatile Organic Compound Emissions From Fountain Solution Alcohol

Because IPA is a VOC, annual emissions from the fountain are equal to the amount of alcohol used. For Model Plant A-III, where 306 tons of alcohol were estimated in Section B.1.2 as the amount of IPA used per year in the fountain, 306 tons of VOC also were estimated to be emitted from the fountain.

B.2.3 Calculation of Volatile Organic Compound Emissions From Cleaning Solutions

Emissions of VOC's from the model plants from the use of cleaning solution were calculated using annual cleaning solution use (11 tons) as determined in Section B.1.3 above, and Equation (B-6) below:

$$\text{VOC emissions from cleaning solutions} = \text{weight of cleaning solution} \times \frac{\text{percent VOC}}{100} \quad (\text{B-6})$$

The cleaning solutions used in the baseline by the model plants were considered to be 100 percent VOC. Therefore, as with IPA in the fountain, the annual amount of VOC's estimated

to be emitted from cleaning solutions for the model plants was equal to the annual use of cleaning solution. For Model Plant A-III, VOC emissions were equal to 11 tons per year, the amount of cleaning solution used, as calculated above in Section B.1.3. State and local agencies are advised to use actual VOC data for cleaning products whenever possible.

B.3.0 CALCULATION OF CONTROLLED VOLATILE ORGANIC COMPOUND EMISSIONS FROM INKS

Controlled VOC emissions from ink due to application of abatement devices to heatset model plants were shown in Chapter 5.0, Table 5-2. The amount of VOC's emitted was calculated using Equation (B-7) below, and the estimated control device efficiency (CDE):

$$\begin{array}{r} \text{uncontrolled} \\ \text{VOC emissions} \\ \text{from ink} \end{array} \times \frac{100-\text{CDE}}{100} = \begin{array}{r} \text{controlled} \\ \text{VOC emissions} \\ \text{from ink} \end{array} \quad (\text{B-7})$$

Uncontrolled VOC emissions were equal to the annual VOC emissions from ink as calculated using Equation (B-4) above (Section B.2.1).

An example calculation of controlled VOC emissions from ink is shown in Equation (B-8) for Model Plant A-III, using a condenser filter with carbon as a control device. This device has an estimated control efficiency of 95 percent.

$$109 \text{ tons VOC from ink} \times 0.05 = 5.5 \text{ tons VOC emitted} \quad (\text{B-8})$$

B.4.0 CALCULATION OF CONTROLLED VOLATILE ORGANIC COMPOUND EMISSIONS FROM FOUNTAIN SOLUTION

Control of VOC emissions from fountain solution alcohol can be achieved by reducing the level of alcohol in the fountain, refrigerating the fountain solution, or using alcohol substitutes. The following sections illustrate the calculations used for each of these control strategies. Controlled emissions from fountain solution were shown in Chapter 5.0, Table 5-3.

B.4.1 Reduction of Alcohol

VOC emissions with reduction of alcohol were calculated using Equation (B-9) below:

$$\begin{array}{l} \text{VOC emissions} \\ \text{at baseline} \\ \text{concentration} \end{array} \times \frac{\text{lower \% alcohol}}{\text{baseline \% alcohol}} = \begin{array}{l} \text{VOC emissions} \\ \text{from fountain} \\ \text{solution at lower} \\ \text{alcohol levels} \end{array} \quad (\text{B-9})$$

For the model plants using alcohol, either 10 or 17 percent (by volume) was considered the baseline, depending on the type of process. State and local agencies are advised to use actual baseline levels whenever possible. A sample calculation for Model Plant A-III is shown in Equation (B-10) for reduction of alcohol to 3 percent (by volume).

$$306 \text{ tons VOC} \times (3/17) = 54 \text{ tons VOC emitted} \quad (\text{B-10})$$

B.4.2 Refrigeration of Fountain Solution

Refrigeration of fountain solution containing alcohol reduces evaporation of alcohol from the fountain. Annual alcohol use and, consequently, VOC emissions are reduced. On the basis of vendor data, VOC emission reduction from refrigeration of the fountain was estimated at 44 percent. Section B.6.0 below shows theoretical calculations that were used to support this estimation.

Emissions from a refrigerated fountain solution were calculated using Equation (B-11) below:

$$\begin{array}{l} \text{VOC emissions} \\ \text{from an} \\ \text{unrefrigerated} \\ \text{fountain} \end{array} \times (1 - 0.44) = \begin{array}{l} \text{VOC emissions} \\ \text{from a} \\ \text{refrigerated} \\ \text{fountain} \end{array} \quad (\text{B-11})$$

For Model Plant A-III, with an estimated 306 tons of alcohol used per year, VOC emissions with refrigeration of the fountain to below 60°F (at the same volume percent of alcohol) are calculated as follows:

$$306 \text{ tons VOC} \times 0.56 = 171 \text{ tons VOC emitted} \quad (\text{B-12})$$

If alcohol levels are reduced and then refrigerated, Equation (B-9) is used first to calculate the reduction in alcohol use; Equation (B-11) is then used to calculate the VOC emissions with refrigeration, at the reduced level of alcohol consumption.

B.4.3 Use of Alcohol Substitutes

The changeover from alcohol in the fountain to the use of alcohol substitutes was calculated from the baseline amount of alcohol used, according to the following equation:

$$\frac{\text{weight of alcohol used}}{10} = \text{weight of alcohol substitute} \quad (\text{B-13})$$

For Model Plant A-III, changeover to alcohol substitutes was calculated as follows:

$$306 / 10 = 31 \text{ tons of alcohol substitute} \quad (\text{B-14})$$

The resulting VOC emissions from the use of alcohol substitutes were calculated according to the following equation:

$$\text{weight of alcohol substitute} \times 0.10 = \text{VOC emissions from alcohol substitute} \quad (\text{B-15})$$

where the VOC content of the alcohol substitutes was estimated to be 10 percent. For Model Plant A-III, VOC emissions from the use of alcohol substitutes was calculated as follows:

$$31 \text{ tons alcohol substitute} \times 0.10 = 3.1 \text{ tons VOC emitted} \quad (\text{B-16})$$

State and local agencies are advised to use actual VOC data whenever possible.

B.5.0 CALCULATION OF CONTROLLED VOLATILE ORGANIC COMPOUND EMISSIONS FROM CLEANING SOLUTIONS

Control of VOC emissions from cleaning solutions is implemented by reducing the VOC content of the cleaning solution. For a change to 30 (by weight) percent cleaning solution (as used), the resulting emissions were calculated using Equation (B-17) below:

$$\begin{array}{l} \text{weight of} \\ \text{cleaning} \\ \text{solution} \end{array} \times \frac{30}{100} = \begin{array}{l} \text{VOC emissions} \\ \text{from cleaning} \\ \text{solutions} \end{array} \quad (\text{B-17})$$

For Model Plant A-III, cleaning solution emissions with a lower VOC cleaning solution (30 percent) were calculated as follows:

$$11 \text{ tons VOC} \times 0.30 = 3.3 \text{ tons VOC emitted} \quad (\text{B-18})$$

B.6.0 THEORETICAL DETERMINATION OF THE CHANGE IN ISOPROPYL ALCOHOL EVAPORATION RATE WITH TEMPERATURE

The evaporation rate of IPA from the printing rollers temperature decreases as temperature decreases. Using Fick's law for molecular diffusion, the theoretical rate of evaporation at any temperature can be estimated. The following equation estimates the theoretical rate of diffusion for IPA diffusing through stagnant, non-diffusing air from point 1 at the IPA surface to point 2 a distance from the surface:

$$N_{\text{IPA}} = \frac{D_{\text{IPA-A}}}{R T (Z_2 - Z_1)} \cdot \frac{P}{P_{\text{A-M}}} \cdot (P_{\text{IPA-1}} - P_{\text{IPA-2}}) \quad (\text{B-19})$$

where:

$$\begin{array}{ll} D_{\text{IPA-A}} & = \text{Diffusivity of IPA into air (A), square} \\ & \text{feet per hour (ft}^2\text{/hr)} \\ P & = \text{Total Pressure, atmospheres (atm)} \end{array}$$

R	=	Gas Law Constant, cubic feet-atmosphere per pound mole-degree Rankine ($\text{ft}^3\text{-atm/lb mole-}^\circ\text{R}$)
T	=	Temperature, $^\circ\text{R}$
Z_2-Z_1	=	Diffusion path, feet
$P_{\text{IPA}-1}$	=	Partial Pressure of IPA at liquid surface (1), atm
$P_{\text{IPA}-2}$	=	Partial Pressure of IPA in air (2), atm
$P_{\text{A}-1}$	=	Partial Pressure of air at liquid surface, atm
$P_{\text{A}-2}$	=	Partial Pressure of air a distance from the surface, atm
$P_{\text{A}-\text{M}}$	=	Log Mean Partial Pressure of air, atm
N_{IPA}	=	Evaporation Rate of IPA, pound mole per square foot-hour (lb-mol/hr-ft^2)

Diffusion paths (Z) of 0.001, 0.005, and 0.01 ft were used to calculate evaporation rates for IPA at temperatures from 40 to 90°F (500 to 550 °R). The concentration of IPA in the liquid was assumed to be constant at 25 percent (by weight). For the range in IPA concentrations in offset lithographic printing (from 0 to 35 percent), this assumption results in, at most, a 0.2 percent difference from the evaporation rate calculated at 25 percent.

Table B-1 presents IPA evaporation rates versus temperature, generated with Equation B-19, for six different temperatures and three diffusion path lengths. Figure B-1 shows the same data in graphical form. Figure B-2 shows the percent decrease in evaporation rate for each 20°F difference in temperature.

The steps in the calculations are shown below for a diffusion path of 0.01 ft and a temperature of 70°F.

1. Calculate the mole fraction (MF) of IPA in solution.

The following assumptions were used:

100 pounds of fountain solution

25 percent (by weight) IPA in water

and the following values:

1 mole IPA = 60.1 pounds

1 mole water = 18 pounds

TABLE B-1. ESTIMATION OF THE EVAPORATION RATE OF ISOPROPANOL AT SIX TEMPERATURES AND THREE DIFFUSION PATH LENGTHS

Temperature (°F)	Estimate of Diffusion Path (ft)	Evaporation Rate of IPA (lb/hr-sq.ft)
40	0.01	8.8×10^{-3}
50	0.01	1.3×10^{-2}
60	0.01	1.8×10^{-2}
70	0.01	2.6×10^{-2}
80	0.01	3.5×10^{-2}
90	0.01	4.8×10^{-2}
40	0.005	1.6×10^{-2}
50	0.005	2.6×10^{-2}
60	0.005	3.6×10^{-2}
70	0.005	5.1×10^{-2}
80	0.005	7.1×10^{-2}
90	0.005	9.6×10^{-2}
40	0.001	8.8×10^{-2}
50	0.001	1.3×10^{-1}
60	0.001	1.8×10^{-1}
70	0.001	2.6×10^{-1}
80	0.001	3.5×10^{-1}
90	0.001	4.8×10^{-1}

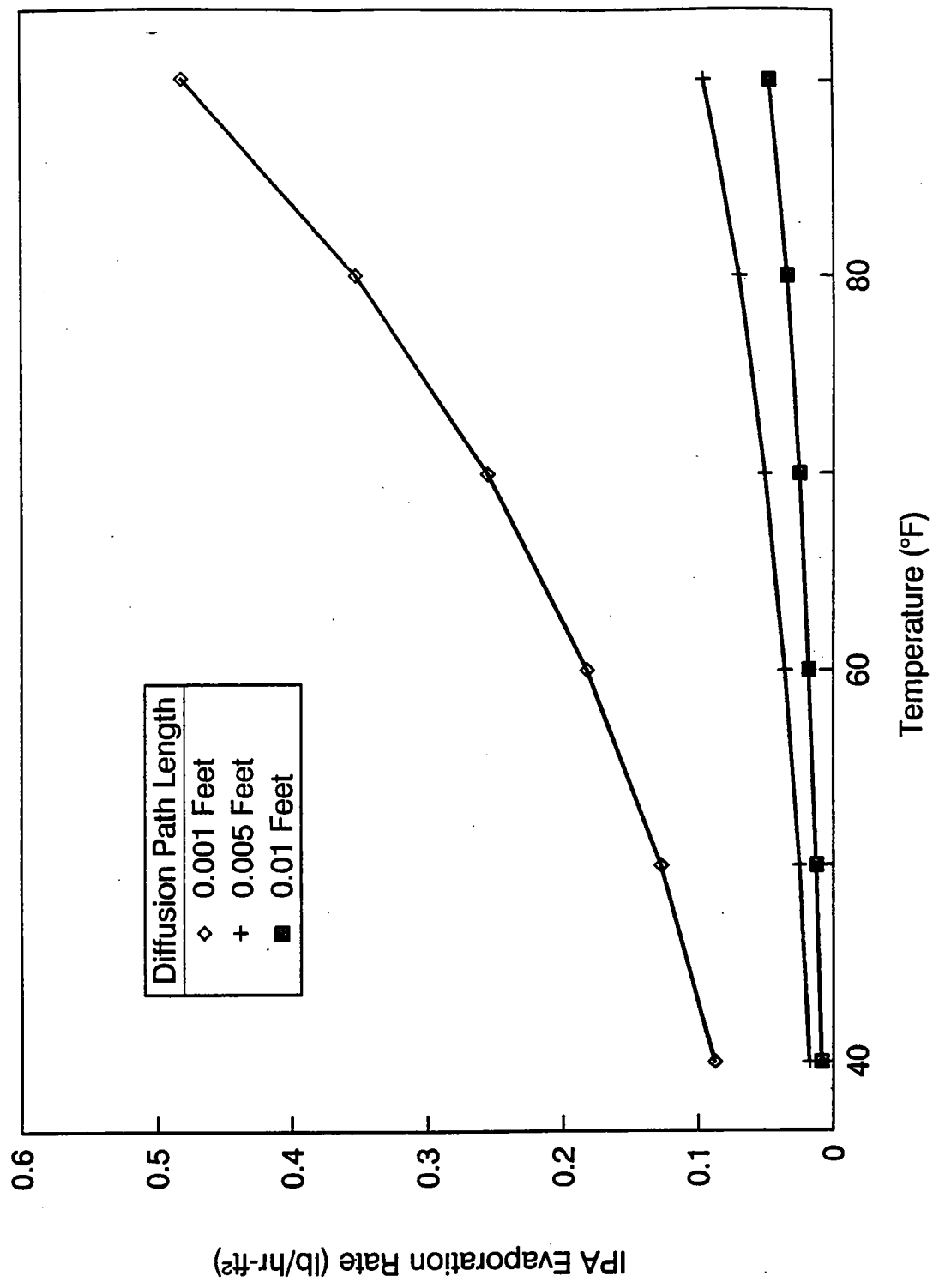


Figure B-1. Isopropanol evaporation rate vs. temperature for three estimated diffusion path lengths (25 wt% IPA).

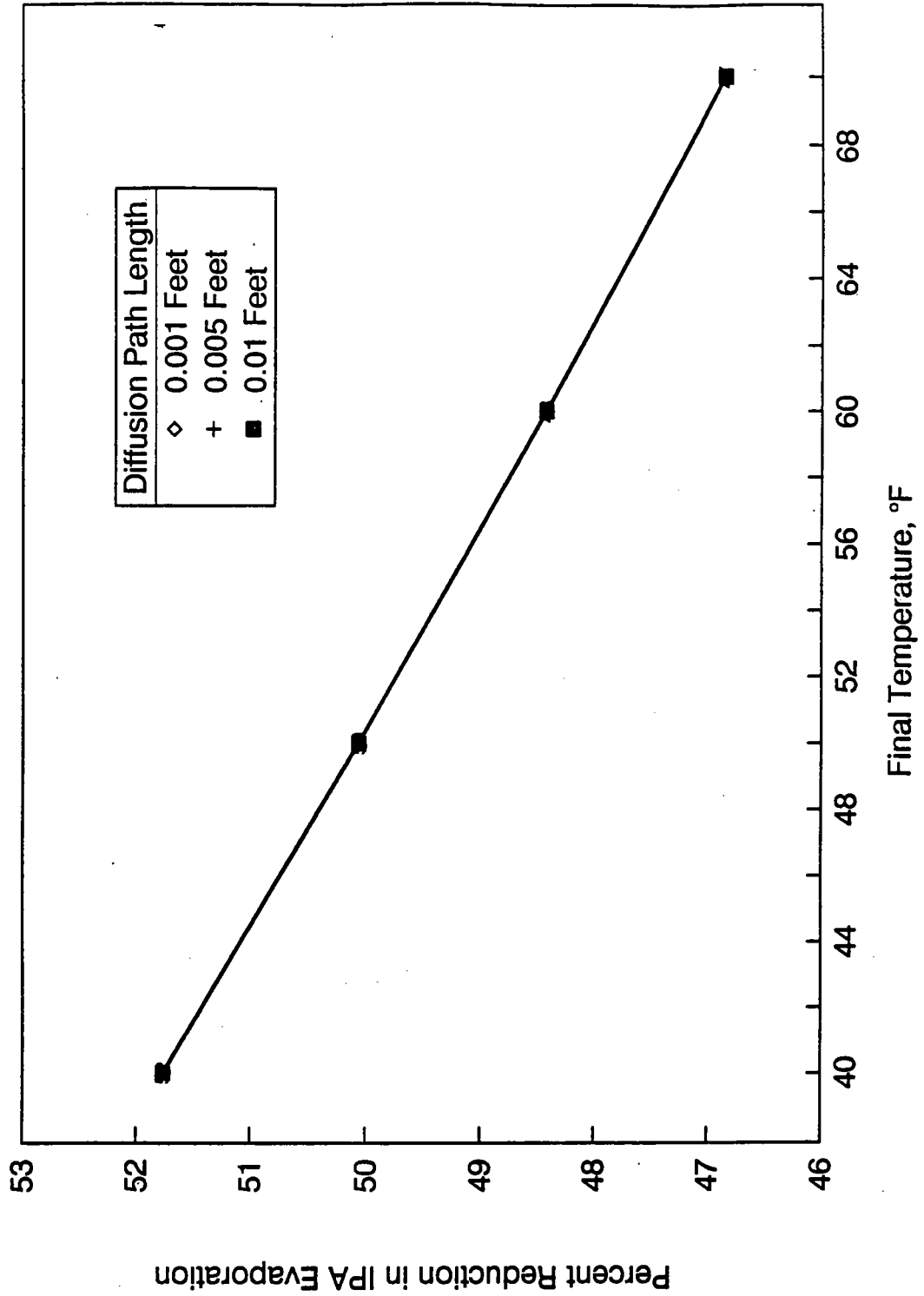


Figure B-2. Percent reduction in IPA evaporation rate with three estimated diffusion path lengths.

$$MF_{IPA} = \frac{\frac{25 \text{ lb IPA}}{\text{lb solution}} \times \frac{1 \text{ lb-mol}}{60.1 \text{ lb IPA}}}{\left(\left(\frac{25 \text{ lb IPA}}{100 \text{ lb sol.}} \times \frac{1 \text{ lb-mol}}{60.1 \text{ lb IPA}} \right) + \left(\frac{75 \text{ lb water}}{100 \text{ lb sol.}} \times \frac{1 \text{ lb-mol}}{18 \text{ lb water}} \right) \right)}$$

$$MF_{IPA} = 0.09086$$

2. Calculate the vapor pressure (VP) of IPA at 70°F, using Antoine's Equation.

$$\log_{10} VP_{IPA} = A - \left[\frac{B}{T + C} \right]$$

where:

$$A = 8.117$$

$$B = 158.92$$

$$C = 219.61$$

$$T = \text{temperature, } ^\circ\text{C}$$

and A, B, and C are constants.

$$VP_{IPA} = 35.45 \text{ mmHg at } 70^\circ\text{F}$$

3. Calculate the partial pressure (P) of IPA at the fountain solution liquid surface (1), in atmospheres (atm):

$$P_{IPA-1} = VP \times MF$$

$$P_{IPA-1} = (35.45 \text{ mmHg}/760 \text{ mm Hg}) \times 0.09086 = 0.0042$$

4. Calculate the partial pressure of air at the liquid surface (P_{A-1}):

$$P_{A-1} = 1 - P_{IPA-1} = 1 - 0.0042 = 0.9958 \text{ atm}$$

5. Calculate the log mean partial pressure of air

$$P_{A-M} = \left\{ \frac{(1 - P_{A-1})}{[\ln(1/P_{A-1})]} \right\} = 0.09979$$

6. Calculate the evaporation rate of IPA using Equation B-19 with the following constants and assumptions:

$$D_{IPA-A} = 0.3875 \text{ ft}^2/\text{hr}$$

$$\text{Total pressure} = 1 \text{ atm}$$

Partial pressure of IPA at a distance (0.01 ft) from the liquid surface = 0

$$R = 0.7302 \text{ (ft}^3 \text{ - atm)/(lb mol - } ^\circ\text{R)}$$

$$T = 530 \text{ } ^\circ\text{R (70}^\circ\text{F)}$$

$$z_2 - z_1 = 0.01 \text{ ft}$$

and the values calculated in Steps 3 and 5, above.

$$N_{IPA} = \frac{0.03875 \times 1 \times (0.0042 - 0)}{0.7302 \times 530 \times 0.01 \times 0.9979} = 0.0042 \text{ lb-mole/hr-ft}^2$$

7. Calculate the evaporation rate of IPA on a pound basis:
 $0.0042 \text{ (lb-mole/hr-ft}^2\text{)} \times 60.1 \text{ lb/lb-mole} = 0.026 \text{ lb/hr-ft}^2$

APPENDIX C
COST CALCULATIONS

APPENDIX C
COST CALCULATIONS

The following sections provide background information and sample calculations to support the information presented in Chapter 6.0, cost calculations. Section C.1.0 presents the design assumptions common to all sizing for the add-on control. Section C.2.0 presents calculations and assumptions used to develop thermal incinerator costs. Section C.3.0 presents catalytic incinerator cost calculations. Section C.4.0 presents calculations and assumptions used to develop condenser filter costs. Section C.5.0 discusses the calculations used to determine the costs of material substitution and process modifications that lower VOC emissions from fountain and cleaning solutions.

C.1.0 DESIGN BASIS FOR ADD-ON CONTROLS ON HEATSET PRESSES

Heatset web printing facilities commonly employ add-on control devices downstream of the dryer to control VOC emissions. The Model Plants A-I through A-IV described in Chapter 3.0 of this document represent the industry for purposes of illustrating cost estimation. Table C-1 presents the design assumptions for sizing the dryer and the add-on control equipment. The exhaust equation for estimation of total exhaust is supplied by the vendor. Total dryer exhaust is estimated using the following relationships:

$$\text{Dryer Exhaust (scfm)} = 0.033 * \text{Web speed (fpm)} * \text{press width (inches)}$$

$$\text{Total Exhaust (scfm)} = \text{dryer exhaust} * \text{number of dryers}$$

Intermediate cost results are shown in Table C-2.

Detailed cost calculations specific to each add-control device are shown in Sections C.2.0, C.3.0, and C.4.0.

TABLE C-1. DESIGN BASIS FOR ADD-ON CONTROLS ON HEATSET PRESSES

Model Plant Code ^a	Number of Presses	No. of Units per Press	Press Width (in.)	Web Speed (ft/min)	Annual Ink Use (lb/Yr)	Number of Dryers ^b
A-I	1	6	38	1,600	154,000	2
A-II	2	8	38	2,000	340,000	4
A-III	4	8	38	2,000	680,000	8
A-IV	6	8	38	2,000	1,236,000	12

a Model plant code refers to model plants described in more detail in Chapter 3.

b Number of dryers is based on one single dryer for every four units and is rounded to the next largest whole dryer.

C.2.0 THERMAL INCINERATOR CALCULATIONS

The calculations are based on OAQPS Control Cost Manual, Chapter 3. The stream costed in this example is Model Plant A-III, a heatset facility. The dryer exhaust characteristics for this model plant are as follows:

VOC to be controlled	:	Ink Solvents
MW	:	175.4 lb/lb mole
Flow rate (total)	:	20,000 scfm
VOC flow rate	:	72.5 lb/hr
Heat value	:	1.2 Btu/scf
Oxygen content	:	21%
Inert content	:	Assume all N ₂

C.2.1 Sizing Calculations for Thermal Incinerators

- A. If the exhaust stream is not halogenated, heat recovery is allowed. Four different options are considered: 0, 35, 50, and 70 percent heat recovery.
- B. Calculate total moles of the vent stream and quantify moles of VOC, O₂, and inerts.
 1. VOC moles:
$$\begin{aligned} \text{VOC moles} &= (72.533 \text{ lb/hr}) (\text{hr}/60 \text{ min}) \\ &\quad (\text{lb}\cdot\text{mole}/175.4 \text{ lb}) \\ &= 0.007 \text{ lb}\cdot\text{moles}/\text{min} \end{aligned}$$
 2. Total vent stream moles:
$$\begin{aligned} \text{Vent moles} &= (20,000 \text{ scfm}) (\text{lb}\cdot\text{mole}/392 \text{ scf}) \\ &= 51.02 \text{ lb}\cdot\text{moles}/\text{min} \end{aligned}$$
 3. Oxygen moles: (51.02 lb moles/min) (0.21 moles O₂/mole air)
$$\text{O}_2 \text{ moles} = 10.71 \text{ lb moles O}_2/\text{min}$$
 4. Inert moles:
$$\begin{aligned} \text{Inert moles} &= \text{Vent moles} - \text{VOC moles} - \text{O}_2 \text{ moles} \\ &= (51.02 - 0.007 - 10.71) \\ &\quad \text{lb}\cdot\text{mole}/\text{min} \\ &= 40.30 \text{ lb}\cdot\text{mole}/\text{min} \end{aligned}$$

TABLE C-2. INTERMEDIATE COST RESULTS FOR MODEL PLANTS WITH ADD-ON CONTROLS

Model Plant Code	Control Device	Total Exhaust (scfm)	VOC Inlet Concentration (ppm)	Heat Recovery (%)	Auxiliary Fuel Required (scfm)	Natural Gas Cost (\$/yr)	Electrical Cost (\$/yr)	Steam Costs (\$/yr)
A-I	Thermal Incinerator	4,000	405	70	42	25,151	3,196	0
A-I	Catalytic Incinerator	4,000	405	50	18	10,693	2,014	0
A-I	Condenser Filter w/Carbon	4,000	405	0	--	--	3,200	604
A-I	Condenser Filter	4,000	405	0	--	--	3,200	0
A-II	Thermal Incinerator	10,000	179	70	108	64,260	6,853	0
A-II	Catalytic Incinerator	10,000	179	35	61	36,291	3,602	0
A-II	Condenser Filter w/Carbon	10,000	179	0	--	--	20,000	1333
A-II	Condenser Filter	10,000	179	0	--	--	20,000	0
A-III	Thermal Incinerator	20,000	179	70	216	128,520	13,707	0
A-III	Catalytic Incinerator	20,000	179	35	122	72,468	7,181	0
A-III	Condenser Filter w/Carbon	20,000	179	0	--	--	40,000	2666
A-III	Condenser Filter	20,000	179	0	--	--	40,000	0
A-IV	Thermal Incinerator	30,000	216	70	314	186,563	20,553	0
A-IV	Catalytic Incinerator	30,000	216	35	174	103,644	10,802	0
A-IV	Condenser Filter w/Carbon	30,000	216	0	--	--	60,000	4845
A-IV	Condenser Filter	30,000	216	0	--	--	60,000	0

Note--Model plant code refers to model plants described in more detail in Chapter 3.

- C. Calculate combustion and dilution air.
Note: Additional air is not required, since sufficient oxygen is already present in the vent stream.
Note: No dilution air or combustion air calculations are necessary, since sufficient O₂ is already present in the vent stream. Therefore,
- a. Dilution air flow = 0 scfm
 - b. Combustion air flow = 0 scfm
 - c. New flow = old flow = 20,000 scfm
- D. Check the heat value of the precombustion vent stream to see if it is acceptable from a safety perspective. Streams would be diluted as necessary to ensure that heat contents are below maximums. Since 1.2 Btu/scf < 95 Btu/scf, no dilution is required for this stream.
- E. Minimum incinerator flow is 50 scfm. Streams less than 50 scfm will be increased by addition of air. Since 20,000 scfm > 50 scfm, no additional air is required.
- F. Establish temperature that incinerator operates:
Halogenated: 2,000°F
Nonhalogenated: 1,600°F
This stream is nonhalogenated and is incinerated at 1,600°F.
- G. Nonhalogenated streams are potential candidates for heat recovery.
If the heat value of the entire vent stream is below 13 Btu/scf (≈25% LEL), then the entire vent stream is eligible for heat (energy) recovery in a heat exchanger.
Since 1.2 < 13, this stream is a candidate for energy recovery.

H. Calculate the auxiliary fuel (Q_{af}) requirement.

$$Q_{af} = \frac{\{0.0739 * \text{Newflow} * [0.255 * (1.1 * \text{Incinerator Temperature} - \text{Temperature Gas} - 0.1 * 77) - (\text{Heat Value}/0.0739)]\}}{\{0.0408 * [21,502 - 1.1 * 0.255 * (\text{Incinerator Temperature} - 77)]\}}$$

$$\text{Incinerator Temperature} = 1,600^{\circ}\text{F}$$

1. For 0 percent heat recovery,
Gas temperature = 250°F
2. For 35 percent heat recovery,
Gas temperature = $0.35 (1600 - 250) + 250$
= 722.5°F
3. For 50 percent heat recovery,
Gas temperature = $0.50 (1600 - 250) + 250$
= 925°F
4. For 70 percent heat recovery,
Gas temperature = $0.70 (1600 - 250) + 250$
= $1,195^{\circ}\text{F}$

Note: For each heat recovery level, there will be different auxiliary fuel flows, with lower auxiliary fuel flows required for higher energy recovery scenarios. However, capital investment costs for higher heat recovery systems are also higher, so an economic tradeoff is involved in selecting the lowest cost systems. System costs are calculated for all four scenarios and the system with the lowest annualized is selected.

5. For 0 percent heat recovery and $T = 250^{\circ}\text{F}$,

$$Q_{af} = \frac{[.0739 * 20,000 * [.255 * (1.1 * 1,600 - T - 0.1 * 77) - (1.2/.0739)]]}{[0.0408 * [21,502 - (1.1 * .255 * (1,600 - 77))]}$$

$$Q_{af} = \frac{[636,421.62 - 376.89T]}{859.85}$$

$$Q_{af} = 630.5 \text{ scfm}$$

(See OAQPS Control Cost Manual, Incinerator Chapter, for derivation and assumptions.)

6. At 35 percent heat recovery,
 $Q_{af} = 423.4 \text{ scfm for } T = 722.5^{\circ}\text{F}$
7. At 50 percent heat recovery,
 $Q_{af} = 334.7 \text{ scfm for } T = 925^{\circ}\text{F}$
8. At 70 percent heat recovery,
 $Q_{af} = 216.3 \text{ scfm for } T = 1,195^{\circ}\text{F}$
- I. Ensure that sufficient auxiliary fuel is added to stabilize flame (5 percent of TEI).
1. Thermal Energy

$$\text{Input (TEI)} = 0.0739 * (\text{new flow} + Q_{af}) * 0.255 * (\text{incinerator temperature} - 77)$$

At 0 percent heat recovery,

$$\text{TEI} = 0.0739 * (20,000 + 630.5) * 0.255 * (1,600 - 77)$$

$$\text{TEI} = 592,098$$
2. $Q_{af} = (0.05 * 592,098) / (0.0408 * 21,502)$
 $= 33.7 \text{ scfm} < 630.5 \text{ scfm}.$

Enough fuel is added to stabilize flame.
3. At 35 percent heat recovery,

$$\text{TEI} = 0.0739 * (20,000 + 423.4) * 0.255 * (1,600 - 77) = 586,155$$

$$Q_{af} = 33.4 \text{ scfm} < 423.4 \text{ scfm}$$
4. At 50 percent heat recovery,

$$\text{TEI} = 0.0739 * (20,000 + 334.7) * 0.255 * (1,600 - 77) = 583,609$$

$$Q_{af} = 33.3 \text{ scfm} < 334.7 \text{ scfm}$$
5. At 70 percent heat recovery,

$$\text{TEI} = 0.0739 * (20,000 + 216.3) * 0.255 * (1,600 - 77) = 580,211$$

$$Q_{af} = 33.1 \text{ scfm} < 216.3 \text{ scfm}$$
- J. Calculate the total volumetric flow rate of gas through the incinerator, Q_{fi} . Include auxiliary air for the natural gas.

1. $Q_{fi} = \text{new flow} + Q_{af}$
(No combustion air for auxiliary fuel is needed, since sufficient oxygen is present in waste gas stream.)
2. $Q_{fi} = \text{New flow} + Q_{af}$
 $Q_{fi} = 20,000 + 630.5$
 $= 20,630 \text{ scfm}$
 At heat recovery = 35 percent, $Q_{fi} = 20,423 \text{ scfm}$
 At heat recovery = 50 percent, $Q_{fi} = 20,335 \text{ scfm}$
 At heat recovery = 70 percent, $Q_{fi} = 20,216 \text{ scfm}$

C.2.2 Estimating Thermal Incinerator Total Capital Investment

- A. The equipment cost (EC) algorithms are only good for the range of 500 scfm to 50,000 scfm. The minimum design size is 500 scfm. The CE index used is from May 1989.

$$\text{Design } Q = Q_{fi} > 500 \text{ scfm}$$

1. For 0 percent heat recovery,
 $EC = 10,294 * (\text{Design } Q^{.2355}) * (\# \text{ incinerators}) * (\text{CE INDEX}/340.1)$
 $EC = 10,294 * (20,630^{.2355}) * 1 * (355.6/340.1)$
 $EC = \$111,687$
2. For 35 percent heat recovery,
 $EC = 13,149 * (\text{Design } Q^{.2609}) * (\# \text{ incinerators}) * (\text{CE INDEX}/340.1)$
 $EC = 13,149 * (20,423^{.2609}) * (1) * (355.6/340.1)$
 $EC = \$183,129$
3. For 50 percent heat recovery,
 $EC = 17,056 * (\text{Design } Q^{.2502}) * (\# \text{ incinerators}) * (\text{CE INDEX}/340.1)$
 $EC = 17,056 * (20,335^{.2502}) * (1) * (355.6/340.1)$
 $EC = \$213,381$
4. For 70 percent heat recovery,
 $EC = 21,342 * (\text{Design } Q^{.2500}) * (\# \text{ incinerators}) * (\text{CE INDEX}/340.1)$
 $EC = 21,342 * (20,216^{.2500}) * (1) * (355.6/340.1)$
 $EC = \$266,081$

- B. Add duct cost. On the basis of an article in Chemical Engineering (May 1990) and assuming 1/8-in. carbon steel and 24-in. diameter with two elbows per 100 ft.

$$\text{Duct cost} = \{ [(210 * 24^{0.839}) + (2 * 4.52 * 24^{1.43})] * (\text{length}/100) \} * (\text{CE INDEX}/352.4)$$

$$\text{Duct cost} = \$11,722.52 \text{ (for length of 300 ft)}$$

- C. Add auxiliary collection fan cost, based on 1988 Richardson Manual.

$$\text{Fan cost} = (79.1239 * \text{Design } Q^{0.5612}) * 355.6/342.5$$

1. For 0 percent heat recovery, design $Q = 20,630$ scfm, so fan cost = \$21,672
2. For 35 percent heat recovery, design $Q = 20,423$ scfm, so fan cost = \$21,550
3. For 50 percent heat recovery, design $Q = 20,335$ scfm, so fan cost = \$21,498
4. For 70 percent heat recovery, design $Q = 20,216$ scfm, so fan cost = \$21,427

- D. Total Equipment Cost (EC_{tot}), is given by:

$$EC_{\text{tot}} = EC + \text{duct cost} + \text{fan cost}$$

1. For 0 percent heat recovery,

$$\begin{aligned} EC_{\text{tot}} &= EC + \text{duct cost} + \text{fan cost} \\ &= 111,687 + 11,723 + 21,672 \\ &= \$145,082 \end{aligned}$$
2. For 35 percent heat recovery,

$$\begin{aligned} EC_{\text{tot}} &= EC + \text{duct cost} + \text{fan cost} \\ &= 183,129 + 11,723 + 21,550 \\ &= \$216,402 \end{aligned}$$
3. For 50 percent heat recovery,

$$\begin{aligned} EC_{\text{tot}} &= EC + \text{duct cost} + \text{fan cost} \\ &= 213,381 + 11,723 + 21,498 \\ &= \$246,602 \end{aligned}$$
4. For 70 percent heat recovery,

$$EC_{\text{tot}} = EC + \text{duct cost} + \text{fan cost}$$

$$= 266,081 + 11,723 + 21,427$$

$$= \$299,231$$

E. Purchased Equipment Cost (PEC) is given by:

$$PEC = 1.18 * EC_{tot}$$

$$\text{For 0 percent heat recovery, } PEC = \$171,197$$

$$\text{For 35 percent heat recovery, } PEC = \$255,354$$

$$\text{For 50 percent heat recovery, } PEC = \$290,990$$

$$\text{For 70 percent heat recovery, } PEC = \$353,093$$

F. Estimate Total Capital Investment (TCI).

Total capital investment includes the following cost items:

Purchased Equipment Cost	PEC
Foundation & Supports	0.08 PEC
Handling & Erection	0.14 PEC
Electrical	0.04 PEC
Piping (Ductwork & Valving)	0.02 PEC
Insulation for Ductwork	0.01 PEC
Painting	0.01 PEC
Engineering	0.10 PEC
Construction & Field Expenses	0.05 PEC
Contractor Fees	0.10 PEC
Start-Up	0.02 PEC
Performance Test	0.01 PEC
Contingencies	<u>0.03 PEC</u>
	1.61 PEC

Where 1.61 is the installation factor for Design Q $\geq 20,000$.

If Design Q $< 20,000$ the installation factor = 1.25 (OCCM)

1. If 0 percent heat recovery,

$$TCI = 1.61 * PEC$$

$$= 1.61 * 171,197$$

$$= \$275,627$$

2. If 35 percent heat recovery,

$$TCI = 1.61 * PEC$$

$$= 1.61 * 255,354$$

$$= \$411,120$$

3. If 50 percent heat recovery,

$$\begin{aligned} \text{TCI} &= 1.61 * \text{PEC} \\ &= 1.61 * 290,990 \\ &= \$468,494 \end{aligned}$$

4. If 70 percent heat recovery,

$$\begin{aligned} \text{TCI} &= 1.61 * \text{PEC} \\ &= 1.61 * 353,093 \\ &= \$568,480 \end{aligned}$$

C.2.3 Calculating Annual Costs for Thermal Incinerators

A. Operating labor (OL), including supervision
(15 percent)

1. Assume OL rate = \$15.64/hr
(0.5 hr per shift)

Assume operating hours = 3,000

$$\begin{aligned} \text{OL} &= (0.5 * \text{Operating hours}) / 8 * \\ &(\$15.64/\text{hr}) (1.15) \end{aligned}$$

$$\text{OL} = \$3,372/\text{yr}$$

B. Maintenance labor (ML) and materials

$$\text{ML} = (0.5/8 * 3,000) * (\$17.21/\text{hr})$$

$$\text{ML} = \$3,227$$

$$\text{Materials} = \text{ML} = \$3,227$$

C. Utilities = Natural Gas and Electrical Costs (Elec)

Assume value of natural gas = \$3.30/1,000 scf

1. For 0 percent heat recovery,

$$\begin{aligned} \text{Natural gas} &= (3.30/1,000) * Q_{af}(\text{scfm}) * 60(\text{min/hr}) \\ &* \text{Operating hours} \end{aligned}$$

$$\begin{aligned} \text{Natural gas} &= (3.30/1,000) * (630.5)(\text{scfm}) * (60) * \\ &3,000 \\ &= \$374,517 \end{aligned}$$

$$\text{Power} = (1.17 * 10^{-4} * Q_{fi} * 4) / 0.60$$

$$= (1.17 * 10^{-4} * 20,630 * 4) / 0.60$$

$$= 16.09 \text{ kW}$$

$$\text{Elec} = (0.061 \text{ \$/kWh}) * (16.09 \text{ kW}) * (3,000\text{hr})$$

$$= \$2,945$$

2. For 35 percent heat recovery,

$$\begin{aligned} \text{Natural gas} &= (3.30/1,000) * (423.4) * (60) * \\ &(3,000) \end{aligned}$$

$$\begin{aligned}
&= \$251,500 \\
\text{Power} &= (1.17 * 10^{-4} * 20,423 * 8)/0.60 \\
&= 31.86 \text{ kW} \\
\text{Elec} &= (0.061 \text{ \$/kWh}) * (21.86 \text{ kW}) * \\
&\quad (3,000\text{hr}) \\
&= \$5,830
\end{aligned}$$

3. For 50 percent heat recovery,

$$\begin{aligned}
\text{Natural gas} &= (3.3/1,000) * (334.7) * (60) * \\
&\quad (3,000) \\
&= \$198,811 \\
\text{Power} &= (1.17 * 10^{-4} * 20,335 * 12)/0.60 \\
&= 47.58 \text{ kW} \\
\text{Elec} &= (0.061 \text{ \$/kWh}) * (47.58 \text{ kW}) * \\
&\quad (3,000\text{hr}) \\
&= \$8,708
\end{aligned}$$

4. For 70 percent heat recovery,

$$\begin{aligned}
\text{Natural gas} &= (3.3/1,000) * (216.3) * (60) * \\
&\quad (3,000) \\
&= \$128,482 \\
\text{Power} &= (1.17 * 10^{-4} * 20,216 * 19)/0.60 \\
&= 74.90 \text{ kW} \\
\text{Elec} &= \$13,707
\end{aligned}$$

D. Total Direct Annual Cost (DAC) is given by:
DAC = OL + ML + Material + Natural Gas + Elec

1. For 0 percent heat recovery,

$$\begin{aligned}
\text{DAC} &= 3,372 + 3,227 + 3,227 + 374,517 + 2,945 \\
&= \$387,288/\text{yr}
\end{aligned}$$

2. For 35 percent heat recovery,

$$\begin{aligned}
\text{DAC} &= 3,372 + 3,227 + 3,227 + 251,500 + 5,830 \\
&= \$267,156/\text{yr}
\end{aligned}$$

3. For 50 percent heat recovery,

$$\begin{aligned}
\text{DAC} &= 3,372 + 3,227 + 3,227 + 198,811 + 8,708 \\
&= \$217,344/\text{yr}
\end{aligned}$$

4. For 70 percent heat recovery,

$$\begin{aligned}
\text{DAC} &= 3,372 + 3,227 + 3,227 + 128,482 + 13,707 \\
&= \$152,015/\text{yr}
\end{aligned}$$

- E. Overhead = $0.60 * (OL + ML + Material)$
 = \$5,896/yr
- F. Administrative = 2 percent of TCI, Tax = 1 percent
 of TCI, Insurance = 1 percent of TCI.
- 1. For 0 percent heat recovery,
 Administration = $(0.02)(275,627)$
 = \$5,513/yr
 Tax = $0.01 * TCI$
 Tax = \$2,756/yr
 Insurance = $0.01 * TCI$
 = \$2,756/yr
- 2. For 35 percent heat recovery,
 Administration = $(0.02)(411,120)$
 = \$8,222/yr
 Tax = \$4,111/yr
 Insurance = \$4,111/yr
- 3. For 50 percent heat recovery,
 Administration = $(0.02)(468,494)$
 = \$9,370/yr
 Tax = \$4,685/yr
 Insurance = \$4,685/yr
- 4. For 70 percent heat recovery,
 Administration = $(0.02)(568,480)$
 = \$11,370/yr
 Tax = \$5,685/yr
 Insurance = \$5,685/yr
- G. Annualized Capital Recovery Costs (CRC) is given
 by:
 CRC = CRF * TCI, where CRF is the Capital
 Recovery Factor. Assuming 10-year
 equipment life and 10 percent interest,
 CRF = 0.16275.
- 1. For 0 percent heat recovery,
 CRC = $0.16275 * 275,627$
 = \$44,858

2. For 35 percent heat recovery,

$$\begin{aligned} \text{CRC} &= 0.16275 * 411,120 \\ &= \$66,910 \end{aligned}$$
 3. For 50 percent heat recovery,

$$\begin{aligned} \text{CRC} &= 0.16275 * 468,494 \\ &= \$76,247 \end{aligned}$$
 4. For 70 percent heat recovery,

$$\begin{aligned} \text{CRC} &= 0.16275 * 568,480 \\ &= \$92,520 \end{aligned}$$
- H. Total Indirect Annual Cost (IAC) is given by:

$$\begin{aligned} \text{IAC} &= \text{overhead} + \text{administrative} + \text{tax} \\ &\quad + \text{insurance} + \text{CRC} \end{aligned}$$
1. For 0 percent heat recovery,

$$\begin{aligned} \text{IAC} &= 5,896 + 5,513 + 2,756 + 2,756 + 44,858 \\ &= \$61,779/\text{yr} \end{aligned}$$
 2. For 35 percent heat recovery,

$$\begin{aligned} \text{IAC} &= 5,896 + 8,222 + 4,111 + 4,111 + 66,910 \\ &= \$89,250/\text{yr} \end{aligned}$$
 3. For 50 percent heat recovery,

$$\begin{aligned} \text{IAC} &= 5,896 + 9,370 + 4,685 + 4,685 + 76,247 \\ &= \$100,883/\text{yr} \end{aligned}$$
 4. For 70 percent heat recovery,

$$\begin{aligned} \text{IAC} &= 5,896 + 11,370 + 5,685 + 5,685 + 92,520 \\ &= \$121,156/\text{yr} \end{aligned}$$
- I. Total Annual Cost (TAC) is given by:

$$\begin{aligned} \text{TAC} &= \text{IAC} + \text{DAC} = \text{total indirect annual cost} + \\ &\quad \text{total direct annual cost} \end{aligned}$$
1. For 0 percent heat recovery,

$$\begin{aligned} \text{TAC} &= 61,779 + 387,288 \\ &= \$449,067/\text{yr} \end{aligned}$$
 2. For 35 percent heat recovery,

$$\text{TAC} = \$356,406/\text{yr}$$
 3. For 50 percent heat recovery,

$$\text{TAC} = \$318,227/\text{yr}$$
 4. For 70 percent heat recovery,

$$\text{TAC} = \$273,171/\text{yr}$$

Note that the lowest TAC is obtained from the 70 percent heat recovery system. Therefore, this system is selected as the optimum thermal incinerator design.

C.3.0 CATALYTIC INCINERATOR CALCULATIONS

The calculations are based on QAOPS Control Cost Manual, Chapter 3.0. The stream costed in this example is Model Plant A-III, a heatset facility. The dryer exhaust characteristics for this model plant are:

VOC to be controlled	:	Ink Solvents*
MW	:	175.4 lb/lb mole
Flow rate (total)	:	20,000 scfm
VOC flow rate	:	72.5 lb/hr
Heat value	:	1.2 Btu/scf
Oxygen content	:	21%
Inert content	:	Assume all N ₂
Gas inlet temperature	:	250°F

C.3.1 Sizing Calculations for Catalytic Incineration

The information and calculations of Section C.2.1 A through J also apply to catalytic incinerators and the cost estimates for Model Plant A-III. The following steps are necessary to complete the sizing calculations.

K. Establish the desired outlet temperature of the catalyst bed, T_{fi} .

$$T_{fi} = 700^{\circ}\text{F}$$

L. Calculate the waste gas temperature at the exit of the preheater.

1. For 0 percent heat recovery,

$$\text{Gas Temperature } (T_{wo}) = 250^{\circ}\text{F}$$

2. For 35 percent heat recovery,

$$\begin{aligned}\text{Gas Temperature} &= 0.35 (700 - 250) + 250 \\ &= 407.5^{\circ}\text{F}\end{aligned}$$

3. For 50 percent heat recovery,

$$\begin{aligned}\text{Gas Temperature} &= 0.50 (700 - 250) + 250 \\ &= 475^{\circ}\text{F}\end{aligned}$$

4. For 70 percent heat recovery,
 Gas Temperature = $0.70 (700 - 250) + 250 T_{wo}$
 = 565°F

M. Calculate the auxiliary fuel requirement, Q_{af}

$$Q_{af} = \frac{\{0.0739 * \text{Newflow} * [0.248 * (1.1 * \text{Incinerator Temperature} - \text{Temperature Gas} - 0.1 * 77) - (\text{Heat value}/0.0739)]\}}{0.0408 * [21,502 - 1.1 * 0.255 * (\text{incinerator temperature} - 77)]}$$

 Incinerator temperature = $2,000^{\circ}\text{F}$

1. For 0 percent heat recovery,

$$Q_{af} = \frac{0.0739 * 20,000 * [0.248 * (1.1 * 700 - T - 0.1 * 77) - (1.2 / 0.739)]}{0.0408 * [21,502 - (1.1 * 0.248 * (700 - 77))]}$$

$$Q_{af} = \frac{255,416.727 - 366.54T}{870.35}$$

$$Q_{af} = 189 \text{ scfm for } T = 250^{\circ}\text{F}$$

2. For 35 percent heat recovery,

$$Q_{af} = 122 \text{ scfm for } T = 407.5^{\circ}\text{F}$$

3. For 50 percent heat recovery,

$$Q_{af} = 94 \text{ scfm for } T = 475^{\circ}\text{F}$$

4. For 70 percent heat recovery,

$$Q_{af} = 56 \text{ scfm for } T = 565^{\circ}\text{F}$$

N. Verify that the auxiliary fuel requirements are sufficient to stabilize the burner flame.

$$\text{Thermal Energy Input (TEI)} = 0.0739 * (\text{New Flow} + Q_{af}) * (0.248 * (\text{Incinerator Temperature} - 250))$$

1. For 0 percent heat recovery,

$$\text{TEI} = 0.0739 * (20,000 + 189) * (.248 * (700 - 250))$$

$$\text{TEI} = 166,504$$

$$Q_{af} = (0.05 * 166,504) / (0.0408 * 21,502) = 9.49$$

Note: Verification $9.49 < 189$, therefore, sufficient fuel is added to stabilize the burner flame.

2. For 35 percent heat recovery,
- $$\text{TEI} = 0.0739 * (20,000 + 122) * (0.248 * (700 - 250))$$
- $$\text{TEI} = 165,951$$
- $$\text{Q}_{af} = (0.05 * 165,951) / (0.0408 * 21,502)$$
- $$\text{Q}_{af} = 9.5$$
- Note: Verification $9.5 < 122$; therefore, sufficient fuel is added to stabilize the burner flame.
3. For 50 percent heat recovery,
- $$\text{TEI} = 0.0739 * (20,000 + 94) * (0.248 * (700 - 250))$$
- $$\text{TEI} = 165,720$$
- $$\text{Q}_{af} = (0.05 * 165,720) / (0.0408 * 21,502)$$
- $$\text{Q}_{af} = 9.4$$
- Note: Verification $9.4 < 94$; therefore, sufficient fuel is added to stabilize the burner flame.
4. For 70 percent heat recovery,
- $$\text{TEI} = 0.0739 * (20,000 + 56) * (0.248 * (700 - 250))$$
- $$\text{TEI} = 165,407$$
- $$\text{Q}_{af} = (0.05 * 165,407) / (0.0408 * 21,502)$$
- $$\text{Q}_{af} = 9.4$$
- Note: Verification $9.4 < 56$; therefore, sufficient fuel is added to stabilize the burner flame.
0. Estimate the inlet temperature to the catalyst bed, T_{fi} (to ensure that the inlet temperature is sufficient to ignite the combustible organic compounds in the catalyst that was selected for use).
- $$\text{T}_{ri} = \frac{\{0.0408 * \text{Q}_{af} * [21,502 + (1.1 * 0.248 * 77)] + [0.0739 * 20,000 * 0.248 * (\text{temperature gas} + 0.1 * 77)]\}}{\{1.1 * 0.248 * [(0.0408 * \text{Q}_{af}) + (0.0739 * 20,000)]\}}$$

1. For 0 percent heat recovery,
 $(Q_{af} = 189 \text{ scfm}, T_{wo} = 250^{\circ}\text{F})$

$$T_{ri} = \frac{878.14Q_{af} + 366.54T_{wo} + 2822.39}{.011Q_{af} + 403.1984}$$

 $T_{ri} = 643^{\circ}\text{F}$

Note: On the basis of ignition temperatures shown in Table 3.2 of OAOPS Control Cost Manual, 643°F is sufficient to ignite the organic compounds of interest.

2. For 35 percent heat recovery,
 $(Q_{af} = 122 \text{ scfm}, T_{wo} = 407.5^{\circ}\text{F})$
 $T_{ri} = 641^{\circ}\text{F}$

Note: 641°F is sufficient to ignite the organic compounds of interest.

3. For 50 percent heat recovery,
 $(Q_{af} = 94 \text{ scfm}, T_{wo} = 475^{\circ}\text{F})$
 $T_{ri} = 642^{\circ}\text{F}$

Note: 642°F is sufficient to ignite the organic compounds of interest.

4. For 70 percent heat recovery,
 $(Q_{af} = 56 \text{ scfm}, T_{wo} = 565^{\circ}\text{F})$
 $T_{ri} = 642^{\circ}\text{F}$

Note: 642°F is sufficient to ignite the organic compounds of interest.

P. Calculate the total volumetric flow rate of gas through the incinerator, Q_{fi} .

$$Q_{fi} = Q_{wo} + Q_a + Q_{af}$$

1. For 0 percent heat recovery,
 $Q_{fi} = 20,000 + 0 + 189$
 $= 20,189 \text{ scfm}$

2. For 35 percent heat recovery,
 $Q_{fi} = 20,000 + 0 + 122$
 $= 20,122 \text{ scfm}$

3. For 50 percent heat recovery,
 $Q_{fi} = 20,000 + 0 + 94$
 $= 20,094 \text{ scfm}$

4. For 70 percent heat recovery,
 $Q_{fi} = 20,000 + 0 + 56$
 $= 20,056 \text{ scfm}$
- Q. Calculate the volume of catalyst in the catalyst bed.
 space velocity: $\bar{\emptyset} = \frac{Q_{fi}}{V_{cat}}$
 $V_{cat} =$ Overall bulk volume of the catalyst bed,
 including voids between the particles
 (ft³)

Assuming space velocity = 500 min⁻¹.

1. For 0 percent heat recovery,
 $Q_{fi} @ 60^{\circ}\text{F} = 20,189 \left(\frac{60 + 460}{77 + 460} \right)$
 $= 19,550 \text{ ft}^3/\text{min}$
 $V_{cat} = \left(\frac{19,550 \text{ ft}^3/\text{min}}{500 \text{ min}^{-1}} \right)$
 $= 39.1 \text{ ft}^3$
2. For 35 percent heat recovery,
 $Q_{fi} @ 60^{\circ}\text{F} = 20,122 (0.968)$
 $= 19,485 \text{ ft}^3/\text{min}$
 $V_{cat} = \left(\frac{19,485 \text{ ft}^3/\text{min}}{500 \text{ min}^{-1}} \right)$
 $= 39.0 \text{ ft}^3$
3. For 50 percent heat recovery,
 $Q_{fi} @ 60^{\circ}\text{F} = 20,094 (0.968)$
 $= 19,457 \text{ ft}^3/\text{min}$
 $V_{cat} = \left(\frac{19,457 \text{ ft}^3/\text{min}}{500 \text{ min}^{-1}} \right)$
 $= 38.9 \text{ ft}^3$
4. For 70 percent heat recovery,
 $Q_{fi} @ 60^{\circ}\text{F} = 20,056 (0.968)$
 $= 19,421 \text{ ft}^3/\text{min}$
 $V_{cat} = \left(\frac{19,421 \text{ ft}^3/\text{min}}{500 \text{ min}^{-1}} \right)$
 $= 38.8 \text{ ft}^3$

C.3.2 Estimating Catalytic Incinerator Total Capital Investment

- A. The EC algorithms are applicable for the flowrate of 2,000 scfm to 50,000 scfm for fixed bed or monolithic catalysts.

1. For 0 percent heat recovery,
 - $Q_{tot} = 20,279 \text{ scfm}$
 - $EC = 1,105 Q_{tot}^{0.5471} * (CE \text{ index}/340.1)$
 - $EC = 1,105 (20,189^{0.5471}) * (355.6/340.1)$
 - $EC = \$261,846$
2. For 35 percent heat recovery,
 - $Q_{tot} = 20,122 \text{ scfm}$
 - $EC = 3,623 (Q_{tot}^{0.4189}) * (1.0456)$
 - $EC = \$240,564$
3. For 50 percent heat recovery,
 - $Q_{tot} = 20,094 \text{ scfm}$
 - $EC = 1,215 (Q_{tot}^{0.5575}) * (1.0456)$
 - $EC = \$318,340$
4. For 70 percent heat recovery,
 - $Q_{tot} = 20,056 \text{ scfm}$
 - $EC = 1,443 (Q_{tot}^{0.5527}) * (1.0456)$
 - $EC = \$360,140$
- B. Add duct cost. On the basis of an article in Chemical Engineering (May 1990) and assuming 1/8 in. carbon steel and 24 in. diameter with two elbows per 100 ft.
 - $$\text{Duct cost} = \{ (210 * 24^{0.839}) + (2 * 4.52 * 24^{1.43}) * (\text{length}/100) \} * (CE \text{ index}/352.4)$$
 - $$\text{Duct cost} = \$11,722.52 \text{ (for length of 300ft)}$$
- C. Add auxiliary collection fan cost, linear regression of data presented in 1988 Richardson Manual.
 - $$\text{Fan cost} = (79.1239 * \text{design } Q^{0.5612}) * (355.6/342.5)$$
 1. For 0 percent heat recovery,
 - $\text{Design } Q = 20,189 \text{ scfm}$
 - $\text{Fan cost} = (79.1239 * 20,189^{0.5612}) * 1.038$
 - $\text{Fan cost} = \$21,406$
 2. For 35 percent heat recovery,
 - $\text{Design } Q = 20,122 \text{ scfm}$
 - $\text{Fan cost} = \$21,366$

3. For 50 percent heat recovery,
 Design Q = 20,094 scfm
 Fan cost = \$21,349
 4. For 70 percent heat recovery,
 Design Q = 20,056 scfm
 Fan cost = \$21,327
- D. Total Equipment Cost (EC_{tot}) is given by:
- $$EC_{tot} = EC + \text{duct cost} + \text{fan cost}$$
1. For 0 percent heat recovery,
 $EC_{tot} = 261,846 + 11,723 + 21,406$
 $EC_{tot} = \$294,975$
 2. For 35 percent heat recovery,
 $EC_{tot} = 240,564 + 11,723 + 21,366$
 $EC_{tot} = \$273,653$
 3. For 50 percent heat recovery,
 $EC_{tot} = 318,340 + 11,723 + 21,349$
 $EC_{tot} = \$351,412$
 4. For 70 percent heat recovery,
 $EC_{tot} = 360,140 + 11,723 + 21,327$
 $EC_{tot} = \$393,190$
- E. Purchased equipment cost (PEC) is given by:
- $$PEC = 1.18 * EC_{tot}$$
1. For 0 percent heat recovery,
 $PEC = \$348,071$
 2. For 35 percent heat recovery,
 $PEC = \$322,911$
 3. For 50 percent heat recovery,
 $PEC = \$414,666$
 4. For 70 percent heat recovery,
 $PEC = \$463,964$
- F. Total capital investment (TCI) is given by:
- $$TCI = 1.61 * PEC$$
1. For 0 percent heat recovery,
 $TCI = \$560,394$
 2. For 35 percent heat recovery,
 $TCI = \$519,887$

3. For 50 percent heat recovery,
TCI = \$667,612
4. For 70 percent heat recovery,
TCI = \$746,982

C.3.3 Calculation of Annual Costs for Catalytic Incinerators

- A. Operating labor (OL) including supervision (15 percent)
 1. Assume OL rate = \$15.64/hr
(0.5 hr per shift)
Assume operating hours = 3,000
OL = $(0.5 * \text{Operating hours}) / 8 * (\$15.64/\text{hr})$
(1.15)
OL = \$3,372
- B. Maintenance labor (ML) and materials
ML = $(0.5/8 * 3,000) * (\$17.21/\text{hr})$
ML = \$3,227
Materials = ML = \$3,227
- C. Catalyst replacement (in 1990 dollars)
100 percent of catalyst replaced every three years;
assume metal oxide catalyst used.
Cat cost = \$650/ft³ in 1988 dollars or
Cat cost = \$673/ft³ in 1990 dollars
 1. For 0 percent heat recovery,
V_{cat} = 39.1 ft³
Cat cost = $(39.1 \text{ ft}^3) (\$673/\text{ft}^3) * 0.40211$
Cat cost = \$10,581
 2. For 35 percent heat recovery,
V_{cat} = 39.0 ft³
Cat cost = \$10,554
 3. For 50 percent heat recovery,
V_{cat} = 38.9 ft³
Cat cost = \$10,527
 4. For 70 percent heat recovery,
V_{cat} = 38.8 ft³
Cat cost = \$10,500

D. Utilities = Natural Gas and Electrical costs
 Assume value of natural gas = \$3.30/1,000 scfm

1. For 0 percent heat recovery,
 Natural gas = $(3.30/1,000) * Q_{af} * 60 \text{ min/hr} * \text{Operating hour}$
 Natural gas = $(3.30/1,000) * 189 * 60 * 3000$
 Natural gas = \$112,266

2. For 35 percent heat recovery,
 Natural gas = $Q_{af} * 594$
 Natural gas = $122 * 594$
 Natural gas = \$72,468

3. For 50 percent heat recovery,
 Natural gas = $Q_{af} * 594$
 Natural gas = $94 * 594$
 Natural gas = \$55,836

4. For 70 percent heat recovery,
 Natural gas = $Q_{af} * 594$
 Natural gas = $56 * 594$
 Natural gas = \$33,264

E. Power = $(1.17 * 10^{-4} * Q_{fi} * \Delta P) / 0.60$,
 where ΔP = total pressure drop across the system.

1. For 0 percent heat recovery,
 $\Delta P = 6$
 $Q_{fi} = 20,189$
 Power = $1.95 * 10^{-4} * Q_{fi} * \Delta P$
 Power = 23.62 kW

2. For 35 percent heat recovery,
 $\Delta P = 10$
 $Q_{fi} = 20,122$
 Power = $1.95 * 10^{-4} * Q_{fi} * \Delta P$
 Power = 39.24 kW

3. For 50 percent heat recovery,
 $\Delta P = 14$
 $Q_{fi} = 20,094$
 Power = $1.95 * 10^{-4} * Q_{fi} * \Delta P$
 Power = 54.86 kW

4. For 70 percent heat recovery,
 $\Delta P = 21$
 $Q_{fi} = 20,056$
 $\text{Power} = 1.95 * 10^{-4} * Q_{fi} * \Delta P$
 $\text{Power} = 82.13 \text{ kW}$
- F. Elec Cost = $(\$0.061/\text{kW}) * (\text{POW}) * (3,000)$
1. For 0 percent heat recovery,
 $\text{POW} = 23.62 \text{ kW}$
 $\text{Elec Cost} = \$4,322/\text{yr}$
2. For 35 percent heat recovery,
 $\text{POW} = 39.24 \text{ kW}$
 $\text{Elec Cost} = \$7,181/\text{yr}$
3. For 50 percent heat recovery,
 $\text{POW} = 54.86 \text{ kW}$
 $\text{Elec Cost} = \$10,039/\text{yr}$
4. For 70 percent heat recovery,
 $\text{POW} = 82.13 \text{ kW}$
 $\text{Elec Cost} = \$15,030/\text{yr}$
- G. Total direct costs (TDC) + materials
 $\text{TDC} = \text{Operating labor} + \text{ML} + \text{maintenance}$
 $\text{material} + \text{cat cost} + \text{nat gas} + \text{elec cost}$
1. For 0 percent heat recovery,
 $\text{TDC} = 3,372 + 3,227 + 3,227 + 10,581 + 112,266 + 4,322$
 $\text{TDC} = \$136,995$
2. For 35 percent heat recovery,
 $\text{TDC} = 3,372 + 3,227 + 3,227 + 10,554 + 72,468 + 7,181$
 $\text{TDC} = \$100,029$
3. For 50 percent heat recovery,
 $\text{TDC} = 3,372 + 3,227 + 3,227 + 10,527 + 55,836 + 10,039$
 $\text{TDC} = \$86,228$
4. For 70 percent heat recovery,
 $\text{TDC} = 3,372 + 3,227 + 3,227 + 10,500 + 33,264 + 15,030$
 $\text{TDC} = \$68,620$

H. Overhead = 0.60 *(Operating labor + ML +
materials)
= \$5,896/yr

I. Administrative = 2 percent of TCI
Tax = 1 percent of TCI
Insurance = 1 percent of TCI

1. For 0 percent heat recovery,
Administrative = (0.02) (560,394)
= \$11,208
Tax = (0.01) (560,394)
= \$5,604
Insurance = (0.01) (560,394)
= \$5,604

2. For 35 percent heat recovery,
Administrative = (0.02) (519,887)
= \$10,398
Tax = (0.01) (519,887)
= \$5,199
Insurance = (0.01) (519,887)
= \$5,199

3. For 50 percent heat recovery,
Administrative = (0.02) (667,612)
= \$13,352
Tax = (0.01) (667,612)
= \$6,676
Insurance = (0.01) (667,612)
= \$6,676

4. For 70 percent heat recovery,
Administrative = (0.02) (746,982)
= \$14,940
Tax = (0.01) (746,982)
= \$7,470
Insurance = (0.01) (746,982)
= \$7,470

J. Annualized Capital Recovery Costs (AnnCap) is given
by:

AnnCap = CRF [TCI - 1.08 (cat cost)]

- AnnCap = 0.16275 * [TCI - 1.08 (cat cost)]
1. For 0 percent heat recovery,
 - TCI = 560,394
 - cat cost = 10,581
 - AnnCap = 0.16275 * 548,967
 - AnnCap = \$89,344
 2. For 35 percent heat recovery,
 - TCI = 519,887
 - cat cost = 10,554
 - AnnCap = 0.16275 * 508,489
 - AnnCap = \$82,757
 3. For 50 percent heat recovery,
 - TCI = 667,612
 - cat cost = 10,527
 - AnnCap = 0.16275 * 656,243
 - AnnCap = \$106,804
 4. For 70 percent heat recovery,
 - TCI = 746,982
 - cat cost = 10,500
 - AnnCap = 0.16275 * 735,642
 - AnnCap = \$119,726
- K. Total indirect capital cost (IC) is given by:
- IC = overhead + administrative + tax + insurance + AnnCap
1. For 0 percent heat recovery,
 - IC = 5,896 + 11,208 + 5,604 + 5,604 + 89,344
 - IC = \$117,656
 2. For 35 percent heat recovery,
 - IC = 5,896 + 10,398 + 5,199 + 5,199 + 82,757
 - IC = \$109,449
 3. For 50 percent heat recovery,
 - IC = 5,896 + 13,352 + 6,676 + 6,676 + 106,804
 - IC = \$139,404
 4. For 70 percent heat recovery,
 - IC = 5,896 + 14,940 + 7,470 + 7,470 + 119,726
 - IC = \$155,502

- L. Total annual cost (TAC) is:
- $$\text{TAC} = \text{IC} + \text{TDC}$$
1. For 0 percent heat recovery,

$$\text{TAC} = 117,656 + 136,995$$

$$\text{TAC} = \$254,652$$
 2. For 35 percent heat recovery,

$$\text{TAC} = 109,449 + 100,029$$

$$\text{TAC} = \$209,478$$
 3. For 50 percent heat recovery,

$$\text{TAC} = 139,404 + 86,228$$

$$\text{TAC} = \$225,632$$
 4. For 70 percent heat recovery,

$$\text{TAC} = 155,502 + 68,620$$

$$\text{TAC} = \$224,122$$

Note that the lowest total annual cost is obtained from the 35 percent heat recovery system. Therefore, this system is selected as the optimum catalytic incinerator design.

C.4.0 CONDENSER FILTER CALCULATIONS

This section presents the calculations used to estimate the cost of applying condenser filters to dryer exhaust streams. Costs are based on vendor quotes and vendor responses to questionnaires as described in Chapter 6.0. Model Plant A-III was used in the sample calculations. The exhaust stream characteristics are shown in Table C-2.

C.4.1 Estimating Total Capital Investment

- A. As shown in Table C-2, Model Plant A-III has an exhaust stream of 20,000 scfm. From Table 6-2, the EC for a condenser filter sized to handle 10,000 scfm is \$170,000. Assuming two condenser filters will be used, each rated at 10,000 scfm, the equipment cost for the condenser filters (EC_{cf}) is given by:

$$EC_{cf} = \$170,000 * 2$$

$$EC_{cf} = \$340,000$$
- B. For a system with a carbon adsorption unit as the final stage of gas treatment, calculate the EC of

the carbon adsorption unit (EC_{ad}) using the following equation (supplied by vendor):

$$EC_{ad} = EC_{cf} * 0.20$$

$$EC_{ad} = (340,000) * 0.20$$

$$EC_{ad} = \$68,000$$

- C. Ductwork costs are calculated on the basis of an article in Chemical Engineering (May 1990) and assuming 1/8 in. carbon steel and 24 in. diameter duct with two elbows every 100 ft.

$$\text{Duct cost} = [(210 * 24^{0.839}) + (2 * 4.52 * 24^{1.43})] * 3 * (\text{CE Index} / 352.4)$$

$$\text{Duct cost} = (11,617) * (355.6 / 352.4)$$

$$\text{Duct cost} = \$11,723 \text{ (for length of 300 ft)}$$

- D. Fan cost is calculated on the basis of the following equation derived from 1988 data from The Richardson Manual:

$$\text{Fan cost} = (79.1239 * Q^{0.5612}) * \text{CE Index} / 342.5$$

$$\text{Fan cost} = \$20,508 \text{ (for } Q = 20,000 \text{ scfm)}$$

- E. Total equipment cost (EC_{tot}) is given by:

$$EC_{tot} = EC_{cf} + EC_{ad} + \text{duct cost} + \text{fan cost}$$

$$EC_{tot} = 340,000 + 68,000 + 11,723 + 20,508$$

$$EC_{tot} = \$440,230$$

- F. Cost of auxiliaries/instrumentation (equations supplied by vendors) is given by:

$$\text{Auxiliaries} = 0.056 * EC_{tot}$$

$$\text{Auxiliaries} = \$24,653$$

- G. Cost of taxes (equations supplied by vendors) is given by:

$$\text{Tax} = 0.06 * EC_{tot}$$

$$\text{Tax} = \$26,414$$

- H. Cost of freight (equations supplied by vendors) is given by:

$$\text{Freight} = 0.006 * EC_{tot}$$

$$\text{Freight} = \$2,641$$

- I. Purchased equipment cost (PEC) is given by:

$$PEC = EC_{tot} + \text{auxiliaries} + \text{tax} + \text{freight}$$

$$\text{PEC} = 440,230 + 24,653 + 26,414 + 2,641$$

$$\text{PEC} = \$493,938$$

- J. Total direct cost (TDC) (using installation factors presented in Table 6-2) is given by:

$$\text{TDC} = 1.27 * \text{PEC}$$

$$\text{TDC} = \$627,302$$

- K. Total indirect cost (TIC) = $0.22 * \text{PEC}$

$$\text{TIC} = \$108,666$$

- L. Total capital investment (TCI) = $\text{TDC} + \text{TIC}$

$$\text{TCI} = 627,302 + 108,666$$

$$\text{TCI} = \$735,968$$

C.4.2 Estimating Total Annual Cost

- A. Operating labor (OL) for condenser filters is estimated using the annual cost assumptions listed in Table 6-3 (i.e., 0.5 hr per 8-hr shift). For systems with carbon adsorbers, use 1.0 hr per 8-hr shift.

1. Assume OL rate = \$15.64/hr, and operating hours = 3,000 hr/year

$$\text{OL} = (1/8) * (\text{Operating hours}) * (\text{labor rate})$$

$$\text{OL} = (1/8) * 3,000 * 15.64$$

$$\text{OL} = \$5,865$$

2. Assume supervisory cost is 15 percent of labor

$$\text{Supervisory cost} = 0.15 * \text{OL}$$

$$\text{Supervisory cost} = \$880$$

- B. Maintenance labor (ML) and materials

1. $\text{ML} = 0.8/8 * 3,000 * 17.21$

$$\text{ML} = \$5,163$$

2. $\text{Materials} = \text{ML}$

$$\text{Materials} = \$5,163$$

3. Carbon replacement (materials and labor), assuming a 5-year carbon life and 10 percent loading (based on vendor quote) is given by:

$$\begin{aligned} \text{Mass of Carbon} &= \left(\text{VOC} \frac{\text{lb}}{\text{hr}}\right) * \left(16 \frac{\text{hr}}{\text{day}}\right) * \left(10 \frac{\text{lb carbon}}{\text{lb VOC}}\right) \\ &= (217,600/3,000) * 16 * 10 \\ &= 11,605 \text{ lbs carbon} \end{aligned}$$

$$\begin{aligned} \text{Cost of Carbon} &= (11,605 \text{ lb}) * (2 \text{ \$/lb}) * 1.08 \\ &= \$25,067 \end{aligned}$$

Replacement

$$\begin{aligned} \text{Labor} &= (0.05 \text{ \$/lb}) * 11,605 \text{ lb} \\ &= \$580 \end{aligned}$$

Annual Carbon Replacement Costs

$$\begin{aligned} (\text{Materials \& Labor}) &= (25,057 + 580) * \text{CRF} \\ &= \$25,647 * 0.2638 \\ &= \$6,766/\text{yr} \end{aligned}$$

C. Electricity for condenser filter fans

Electrical costs for condenser filters estimated to be \$2/yr per scfm (based on vendor quote).

Therefore:

$$\begin{aligned} \text{Elec}_{\text{cf}} &= 2 * 20,000 \\ \text{Elec}_{\text{cf}} &= \$40,000/\text{yr} \end{aligned}$$

D. Electricity for carbon bed fan

Additional electricity costs for carbon bed systems are assumed negligible, based on vendor quotes. Since the model plants have 8-hr downtime each day, there is no need for fans to dry bed after desorption. The large system fans required for the condenser filter system are assumed capable of overcoming the additional pressure drop through the carbon bed.

E. Steam costs

Steam costs for carbon bed are calculated assuming 3.5 lb steam/lb VOC and a cost of \$3.5/1000 lb steam. Therefore:

$$\begin{aligned} \text{Steam} &= 3.5 * (3.5/1,000) * (217,000) \\ \text{Steam} &= \$2,666 \end{aligned}$$

- F. Total direct annual costs (DAC) is given by:
DAC = OL + Supervisor + ML + Materials + Annual
Carbon Replacement Cost + Elec_{cf} + Steam
DAC = \$65,839/yr
- G. Overhead = 0.60 * (OL + ML + Materials +
Supervisor)
Overhead = \$9,317/yr
- H. Administration = (0.02) * TCI
Administration = \$14,719/yr
- I. Property taxes = (0.01) * TCI
Property taxes = \$7,360/yr
- J. Insurance = (0.01) * TCI
Insurance = \$7,360/yr
- K. Capital recovery costs (CRC)
CRC are calculated using the capital recovery factor
(CRF) on the basis of a 10-yr equipment life and 10
percent interest rate:
CRC's = CRF * TCI
CRC's = 0.16280 * \$735,968
CRC's = \$119,816/yr
- L. Total indirect annual costs (IAC) is given by:
IAC = Overhead + Administration + Tax +
Insurance + CRC's
IAC = 9,317 + 14,719 + 7,360 + 7,360 + 119,816
IAC = \$158,571/yr
- M. Recovery credits (RC's)
RC's are calculated on the basis of \$0.63/gal value
and 4 gal of solvent recovered per 100 lb of ink
used (for 90 percent recovery):
RC's = (4/100) * 0.63 * 680,000 lb/yr * 95/90
RC's = \$18,088/yr
Note that the (95/90) correction factor accounts for
95 percent solvent recovery for carbon bed systems.
- N. Total annual cost (TAC) = DAC + IAC - RC
TAC = 65,839 + 158,571 - 18,088
TAC = \$206,322/yr

C.5.0 COSTS OF MATERIAL SUBSTITUTION AND PROCESS
MODIFICATIONS

The following sections show calculations for the costs of material substitution in fountain and cleaning solutions and process modifications to the fountain by magnetism and/or refrigeration of the fountain. Model Plant A-III was used in the example calculations.

C.5.1 Reduction in Alcohol

Alcohol reduction in the fountain results in a net savings to the printer. Since the cost of IPA was estimated at \$0.46 per pound, savings for the model plants from reducing IPA were calculated according to the following equation:

$$\begin{array}{rcll} \text{savings} & = & \text{alcohol} & \\ (\$) & & \text{reductions} & \\ & & (\text{tons/yr}) & \\ & \times & 2,000 & \\ & & (\text{lb/ton}) & \\ & \times & \$0.46 & \\ & & \text{per pound} & \\ & & \text{IPA} & \end{array} \quad (\text{C-1})$$

For Model Plant A-III, reduction to 3 percent alcohol resulted in an emission reduction of 252 tons VOC per year (see Chapter 5.0). Since IPA is 100 percent VOC, IPA reduction also was 252 tons per year. Using Equation C-1, the following calculation was used to estimate savings from alcohol reduction for Model Plant A-III:

$$\$232,000 = 252 \text{ tons IPA} \times 2000 \times \$0.46 \text{ reduced}$$

C.5.2 Use of Alcohol Substitutes

The use of alcohol substitutes as a control option for the model plants involves the elimination of alcohol, with a resulting savings, and the addition of alcohol substitutes, at a cost of \$1.55 per pound.

The costs from the use of alcohol substitutes are determined from the weight of alcohol substitute used to replace 306 tons of alcohol. See Equations 7 and B-7 (Chapter 5 and Appendix B, respectively) and the following equation:

$$\begin{array}{rcll} \text{cost} & = & \text{amount of alcohol} & \\ (\$) & & \text{substitute} & \\ & & (\text{pounds}) & \\ & \times & \$1.55 & \\ & & \text{per pound of} & \\ & & \text{alcohol substitute} & \end{array} \quad (\text{C-2})$$

For Model Plant A-III, this results in an alcohol substitute cost calculated as follows:

\$94,000 to remove = 61,200 pounds of x \$1.55 per pound
306 tons of alcohol alcohol substitute used substitute

For Model Plant A-III, the savings from alcohol reduction are calculated as in Equation C-1 above, for complete elimination of alcohol. For Model Plant A-III, the savings from alcohol reduction are:

$$\$281,000 = 306 \text{ tons IPA} \times 2000 \times \$0.46 \text{ reduced}$$

The overall costs for Model Plant A-III are equal to the savings from alcohol reduction minus the cost from using alcohol substitutes, shown below:

$$\$281,000 - 94,000 = \$187,000 \text{ savings with alcohol substitutes}$$

C.5.3 Use of Refrigerated Circulators

The cost of refrigerated circulators includes equipment costs as well as savings from reducing the amount of alcohol added to the fountain solution to maintain the same level of alcohol as before refrigeration.

The costs for refrigerated circulators are calculated on the basis of the cost factors shown in Table 6-6, Chapter 6.0. Capital costs are multiples of \$26,140, the total capital investment for each refrigerated circulator. In the cost analysis for the model plants, it was estimated that two refrigerated circulators were used per press.

For Model Plant A-III with four presses, eight refrigerated circulators were used to estimate costs for this control option, for a total capital cost of \$209,000.

Total annualized costs were determined from direct and indirect annual costs using the total capital investment and the cost factors of Chapter 6.0. For Model Plant A-III, the indirect annual costs are calculated as follows:

Administrative Charges,	
Property Taxes, and	
Insurance	= 0.04 * TCI
	= 0.04 * 209,000
	= \$8,360/yr
Capital Recovery	
Costs	= 0.1628 * TCI
	= \$34,025/yr

$$\begin{aligned} \text{Capital Recovery} \\ \text{Costs} &= 0.1628 * \text{TCI} \\ &= \$34,025/\text{yr} \end{aligned}$$

$$\begin{aligned} \text{Indirect Annual} \\ \text{Costs} &= 8,360 + 34,025 \\ &= \$42,385/\text{yr} \end{aligned}$$

For Model Plant A-III, the direct annual costs were calculated as follows:

$$\begin{aligned} \text{Electricity Cost} &= 8.05 \text{ kW} * 3000 \text{ hr/yr} * \\ \text{Electricity Cost} &= 0.061 \text{ \$/kWh} * \text{no. of circulators} \\ \text{Electricity Cost} &= 8.05 * 3000 * 0.061 * 8 \\ \text{Electricity Cost} &= \$11,785/\text{yr} \\ \text{Indirect Annual} \\ \text{Costs} &= \$42,385/\text{yr} \end{aligned}$$

Total annual costs for Model Plant A-III are the sum of the direct and indirect annual cost, shown below:

$$\begin{aligned} \text{Total Annual Costs} &= 42,385 + 11,785 \\ &= \$54,000/\text{yr} \end{aligned}$$

The reduction in alcohol consumption was calculated as 44 percent of the unrefrigerated level. The following equation was used:

$$\begin{aligned} \text{reduction in} \\ \text{alcohol consumption} \\ \text{with} \\ \text{refrigeration} \\ \text{(tons/year)} &= \frac{\text{alcohol use} \\ \text{without} \\ \text{refrigeration} \\ \text{(tons/year)}}{x 0.44} \quad (\text{C-3}) \end{aligned}$$

For Model Plant A-III, the reduction in consumption of alcohol from refrigeration of the fountain, from a baseline of 306 tons of IPA used per year, was calculated as follows:

$$\begin{aligned} \text{reduction in} \\ \text{alcohol consumption} \\ \text{with refrigeration} \\ \text{(tons/year)} &= 306 * 0.44 \\ &= 135 \text{ tons/yr} \end{aligned}$$

A savings of \$124,000 was calculated using Equation C-1 and the amount of alcohol eliminated (135 tons/yr).

Therefore, the overall costs for refrigerated circulators for Model Plant A-III are equal to the total annualized costs

minus the savings from reducing alcohol consumption, as shown below:

$$\begin{array}{rcl} \$70,000 & = & \$124,000 - \$54,000 \\ \text{total} & & \text{savings} \quad \text{costs} \\ \text{savings} & & \end{array}$$

C.5.4 Use of Magnetism

The costs of magnetism of the fountain solution for the model plants were calculated from equipment costs for the magnet provided by the vendor. Equipment costs are estimated at \$350 per magnet, assuming one magnet per unit; installation costs are expected to be minimal. For Model Plant A-III, with 22 units on the average, the TCI is calculated as follows:

$$\$7,700 = 22 \text{ units} \times \$350 \text{ per unit (one magnet per unit)}$$

The annualized equipment costs are calculated using a capital recovery factor of 0.163. For Model Plant A-III, total annual costs were calculated from the annualized equipment costs ($0.163 * \text{TCI}$) and indirect annual costs for taxes, insurance, and administration charges ($0.04 * \text{TCI}$), as follows:

$$\text{Total Annual Cost} = (\text{TCI} * 0.163) + (\text{TCI} * 0.04) \quad (\text{C-4})$$

For Model Plant A-III, the total annual costs for magnetism of the fountain solution were calculated using Equation C-4, as shown below:

$$\$1,561 = (7,700 * 0.163) + (7,700 * 0.04)$$

APPENDIX D

OFFSET LITHOGRAPHIC PRINTING
CTG MODEL RULE

APPENDIX D

OFFSET LITHOGRAPHIC PRINTING CTG MODEL RULE

D.1 INTRODUCTION

This appendix presents a model rule to limit volatile organic compound (VOC) emissions from offset lithographic printing operations. This rule is for informational purposes only and, as such, is not binding on the air quality management authority. However, the EPA expects that State and local air quality rules developed pursuant to this CTG will address all the elements covered in the model rule.

The remainder of this appendix contains the model rule. Separate sections cover the following rule elements: applicability, definitions, emissions standards, equipment standards, emissions standards testing, equipment standards testing, monitoring requirements, and reporting/recordkeeping.

D.2 APPLICABILITY

The provisions set forth in this model rule apply to the offset lithographic printing industry only. There are four types of offset lithographic printing: heatset web, non-heatset web (non-newspaper), non-heatset sheet-fed, and newspaper (non-heatset web). An affected facility may be defined as follows: one or more printing operations involved in at least one type of offset lithographic printing process.

Other types of printing operations, such as flexography, rotogravure, or letterpress, may be present in an offset lithographic printing facility; however, these operations are not subject to the requirements set forth in this model rule.

D.3 DEFINITIONS

Alcohol substitutes. Nonalcohol additives that contain VOC's and are used in the fountain solution. Some additives are used to reduce the surface tension of water; others (especially in the newspaper industry) are added to prevent piling (ink build-up).

Batch. A supply of fountain solution that is prepared and used without alteration until completely used or removed from the printing process.

Cleaning solution. Liquids used to remove ink and debris from the operating surfaces of the printing press and its parts.

Dampening system. Equipment used to deliver the fountain solution to the lithographic plate.

Fountain solution. A mixture of water, nonvolatile printing chemicals, and an additive (liquid) that reduces the surface tension of the water so that it spreads easily across the printing plate surface. The fountain solution wets the nonimage areas so that the ink is maintained within the image areas. Isopropyl alcohol, a VOC, is the most common additive used to reduce the surface tension of the fountain solution.

Heatset. Any operation where heat is required to evaporate ink oil from the printing ink. Hot air dryers are used to deliver the heat.

Lithography. A printing process where the image and nonimage areas are chemically differentiated; the image area is oil receptive and the nonimage area is water receptive. This method differs from other printing methods, where the image is a raised or recessed surface.

Non-heatset. Any operation where the printing inks are set without the use of heat. For the purposes of this rule, ultraviolet-cured and electron beam-cured inks are considered non-heatset.

Offset. A printing process that transfers the ink film from the lithographic plate to an intermediary surface (blanket), which, in turn, transfers the ink film to the substrate.

Press. A printing production assembly composed of one or many units to produce a printed sheet or web.

Sheet-fed. A printing operation where individual sheets of substrate are fed to the press sequentially.

Unit. The smallest complete printing component of a printing press.

Web. A continuous roll of paper used as the printing substrate.

D.4 EMISSION STANDARDS

(a) Any person who owns or operates a heatset offset lithographic printing press shall reduce VOC emissions from the press dryer exhaust vent by 90 percent (weight) of total organics (minus methane and ethane), or maintain a maximum dryer exhaust outlet concentration of 20 ppmv (as C₁), whichever is less stringent when the press is in operation.

D.5 EQUIPMENT STANDARDS

(a) Any person who owns or operates a heatset web offset lithographic printing press that uses alcohol in the fountain solution shall maintain total fountain solution alcohol to 1.6 percent or less (by volume). Alternatively, a standard of 3 percent or less (by volume) alcohol may be used if the fountain solution containing alcohol is refrigerated to less than 60°F.

(b) Any person who owns or operates a non-heatset web offset lithographic printing facility that use alcohol in the fountain solution shall eliminate the use of alcohol in the fountain solution. Alternatively, nonalcohol additives or alcohol substitutes can be used to accomplish the total elimination of alcohol use.

(c) Any person who owns or operates a sheet-fed offset lithographic printing facility shall maintain the use of alcohol at 5 percent or less (by volume). Alternatively, a standard of 8.5 percent or less (by volume) alcohol may be used if the fountain solution is refrigerated to below 60°F.

(d) Any person who owns or operates any type of offset lithographic printing press shall be considered in compliance with this regulation if the only VOC's in the fountain solution are in nonalcohol additives or alcohol substitutes, so that the concentration of VOC's in the fountain solution is 3.0 percent or less (by weight). (The fountain solution should not contain any alcohol.)

(e) Any person who owns or operates an offset lithographic printing press shall reduce VOC emissions from

cleaning solutions by using cleaning solutions with a 30 percent or less (as used) VOC content.

D.6 EMISSIONS STANDARDS TESTING

(a) For the purpose of demonstrating compliance with the emission control requirements of this rule, the affected facility shall be run at typical operating conditions and flow rates during any emission testing.

(b) Emission tests shall include an initial test when the control device is installed and operating that demonstrates compliance with either the 90 percent (by weight) reduction or the 20 ppmv emission limit.

(c) The following EPA methods (in 40 CFR 60, Appendix A) shall be used to demonstrate compliance with the emission limit or percent reduction efficiency requirements listed in D.4(a) above. Alternate methods may be used with the approval of the Administrator.

(1) The EPA Method 1 or 1A, as appropriate, shall be used to select the sampling sites. The control device sampling sites for determining efficiency in reducing total organics (less methane and ethane) from the dryer exhaust shall be placed before the control device inlet (after the dryer) and at the outlet of the control device.

(2) The EPA Method 2, 2A, 2C, or 2D, as appropriate, shall be used to determine the volumetric flow rate of the exhaust stream.

(3) The EPA Method 25 or 25A shall be used to determine the VOC concentration of the exhaust stream entering and exiting the control device. Good judgment is required in determining the best applicable VOC test method for each situation.

(i) For thermal and catalytic incinerators, EPA Method 25 shall be used, except in cases where the allowable outlet VOC concentration of the control device is less than 50 ppmv as carbon, in which case EPA Method 25A shall be used.

(ii) The EPA Method 25 specifies a minimum probe and filter temperature of 265°F. To prevent condensation, the probe and filter should be heated to the gas stream temperature, typically closer to 350°F.

D.7 EQUIPMENT STANDARDS TESTING

(a) Fountain Solution Testing

(1) A sample of the fountain solution (as used) shall be taken from the fountain tray or reservoir containing a fresh batch of fountain solution (after mixing) for each unit or centralized reservoir to determine fountain solution alcohol content in accordance with Section D.5(a) through (c), above, before the fountain solution is used.

(2) Direct measurement of the alcohol content of the fountain solution sample(s) should be performed with a modification of the EPA Method 415.1 (under development).

(3) Alternatively, a sample of the fountain solution (as used) may be taken from the fountain tray or reservoir of fountain solution during use and measured with a hydrometer or refractometer that has been standardized with tests performed in accordance with Section D.7(a)(1) and (2). The unit shall be considered in compliance with Section D.5(a) through (c) if the refractometer or hydrometer measurement is less than or equal to the measurement obtained with a modification of the EPA Method 415.1 [Section D.7(a)(2)], plus 10 percent.

(4) The VOC content of a fountain solution containing alcohol substitutes or nonalcohol additives shall be established with proper recordkeeping, and manufacturer's laboratory analysis of the VOC content of the concentrated alcohol substitute. Records should include the amount of concentrated substitute added per quantity of fountain water; date and time of preparation; and calculated VOC content of

the final solution to fulfill the requirements in D.5(d), above.

(b) Refrigeration Equipment Testing

(1) A thermometer or other temperature detection device capable of reading to 0.5°F shall be used to ensure that a refrigerated fountain solution containing alcohol is below 60°F at all times.

(c) Cleaning Solution Testing

(1) A sample of the cleaning solution (as used) shall be taken to demonstrate compliance with the cleaning solution VOC content limitations listed in D.5(e), above.

(2) A modification of the EPA Method 415.1 shall be used to determine the VOC content of the cleaning solution (as used).

D.8 MONITORING REQUIREMENTS

(a) Add-On Dryer Exhaust Control Device

(1) The owner or operator of a heatset offset lithographic printing press shall install, calibrate, maintain, and operate a temperature monitoring device, according to the manufacturer's instructions, at the outlet of the control device. The monitoring temperature should be set during testing required to demonstrate compliance with the emission standard in D.6(3). Monitoring should be performed only when the unit is operational.

(2) The temperature monitoring device shall be equipped with a continuous recorder and shall have an accuracy of 0.5°F.

(3) The dryer pressure shall be maintained lower than the press room air pressure such that air flows into the dryer at all times when the press is operating. A 100 percent emissions capture efficiency for the dryer shall be demonstrated using an air flow direction measuring device.

(b) Fountain Solution VOC Concentration

(1) The purpose of monitoring the alcohol concentration in the fountain is to provide data that can be correlated to the amount of material used when the fountain solution complies with the limits listed in D.5(a) through (d), above.

The following methods may be used to measure the concentration of alcohol in the fountain solution frequently.

(2) The owner or operator of any offset lithographic printing press shall monitor the alcohol concentration of the fountain solution with a refractometer, that is corrected for temperature, at least once per 8-hour shift or once per batch, whichever is longer. The refractometer shall have a visual, analog, or digital readout with an accuracy of 0.5 percent. A standard solution shall be used to calibrate the refractometer for the type of alcohol used in the fountain. Alternatively, the refractometer shall be standardized against measurements performed to determine compliance, according to the procedures described in Section D.7(a)(1) and (2).

(3) Alternatively, the owner or operator of any offset lithographic printing press shall monitor fountain solution alcohol concentration with a hydrometer, equipped with a temperature correction, at least once per 8-hour shift or once per batch, whichever is longer. The hydrometer shall have a visual, analog, or digital readout with an accuracy of 0.5 percent. A standard solution shall be used to calibrate the hydrometer for the type of alcohol used in the fountain. Alternatively, the hydrometer shall be standardized against measurements performed to determine compliance, according to the procedures described in Section D.7(a)(1) and (2).

(4) The VOC content of the fountain solution may be monitored with a conductivity meter if it is determined that a refractometer or hydrometer cannot be used for the type of VOC's in the fountain solution. The conductivity meter reading for the fountain solution shall be referenced to the conductivity of the incoming water.

(5) If, through recordkeeping for a period of 6 months or more, the printing process is shown to consistently meet the requirements in D.5(d) and D.7(a)(4) above, the monitoring requirement can be waived or extended to a longer period of time.

(c) Fountain Solution Temperature

(1) The owner or operator of any offset lithographic printing press using refrigeration equipment on the fountain shall install, maintain, and continuously operate a temperature monitor of the fountain solution reservoir.

(2) The temperature monitor shall be attached to a continuous recording device such as a strip chart, recorder, or computer.

(d) Cleaning Solution

(1) For any offset lithographic printing press with continuous cleaning equipment, flow meters are required to monitor water and cleaning solution flow rates. The flow meters should be calibrated so that the VOC content of the mixed solution complies with the requirements of D.5(e), above.

D.9 REPORTING/RECORDKEEPING

(a) The owner or operator of any offset lithographic printing press shall record and report the following key parameters on a daily basis.

(1) The type of control device operating on the heatset offset lithographic printing press and the operating parameters specified in D.8(a), above.

(2) The equipment standard selected to comply with the requirements listed in D.5(a) through (e), above.

(3) The VOC content of the fountain and cleaning solutions, to comply with the requirements listed in D.7, D.8(b), and D.8(d), above.

(4) The temperature of the fountain solution to comply with the requirements listed in D.8(c), above, if applicable.

(5) For manual cleaning methods, the amount of cleaning solution and amount of water added per batch of cleaning solution mixed.

(6) For automatic cleaning methods, the flow rates of water and cleaning solution concentrate, as specified in D.8(d), above.

(7) Corrective actions taken when exceedances of any parameters monitored according to the requirements of D.6 through D.8, above, occur.

APPENDIX E

**ESTIMATED NATIONAL IMPACTS OF RECOMMENDED RACT
ON U.S. FACILITIES IN NONATTAINMENT AREAS**

TABLE E-1. ESTIMATED NATIONAL EMISSIONS AND COSTS OF RACT FOR CONTROL OF VOC'S FROM INK.

Model Plant Code ^a	Number of Facilities in Nonattainment Areas	VOC Emissions from Ink (TPY)				Total Cost
		Baseline	Total VOC Removed	After Control	Total Cost	
A-I	77	871	668	203	\$1,513,392	
A-II	122	3,035	2,329	707	\$4,433,742	
A-III	319	15,874	12,179	3,695	\$20,464,574	
A-IV	308	27,866	21,379	6,487	\$27,614,987	
Subtotal	826	47,647	36,555	11,091	\$54,026,696	
B-I	158	214	0	214	\$0	
B-II	535	1,591	0	1,591	\$0	
B-III	1,198	7,107	0	7,107	\$0	
B-IV	397	4,294	0	4,294	\$0	
Subtotal	2,288	13,205	0	13,205	\$0	
C-I	14,362	251	0	251	\$0	
C-II	12,131	425	0	425	\$0	
C-III	2,624	276	0	276	\$0	
C-IV	1,733	394	0	394	\$0	
Subtotal	30,850	1,346	0	1,346	\$0	
D-I	419	21	0	21	\$0	
D-II	93	22	0	22	\$0	
D-III	42	29	0	29	\$0	
D-IV	21	50	0	50	\$0	
D-V	8	44	0	44	\$0	
D-VI	4	43	0	43	\$0	
Subtotal	587	209	0	209	\$0	
Total	34,551	62,407	36,555	25,852	\$54,026,696	

^aRefers to model plants described in more detail in Chapter 3.0.

TABLE E-2. ESTIMATED NATIONAL EMISSIONS AND COSTS OF RACT FOR CONTROL OF VOC'S FROM FOUNTAIN SOLUTIONS.

Model Plant Code ^a	Number of Facilities in Nonattainment Areas	VOC Emissions from the Fountain (TPY)				Total Cost ^b
		Baseline	Total VOC Removed	After Control		
A-I	77	4,294	3,855	439	(\$3,527,090)	
A-II	122	14,966	13,436	1,530	(\$12,361,126)	
A-III	319	78,263	70,261	8,002	(\$64,640,496)	
A-IV	308	137,390	123,343	14,047	(\$113,475,479)	
Subtotal	826	234,914	210,895	24,019	(\$194,004,191)	
B-I	158	5,178	1,278	3,900	(\$1,172,319)	
B-II	535	38,416	9,484	28,932	(\$8,725,517)	
B-III	1,198	172,758	42,651	130,107	(\$39,238,886)	
B-IV	397	104,090	25,698	78,392	(\$23,642,188)	
Subtotal	2,288	320,442	79,112	241,331	(\$72,778,910)	
C-I	14,362	13,822	9,789	4,033	(\$9,006,008)	
C-II	12,131	22,377	15,848	6,529	(\$14,580,103)	
C-III	2,624	15,783	11,178	4,605	(\$10,283,981)	
C-IV	1,733	23,628	16,734	6,894	(\$12,935,265)	
Subtotal	30,850	75,610	53,549	22,061	(\$46,805,357)	
D-I	419	29	0	29	\$0	
D-II	93	28	0	28	\$0	
D-III	42	42	0	42	\$0	
D-IV	21	69	0	69	\$0	
D-V	8	61	0	61	\$0	
D-VI	4	60	0	60	\$0	
Subtotal	587	290	0	290	\$0	
Total	34,551	631,256	343,556	287,700	(\$313,588,458)	

^aRefers to model plants described in more detail in Chapter 3.0.
^bNumbers in parentheses are savings.

TABLE E-3. ESTIMATED NATIONAL EMISSIONS AND COSTS OF RACT FOR CONTROL OF VOC'S FROM CLEANING SOLUTIONS.

Model Plant Code ^a	Number of Facilities in Nonattainment Areas	VOC Emissions from the Fountain (TPY)			Total Cost
		Baseline	Total VOC Removed	After Control	
A-I	77	191	134	57	\$84,080
A-II	122	665	465	199	\$292,755
A-III	319	3,474	2,432	1,042	\$1,529,563
A-IV	308	6,098	4,269	1,830	\$2,685,126
Subtotal	826	10,428	7,300	3,128	\$4,591,523
B-I	158	392	274	118	\$172,527
B-II	535	2,916	2,041	875	\$1,283,805
B-III	1,198	13,046	9,132	3,914	\$5,744,251
B-IV	397	7,861	5,502	2,358	\$3,461,022
Subtotal	2,288	24,214	16,950	7,264	\$10,661,605
C-I	14,362	14,362	10,053	4,309	\$6,323,589
C-II	12,131	24,262	16,983	7,279	\$10,682,559
C-III	2,624	20,992	14,694	6,298	\$9,242,778
C-IV	1,733	29,461	20,623	8,838	\$12,971,678
Subtotal	30,850	89,077	62,354	26,723	\$39,220,603
D-I	419	629	440	189	\$276,729
D-II	93	419	293	126	\$184,266
D-III	42	344	241	103	\$151,639
D-IV	21	344	241	103	\$151,639
D-V	8	271	190	81	\$119,409
D-VI	4	219	153	66	\$96,514
Subtotal	587	2,226	1,558	668	\$980,196
Total	34,551	125,946	88,162	37,784	\$55,453,927

^aRefers to model plants described in more detail in Chapter 3.0.

TABLE E-4. TOTAL ESTIMATED NATIONAL VOC EMISSION IMPACTS OF RACT
FOR OFFSET LITHOGRAPHIC PRINTING.

Model Plant Code ^a	Number of Facilities in Nonattainment Areas	Total VOC Emissions (TPY)		
		Baseline	Total VOC Removed	After Control
A-I	77	5,356	4,657	699
A-II	122	18,667	16,230	2,436
A-III	319	97,611	84,872	12,739
A-IV	308	171,355	148,991	22,363
Subtotal	826	292,988	254,750	38,239
B-I	158	5,784	1,552	4,232
B-II	535	42,923	11,525	31,399
B-III	1,198	192,911	51,783	141,129
B-IV	397	116,244	31,200	85,145
Subtotal	2,288	357,862	96,062	261,805
C-I	14,362	28,435	19,842	8,594
C-II	12,131	47,063	32,831	14,233
C-III	2,624	37,051	25,872	11,179
C-IV	1,733	53,483	37,357	16,127
Subtotal	30,850	166,033	115,893	50,133
D-I	419	679	440	239
D-II	93	469	293	176
D-III	42	415	241	174
D-IV	21	464	241	222
D-V	8	376	190	186
D-VI	4	323	153	169
Subtotal	587	2,725	1,558	1,167
Total	34,551	819,806	468,273	351,336

^aRefers to model plants described in more detail in Chapter 3.0.

TABLE E-5. TOTAL ESTIMATED NATIONAL COST OF RACT FOR OFFSET LITHOGRAPHIC PRINTING,
EXCLUDING SAVINGS.

Model Plant Code ^a	Number of Facilities in Nonattainment Areas	Inks	Fountain Solutions ^b	Cleaning Solutions	Total ^c
A-I	77	\$1,513,392	(\$3,527,090)	\$84,080	\$1,597,472
A-II	122	\$4,433,742	(\$12,361,126)	\$292,755	\$4,726,498
A-III	319	\$20,464,574	(\$64,640,496)	\$1,529,563	\$21,994,137
A-IV	308	\$27,614,987	(\$113,475,479)	\$2,685,126	\$30,300,113
Subtotal	826	\$54,026,696	(\$194,004,191)	\$4,591,523	\$58,618,219
B-I	158	\$0	(\$1,172,319)	\$172,527	\$172,527
B-II	535	\$0	(\$8,725,517)	\$1,283,805	\$1,283,805
B-III	1,198	\$0	(\$39,238,886)	\$5,744,251	\$5,744,251
B-IV	397	\$0	(\$23,642,188)	\$3,461,022	\$3,461,022
Subtotal	2,288	\$0	(\$72,778,910)	\$10,661,605	\$10,661,605
C-I	14,362	\$0	(\$9,006,008)	\$6,323,589	\$6,323,589
C-II	12,131	\$0	(\$14,580,103)	\$10,682,559	\$10,682,559
C-III	2,624	\$0	(\$10,283,981)	\$9,242,778	\$9,242,778
C-IV	1,733	\$0	(\$12,935,265)	\$12,971,678	\$12,971,678
Subtotal	30,850	\$0	(\$46,805,357)	\$39,220,603	\$39,220,603
D-I	419	\$0	\$0	\$276,729	\$276,729
D-II	93	\$0	\$0	\$184,266	\$184,266
D-III	42	\$0	\$0	\$151,639	\$151,639
D-IV	21	\$0	\$0	\$151,639	\$151,639
D-V	8	\$0	\$0	\$119,409	\$119,409
D-VI	4	\$0	\$0	\$96,514	\$96,514
Subtotal	587	\$0	\$0	\$980,196	\$980,196
Total	34,551	\$54,026,696	(\$313,588,458)	\$55,453,927	\$109,480,623

^aRefers to model plants described in more detail in Chapter 3.0.

^bNumbers in parentheses are savings.

^cAssumes the costs/savings of fountain solution controls are zero.

TABLE E-6. TOTAL ESTIMATED NATIONAL COSTS OF RACT FOR OFFSET LITHOGRAPHIC PRINTING, INCLUDING SAVINGS.

Model Plant Code ^a	Number of Facilities in Nonattainment Areas	Inks	Fountain Solutions ^b	Cleaning Solutions	Total ^{b,c}
A-I	77	\$1,513,392	(\$3,527,090)	\$84,080	(\$1,929,618)
A-II	122	\$4,433,742	(\$12,361,126)	\$292,755	(\$7,634,628)
A-III	319	\$20,464,574	(\$64,640,496)	\$1,529,563	(\$42,646,359)
A-IV	308	\$27,614,987	(\$113,475,479)	\$2,685,126	(\$83,175,366)
Subtotal	826	\$54,026,696	(\$194,004,191)	\$4,591,523	(\$135,385,972)
B-I	158	\$0	(\$1,172,319)	\$172,527	(\$999,792)
B-II	535	\$0	(\$8,725,517)	\$1,283,805	(\$7,441,712)
B-III	1,198	\$0	(\$39,238,886)	\$5,744,251	(\$33,494,636)
B-IV	397	\$0	(\$23,642,188)	\$3,461,022	(\$20,181,166)
Subtotal	2,288	\$0	(\$72,778,910)	\$10,661,605	(\$62,117,305)
C-I	14,362	\$0	(\$9,006,008)	\$6,323,589	(\$2,682,419)
C-II	12,131	\$0	(\$14,580,103)	\$10,682,559	(\$3,897,545)
C-III	2,624	\$0	(\$10,283,981)	\$9,242,778	(\$1,041,203)
C-IV	1,733	\$0	(\$12,935,265)	\$12,971,678	\$36,414
Subtotal	30,850	\$0	(\$46,805,357)	\$39,220,603	(\$7,584,754)
D-I	419	\$0	\$0	\$276,729	\$276,729
D-II	93	\$0	\$0	\$184,266	\$184,266
D-III	42	\$0	\$0	\$151,639	\$151,639
D-IV	21	\$0	\$0	\$151,639	\$151,639
D-V	8	\$0	\$0	\$119,409	\$119,409
D-VI	4	\$0	\$0	\$96,514	\$96,514
Subtotal	587	\$0	\$0	\$980,196	\$980,196
Total	34,551	\$54,026,696	(\$313,588,458)	\$55,453,927	(\$204,107,835)

^aRefers to model plants described in more detail in Chapter 3.0.

^bNumbers in parentheses are savings.

^cIncludes savings from fountain solution alcohol reduction.