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Control Techniques Guidelines for Flexible Package Printing

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I. Introduction

Clean Air Act (CAA) section 172(c)(1) provides that state implementation plans (SIPs) for nonattainment areas must include "reasonably available control measures" (RACM), including "reasonably available control technology " (RACT), for sources of emissions. Section 182(b)(2)(A) provides that for certain nonattainment areas, States must revise their SIPs to include RACT for sources of VOC emissions covered by a control techniques guidelines (CTG) document issued after November 15, 1990 and prior to the area's date of attainment.

The United States Environmental Protection Agency (EPA) defines 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." 44 FR 53761 (Sept. 17, 1979). In subsequent Federal Register notices, EPA has addressed how states can meet the RACT requirements of the Act.

CAA section 183(e) directs EPA to list for regulation those categories of products that account for at least 80 percent of the VOC emissions, on a reactivity-adjusted basis, from consumer and commercial products in areas that violate the NAAQS for ozone (i.e., ozone nonattainment areas). EPA issued the list on March 23, 1995, and has revised the list periodically. See 60 FR 15264 (March 23, 1995); see also 71 FR 28320 (May 16, 2006), 70 FR 69759 (Nov. 17, 2005); 64 FR 13422 (Mar. 18, 1999). Flexible package printing materials is included on the current section 183(e) list.

The CTG is intended to provide state and local air pollution control authorities information that should assist them in determining RACT for volatile organic compounds (VOC) from flexible package printing facilities. In developing this CTG, EPA, among other things, evaluated the sources of VOC emissions from this industry and the available control approaches for addressing these emissions, including the costs of such approaches. Based on available information and data, EPA provides recommendations for RACT for VOC from flexible package printing facilities.

States can use the recommendations in this CTG for VOC from this source category to inform their own determination as to what constitutes RACT in their particular nonattainment areas. The information contained in this document is provided only as guidance. This guidance does not change, or substitute for, applicable sections of the CAA or EPA's regulations; nor is it a regulation itself. This document does not impose any legally binding requirements on any entity. It provides only recommendations for state and local air pollution control agencies to consider in determining RACT. State and local pollution control agencies are free to implement other technically-sound approaches that are consistent with the CAA and EPA's implementing regulations.

The recommendations contained in this CTG are based on data and information currently available to EPA. These general recommendations may not apply to a particular situation based upon the circumstances of a particular source. Regardless of whether a State chooses to implement the recommendations contained herein through State rules, or to issue State rules that adopt different approaches for implementation of RACT for VOCs from flexible package printing, States must submit their RACT rules to EPA for review and approval as part of the SIP process. EPA will evaluate the rules and determine, through notice and comment rulemaking in the SIP process, whether they meet the RACT requirements of the Act and EPA's regulations. To the extent a State adopts any of the recommendations in this guidance into its State RACT rules, interested parties can raise questions and objections about the substance of this guidance and the appropriateness of the application of this guidance to a particular situation during the development of the State rules and EPA's SIP approval process.

CAA section 182(b)(2) provides that a CTG issued after November 15, 1990 and before the date of attainment must include the date by which States must submit SIP revisions in response to the CTG. States subject to section 182(b) should submit their SIP revisions within one year of the date of issuance of the final CTG for flexible package printing. States subject to CAA section 172(c)(1) may take action in response to this guidance, as necessary to attain.

II. Background and Overview

In December 1978, EPA published a CTG for graphic arts (rotogravure printing and flexographic printing) that included flexible package printing.[1] The 1978 CTG discusses the flexible package printing industry, the nature of VOC emissions from that industry, available control technologies for addressing such emissions, the costs of available control options, and other items. The 1978 CTG is included as an Appendix to this CTG. The proposed recommended approaches for RACT in this document build upon those identified in the 1978 CTG for graphic arts.

EPA also published a national emission standard for hazardous air pollutants (NESHAP) for the printing and publishing industry (40 CFR Part 60, Subpart KK) in May 1996, which is applicable to flexible package printing.[2] The background information document used to support the 1996 NESHAP included an analysis of the industry based on surveys completed by flexible package printers.[3]

EPA developed the recommended approaches contained in this document after conducting a comprehensive review of current existing state and local VOC emission reduction approaches for flexible package printing, reviewing the 1978 CTG and the 1996 NESHAP background information document, and considering information obtained since promulgation of the NESHAP. Similar to the 1978 CTG, this document contains recommendations for reducing VOC emissions based on the use of add on controls. The recommendations in this CTG reflect, however, the technological improvements that have occurred with regard to such controls since 1978. This CTG also contains recommendations for establishing work practice standards for cleaning.

The remainder of this document is divided into six (6) sections. Section III describes the scope of sources to which this CTG applies. Section IV provides a summary of the processes associated with the flexible package printing and identifies the sources of VOC emissions from those processes. Section V describes the available control approaches for addressing VOC emissions from this source category and summarizes state and local regulatory approaches for addressing such emissions. Section VI provides our proposed recommendations for RACT for VOC emissions from flexible package printing. Section VII discusses the cost-effectiveness of the recommended control approaches. References are provided in Section VIII.

III. Applicability

This CTG provides control recommendations for reducing VOC emissions from inks, coatings, adhesives and cleaning materials used in flexible packaging printing. This section discusses our recommendations for applicability of these control recommendations. State and local agencies have the discretion to consider other applicability criteria for their regulations.

We recommend applying the control recommendations for flexible packaging printing cleaning materials to flexible packaging printing operations that emit at least 6.8 kg/day (15 lb/day) actual emissions of VOC before consideration of controls. State and local agencies have discretion to consider the 15 lb VOC per day applicability level, an equivalent applicability level expressed on a monthly basis (e.g., 450 lb/month), an equivalent applicability level expressed on a 12-month rolling basis (e.g., 3 tons per 12-month rolling period), or other applicability levels for their regulations.

The recommendations for controlling VOC emissions from flexible packaging printing cleaning materials are work practice recommendations. Since work practices are carried out on a facility-wide basis, we believe it is particularly appropriate for the applicability of work practices to be determined on a facility-wide basis. For purposes of determining whether the 15 lb/day actual emissions applicability threshold or an equivalent threshold is met at a given facility, we recommend that a flexible packaging printer should consider emissions from all flexible packaging printing and related cleaning activities at the facility prior to controls.

The 15 lb VOC per day level is consistent with the applicability threshold contained in many previous CTGs. It is also consistent with the purpose of the section 183(e) program. In section 183(e), Congress directed EPA to assist States in achieving VOC emission reductions from consumer and commercial products. These products individually may result in relatively small amounts of VOC emissions, but, in the aggregate, they contribute significantly to ozone formation in nonattainment areas. Given the nature of the products and sources at issue here, we believe that the 15 lb VOC per day applicability threshold or equivalent is appropriate for flexible packaging printing cleaning materials.

We recommend applying the control recommendations for inks, coatings and adhesives only to those presses with potential to emit from the dryer, prior to controls, of at least 25 tpy of VOC (petroleum ink oil) from inks, coatings and adhesives combined. We recommend providing printers with the option of using an enforceable limitation on potential emissions to keep an individual press below this 25 tpy potential to emit threshold. Guidance on limiting potential to emit from printing operations is provided in the Technical Support Document (TSD) for Title V Permitting of Printing Facilities (see Appendix A).[4] We recommend this higher threshold for the control recommendations concerning inks, coatings, and adhesives because not all flexible packaging presses can use low VOC content inks, coatings, and adhesives. We believe that control of a press that is above the 25 tpy threshold will generally be cost effective. Add-on controls for presses with potential to emit below 25 tpy will generally be too costly for the emission reduction that would be achieved.

For those facilities where actual emissions from flexible packaging printing operations are greater than 15 lb/day before consideration of controls and where potential to emit is less than 25 tpy of VOC on a per press basis before controls, we recommend applying only the recommended work practices for cleaning.

The Flexible Packaging Association (FPA) estimated that in 2005, there were 1,071 flexible packaging facilities.[5] FPA did not identify which of these facilities conduct flexible package printing operations (to which this CTG is applicable), but EPA concluded that the number of flexible package printing facilities is less than 1,071. To estimate the total number of flexible package printing facilities and subsequently estimate the number of facilities in current nonattainment areas that would meet the applicability threshold in this CTG, EPA reviewed data obtained during development of the 1996 NESHAP and data from the 2002 NEI.[6]

The 1996 NESHAP background information document reported that the Gravure Association of America estimated that in 1994 there were an estimated 400 locations within the U.S. that conducted rotogravure printing operations, but made no distinction between rotogravure package/product printing (to which this CTG is applicable) and rotogravure publication printing locations (to which this CTG is not applicable). As part of the NESHAP project, EPA identified 108 locations thought to operate package/product rotogravure printing equipment. The 108 package/product rotogravure facilities include both area and major sources of HAP. EPA also identified 520 facilities conducting wide web flexographic printing operations (to which this CTG is applicable) as part of the NESHAP project. The 520 wide-web flexographic facilities include both area and major sources of HAP. Of these 520 facilities conducting wide-web flexography, EPA estimates that approximately 221 facilities are potential flexible packaging printers. Thus, the NESHAP data indicate that there are approximately 329 potential flexible package printers.

An additional search of the 2002 NEI (April 11, 2006 version) database for SIC codes 2671, 2673, 2674, and 3497, identified 146 unique facilities (i.e., not already identified as part of the NESHAP project). This number may be artificially high because many of the facilities could not be definitively confirmed as flexible package printers;

however, these facilities were not omitted from the facility list. A search of the 2002 NEI (April 11, 2006 version) database for NAICS codes 322221, 326112, 322223, 326111, 322224, 322225, and 332999 was conducted to identify additional flexible package printing facilities. The number of unique facilities (i.e., not already identified as part of the NESHAP project or as part of the 2002 NEI SIC search discussed above) identified that 107 facilities could be flexible package printers. This number may be artificially high because many of the facilities could not be definitively confirmed as flexible package printers; however, these facilities were not omitted from the facility list. In total, the NEI search resulted in 253 potential flexible packaging printers.

The NESHAP and the NEI search combined identified a total of 582 facilities that could be flexible package printers. Of the 582 facilities identified as potential flexible package printers, a total of 219 facilities are located in ozone nonattainment areas (based on April 2004 designations). Based on VOC emissions data, we estimate that there are approximately 100 facilities in ozone nonattainment areas that have emissions of greater than 15 pounds per day (lb/day).

IV. Process Description and Sources of VOC Emissions

A. Definition of Flexible Packaging

Flexible packaging refers to any package or part of a package the shape of which can be readily changed. Flexible packaging includes, but is not limited to, bags, pouches, liners, and wraps utilizing paper, plastic, film, aluminum foil, metalized or coated paper or film, or any combination of these materials.[7] Flexible package manufacturers are sometimes referred to as "converters." The word "converted" in this use is an industry-specific term that refers to the fact that flexible packaging materials start out as rolls of paper or foil, or beads of plastic resin, and are "converted" into a package or roll of packaging material.

Printing on flexible packaging is almost entirely conducted by rotogravure and wide-web flexographic printing. The ratio of rotogravure printing to flexographic printing among converters is approximately 1:4. Flexible packaging printers are likely to be included under SIC codes 2671, 2673, 2674, and 3497. Typical NAICS codes for this industry include 322221, 326112, 322223, 326111, 322224, 322225, and 332999. Flexible package printers could also be classified under other SIC and NAICS codes as well depending on other processes conducted at the facility.

Printing, coating, and laminating may all be performed on or in-line with a flexible package printing press and these activities are included in the source category. One portion of the flexible packaging industry provides fully printed packaging materials (designated "preformed specialty bags") to contract packagers. Another portion provides combination or laminated materials (designated converted wrap) for printing and/or final packing by captive packaging operations. Applying coatings is a major capability of flexible packaging converters, so the same facilities may be used to manufacture non-packaging materials such as gift wraps and hot stamp foils. The industry makes a distinction between labels and wrappers, which are package components, from a product that becomes the entire package and should be called a flexible package. Any printing of shrink-wrap labels or wrappers conducted on or in-line with a flexible package printing press is also considered to be included under the flexible packaging source category. Printing of self-adhesive labels would not be considered flexible packaging.

Rigid packaging printing operations are often times co-located with flexible package printing operations. Folding cartons, some labels and wrappers, gift wraps, wall coverings, vinyl products, decorative laminates, floor coverings, tissue products, and miscellaneous specialty products are not considered flexible packaging.

B. Printing Processes and Emissions

There are two types of printing processes used by flexible package printing facilities: (1) rotogravure printing; and (2) flexographic printing.

Rotogravure Printing

Rotogravure printing is a printing process in which an image (type and art) is etched or engraved below the surface of a plate or cylinder. On a rotogravure cylinder, the printing image consists of millions of minute cells. Rotogravure requires very fluid inks which will flow from the cells to the substrate at high press speeds. In addition to inks, coatings and adhesives may be applied with rotogravure cylinders. These materials dry by evaporation as the substrate passes through hot air dryers. Solvent-borne or waterborne ink systems can be used but these ink systems are not interchangeable. Both the printing cylinders and the drying systems are specific to the solvent system in use. The evaporated components of the ink and other materials contain VOC to varying extents. Additional VOC may be present in solvents used to clean presses and press components. Rotogravure can be divided into the publication, product, and packaging segments. For this source category, we are interested in the flexible packaging, which is a part of the packaging segment. Because of the expense and complexity of rotogravure cylinder engraving, it is particularly suited to long run printing jobs.

Rotogravure package printing uses a wide variety of different ink systems, including VOC based ink systems and waterborne ink systems. Numerous specially mixed colors are applied at various times in this industry segment. In addition, a wide range of materials are applied with rotogravure cylinders in this segment of the industry. A variety of coatings and adhesives are applied on or in-line with rotogravure presses. Because of the variety of materials applied, the approach to VOC control in packaging rotogravure facilities varies. Packaging gravure facilities use a variety of thermal and catalytic oxidizers and activated carbon based solvent recovery systems. Use of waterborne inks for rotogravure printing is increasing.[8]

Printing is only one stage (often minor) in the manufacturing and is, in many cases, a relatively small part of the total packaging production process. In many cases, operations such as laminating, cutting, and folding make up a greater proportion of the value of the package than the printing operation.

Due to the wide variety of ink types and colors that are used in this segment of the printing industry, ink is typically received in drums (or smaller container sizes) and tote bins. Only rarely is bulk ink received and stored in tanks.

Flexographic Printing

In flexographic printing, the image is raised above the printing plate, and the image carrier is made of rubber or other elastomeric materials. The major applications of flexographic printing are flexible and rigid packaging; tags and labels; newspapers, magazines, and directories; and paper towels, tissues, etc. Because of the ease of plate making and press set up, flexographic printing is more suited to short production runs than rotogravure.

Flexographic inks must be very fluid to print properly. Flexographic inks include both waterborne and solvent based systems. Solvents used must be compatible with the rubber or polymeric plates; thus, aromatic solvents are not used. Some of the components of solvent based flexographic ink include ethyl, n-propyl and iso-propyl alcohols; glycol ethers, aliphatic hydrocarbons, acetates and esters. A variety of coatings and adhesives are applied on or in-line with flexographic presses including solvent-borne, waterborne, wax coatings, wax laminations, extrusion coatings, extrusion laminations, 100 percent solid adhesives, ultra-violet cured coatings, electron beam cured coatings, hot melt coatings, and cold seal coatings.

Flexographic printing can be divided between publication, packaging, and product printing. For this source category, only the flexible packaging segment is considered. Wide web flexographic presses (defined to include presses of 18 inches or greater in width) are used to print flexible and rigid packaging.

Flexographic presses can be divided into three main types depending on the relative relationship of the print stations. Stack presses have individual print stations oriented vertically with the unwind and rewind sections on the same side of the print stations. Stack presses are easily accessible for rapid changeovers between press runs.

Stack presses are a vintage design that is not easily enclosed for VOC emissions capture. Common impression presses (also called central impression presses) have the print stations around the circumference of a single large impression cylinder. The web is constantly supported between print stations, which is an advantage for printing on stretchable materials. More recent models of central impression presses include capture systems within the press design. In-line presses have the print stations in a horizontal row (the geometry is similar to rotogravure presses). These presses have an advantage when used with additional converting (such as cutting, gluing, and laminating) equipment.

C. Definition of Press

Rotogravure press means an unwind or feed section, which may include more than one unwind or feed station (such as on a laminator), a series of individual work stations, one or more of which is a rotogravure print station, any dryers associated with the work stations, and a rewind, stack, or collection section. Inboard and outboard work stations, including those employing any other technology, such as flexography, are included if they are capable of printing or coating on the same substrate.

Flexographic press means an unwind or feed section, which may include more than one unwind or feed station (such as on a laminator), a series of individual work stations, one or more of which is a flexographic print station, any dryers (including interstage dryers and overhead tunnel dryers) associated with the work stations, and a rewind, stack, or collection section. The work stations may be oriented vertically, horizontally, or around the circumference of a single large impression cylinder. Inboard and outboard work stations, including those employing any other technology, such as rotogravure, are included if they are capable of printing or coating on the same substrate.

D. Definition of Cleaning for Flexible Packaging Printing

Cleaning for flexible package printing can be characterized as cleaning of a press, press parts, or removing dried ink from areas around a press. In general, it would not include cleaning electronic components of a press, cleaning in pre-press (e.g., platemaking) or post-press (e.g., binding) operations, or use of janitorial supplies (e.g., detergents or floor cleaners) to clean areas around a press. Cleaning would also not include parts washers or cold cleaners.

V. Available Controls and State and Local Regulatory Approaches

There are two main sources of VOC emissions from flexible package printing for both rotogravure and flexographic: (1) evaporation of VOC from inks, coatings, and adhesives, and (2) evaporation of VOC from cleaning materials.

There are two approaches to reducing VOC emissions from inks, coatings, and adhesives used in the flexible package printing industry: (1) adding/improving add-on controls, and (2) material reformulation or substitution. The first approach includes improving capture and/or control systems or adding control systems where none are in use. Capture and control can be addressed separately, although in many cases, improved capture is achieved through an increase in the amount of air handled and can necessitate upgrades to existing control devices. The second approach, focusing on pollution prevention, is to substitute low VOC or VOC-free materials for materials (inks, coatings, and adhesives) presently in use.

A. Inks, coatings, and adhesives

Add-On Controls - Capture Systems

Capture systems are designed to collect solvent laden air and direct it to a control device. In rotogravure and flexographic printing processes, most of the solvent is removed from the printed substrate by evaporation in a dryer. The exhaust from the dryer can be ducted to a control device. Additional systems such as floor sweeps and hoods are often used to collect solvents that evaporate from other parts of the printing press, in addition to those collected from the dryer. Pressroom ventilation air can also be exhausted to a control device. Some presses are contained and operated within permanent total enclosures. Solvent laden air from several presses may be combined and ducted to a common control device.

Differences in capture efficiency of the exhaust contribute much more to the variation in overall efficiencies than the choice of control device. Test procedures have been established for determining capture efficiency and for confirming the presence of permanent total enclosures (PTE). Capture efficiency can be determined according to the EPA protocols for testing with temporary total enclosures that are specified in Methods 204 and 204A through F of 40 CFR Part 51 Appendix M. In order to assume a capture efficiency of 100 percent, you must confirm that your capture system is a PTE by demonstrating that it meets the requirements of Section 6 of Method 204 of 40 CFR Part 51 Appendix M and that all exhaust gases from the enclosure are delivered to a control device. More information on determining capture efficiency for rotogravure and flexographic printing presses, including alternative capture efficiency test procedures that do not use temporary total enclosure, is presented in the Printing and Publishing NESHAP (40 CFR Part 63 Subpart KK).

Capture systems can be improved through collection of additional solvent laden air from the press area and through construction of additional hooding and press enclosures. In theory, capture can be improved to (nearly) 100 percent for any press or pressroom by retrofitting walls and increasing ventilation to meet the requirements of permanent total enclosures. Many new presses have been installed within permanent total enclosures. Some existing facilities have modified their pressrooms to serve as permanent total enclosures. There may be space constraints, such as close proximity to other machines, that limit the ability of some presses to be enclosed. Enclosing some presses may limit access to the unit and may cause increased temperatures within the enclosure, which could be an exposure concern for workers.

The RACT recommendations in the 1978 CTG considered capture and control of VOC emissions from flexographic and rotogravure presses. Packaging rotogravure presses were estimated to have a capture efficiency of 75 percent. A lower capture efficiency of 70 percent was estimated for flexographic presses due to the manner of construction of the stacked presses and central impression presses in use at that time.

There have been significant improvements in capture efficiency of flexographic presses and rotogravure presses since 1978. These improvements can be attributed to replacement of aging presses with newer presses, enclosed doctor blades, and improvements in dryer technology. In addition, more recent models of central impression presses used for flexographic printing and in-line presses used for flexographic printing or rotogravure printing now incorporate capture systems within the press design. Since around 1990, many vendors have guaranteed capture efficiency of 85 to 90 percent without use of a permanent total enclosure.

Many package rotogravure printing and wide-web flexographic printing facilities use low VOC and low HAP inks and coatings. Dryer exhausts from these facilities, presses, or individual work stations may be vented to the atmosphere without the use of a control device.

Add-On Controls - Control Devices

The control devices in use in flexible packaging rotogravure and flexographic printing processes include carbon adsorbers, thermal oxidizers, and catalytic oxidizers. In contrast to oxidation techniques, carbon adsorption does not destroy the VOC in the treated air but recovers it for reuse. The selection of a control device is influenced by the type of inks, coatings, and adhesives applied on the press, the volume of solvent laden air to be treated, and the operating schedule of the facility. The RACT recommendations in the 1978 CTG considered carbon adsorbers and oxidizers with 90 percent control device efficiency. Today, these control devices can achieve at least 95 percent control device efficiency.

Low- and No-VOC Inks, Coatings, and Adhesives

Pollution prevention has been achieved by many facilities in the packaging rotogravure and flexographic printing industries. Many facilities use waterborne inks, and these inks typically contain a small proportion of alcohols or glycol ethers which function to reduce surface tension and improve flow characteristics. Their use may require redesign of the system (changes in ink formulation, cylinder engraving, press operation, and dryer design) for rotogravure flexible package printing. While use of waterborne inks reduces or eliminates VOC emissions, their higher surface tension and slower drying rate continue to be obstacles to their expanded use. Flexible packaging printers use a wide variety of coatings and adhesives including solvent-borne, waterborne, wax coatings, wax laminations, extrusion coatings, extrusion laminations, 100 percent solid adhesives, ultra-violet cured coatings, electron beam cured coatings, hot melt coatings, and cold seal coatings.

Packaging rotogravure facilities and flexographic facilities produce a wide variety of products, and flexible packaging producers, in particular, print on many different substrates within the same facility. Many facilities use hundreds of different inks to print various custom colors required by their packaging customers. Low VOC inks, coatings, and adhesives may not be available to meet all of the performance requirements. Low VOC inks may not be available for all of the substrates and in all of the colors required by some facilities.

B. Cleaning Materials

The recommended approach to reduce VOC emissions from cleaning materials used in flexible package printing includes use of work practices. Work practices such as keeping solvent containers closed except when filling, draining or conducting cleaning operations, keeping used shop towels in closed containers, and conveying cleaning materials from one location to another in closed containers or pipes reduce VOC emissions. The work practice recommendations for cleaning apply to flexible packaging printing facilities emitting 15 lb/day or more before consideration of controls from all covered flexible packaging printing and cleaning activities at the facility. . EPA recommends that when States develop RACT rules in response to the Industrial Cleaning Solvents CTG, see EPA 453/R-06-001 (Sept. 2006), they consider excluding from those rules the cleaning activities covered by this CTG (See 71 FR 44540).

C. Summary of State and Local Regulations

Many States and local agencies have adopted regulations for controlling emissions from flexible package printing. At least 34 States and several more local agencies have regulations that control VOC emissions from rotogravure and flexographic printing for flexible packaging. The majority of these agencies have adopted control levels consistent with the 1978 RACT levels of 65 percent overall control for rotogravure and 60 percent overall control for flexography, or use of waterborne or other low VOC inks with less than or equal to 25 percent by volume VOC in their volatile fraction, more than 60 percent volume solids less water and less exempt compounds, or less than 0.5 kg VOC per kg solids. The 65 percent overall control efficiency for rotogravure was based on a 90 percent control device efficiency and approximately 72 percent capture efficiency; the 60 percent overall control efficiency for flexography was based on a 90 percent control device efficiency and approximately 66 percent capture efficiency.

The requirements for several State and local agencies that have adopted regulations more stringent than the current RACT requirements are summarized below in Table 1. Local agencies in California with regulations more stringent than RACT have requirements ranging from 66 to 85 percent overall control efficiency.

A few local air pollution control agencies have also adopted requirements for cleaning materials. A cleaning materials summary is provided in Table 2. There is a wide range of VOC limits for cleaning materials, from 0.42 lb VOC/gal material to 6.8 lb VOC/gal including water.

Table 1. Summary of State and Local Agency Rules with Requirements More Stringent than the Recommendations for RACT Provided in the 1978 CTG

State or Local Agency	Summary of State or Local requirements
New Jersey	75 percent capture efficiency for rotogravure, 70 percent capture efficiency for flexography, and 95 percent control device efficiency for thermal oxidizers.
North Carolina	95 percent control device efficiency
California:	
Antelope Valley	67 percent overall control efficiency
Bay Area	85 percent overall control efficiency
El Dorado County	95 percent control device efficiency and 70 percent capture efficiency
Kern County	95 percent control device efficiency and 90 percent capture efficiency; <u>or</u> 75 percent overall control on a daily basis
Placer County	95 percent control device efficiency and 70 percent capture efficiency
Santa Barbara	67 percent overall control efficiency
South Coast	75 percent overall control efficiency
San Joaquin Valley	67 percent overall control efficiency
San Diego County	85 percent overall control efficiency
Sacramento Metro	95 percent control device efficiency and 70 capture efficiency
Ventura County	75 percent overall control efficiency
Yolo-Solano County	75 percent overall control efficiency

Table 2. Summary of State and Local Agency Limits for Cleaning Solvents Used for Flexible Package Printing

State or Local Agency	Cleaning Requirement
California:	
Bay Area	<u>Rotogravure Printing</u>: 6.7 lb VOC/gal including water <u>or</u> partial pressure of 25 mm Hg at 20C <u>Flexographic Printing</u>: 6.8 lb VOC/gal including water <u>and</u> partial pressure of 21 mm Hg at 20C
Santa Barbara	<u>Ink Application Equipment Cleaning, Printing</u>: 3.75 lb VOC/gal <u>and</u> 33 mm Hg at 20C
San Joaquin Valley	<u>Ink Application Equipment, Flexographic Printing</u>: 0.42 lb VOC/gal material <u>Ink Application Equipment, Rotogravure Printing, Packaging</u>: 0.42 lb VOC/gal material
San Diego County	<u>Cleaning Solvent</u>: 1.66 lb VOC/gal material <u>or</u> total vapor pressure of 45 mm Hg at 20C
Sacramento Metropolitan	<u>Application Equipment, Flexographic Printing</u>: 0.83 lb VOC/gal including water and exempt compounds
South Coast	<u>Ink Application Equipment, Flexographic Printing</u>: 0.21 lb VOC/gal <u>Ink Application Equipment, Rotogravure Printing, Packaging</u>: 0.21 lb VOC/gal
Ventura County	<u>Ink Application Equipment, Flexographic Printing, Other Flexographic</u>: 0.83 lb VOC/gal <u>and</u> 3 mm Hg at 20C <u>Ink Application Equipment, Rotogravure Printing, Packaging</u>: 0.83 lb VOC/gal <u>and</u> 3 mm Hg at 20C

VI. Recommended Control Options

Recommendations for controlling VOC emissions from inks, coatings, adhesives and cleaning materials used in flexible package printing operations are as follows:

A. Coatings, inks and adhesives used on flexible package printing presses

The recommended level of control for VOC emissions from coatings, inks and adhesives used on flexible package printing presses is tied to the first installation date of the equipment. The first installation date for a piece of equipment does not change if the equipment is later moved to a new location. For example, a brand new press first installed in 1992 is moved to a new location in 1998 – the first installation date for this press is still 1992. Or, if a brand new control device first installed in 2004 is moved to a new location in 2009 – the first installation date for this control device is still 2004. The first installation date for a control device does not change if it is later used to control a new press. For example, a brand new press is installed in 2009 and emissions from this press are controlled by a control device that was first installed in 2002 - the first installation date for this press is 2009 and the first installation date for this control device is still 2002.

The recommended control levels in the final CTG include the following:

- 65 percent overall control for a press that was first installed prior to March 14, 1995 and that is controlled by an add-on APCD whose first installation date was prior to the effective date of the State RACT rule.
- 70 percent overall control for a press that was first installed prior to March 14, 1995 and that is controlled by an add-on APCD whose first installation date was on or after the effective date of the State RACT rule.
- 75 percent overall control for a press that was first installed on or after March 14, 1995 and that is controlled by an add-on APCD whose first installation date was prior to the effective date of the State RACT rule.
- 80 percent overall control for a press that was first installed on or after March 14, 1995 and that is controlled by an add-on APCD whose first installation date was on or after the effective date of the State RACT rule.

March 14, 1995 was the proposal date for the 1996 NESHAP for the printing and publishing industry. To provide information on the derivation or basis of the overall control levels, the 65 percent overall control efficiency is based on a capture efficiency of 75 percent and a control device efficiency of 90 percent. The 70 percent overall control efficiency is based on a capture efficiency of 75 percent and a control device efficiency of 95 percent. The 75 percent overall control efficiency is based on capture efficiency of 85 percent and control device efficiency of 95 percent. The 80 percent overall control efficiency is based on a capture efficiency of 85 percent and a control device efficiency of 95 percent. It is not suggested that facilities meet the individual capture efficiency or the individual control efficiencies; the recommendation is for achieving the overall control efficiency. As an alternative to emission reduction percentages specified above, we also recommend providing the following two equivalent VOC content limits which can be met by use of low VOC content materials or combinations of materials and controls as follows: (1) 0.8 kg VOC/kg solids applied, or (2) 0.16 kg VOC/kg materials applied. These VOC content limits are consistent with an 80 percent overall emissions reduction level and reflect similar control levels as the capture and control option. The VOC content limits can be met by averaging the VOC content of materials used on a single press, i.e., within a line. The use of averaging to meet the VOC content limits is not recommended for cross-line, i.e., across multiple lines.

B. Cleaning Materials Work Practices at Flexible Package Printing Presses

We recommend that the following work practices be employed for cleaning materials: keeping cleaning materials and used shop towels in closed containers, and conveying cleaning materials from one location to another in closed containers or pipes.

VII. Cost Effectiveness of Recommended Control Options

Emissions data are available for most of the facilities identified. The emissions data include VOC data for those facilities identified in the 2002 NEI database. The VOC data available from the 2002 NEI were supplemented with additional HAP data available from the 1996 NESHAP where appropriate. For facilities identified as part of the 1996 NESHAP only, the HAP data from the NESHAP were used. In the instance that only HAP data are available for a specific facility, the assumption was made that VOC emissions are equal to HAP emissions, with the recognition that most facilities use and emit some VOC that are not HAP. (HAP emissions data from the 1996 NESHAP reflect pre-implementation levels of that rule and do not account for reductions made to comply with the NESHAP.) In addition, the VOC data obtained from the NEI are the total emissions from the source and may include VOC emissions data from other source categories at the facility in addition to emissions from flexible package printing.

Baseline VOC emissions are estimated at 28,000 tons per year (ton/yr) for 390 of the 582 facilities identified with available emissions data. The average VOC emissions per facility were 71 ton/yr. An upper bound on the nationwide baseline VOC emissions for flexible package printing can be estimated by assuming that there may be up to 1,071 facilities and that the facilities with emissions data are representative of the total population. In this case, nationwide baseline VOC emissions from flexible package printing would be approximately 76,000 ton/yr. As a lower bound on the nationwide baseline VOC emissions, it was estimated that there are approximately 582 facilities. In this case, nationwide baseline VOC emissions from flexible package printing would be approximately 42,000 ton/yr. Therefore the nationwide baseline emissions range from approximately 42,000 to 76,000 ton/yr. Nonattainment area VOC emissions from flexible package printing facilities (based on April 2004 designations) are estimated to range from 8,636 to 16,364 Mg/yr (9,500 to 18,000 tpy).

Many facilities located in ozone nonattainment areas are already meeting the control levels being recommended in this CTG. These facilities may be using capture and control systems or low VOC content inks, coatings, and adhesives. The costs for facilities not using low VOC content inks, coatings, and adhesives that are not already using control equipment, will vary depending on the flow rate, hourly solvent use rate, and operating hours. Although we do not have detailed information for the industry as a whole, we have information for some sources from which we can estimate the likely emissions reductions and costs for a typical source subject to control for the first time (see Appendix B). For a press exhausting approximately 5,800 cubic feet per minute, operating 2000 hours per year, and achieving 70 percent capture efficiency, we estimate the VOC emission reduction to range from 30 to 60 megagrams (Mg) (33 to 66 tons) per year and the cost effectiveness to range from $1,400/Mg to $3,100/Mg ($1,300/ton to $2,800/ton) depending on the average hourly solvent use rate.[9] At lower solvent use rates, the cost per ton of emission controlled would likely be higher. Increasing the hourly solvent use rate, annual operating hours, or capture efficiency of this size press would increase the annual VOC emission reduction and improve the cost effectiveness. Larger presses with proportionately larger hourly solvent use rates would also have larger annual VOC emission reductions and better cost effectiveness than smaller presses.

VIII. References

1. *Control of Volatile Organic Emissions from Existing Stationary Sources – Volume VIII: Graphic Arts – Rotogravure and Flexography*. EPA Publication No. EPA-450/2-78-033. U.S. Environmental Protection Agency. Research Triangle Park, NC. December 1978.

2. 40 CFR part 63, subpart KK. National Emissions Standards for Hazardous Air Pollutants: Printing and Publishing Industry.

3. *National Emission Standards for Hazardous Air Pollutants: Printing and Publishing Industry Background Information for Proposed Standards.* EPA Publication No. EPA-453/R-95/-002a. U.S. Environmental Protection Agency. Research Triangle Park, NC. February 1995.

4. *Technical Support Document (TSD) for Title V Permitting of Printing Facilities.* Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. Research Triangle Park, NC 27711. January 2005.

5. *2005 State of the Flexible Packaging Industry Report*. Flexible Packaging Association (FPA). Linthicum, Maryland.

6. 2002 National Emissions Inventory. U.S. Environmental Protection Agency. Dated April 11, 2006.

7. 40 CFR part 63, subpart JJJJ. National Emissions Standards for Hazardous Air Pollutants: Paper and Other Web Coating.

8. *Printing Industry and Use Cluster Profile*. U.S. Environmental Protection Agency. EPA Publication No. 744-R-94-003. June 1994.

9. *Flexographic Ink Options: A Cleaner Technologies Substitutes Assessment*. EPA Publication No. EPA 744-R-02-001-A. U.S. Environmental Protection Agency.

Appendix A

Guideline Series: Control of Volatile Organic Emissions from Existing Stationary Sources—Volume VIII: Graphic Arts – Rotogravure and Flexography. EPA Publication No. EPA-450/2-78-033. U.S. Environmental Protection Agency. Research Triangle Park, NC. December 1978.

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Technical Support Document (TSD) for Title V Permitting of Printing Facilities. Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. Research Triangle Park, NC 27711. January 2005.

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Appendix B

Estimated Costs Associated with the Recommendations Contained in the Control Techniques Guideline for Flexible Package Printing

I. Introduction

This memorandum presents the estimated costs associated with implementing the recommendations in the CTG for controlling volatile organic compounds (VOCs) emissions from flexible package printing facilities in ozone nonattainment areas. As explained in the CTG, the CTG is guidance for State and local pollution control agencies to use in determining "reasonably available control technology" (RACT) for VOCs from flexible package printing. State and local pollution control agencies are free to adopt the recommendations contained in the CTG, or implement other technically-sound approaches for RACT, provided those approaches are consistent with the CAA and EPA's implementing regulations. Accordingly, there is necessarily some uncertainty in any prediction of costs and emission impacts associated with the recommendations contained in the CTG. For purposes of this analysis, we assume that all states will adopt the recommendations in the CTG.

Costs were estimated for add-on air pollution control devices (APCD) likely to be used to control emissions to the reasonably available control technology (RACT). A discussion of RACT for flexible package printing facilities is provided in section VI, Recommended Control Options, of the CTG.

Costs were developed for a fixed bed catalytic oxidizer achieving 95 percent destruction efficiency.

II. Description of Cost Analysis

The cost analysis discussions include specific information that details the assumptions and methodology used in costing APCDs. The Air Compliance Advisor (ACA) was used to estimate costs based on February 2003 dollars. In estimating the total capital investment (TCI) for the add-on APCDs, the equipment costs were based on February 2003 dollars and were scaled to represent costs for 2005 dollars. Purchased equipment costs (PEC) generally include the control device and auxiliary equipment costs, instrumentation costs, sales tax, and freight costs. Costs for instrumentation (10 percent), sales tax (3 percent), and freight (5 percent) were estimated to be 18 percent of control device and auxiliary equipment costs.

Several components of the annual costs include direct annual costs such as labor wages and maintenance costs, utilities, and raw materials. Common costs for indirect annual costs include overhead and administrative charges. Direct costs are listed in Table 1.

Table 1. Common Assumptions for Annual Cost Calculations

Parameter/Factor	
Direct Annual Costs	
Operator Wage Rate (except steam stripper)	$12.95/hr
Maintenance Labor Wage Rate	$14.95/hr
Supervisor Labor Cost	15 percent of Operator labor cost
Maintenance materials cost	100 percent of Maintenance Labor cost
Utilities Natural Gas Cost Electricity Cost	 $3.30 per 1,000 scf $0.059 per kW-hr
Indirect Annual Costs	
Overhead	60 percent of all labor and maintenance material costs
Admin, Property Taxes, and Insurance	4 percent of TCI

Typical or average facility and individual press operating conditions for flexographic printing were presented in a recent EPA Design for Environment (DfE) document.[1] In the DfE report, catalytic oxidizer add-on APCDs were costed for a facility with four new 48-inch wide, 8-color presses. The total dryer air flow rate for each press was 5,800 cubic feet per minute (cfm) and the air exhaust rate for each press was 2,900 cfm (50 percent recirculation). The dryer exhaust temperature was 150 degrees Fahrenheit (ºF). Capture efficiency was assumed to be 70 percent. A 5,800 cfm catalytic oxidizer controlled the exhaust from two presses. See referenced document for additional discussion.

For this analysis catalytic oxidizer add-on APCDs were first costed for similar single presses with no recirculation – i.e., the air exhaust rate for each press is 5,800 standard cubic feet per minute (scfm) and a 5,800 scfm catalytic oxidizer controlled the exhaust from a single press. Capture efficiency was assumed to be 70 percent. The parameters for these presses were input to ACA to calculate TCI and TAC. The costs were estimated based on one catalytic oxidizer serving one printing press with no recirculation; the costs for other types of incinerators and oxidizers were also looked at however the most cost effective type was chosen as facilities are most likely to select cost effective controls. The TCI for the fixed bed catalytic oxidizer is estimated at $306,000 in February 2003 dollars. Using Marshall & Swift indices of 1116.4 for first quarter 2003 and 1244.5 for 2005, the TCI was scaled to $341,000 in 2005 dollars.[2,3]

The TAC was then estimated for three VOC loading scenarios:

(1) for a press with 17.5 tons per year (ton/yr) solvent loading and a press operating 2000 hours per year (hr/yr), the solvent loading in the captured stream is 17.5 pounds per hour (lb/hr) VOC, the VOC is assumed to be toluene, and the VOC concentration is 210 parts per million by volume (ppmv),

(2) for a press with 35 tons per year (ton/yr) solvent loading and a press operating 2000 hours per year (hr/yr), the solvent loading in the captured stream is 35 pounds per hour (lb/hr) VOC, the VOC is assumed to be toluene, and the VOC concentration is 420 parts per million by volume (ppmv), and

(3) for a press with 70 ton/yr solvent loading and a press operating 2000 hr/yr, the solvent loading is 70 lb/hr VOC, the VOC is assumed to be toluene, and the VOC concentration is 840 ppmv.

These scenarios are shown in Table 2. (With 70 percent capture efficiency, the solvent use rate for a press is 25 lb/hr or 25 ton/yr for the first scenario, 50 lb/hr or 50 ton/yr for the second scenario and 100 lb/hr or 100 ton/yr for the third scenario.) The TAC for the first scenario is $85,000 per year, for the second scenario is $83,000 and for the third scenario is $79,000 per year in February 2003 costs. These costs were scaled to 2005 dollars and are $95,000 per year, $93,000 per year and $88,000 per year, respectively.

The catalytic oxidizer achieves 16.6 ton/yr of VOC control (95 percent of 17.5 ton/yr) in scenario one, 33.3 ton/yr of VOC control (95 percent of 35 ton/yr) in scenario 2, and 66.5 ton/yr of VOC control (95 percent of 70 ton/yr) in scenario 3. The cost effectiveness is $5,700 per ton ($/ton) for scenario 1, $2,800/ton for scenario 2, and $1,300/ton for scenario 3.

Table 2. VOC Loading Scenarios for Flexible package printing Presses

Parameter	Scenario 1	Scenario 2	Scenario 3
Solvent usage, ton/yr	25	50	100
Capture efficiency, %	70%	70%	70%
Control device efficiency, %	95%	95%	95%
Operating hours, hr/yr	2000hr/yr	2000hr/yr	2000hr/yr
Exhaust rate/oxidizer capacity	5800 scfm	5800 scfm	5800 scfm
TCI, $	$341,000	$341,000	$341,000
Solvent loading, lb/hr	17.5 lb/hr	35 lb/hr	70 lb/hr
Assumed VOC compound	toluene	toluene	toluene
VOC concentration, ppmv	210ppmv	420ppmv	840ppmv
TAC, $	$95,000	$93,000	$88,000
Solvent loading, ton/yr	17.5 ton/yr	35 ton/yr	70 ton/yr
VOC emission reduction, 95% efficiency	16.6	33.3	66.5
Cost effectiveness, $/ton	5,700	2,800	1,300

Next, the effect of recirculation or lower dryer air exhaust rate was examined for the lowest solvent loading scenario. Three cases were examined: case 1.A with 2,900 cfm, case 1.B with 2,000 cfm, and case 1.C with 1,500 cfm. These cases are shown in Table 3.

For case 1.A, the TCI for the fixed bed catalytic oxidizer is estimated at $208,000 in February 2003 dollars which scales to $232,000 in 2005 dollars. For case 1.B, the TCI for the fixed bed catalytic oxidizer is estimated at $170,000 in February 2003 dollars which scales to $190,000 in 2005 dollars. For case 1.C, the TCI for the fixed bed catalytic oxidizer is estimated at $127,000 in February 2003 dollars which scales to $142,000 in 2005 dollars.

For case 1.A, the TAC is estimated at $56,000 in February 2003 dollars which scales to $62,000 in 2005 dollars. For case 1.B, the TAC is estimated at $46,000 in February 2003 dollars which scales to $51,000 in 2005 dollars. For case 1.C, the TAC is estimated at $36,000 in February 2003 dollars which scales to $46,000 in 2005 dollars.

The catalytic oxidizer achieves 16.6 ton/yr of VOC control (95 percent of 17.5 ton/yr) in cases 1.A, 1.B and 1.C. The cost effectiveness is $3,700/ton for case 1.A, $3,100/ton for case 1.B and $2,400/ton for case 1.C.

Table 3. Effect of recirculation or lower dryer air exhaust rate on Scenario 1

Parameter	Case 1.A	Case 1.B	Case 1.C
Solvent usage, ton/yr	25	25	25
Capture efficiency, %	70%	70%	70%
Control device efficiency, %	95%	95%	95%
Operating hours, hr/yr	2000hr/yr	2000hr/yr	2000hr/yr
Exhaust rate/oxidizer capacity	2900 scfm	2000 scfm	1500 scfm
TCI, $	$232,000	$190,000	$142,000
Solvent loading, lb/hr	17.5 lb/hr	17.5 lb/hr	17.5 lb/hr
Assumed VOC compound	toluene	toluene	toluene
VOC concentration, ppmv	420ppmv	610ppmv	810ppmv
TAC, $	$62,000	$51,000	$46,000
Solvent loading, ton/yr	17.5 ton/yr	17.5 ton/yr	17.5 ton/yr
VOC emission reduction, 95% efficiency	16.6	16.6	16.6
Cost effectiveness, $/ton	3,700	3,100	2,400

III. Nationwide Costs

The nationwide costs for the recommended control approaches in the CTG are presented in Table 4. As noted above, for the purposes of this analysis, we assumed that States would adopt the control approaches recommended in the CTG.

We estimate that 219 facilities are located in ozone nonattainment areas; of these 219 facilities, there are approximately 100 facilities with VOC emissions greater than 15 pounds per day (lb/day).

The nationwide TCI and TAC for the 100 facilities identified above represent the maximum nationwide costs. Because it is not known how many of these 100 facilities have presses which use 25 tons per year or more of VOC combined from inks, coatings and adhesives, or how many of these presses are currently implementing control techniques to reduce VOC emissions which satisfy the recommendations in the CTG, we provide nationwide cost estimates based on the assumptions that 100 percent, 75 percent, 50 percent and 25 percent of the 100 facilities would need to install control equipment to satisfy the recommendations in the CTG.

The high end estimates for each percentage assume 4 presses per facility. The TCI and TAC for the high end estimates are based on scenario 1 above. The low end estimates for each percentage assume 1 press per facility. The TCI and TAC for the low end estimates are based on scenario 3 above.

The assumption that 100 percent of the facilities will need to install control equipment is not likely and overstates the nationwide costs. This is because not all of the 100 facilities will have a press using 25 tons per year or more of VOC combined from inks, coatings, and adhesives, and many facilities are currently implementing control techniques to reduce VOC emissions which satisfy the recommendations in the CTG. Our best estimate is that 25 percent or less of the facilities will need to install control equipment to satisfy the CTG recommendations..

Table 4. Nationwide Cost Estimates.

If 100%, 100 facilities, install control equipment:			
100	Facilities		
$341,000	TCI per facility (1 press)	$34,100,000	Nationwide TCI, low end
$1,364,000	TCI per facility (4 presses)	$136,400,000	Nationwide TCI, high end
$380,000	TAC per facility, high end (4 presses @ $95,000)	$38,000,000	Nationwide TAC, high end
$88,000	TAC per facility, low end	$8,800,000	Nationwide TAC, low end
If 75%, 75 facilities, install control equipment:			
75	facilities		
$341,000	TCI per facility (1 press)	$25,575,000	Nationwide TCI, low end
$1,364,000	TCI per facility (4 presses)	$102,300,000	Nationwide TCI, high end
$380,000	TAC per facility, high end (4 presses @ $95,000)	$28,500,000	Nationwide TAC, high end
$88,000	TAC per facility, low end	$6,600,000	Nationwide TAC, low end
If 50%, 50 facilities, install control equipment:			
50	Facilities		
$341,000	TCI per facility (1 press)	$17,050,000	Nationwide TCI, low end
$1,364,000	TCI per facility (4 presses)	$68,200,000	Nationwide TCI, high end
$380,000	TAC per facility, high end (4 presses @ $95,000)	$19,000,000	Nationwide TAC, high end
$88,000	TAC per facility, low end	$4,400,000	Nationwide TAC, low end
If 25%, 25 facilities, install control equipment:			
25	Facilities		
$341,000	TCI per facility (1 press)	$8,525,000	Nationwide TCI, low end
$1,364,000	TCI per facility (4 presses)	$34,100,000	Nationwide TCI, high end
$380,000	TAC per facility, high end (4 presses @ $95,000)	$9,500,000	Nationwide TAC, high end
$88,000	TAC per facility, low end	$2,200,000	Nationwide TAC, low end

IV. References

1. *Flexographic Ink Options: A Cleaner Technologies Substitutes Assessment*. EPA Publication No. EPA 744-R-02-001-A. U.S. Environmental Protection Agency. 2002.

2. *Chemical Engineering*. November 2003. p. 124.

3. *Chemical Engineering*. March 2006. p. 84.

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