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Best Demonstrated Control Technology for Graphic Arts

control technology center

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BEST DEMONSTRATED CONTROL TECHNOLOGY FOR GRAPHIC ARTS

CONTROL TECHNOLOGY CENTER

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Office of Air Quality Planning and Standards
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BEST DEMONSTRATED CONTROL TECHNOLOGY FOR GRAPHIC ARTS

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PREFACE

The CTC was established by EPA's Office of Research and Development (ORD) and Office of Air Quality Planning and Standards (OAQPS) to provide technical assistance to State and local air pollution control agencies. Three levels of assistance can be accessed through the CTC. First, a CTC HOTLINE has been established to provide telephone assistance on matters relating to air pollution control technology. Second, more in-depth engineering assistance can be provided when appropriate. Third, the CTC can provide technical guidance through publication of technical guidance documents, development of personal computer software, and presentation of workshops on control technology matters.

The technical guidance projects, such as this one, focus on topics of national or regional interest that are identified through contact with State and local agencies.

In this case, the CTC had received numerous requests for assistance in determining BACT/LAER for the graphics arts industry. They had also received reports that several graphics arts facilities were achieving VOC control efficiencies of 90 percent or greater. This study was undertaken to document the reported overall control efficiency for VOC's at a number of rotogravure and flexographic printing facilities.

NOTICE

This report was prepared by Midwest Research Institute, Cary NC. It has been reviewed for technical accuracy by the Emission Standards Division of the Office of Air Quality Planning and Standards and the Air and Energy Engineering Research Laboratory of the Office of Research and Development, U.S. Environmental Protection Agency, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

ACKNOWLEDGEMENT

This report was prepared for the Control Technology Center by Beth Friedman, Chuck Vaught, Charles Hester, and Rebecca Nicholson of Midwest Research Institute. The EPA project officer was Karen Catlett. Also serving on the EPA project review team were James Berry and Bob Blaszczak of the Office of Air Quality Planning and Standards, and Chuck Darvin of the Office of Research and development.

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1.0 INTRODUCTION

The Control Technology Center (CTC) and others within the U. S. Environmental Protection Agency (EPA) have received reports that several graphic arts facilities are achieving VOC control efficiencies of 90 percent or greater and that several facilities are using permanent total enclosures. The CTC also received requests for assistance in determining best available control technology and lowest achievable emissions rate (BACT/LAER) for this industry. This study documents the reported overall control efficiency for volatile organic compounds (VOC's) at a number of rotogravure and flexographic printing facilities. Facilities were contacted for background information to (1) identify facilities with 90 percent control efficiency or greater and (2) document these efficiencies. The overall objective of the effort is to provide assistance to State and local agencies requesting information on BACT and LAER. Documenting that several facilities achieve very high capture and control efficiencies is a necessary approach to this effort.

The information obtained from site visits was used to document the overall control efficiency achieved at each operation. As with any air pollution control problem, overall control efficiency is based on the product of two component efficiencies: capture efficiency and control device efficiency. Previous regulatory efforts have typically focused on the control device component; therefore, existing documentation and test methodologies tend to be more readily available for this efficiency determination. Therefore, the focus of this project was the collection of information related to the efficiency of the capture system. In some cases, limited capture efficiency test data were available; in other cases, information on enclosure system design criteria and operating conditions was collected to determine capture system efficiency. An overall control efficiency was then estimated for each facility. Because one of the facilities had converted to water-based inks, thereby dramatically reducing maximum potential VOC emissions, local regulations did not require a capture system and a control device.

Midwest Research Institute contacted (by telephone) State and local agencies, Regional EPA offices, and graphic arts facilities to obtain information on flexographic and rotogravure graphic arts facilities that reportedly achieved VOC control efficiencies of 90 percent or greater. Nineteen graphic arts facilities and one vinyl flooring manufacturer were contacted. Of the 20 facilities contacted, only seven stated that their overall VOC control efficiency was 90 percent or greater. Of these seven facilities, six were visited by the project team. Two additional facilities that were thought to have adopted particularly innovative capture technologies were later identified by EPA. These facilities were visited as well.

Table 1 is a list of facilities that were visited and a summary of the key characteristics of the facilities. Seven of the facilities are typical graphic arts facilities. Of these seven, six are packaging facilities and one is a publishing facility. The eighth facility, which is a vinyl flooring manufacturer, was visited because the VOC capture and control system (total enclosure plus incinerator) used at this facility promised to be applicable to graphic arts facilities also. In addition, the eighth facility uses a rotogravure printer for its vinyl printing operation, the basic printing process is similar to that used at more typical graphic arts facilities, and the facility is regulated as a graphic arts facility.

2.0 CONCLUSIONS

The following list of conclusions is based on the information collected during the study:

1. The use of capture and control systems and the use of water-based ink systems have been demonstrated to be effective and reliable in achieving a greater than 90 percent overall reduction in VOC emissions from graphic arts facilities using rotogravure and flexographic printing presses. In addition, more recent information reported to EPA indicates that the following graphic arts facilities using solvent-based inks have adopted (or are in the process of adopting) capture and control systems that achieve greater than 90 percent VOC emission reductions:

- Colonial Heights Packaging, Virginia
- Central States Diversified, Minnesota
- Maxwell Communications Corporation, Tennessee
- Princeton Packaging, Incorporated, Pennsylvania

TABLE 1. CHARACTERISTICS OF PLANTS VISITED TO ESTABLISH CURRENT BEST DEMONSTRATED TECHNOLOGY

Company, location	Type of primary printing system	End product	Special characteristics/ add-on control
<u>Plants with total enclosures</u>			
Package Products, Charlotte, NC	Flexographic	Packaging	Catalytic incinerator
Tarkett, Inc., Whitehall, PA	Rotogravure	Vinyl flooring	Regenerative incinerator
Maxwell Graphics, Richmond, VA	Rotogravure	Publishing	Carbon adsorber
Advanced Printing Technology, Morgantown, PA	Rotogravure	Wood grained laminates	Thermal incinerator
Morrill Press, Fulton, NY	Rotogravure	Packaging	Catalytic incinerator
CMS Gilbreth--Bristol Plant, Croydon, PA	Rotogravure	Packaging	Capture systems use recirculation, Regenerative incinerator
CMS Gilbreth--Bensalem Plant, Bensalem, PA	Rotogravure and flexograhic	Packaging	Capture systems use recirculation, Regenerative incinerator
<u>Plant which uses only waterborne coatings</u>			
Amko Plastics, Cincinnati, OH	Flexographic	Packaging	Water-based coatings

Although EPA has not verified these reports, they are an indication of the growing use of high efficiency capture and control systems in the graphics arts industry.

2. The facilities visited demonstrated overall control efficiencies of 94 to over 99 percent;

3. States should be cognizant of the demonstrated control efficiencies obtained in these and other graphic arts facilities and apply this information in future RACT, BACT, and LAER determinations. The previously accepted VOC reductions of 65 percent, often considered to be RACT for this industry, may no longer be considered the maximum reduction capability for graphic arts operations;

4. Only one of the facilities visited was a totally new facility. The other facilities, including the facility using water-based inks, had all been retrofitted with the technology used to reduce VOC emissions;

5. The majority of facilities reporting >90 percent overall control used total enclosures and add-on devices to achieve that level;

6. Permanent total enclosures (PTE's) meeting EPA criteria have been successfully installed and operated at graphic arts facilities using rotogravure and flexographic presses;

7. At some plants, differential pressure controllers in the enclosure were used to maintain a specified pressure drop between the inside of the enclosure and ambient pressure. Maintaining a static pressure drop of about 1.0 pascal (Pa) (0.004 inch [in.] water) across the natural draft opening (NDO) results in internal face velocities of at least 3,600 meters per hour (m/hr) (200 feet per minute [ft/min]), thus meeting EPA Criteria 4, one of the criteria established by EPA for defining a PTE;

8. For facilities utilizing capture and control, well-designed localized air collection and overall air management systems not only enhance the effectiveness of the control system but are also reported to improve the quality of the air in the press room and, as a result, working conditions;

9. There was no degradation in worker safety or health conditions in facilities utilizing permanent total enclosures. Based on comments by management and workers, working conditions were improved in some facilities;

10. The PTE's present no more of a fire hazard than other press rooms. All are designed so that workers can exit quickly in case there is a fire or explosion; and

11. The plant that used water-based inks reported other environmental, health, and safety benefits in addition to reduced VOC emissions. These benefits included reduced amounts of hazardous wastes (and reduced disposal costs), elimination of the need for special storage areas (water-based inks are noncombustible), and significantly improved working conditions.

3.0 DESCRIPTION OF PROCESSES USED BY THE GRAPHIC ARTS INDUSTRY

3.1 FLEXOGRAPHIC PRINTING[1]

Flexography, shown in Figure 1, uses a flexible plate, which may be made of rubber or a photo sensitive polymer known as a photopolymer, and fluid inks. Flexography is well suited for printing on almost all flexible packaging materials since the flexographic inks dry rapidly. Because the plastic substrates on which the ink is placed, such as polyolefins, polystyrene, and polyesters, have nonporous surfaces (i.e., the ink will not penetrate the substrate), it is essential that the inks dry quickly to avoid smearing. Flexographic inks also print well on paper stocks, aluminum foil, paperboard, and paper used for folded cartons, cups and containers.

Flexographic presses are rotary machines with up to eight color stations. Ink is pumped or poured from a storage container to a press "fountain." The ink distribution system usually consists of a fountain roller and an anilox form roller that delivers the ink to the printing plate, although some newer distribution systems eliminate the rubber fountain roller and immerse the anilox form roller in the ink fountain. A doctor blade removes excess ink from the form roller. The ink is transferred from the form roller to the printing plate and from the printing plate to the substrate. A drying oven then dries the printed web.

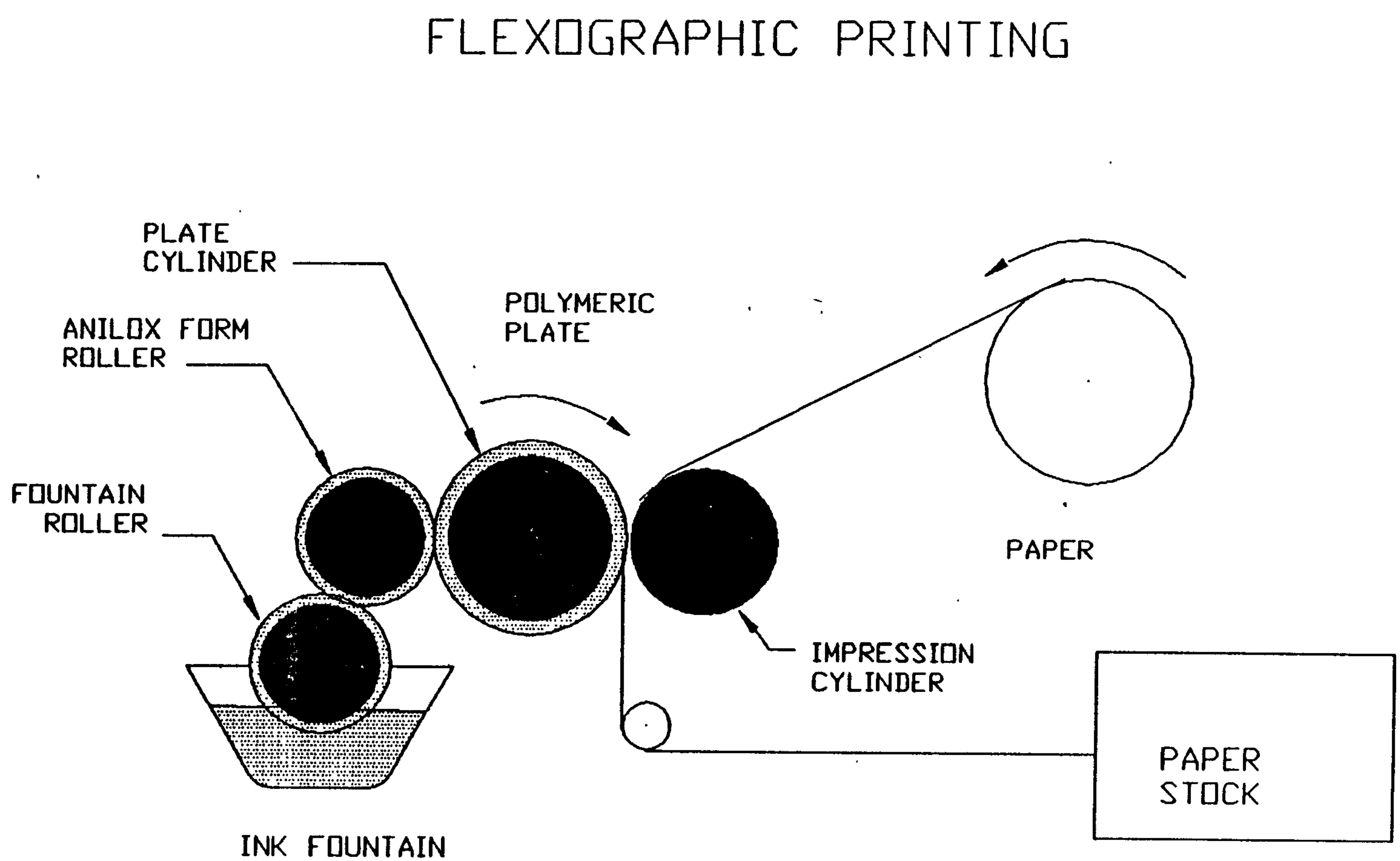

Figure 1. Flexographic printing process.

Flexographic inks consist of one or more resins dissolved in a solvent blend. A combination of solvents may be required, particularly when more than one resin is used. The solvent blend consists primarily of the lower molecular weight alcohols, such as ethyl, n-propyl, and isopropyl. These may be mixed with small amounts of glycol ethers, aliphatic hydrocarbons, acetates, or esters to obtain optimum resin solubility, proper drying speed, and viscosity.

Flexographic inks can also be water-based. Although they are used primarily on porous substrates such as paper and paperboard, they can be used successfully on any substrate if the printer is willing to invest enough effort in devising a workable system. Water-based inks have several advantages, including good press stability and printability, compliance with air pollution regulations, absence of fire hazards, and reduced insurance costs. They are also economical and convenient because water can be used for dilution and for cleaning up. The printing industry has reported some problems with water-based inks. On nonabsorbent substrates such as plastic films, water-based inks do not have the gloss of solvent-based inks and they dry more slowly. Newer types of water-based inks that are more suitable for printing on plastic films are being developed and used.

3.2 ROTOGRAVURE PRINTING[1]

For the gravure printing process shown in Figure 2, the design to be printed is etched or engraved into (below the surface of) the printing cylinder. The printing image consists of thousands of recessed "cells" or indentations per square inch. The depth and width of the cells controls the amount of ink that is metered. The gravure process is used for publication printing and printing folding cartons, flexible packaging, and specialty items such as gift wraps, vinyl plastic film, and vinyl-coated fabrics.

The gravure press consists of the gravure cylinder on which the design to be reproduced is etched, an ink pan in which the cylinder is immersed, a doctor blade that removes excess ink from the surface of the cylinder, and the impression roller that brings the web of material to be printed into contact with the gravure cylinder. A drying oven then dries the printed web.

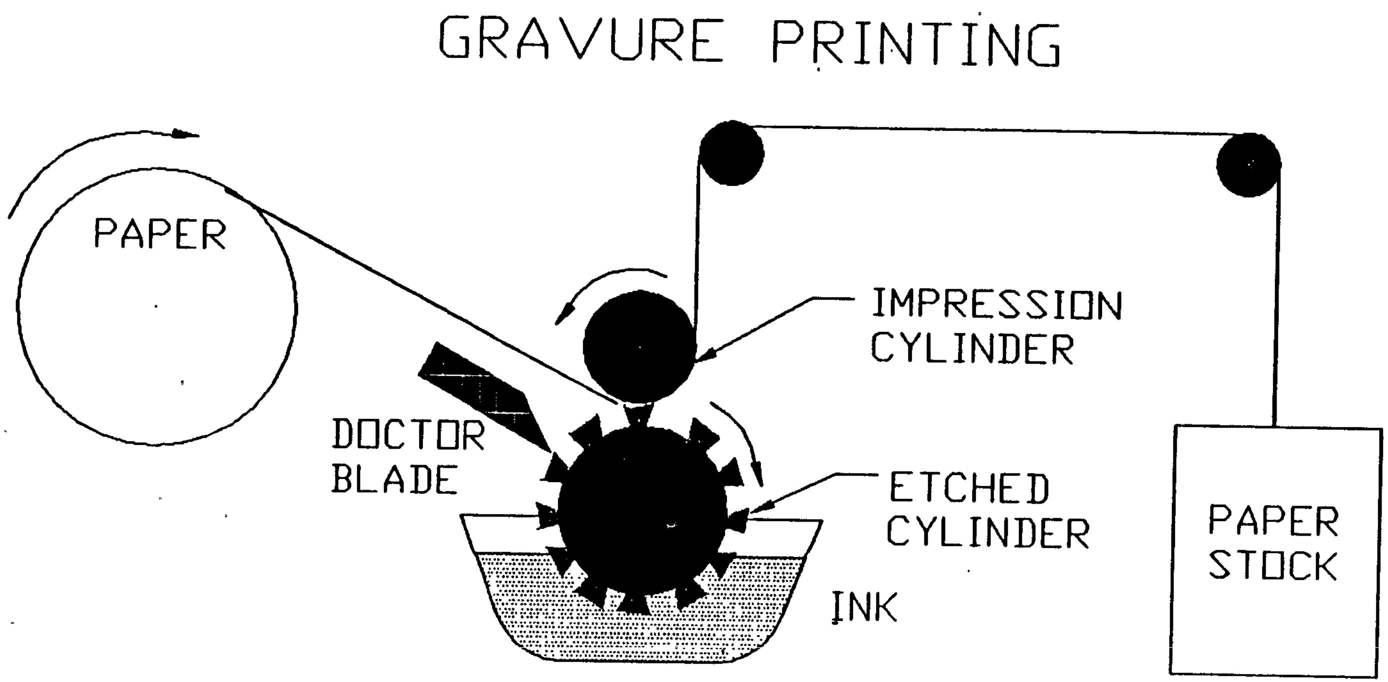

Figure 2. Rotogravure printing process.

Gravure inks are composed of three ingredients: pigment, binder, and solvent. Pigment selection is based on the color desired and any additional properties, such as light fastness, that may be required for the job. The binder ensures that the pigment is evenly dispersed in the liquid ink, prevents bleeding, and helps the pigment adhere to the printed substrate. Binders are selected based on their ability to develop maximum adhesion to the surface to be printed and on the level of gloss and flexibility required in the printed product. The solvent dissolves the binder to form a fluid ink and then evaporates to leave a dried ink film. Organic solvents used in rotogravure inks may be esters, alcohols, ketones, acetates, aromatic hydrocarbons, or aliphatic hydrocarbons. The solvent is selected based on a number of criteria, including complete solubilization or dispersion of the resins, speed of drying, cost efficiency, and compliance with OSHA and EPA standards.

Water-based inks are also being used in gravure printing for some applications, primarily for paper and paperboard, and, to a lesser extent, for film and foil. Research on developing ink resins that are appropriate for water-based systems has resulted in a greater variety of resin being available. These new water-based systems are suitable for use on more substrates, have a wide range of end use properties, and dry more quickly.

4.0 CRITERIA FOR DETERMINING OVERALL CONTROL EFFICIENCY

As previously discussed, the purpose of this study is to verify and document reports that some currently existing rotogravure and flexographic printing plants routinely achieve 90 percent or greater overall control efficiencies for VOC's. For plants using solvent-based inks, control of VOC's is a two-part endeavor involving first the capture of the VOC's and second the destruction or removal of the VOC's from an exhausted air stream. Multiplying the efficiencies of these two endeavors results in the overall VOC control efficiency.

4.1 PERMANENT TOTAL ENCLOSURE CRITERIA

Six of the eight facilities visited were using, or plan to install, PTE's as part of their strategy to capture and control at least 90 percent of press operation emissions. A permanent total enclosure is a structure constructed around a source of emissions so that all VOC emissions are collected and exhausted through a stack or duct to a control device. With a PTE, there are no fugitive emissions. All VOC must exit through a ductwork so that any necessary concentration measurements can be made. The PTE's may be built around a specific press or number of presses, or an entire room may be sealed off and modified to function as a PTE. In either case, EPA has developed a set of design and operational criteria which, when incorporated into the design of an enclosure, should cause its actual capture efficiency to be essentially total. The criteria are as follows:

1. All VOC emissions must be captured and contained for discharge through a control device;

2. The total area of all NDO's shall not exceed 5 percent of the surface area of the enclosure's four walls, floor, and ceiling;

3. All access doors and windows whose areas are not included in Criteria 2 and are not included in the calculation in Criteria 4 shall be closed during routine operation of the process;

4. The average facial velocity (FV) of air through all NDO's shall be at least 3,600 m/hr (200 ft/min), which equates to a pressure drop of 0.004 inches of water. The direction of air through all NDO's shall be into the enclosure; and

5. Any NDO shall be at least 4 equivalent opening diameters from any VOC emitting source.

The PTE criteria were published in the new source performance standard (NSPS) for the magnetic tape industry and the NSPS for the coating of polymeric substrates. Additionally, a policy statement published April 16, 1990, "Guidelines for Developing a State Protocol for the Measurement of Capture Efficiency" contains these criteria. According to these guidelines, if the criteria are met, EPA will presume that the capture efficiency is 100 percent. The facilities discussed in this report that were utilizing, or are in the process of installing, PTE's had all based the design of the PTE's on these criteria.

4.2 DESTRUCTION OR REMOVAL EFFICIENCY CRITERIA

The determination of the destruction or removal efficiency of VOC's exiting the enclosure is generally based on information supplied by the plant on tests conducted to document the performance of the control device. The EPA Reference Method 25 is one method for determining the VOC content into and out of a control device. The EPA has extensive experience with the most commonly used control devices, incinerators and carbon adsorbers, and has information to support that these control devices should achieve efficiencies of at least 95 percent if they are properly designed, operated, and maintained units.

5.0 RESULTS

This section contains a brief summary of each of the eight plants visited and an assessment of their respective VOC capture and control efficiencies.

5.1 PACKAGE PRODUCTS[2]

Package Products Company operates eight flexographic printing presses at its facility in Charlotte, North Carolina. The facility prints a variety of flexible packaging films including plastic candy wrappers and soft drink shrink-wrap. The presses are multicolor units with each color applied sequentially at a different ink station. Each color of ink is dried before the next color is applied. Drying is accomplished with a natural-gas-fired, hot air dryer called the between-the-colors (BC) dryer. The BC dryer blows hot air on the film after each color application. Exhaust slots then collect the evaporated ink solvent. After the final color is applied and dried, the printed film goes into a natural-gas-fired overhead dryer where additional hot air is blown on the film to remove any residual ink solvent. All the presses are located in one large room that has been modified to serve as a PTE capable of capturing fugitive VOC emissions from the presses. The VOC emissions from the room are controlled by seven catalytic incinerators.

5.1.1 Capture Efficiency

Permit conditions established by the Mecklenberg County Department of Environmental Health (MCDEH) at the Package Products facility specify 90 percent VOC removal and, for three of the presses and one laminator, a 120 tons/year combined total emissions limit. Actual combined emissions for the three presses and one laminator were 25 tons/year. One additional press is limited to 40 tons/year of emissions; the plant estimates that actual emissions are less than 2 tons/year. Overall, the facility was credited with achieving LAER for flexographic printing in a nonattainment area for ozone.[3]

The Package Products' PTE is a room of approximately 6,372 cubic meters (m^3) (225,000 cubic foot [ft^3]). All entrances to the room are closed with the exception of a 2.7 square meter (m^2) (96 square foot [ft^2]) doorway between the press room and laminating room, which is covered with overlapping vinyl strips. Clean air is blown toward the vinyl strips from within the enclosed press room in order to impede the movement of dust and dirt drawn into the press room.

Forced makeup air is supplied to the PTE at approximately 850 cubic meters per minute (m^3/min) (30,000 standard cubic feet per minute [scfm]) from the windup end of the presses. Press room air is exhausted through ducts located at the opposite end of the presses at approximately 935 m^3/min (33,000 scfm). There are eight exhaust ducts, one behind each press. Thus, as the air travels across the room from the supply ducts to the exhaust ducts, it picks up fugitive VOC emissions from the presses.

Package Products tested the capture efficiency of the PTE system using three different techniques:

1. Room air balance on portion of air captured and incinerated;
2. Mass balance based on VOC charged to press; and
3. Chemical smoke releases.

At the time of the test program, only four of the eight fugitive pickup ducts were connected to an incinerator because the other incinerators had not yet been installed.

The first technique, the room air balance, showed that 670 m^3/min (23,666 ft^3/min) of fresh air entered the room and 630 m^3/min (22,254 ft^3/min) was captured in the fugitive pickup duct. (Note: Not all of the fugitive pickup ducts and incinerators were installed at this time.) Approximately 42.5 m^3/min (1,500 ft^3/min) of air is collected by the dryers. Results of their air balance analysis led Package Products to conclude that 97.6 percent of the VOC's are captured.

A second technique, a VOC mass balance (liquid-gas), was performed by quantifying the amount of each color ink charged to the presses. Using ink solvent composition data, the quantities of solvents charged to the presses were calculated. The VOC input was compared to the VOC loading measured at the incinerator inlet and a capture efficiency value was calculated.

The capture efficiency values varied from between 42 and 130 percent. This type of variation, although extreme, is not completely unexpected because mass balances on presses are subject to many errors, especially for short-term runs. First, liquid-gas material balances have been historically difficult to close. Second, the physical layout at Package Products has all of the presses in one large room. This configuration can result in a mixing of fugitive emissions from the presses, such that the amount of solvent charged to an individual press may not equal the amount of captured solvent delivered to the control device.

As a third technique to determine qualitatively the effectiveness of the capture system, chemical smoke tubes were used to visually demonstrate airflow patterns in the press room. The assumption was that demonstration of the uninterrupted movement of smoke from the press to the air pickup registers is an indication of optimal capture system performance and minimal press room VOC concentrations. Package Products reports that the experiments showed that the airflow patterns were consistent from the air supply registers, across the press room, to the air pickup registers.

Since these three tests were conducted, the remaining incinerators have been installed, and four more fugitive pickup ducts were connected to the catalytic incinerators.

During the visit, face velocity measurements were taken by the site visit team, using a hot wire anemometer, at the vinyl-strip-covered interior doorway and at a door leading outside that was partially opened. Face velocities recorded at the 2.4 m x 3.7 m (8 ft X 12 ft) doorway with vinyl strip curtains were erratic and generally less than 30.8 m/min (100 ft/min). At times, the airflow appeared to be directed out of the enclosure as the result of a fan that continuously blew air at the doorway from inside the enclosure. Face velocity measurements were also taken at an outside door that was partially opened by plant personnel for the purpose of demonstrating that even if a worker enters or exits the enclosure, a significant inward face velocity is maintained. The measurements showed a consistent face velocity into the enclosure of approximately 169 m/min (550 ft/min).

Table 2 is a summary of the PTE criteria that are satisfied at Package Products. Criteria 1 and 3 are clearly satisfied.

Because of the vinyl strips in place at the 2.4 m x 3.7 m (8 ft x 12 ft) doorway, it was not possible to accurately determine the effective open area of the doorway. The enclosure exhaust system draws 85 m^3/min (3,000 scfm) more than the makeup air system supplies. Theoretically for this exhaust flow rate, a well sealed enclosure with face velocities of 61 m/min (200 ft/min) across the NDO's would have an NDO area of 1.4 m^2 (15 ft^2). The total area of the doorway is 8.9 m^2 (96 ft^2). In order for the criteria to be satisfied, the vinyl strips covering the doorway must cover at least 7.5 m^2 (81 ft^2), or 84 percent of the area of the doorway. Observations made during the visit suggest that over 95 percent of the doorway was effectively covered by the vinyl strips. This analysis indicates that the theoretical face velocity is greater than 61 m/min (200 ft/min), thus satisfying Criteria 4, and that because the area of the NDO must be less than 5 percent of the total surface area of the enclosure, that Criteria 2 is satisfied.

A complicating factor in evaluating Criteria 4 is the erratic face velocity measurements at the 2.4 m x 3.7 m (8 ft x 12 ft) doorway leading from the laminating room. The vinyl strips did not hang uniformly to seal the doorway for at least two reasons. The most obvious reason is the 85 m^3/min (3,000 scfm) that can enter only through the doorway. In addition, however, the ventilation system discharged against the internal side of the door with outside air creates turbulence at the doorway. For this reason this facility deviates somewhat from the ideal total enclosure and it is not possible to make absolute judgments about the probability that fugitive emissions are not somehow aspirated through the strips. It does however seem unlikely.

The worst-case scenario for meeting the fifth criterion is that, in the absence of the vinyl strips, the equivalent diameter of the natural draft opening would be 2.9 m (9.6 ft). The distance between the opening and the nearest emission source is approximately 12.2 m (40 ft). Therefore, Criteria 5 would be met. In reality, the effective area of the natural draft opening is much smaller because of the vinyl strips, which greatly decrease the equivalent diameter of the opening. The fifth criterion is thus certainly met.

TABLE 2. SUMMARY OF PTE CRITERIA AT PACKAGE PRODUCTS IN CHARLOTTE, NORTH CAROLINA

Criteria No.	Plant met criteria
1. All VOC emissions must be captured and contained for discharge through a control device	Yes
2. Total area of NDO's is not to exceed 5 percent of total surface area	Yes
3. Access doors and windows should be closed during normal operation	Yes
4. The average inward face velocity across all NDO's must be at least 3,600 m/hr (200 ft/min)	Yes[a]
5. All sources of emissions within the enclosure should be at least 4 equivalent diameters away from each NDO	Yes

[a]Face velocity measurements were erratic at the 2.4 m x 3.7 m (8 ft x 12 ft) doorway leading from the laminating room. The vinyl strips did not hang uniformly to seal the doorway for at least two reasons. The most obvious reason is the 85 m^3/min (3,000 scfm) that can enter only through the doorway. In addition, however, the ventilation system discharged against the internal side of the door with outside air creates turbulence at the doorway. For this reason this facility deviates somewhat from the ideal total enclosure and it is not possible to make absolute judgments about the probability that fugitive emissions are not somehow aspirated through the strips. It does however seem very unlikely.

Based on the Package Product capture efficiency test program, it appears that the press room enclosure is capable of achieving a high level of capture efficiency. Because the enclosure satisfies the PTE total criteria, the capture efficiency can be assumed to be 100 percent.

5.1.2 Control Device Efficiency

Package Products conducted stack tests on each of the seven incinerators in either August 1987 or February 1986. The purpose of these tests was to determine compliance with the plant's permit conditions. Destruction efficiencies ranged from 98.7 to 99.6 percent.

5.2 TARKETT, INC.[4]

Tarkett, Inc., operates one rotogravure printing press at its facility in Whitehall, Pennsylvania. The facility manufactures vinyl floor covering. The press is a six station unit. The inks are thinned with solvents, primarily methyl ethyl ketone and methyl isobutyl ketone, to achieve the proper viscosity for printing. Each color or ink is dried in a dryer before the next color is applied. The dryer draws air over the web after each color application. The dryers do not require heat because the line speed is low. The plant has been retrofitted with capture and control devices for control of VOC emissions from the press, which is located in a large room that is sealed off to serve as a total enclosure. Emissions are controlled by a regenerative thermal incinerator. Use of the PTE allows the plant to minimize the amount of airflow to be treated by the incinerator.[5]

5.2.1 Capture Efficiency

A 2,095 m^3/min (74,000 acfm) exhaust fan removes air from the total enclosure and induces it through the control device. Doors leading into the enclosure remain closed and are equipped with automatic closing devices. Also, two slots in the enclosure walls allow passage of the web into and out of the press room. These slots serve as the only natural draft openings to the enclosure.

Capture efficiency tests have been conducted by Tarkett in accordance with Pennsylvania regulations. These regulations require Tarkett to design and operate a capture and control system that is consistent with good engineering practices and that provides for an overall reduction in VOC emissions of at least 65 percent. Velocity profiles were measured at the slots where the web enters and exits the press room. Also, differential static pressures were measured across the slots using low-range manometers and anemometers. Based on a liquid-gas material balance, the test contractor reported that capture efficiencies ranged between 97 and 100 percent with the printing room doors open (the test report lacks sufficient detail to independently verify these efficiencies). Although Tarkett intended to measure capture efficiency with the printing room doors closed, this portion of the test was aborted when the incinerator went down. However, it is expected that capture efficiencies will be enhanced with the doors closed.

During our visit, face velocities were measured at the natural draft openings using a hot wire anemometer. Face velocities through the natural draft opening into the enclosure ranged between 45.7 and 91.4 m/min (150 and 300 ft/min) depending upon the position of the probe. The differing face velocities are attributed to the web and web-conveying equipment that are positioned in the natural draft opening, which possibly cause variability in local face velocities. In reality, the effective area of the natural draft opening is a fraction of the area of the slots because of the area occupied by the web-conveying equipment that passes through them.

Table 3 indicates which PTE criteria have been satisfied by Tarkett's enclosure of their rotogravure press. Criteria 1 and 3 are clearly satisfied at Tarkett. The total area of the natural draft openings is 2.4 m^2 (26 ft^2). From our observations it appears that the enclosure has approximately 818 m^2 (8,800 ft^2) of surface area. Therefore, the natural draft opening is much less than 5 percent of the total surface area of the enclosure, and so Criteria 2 is satisfied.

Theoretical face velocities through the natural draft openings into the enclosure can be calculated by dividing the airflow exhausted from the room (1,020 m^3/min [36,000 ft^3/min]) by the total area of the natural draft openings (there is no forced makeup air). The theoretical face velocity through the natural draft openings is 422 m/min (1,384 ft/min), which satisfies Criteria 4. The equivalent diameter of the slots is approximately 0.6 m (2 ft). There are no emission sources (ink decks) within 2.4 m (8 ft) of the natural draft openings, so the fifth criterion is met.

TABLE 3. SUMMARY OF PTE CRITERIA AT TARKETT IN WHITEHALL, PENNSYLVANIA

Criteria No.	Plant met criteria
1. All VOC emissions must be captured and contained for discharge through a control device	Yes
2. Total area of NDO's is not to exceed 5 percent of total surface area	Yes
3. Access doors and windows should be closed during normal operation	Yes
4. The average inward face velocity across all NDO's must be at least 3,600 m/hr (200 ft/min)	Yes
5. All sources of emissions within the enclosure should be at least 4 equivalent diameters away from each NDO	Yes

Although the Tarkett capture data cannot be verified, they do indicate a high level of capture efficiency. Because the enclosure satisfies the PTE criteria, 100 percent capture can be assumed.

The enclosure was recently reviewed by Occupational Health and Safety Administration (OSHA) personnel, and worker exposure was determined to be only 40 percent of the time weighted average exposure limit. Noise levels were well below the 55 decibel limit, and excessive temperature or humidity conditions have not resulted from use of the enclosure. Worker safety is not an issue either, because the presence of fire doors in the enclosure actually contributes to fire protection.[5]

5.2.2 Control Device Efficiency

Tests on the destruction efficiency of the RE-THERM system were done in July 1987. The incinerator destruction efficiency averaged 98 percent for total hydrocarbon as measured by EPA Method 25A.

5.3 MAXWELL GRAPHICS[6]

Maxwell Graphics operates five rotogravure printing presses and one proof press at its facility in Richmond, Virginia. The plant prints the National Enquirer and various advertising inserts on newsprint. The presses are multicolor units with each color being applied sequentially at a different ink station. Each color of ink is dried in a dryer before the next color is applied. The dryers draw warm air over the web after each color application. One new press is located in a large room that is separate from the other presses. This press is equipped with a partial enclosure and was designed to meet lowest achievable emission reduction requirements (Richmond is nonattainment for ozone).[7] Three of the other presses have been modified to enhance local ventilation in response to permit requirements. Captured emissions are controlled by two carbon adsorbers.

5.3.1 Capture Efficiency

While the plant has not installed total enclosures, it has taken steps to enhance capture of fugitive emissions from the press rooms. One press, an Albert-Frankenthal gravure press, is located in a large room separate from the other four older presses. Three doors lead into the room and are equipped with automatic closing devices. Two bay doors accommodate the loading and unloading of trucks. The larger bay door leading outdoors was open during the site visit. The Albert-Frankenthal press is equipped with a partial enclosure above the applicators, and the lower part of the press (near the applicators) has hoods that close to contain vapors from the application section. The partial enclosure above the press draws VOC-laden air through the hoods on the application section of the press and directs it to a carbon adsorber. The room enclosure has no exhaust system of its own. Air in the room enclosure is induced out through the partial enclosure mounted above the press at a rate of 1,500 m^3/min (53,000 ft^3/min). Approximately 1,132 m^3/min (40,000 ft^3/min) of makeup air is fed into the large room. We were not able to detect with a hot wire anemometer any significant airflow (face velocity) into the large room containing the Albert-Frankenthal press. We suspect this was due in part to the large bay door's being open.

Three of the remaining presses (all Goss presses) have been modified to enhance the flow of air through the air spaces of the presses. These modifications include the installation of rubber curtains that drop down to cover the gap between the paint deck and the dryer. The curtains reduce the total area of the opening and increase the velocity of air induced through the remaining spaces. Also, these presses have air exhaust systems designed to remove air from beneath the presses. These presses are installed above a concrete basin. An induction fan at the rewind end of the press induces airflow through the basin beneath the presses, thus contributing to the capture of fugitive VOC's from the presses. The captured emissions are sent to the carbon adsorption system.

To date, no tests have been done to determine independently the capture efficiency of the enclosure. However, Maxwell Graphics performs a metered and computerized daily mass balance of all the inks and solvents used during production. This information is used to trace the use of the solvents and to document the amount of solvent that is not recovered. This is done by totaling the amount of solvent used and subtracting the amount of solvent recovered in the carbon adsorbers. Daily variations between 83 and 115 percent solvent recovery are common. According to the plant, the annual VOC recovery is approximately 94 to 95 percent of all solvents used in the printing process. The relatively high overall efficiency estimate indicates that capture efficiency is above 90 percent.

Table 4 indicates which PTE criteria have been satisfied by Maxwell Graphics efforts to enclose their Albert-Frankenthal rotogravure press. Criteria 1 and 3 are met if the bay door, which was open on the day of the visit, is considered a natural draft opening. The bay door area accounts for approximately 2 percent of the total surface area of the room, which satisfies Criteria 2. Dividing the difference between the exhaust air and makeup air rate (368 m^3/min [13,000 ft^3/min] by the surface area of the natural draft opening (13.0 m^2 [140 ft^2]) indicates that the theoretical face velocity is approximately 28.3 m/min (93 ft/min). Therefore, Criteria 4 is not met. Four times the equivalent diameter of the bay door is 14.2 m (46.7 ft). The Albert-Frankenthal press is approximately 23 m (75 ft) away from the opened bay door; therefore, the fifth criterion is met.

The air quality in the press room improved significantly with the addition of the enclosure systems. The "close capture" of solvent-laden air prevents the solvent fumes from escaping into the room. The OSHA recently dropped the personal exposure limit for toluene to less than 100 parts per million (ppm). The plant said that this change may result in the need for some workers to wear masks. However, without the current enclosure system, the standard would be even more difficult to meet.[7]

The company has always had a training program regarding routes of egress and procedures in the event of a fire or explosion. The addition of the enclosures did not result in any modifications to the safety program, i.e., the enclosures do not present an inherent safety problem.[7]

5.3.2 Control Device Efficiency

There are two separate carbon adsorber systems at the plant. Solvent recovery unit No. 1 has four carbon beds, each with a capacity of 1,416 m^3/min (50,000 ft^3/min). This unit is used to recover solvent from two of the Goss presses and the Motter press. These presses have a combined exhaust rate of 2,974 m^3/min (105,000 ft^3/min). Solvent recovery unit No. 2 has three carbon beds each with a capacity of 1,529 m^3/min (54,000 ft^3/min). This unit recovers solvent from one Goss press, the proof press, and the Albert-Frankenthal press. These three presses have a combined exhaust rate of 2,832 m^3/min (100,000 ft^3/min). Solvents (mostly toluene and xylene) are recovered by steam injection of the beds and are

TABLE 4. SUMMARY OF PTE CRITERIA
SATISFIED AT MAXWELL GRAPHICS IN RICHMOND, VIRGINIA

Criteria No.	Plant met criteria
1. All VOC emissions must be captured and contained for discharge through a control device	Yes
2. Total area of NDO's is not to exceed 5 percent of total surface area	Yes
3. Access doors and windows should be closed during normal operation	Yes
4. The average inward face velocity across all NDO's must be at least 3,600 m/hr (200 ft/min)	No
5. All sources of emissions within the enclosure should be at least 4 equivalent diameters away from each NDO	Yes

sold to ink formulators. Although the efficiency of the system has never been tested, the design efficiency of each unit is 98 percent.

5.4 ADVANCED PRINTING TECHNOLOGY[8]

Advanced Printing Technology operates two rotogravure printing presses at its facility in Morgantown, Pennsylvania.

The presses are multicolor units that print wood-grained laminates used for interior decor. Each color or design is applied sequentially at a different ink station. Each color or application of ink is dried before the next color is applied. The inks are dried with hot gases recovered from the regenerative thermal incinerator. The plant, built in 1987, was designed to incorporate state-of-the-art techniques to capture and control fugitive VOC's. Both presses are located in one large room, which is designed to serve as a PTE. Air is exhausted from this room and sent to a Smith Environmental Corporation thermal incinerator.

5.4.1 Capture Efficiency Criteria

All doors leading into the enclosure remain closed and are equipped with automatic closing devices. The forklift door and product conveyor door are equipped with overlapping vinyl strips that seal off the enclosure and allow personnel and equipment to move in and out of the press room.

Tests were performed in July 1989 to determine the average inward face velocity at the natural draft openings. This determination was made to demonstrate compliance of the enclosure with EPA's proposed PTE criteria. During the test, anemometer readings were taken at the product conveyor and forklift doors. The anemometer readings at the product conveyor door ranged between 102 and 132 m/min (334 and 439 ft/min) and averaged 113 m/min (370 ft/min) into the press room. Likewise, measurements were taken at the forklift door that ranged between 107 and 130 m/min (352 and 426 ft/min) with an average of 119 m/min (389 ft/min) into the press room. During our visit, MRI took anemometer readings that registered over 183 m/min (600 ft/min) at an opening located next to the fork lift door.

Table 5 indicates whether the PTE criteria have been satisfied at the Advanced Printing facility. Advanced Printing is a new facility that was designed and built to meet or exceed these enclosure criteria. Criteria 1 and 3 are clearly met.

TABLE 5. SUMMARY OF PTE CRITERIA AT
ADVANCED PRINTING TECHNOLOGY IN MORGANTOWN, PENNSYLVANIA

Criteria No.	Plant met criteria
1. All VOC emissions must be captured and contained for discharge through a control device	Yes
2. Total area of NDO's is not to exceed 5 percent of total surface area	Yes
3. Access doors and windows should be closed during normal operation	Yes
4. The average inward face velocity across all NDO's must be at least 3,600 m/hr (200 ft/min)	Yes
5. All sources of emissions within the enclosure should be at least 4 equivalent diameters away from each NDO	Yes

The facility is equipped with a pressure sensor to monitor the differential pressure between the enclosure and its surroundings. Because the makeup airflow rate is automatically controlled based upon input from the differential pressure sensor, the airflow rate is subject to variations when disturbances such as door openings or exhaust gas flow rate changes occur. As a result, plant personnel are generally not aware of what the changing makeup airflow rate is at any given time. However, the differential pressure controller has an adjustable control set point that enables maintaining a desired and relatively constant pressure drop between the enclosure and its surroundings. The control set point of Advanced Printing's differential pressure controller is 0.02 inches of water column. Studies performed on industrial ventilation indicate that a static pressure drop of 0.004 inches of water column is sufficient to induce face velocities of 61 m/min (200 ft/min) through natural draft openings. The differential pressure controller used by Advanced Printing is set to maintain a much greater differential pressure. Consequently, face velocities through their two natural draft openings will exceed 61 m/min (200 ft/min), thus satisfying Criteria 4.

The total surface area of the room is approximately 6,568 m^2 (70,700 ft^2). While it is not possible to exactly determine the area of the natural draft openings, the total area must be less than 15 m^2 (161 ft^2) (total area of NDO's without vinyl strips) because the overlapping vinyl strips block the majority of the opening. The area is certainly less than the 5 percent requirement, which would be 94 m^2 (1,010 ft^2) in this case. Therefore, Criteria 2 is met. The natural draft openings are approximately 30.5 m (100 ft) away from any emission source at the presses. The forklift door and product conveyor door have an equivalent diameter of 12 and 3.7, respectively (not considering the placement of the vinyl strips over the door openings). These doors are not within four equivalent diameters of any VOC emission source, so Criteria 5 is met.

In addition to satisfying the EPA criteria for a PTE, the enclosure also easily satisfies OSHA requirements. Plant management indicated that the concentration of VOC's in the enclosure is approximately 30 percent of that allowed by OSHA. Also, the large enclosure allows the workers to have easy access to the two presses with no significant restrictions to workers in the event it becomes necessary to quickly evacuate the enclosure.

5.4.2 Control Device Efficiency

Also in July 1989, Advanced Printing Technology tested the destruction efficiency of the incinerator. The tests showed an average destruction efficiency of 99.3 percent for VOC's entering the incinerator as measured by EPA Method 25A.

5.5 MORRILL PRESS[9]

Morrill Press operates four rotogravure printing presses in Fulton, New York. The plant prints paper and plastic packaging materials for the food processing and other industries. Two of the four presses are new, and the two new presses are subject to prevention of significant deterioration (PSD) regulations. The best available control technology at the time of permitting was 75 percent.[3] In addition to the Federal PSD regulations, these new sources must meet the applicable New York State regulations that require an overall control efficiency of 90 percent for each press.

These presses are located in a large room that serves as an enclosure to capture and collect fugitive VOC emissions from the presses. The VOC emissions from the two presses are reduced individually by two catalytic incinerators.

5.5.1 Capture Efficiency

The plant has made extensive use of local capture devices in addition to the enclosure as a whole. For example, each printing station is equipped with a hood to capture solvent evaporating from the web. Airflows through the hoods are controlled by automatic positioning dampers that are controlled by static pressure in the hoods. This ensures a constant fugitive pickup (capture) by the hoods. In addition, both presses have flexible duct floor sweeps located at each printing station to capture fugitive VOC emissions from beneath the ink decks. Because the floor sweeps are flexible, they can be placed where they will be most effective. To reduce fugitive VOC losses, the inks are mixed as needed and held in 12-gallon kits, which remain covered during printing.

There are two makeup air duct outlets that supply fresh air to the enclosure. One makeup air duct outlet is located inside the enclosure; the maximum airflow rate through this duct is 283 m^3/min (10,000 scfm). This duct is generally not turned on except in the winter months, when additional heat is needed for worker comfort. The other duct is located outside of the enclosure outlet in the cylinder storage room, because it created airflow problems when it was placed in the press room. While this duct is always on, it is not operated at its maximum airflow rate of 1,416 m^3/min (50,000 scfm). Plant personnel said that the fan usually remains on a low speed, but they could not provide any information on the exact volume of air delivered. The air from the cylinder storage room duct outlet is delivered through the adjacent staging room and from there through the only natural draft opening in the enclosure, which is a 7.4 m^2 (80 ft^2) open doorway between the press room and the staging room. Airflow measurements taken at the inlet of each catalytic incinerator indicate that the exhaust rate from the two presses are approximately 402 and 463 m^3/min (14,200 and 16,350 scfm), respectively.

Compliance testing was performed simultaneously on these two presses on May 18, 1989, to determine the VOC capture efficiency (liquid/gas balance) and incinerator VOC destruction efficiency (discussed below) on each line. Total solvent use was measured over a 3-hour period while VOC measurements were made at the inlet and outlet of the two catalytic incinerators. During the test, all outside doors and the doors leading to the dock and cylinder storage areas were closed. The makeup air duct in the cylinder storage room was delivering approximately 1,416 m^3/min (50,000 scfm) (maximum rated capacity), while the makeup air duct in the enclosure remained idle. The doorway between the staging room and the enclosure was open. Face velocity through the natural draft opening was determined by hot wire anemometer to be about 160 m/min (525 ft/min).

For the one press, the VOC capture efficiency averaged 112 percent and the VOC destruction efficiency averaged 97.0 percent. The overall VOC control efficiency was reported as 108.6 percent, which is the product of the capture efficiency and destruction efficiency. The other press had an average VOC capture efficiency of 99.7 percent and a VOC destruction efficiency of 99.6 percent. The overall VOC control efficiency was reported as 99.3 percent. The test team said that the fact that the VOC capture efficiency on each press approached or exceeded 100 percent was apparently due to the collection of fugitive VOC emissions from the other two presses not located within the enclosure. Fugitive emissions from these presses could be entering the enclosure via the NDO or other leaks.

Table 6 is a summary of the PTE criteria that are satisfied at Morrill Press. Criteria 1 is clearly met. Even if one assumed that all seven doors leading into the enclosure remained open during operation, they would comprise approximately 1 percent of the total surface area of the enclosure. Therefore, Criteria 2 is met. Because the presses were not operating at the time of our visit, we were not able to observe the normal operation of the capture and control system. Plant personnel did indicate that all doorways remained closed in the press room except one doorway leading into the staging room, which would satisfy Criteria 3 (the staging room door is considered a natural draft opening). Recent test data have documented that inward face velocities have approached 160 m/min (525 ft/min) at the natural draft opening. Also, the difference between the amount of air exhausted to the two incinerators and the maximum amount of air returning through the makeup air duct in the enclosure is 708 m^3/min (25,000 scfm). Dividing 708 m^3/min (25,000 scfm) by the area of the natural draft opening (7.4 m^2 [80 ft^2]) yields an inward face velocity of 95 m/min (312 ft/min), thus satisfying Criteria 4. The doorway that serves as a natural draft opening is approximately 24.4 m (80 feet) away from the nearest ink station along the presses. The natural draft opening is 7.4 m^2 (80 ft^2), with an equivalent diameter of 2.7 m (8.9 ft). Therefore, Criteria 5 is satisfied.

Although the test program data probably represent an overestimation of capture efficiency, a high level of capture efficiency is indicated. Because the enclosure satisfies the PTE criteria, 100 percent capture efficiency can be assumed. In addition to satisfying EPA criteria plant personnel indicated that VOC exposure levels are less than 50 percent of the level that would trigger worker protection requirements by OSHA.

TABLE 6. SUMMARY OF PTE CRITERIA AT MORRILL PRESS IN FULTON, NEW YORK

Criteria No.	Plant met criteria
1. All VOC emissions must be captured and contained for discharge through a control device	Yes
2. Total area of NDO's is not to exceed 5 percent of total surface area	Yes
3. Access doors and windows should be closed during normal operation	Yes
4. The average inward face velocity across all NDO's must be at least 3,600 m/hr (200 ft/min)	Yes[a]
5. All sources of emissions within the enclosure should be at least 4 equivalent diameters away from each NDO	Yes

[a]No measurements were made during our visit because the plant was not operating. An emissions test dated May 18, 1989, contains measurements taken at an open doorway in the northwest corner of the storage area. The face velocity through this openings was determined using a hot wire anemometer to be approximately 160 m/min (525 ft/min). Theoretical calculations suggest that the minimum face velocity through the NDO to be 95 m/min (312 ft/min).

5.5.2 Control Device Efficiency

The two TEC System HXC catalytic incinerators were installed in 1988. The incinerators are 3-chamber catalytic units designed to treat 142 to 566 m^3/min (5,000 to 20,000 scfm) of air each. Typically these systems will destroy 95 percent of the inlet VOC and are guaranteed to achieve 90 percent destruction. The system is sized to handle the maximum exhaust gas from each press with all stations in service, or 566 m^3/min (20,000 scfm). If the exhaust rate from the press drops below 142 m^3/min (5,000 scfm), incinerator exhaust is recirculated to the inlet to maintain the required minimum airflow and bed temperatures. The TEC Systems HXC unit is equipped with a variety of automatic controls permitting a self-sustaining catalytic oxidation (no auxiliary fuel) if sufficient VOC is present in the inlet gas.

As stated above, control device efficiency on the two incinerators was determined to be 97.0 percent and 99.6 percent, respectively.

5.6 AMKO PLASTICS[10]

Amko Plastics extrudes polyethylene film, prints it, and converts the printed film into finished bags and wraps. The facility employs 11 flexographic presses. Until 1984, Amko Plastics printed using solvent-based (alcohol-based) inks. In 1984 the facility applied for permits to install three new printing presses. The State EPA Office informed Amko it would have to comply with BACT guidelines. Amko then decided to convert to water-based inks. The early days of this conversion resulted in some equipment-related problems. Amko made several modifications to their presses and added new systems that have eliminated most of the early problems. They redesigned air blowers, plenums, and dryer hoods on all of their presses to enhance the drying characteristics of the water-based inks. Changes also had to be made to the anilox and fountain rollers and to the printing plate (refer to Appendix A and to the Amko trip report for details). Amko's newest press, installed in December 1987, was specifically designed to run water-based inks exclusively at press speeds of up to 297 m/min (975 ft/min).

The use of water-based inks has eliminated the need for total enclosures around the presses and emission control equipment to destroy or collect the fugitive VOC's emitted from solvent-based inks. The most notable contrast between Amko's water-based printing operation and other solvent-based printing operations is the lack of any noticeable solvent odors in the press room. Even when standing in the direct vicinity of an operating press, no solvent odors were noticeable.

Although MRI was not able to determine the exact emission reduction achieved by Amko's conversion to water-based inks, estimates indicate that the reduction is significant. In 1983, before the conversion occurred, VOC emissions were estimated to exceed 81.7 Mg/yr (90 tons/yr). In 1989, with more production volume, emissions were estimated at approximately 27.2 Mg/yr (30 tons/yr).

A paper presented at an Air Pollution Control Association (APCA) meeting by Mr. Makrauer, President/CEO of Amko, Inc. (Appendix A), describes in detail the efforts, difficulties, and successes of Amko Plastics, Inc., in converting their flexographic printing operations from solvent-based inks to water-based inks for printing on low density polyethylene film. In Mr. Makrauer's presentation to APCA, and during the site visit, he discussed the following benefits that are associated with the use of water-based inks:

1. Water-based inks are not classified as a combustible material, so containers of water-based inks are not required to be stored in expensive, explosion-protected storage rooms. As a result, water-based inks may be stored conveniently close to the printing presses themselves.

2. The Resource Conservation and Recovery Act requires special conditions to be maintained for outdoor solvent storage tanks, installed either above ground or underground. Special liability coverage is required to protect against environmental contamination damage resulting from tank leakage. Insurance premiums for one underground solvent storage tank were $15,000 per year. Since Amko purchases only small amounts of solvent, it has chosen to do so in 55 gallon drums. By emptying and sealing their underground tank, Amko saves $15,000 each year on this insurance premium.

3. Water evaporates more slowly than solvent; therefore, viscosity changes due to evaporation take place more slowly in water-based inks than in solvent-based inks. With smaller viscosity fluctuations, it is easier to hold consistent color throughout a press run of water-based ink.

4. Water-based inks have greater coverage yield than solvent-based inks. Although the cost per pound of some water-based inks is higher than solvent-based inks, the cost margin is generally less than the increased yield and a net ink cost advantage exists; and

5. A most notable benefit Amko experienced was the improvement of working conditions in the press room. The drastic reduction in the solvent content of inks has significantly reduced solvent vapors, resulting in a noticeable improvement in the quality of ambient press room air.

Even though Amko has succeeded in converting to water-based inks, some difficulties still exist. Some customers refuse to accept bags printed with water-based inks because they may not have the same gloss level as bags printed with solvent-based inks. Amko can generally achieve the same levels of gloss with water-based inks, but some colors occasionally have lower gloss when using standard pigments. In those circumstances, to improve the gloss, Amko uses chip dispersion pigment systems. These pigments cost more than standard pigments.

The plant's biggest waste problem is associated with the wastewater and sludge generated during the cleanup of the presses. Amko spends approximately $60,000 per year to dispose of this material. However, Amko has ordered a dewatering device costing about $40,000 that will dewater the sludge and treat the effluent water to standards acceptable for discharge into the city sewer system. The payback on this equipment is estimated to be 1.5 years.

5.7 CMS GILBRETH PACKAGING SYSTEMS[11]

CMS Gilbreth Packaging Systems operates two plants, one in Croydon, Pennsylvania, and one in Bensalem, Pennsylvania. The plants are known as the Bristol and Bensalem plants, respectively. Both plants print flexible packaging on heat-shrinkable polyvinylchloride (PVC) film, e.g., battery covers and candy wrappers. The Bristol plant operates one eight-station rotogravure press. The Bensalem plant operates 4 rotogravure presses and one flexographic press.

The Bristol plant is currently operating at its permitted VOC emission limit. The plant's owners are not allowed to increase press speed, add shifts, or install additional presses without first reducing the VOC emission rate. On the advice of a consultant, Richmond Tech-Air Corp., the plant instituted a program to install the necessary capture and control system to reduce VOC emissions. A similar system was also designed for the Bensalem plant, which is also subject to LAER requirements.[12] Neither system was fully operational at the time of the site visit.

5.7.1 Capture Efficiency--Bristol Plant

The capture system at the Bristol plant was designed to meet EPA's PTE criteria. Because the capture system was not operational at the time of the visit, it is not possible to document whether the enclosure meets the PTE criteria. Therefore, the discussion in this report will focus on efforts taken by the plant to incorporate air management techniques to minimize the size of airflow to be controlled. Limiting airflow reduces the requisite size of the control device and its operating costs. However, the desire to limit airflow must be balanced against the need to maintain reasonable working conditions within the enclosure. Humidity levels, temperature, solvent fumes, and the effects of machinery on airflow patterns must all be considered.[12]

One technique to reduce the size of airflows is to maintain a quiescent environment in the press room particularly around the printing stations. This condition allows the heavier than air solvent vapors to be readily picked up by the ink tray exhausts and floor sweeps without being scattered by air currents in the room. The ink tray pickup device, which is a rectangular box mounted slightly below the ink fountain, was designed with this condition in mind. Air is drawn through two slots in the pickup device in an attempt to ensure that airflow velocities across the length of the exhaust are uniform. However, measurements made by plant personnel show that the air velocity across the face of the device differs by approximately 366 m/min (1,200 ft/min) from one end to the other. Plant personnel are currently considering ways to equalize the air velocity across the pickup devices.

The press room also contains electrical boxes that are pressurized with purge air that is drawn from inside the press room. Because the electrical boxes are not airtight, leaking air can be swept up under the press and create air currents across the print stations. These air currents then sweep solvent vapors from around the print stations and contribute to an increase in ambient press room VOC levels and a decrease in the VOC capture efficiency of the system. To solve this problem, the plant has installed a lightweight panel wall between the print stations and the pressurized electrical boxes to shield the print stations from the purge air.

The plant also plans to recirculate 425 m^3/min (15,000 ft^3/min) of dryer exhaust in the press room rather than sending the full 623 m^3/min (22,000 ft^3/min) directly to the control device. However, when the recirculation system was placed in service for testing, the result was a significant increase in the VOC concentration of the press room air. This increase proved to be due to the many leaks that existed in the ductwork that carried the recirculating exhaust under positive pressure. Since then, the "cracks" have been caulked to prevent VOC's from leaking into the press room from the ductwork. Unfortunately, at the time of the site visit, the recirculation system was not being operated.

The capture system design also incorporates the idea of close capture in the placement of fugitive pickups. The system consists of an ink tray pickup device that is suspended slightly below the ink tray and a floor sweep positioned at each of the eight print stations for close capture of fugitive VOC's emitted from the press. At each print station, 2.8 m^3/min (100 ft^3/min) of air is drawn through the ink tray pickup device and 26 m^3/min (900 ft^3/min) of air is drawn through the floor sweep. The total fugitive exhaust pickup is therefore 227 m^3/min (8,000 ft^3/min) of air.

The makeup air system is controlled by a differential pressure controller that is set to deliver 57 m^3/min (2,000 ft^3/min) less air to the enclosure than what is taken out through the exhaust. The controller is designed to be used in the differential pressure range of 0.01 to 0.2 inches of water column. Because EPA accepts a differential pressure of 0.004 inches of water column as sufficient to induce a 61 m/min

(200 ft/min) velocity across a natural draft opening, the CMS Gilbreth system should satisfy EPA's PTE Criteria 4.

The fugitive VOC capture system has had a major effect on ambient VOC levels in the press room. Before the system was installed, ambient VOC levels in the press room averaged around 300 ppm as hexane. After installation of the capture system, ambient VOC levels dropped to about 30 ppm. Subsequent installation of the dryer exhaust recirculation system has probably resulted in a further decrease in press room ambient VOC concentrations. In a recent conversation, Mr. Nash said that the facility can now operate the enclosure with the doors closed, run the air conditioner or heating system (as required), and still meet the OSHA standard.[12]

5.7.2 Control Device Efficiency--Bristol Plant

At the time of the site visit, the plant was completing construction on the regenerative thermal oxidizer that will control solvent vapors sent from the capture system. The thermal oxidizer has three beds packed with ceramic beryl saddles. Combustion is a cyclical operation that uses valves to alter the airflow to regenerate the heat stored in the beryl saddles. Once online, the thermal oxidizer, which is rated for 482 m^3/min (17,000 ft^3/min), will receive exhaust gases from both the press room and the ink room.

5.7.3 Capture Efficiency--Bensalem Plant

The five presses at the Bensalem plant are contained in two rooms, which are connected by a 2.4 m by 3.7 m (8 ft x 12 ft) overhead door that remains open. The flow of exhaust air and forced makeup air was designed so that the two print rooms connected by the door serve as a single enclosure. The enclosure is designed to remove approximately 567 m^3/min (20,000 ft^3/min) of room air and to return 510 m^3/min (18,000 ft^3/min) of makeup air. A differential pressure controller identical to the one used at the Bristol plant is used to control the makeup air rate. This differential pressure controller also has a range of 0.01 to 0.2 inches of water column.

One of the presses, the TECMO press, employs the same fugitive VOC control equipment as that used at the Bristol plant. However, during the site visit, the ink tray exhaust hoods were disconnected from the ink trays and were lying on the floor. Apparently, Bensalem plant personnel believe that the wet printed substrate is the source of evaporative losses rather than the ink trays. Mr. Nash, the plant engineer, said that another problem is that the press operators have become so insensitive to the solvent odor that even major changes in the VOC concentration in the room are not detectable by them during the normal work week. Mr. Nash said that unless and until the workplace is essentially odor free for a matter of weeks, the employees may not develop the incentive to improve operating practices. In contrast, at the Bristol facility, where the capture system (particularly the ink tray pickup devices) is utilized, the press operators quickly notice increases in solvent concentrations because they have become accustomed to the lower odor levels.

The plant is working to resolve air management problems related to their relatively complicated exhaust system, and the system is not considered fully operational. Therefore, it was not possible to evaluate whether the system can be judged to meet the total enclosure criteria. Certainly, there was a very strong solvent odor in the room. Recent liquid-gas mass balance capture tests performed by the State concluded that only 48 percent of the solvent vapors were being captured by the enclosure. Plant personnel indicated a lack of confidence in the test methodology, and the system is to be retested.

When it is operational, the enclosure should be capable of meeting EPA's PTE criteria. If the enclosure operates as designed, with all doors closed, there should be no natural draft openings except for unsealed cracks around doorways. Although the set point of the differential pressure controller is not known, the range in which it operates (0.01 to 0.2 inches of water column) exceeds the differential pressure of 0.004 inches of water necessary to maintain inward face velocities of 61 m/min (200 ft/min).

5.7.4 Control Device Efficiency--Bensalem Plant

Approximately 553 m^3/min (19,500 ft^3/min) of air is sent to the thermal oxidizer, which has a capacity to handle 623 m^3/min (22,000 ft^3/min). The thermal oxidizer has three beds packed with ceramic beryl saddles and is operated using regenerative heat recovery. When operational, all air exhausted from the enclosure and from the ink room is to be sent to the thermal oxidizer. No control efficiency test data are available.

6.0 DISCUSSION

6.1 OVERALL CONTROL SUMMARY

A summary of MRI's evaluation of the PTE criteria for the eight plants visited is presented in Table 7. One of the plants elected to reduce VOC emissions by converting to water-based coatings. Therefore, the PTE criteria are not applicable.

Four of the plants have enclosures that clearly satisfy each of the five criteria and may be deemed as "PTE's." One plant failed to meet Criteria 4 (i.e., maintaining at least a 3,600 m/hr [200 ft/min] face velocity across all NDO's) and, therefore, cannot be considered a PTE. Two of the plants have not completed installation of their enclosure systems, and their status as PTE's cannot be determined. However, based on the design and operating data presented during the site visit, it appears that once the enclosures are fully operational that they will meet the PTE criteria.

Table 8 presents a summary of EPA's evaluation of capture efficiency at each of the plants visited. The four plants that have PTE's have been assumed by EPA to have a capture efficiency of 100 percent. Although one plant met four of five PTE criteria, it is not possible to predict the capture efficiency of this enclosure in the absence of capture efficiency test data. As can be seen in Table 8, capture efficiencies are unavailable at this time for the remaining plants as well.

To control the exhaust gases coming from the enclosures, four of the plants use (or plan to use) thermal oxidizers, two of the plants use catalytic incinerators, and one plant uses a carbon adsorber (see Table 1). The control efficiencies of each of these devices as they are operated in the plants visited can be found in Table 8. The EPA has

TABLE 7. SUMMARY OF RESULTS OF EXAMINATION FOR PTE CRITERIA AT ALL PLANTS VISITED

Plant	Satisfied enclosure criteria				
	1[a]	2[b]	3[c]	4[d]	5[e]
Package Products Charlotte, NC	Yes	Yes	Yes	Yes	Yes
Tarkett Whitehall, PA	Yes	Yes	Yes	Yes	Yes
Maxwell Graphics Richmond, VA	Yes	Yes	Yes	No	Yes
Advanced Printing Technology Morgantown, PA	Yes	Yes	Yes	Yes	Yes
Morrill Press Fulton, NY	Yes	Yes	Yes	Yes	Yes
CMS Gilbreth-Bristol, Croydon, PA[f]	-	-	-	-	-
CMS Gilbreth-Bensalem, Bensalem, PA[f]	-	-	-	-	-
Amko Plastics Cincinnati, OH[g]	-	-	-	-	-

[a]All VOC emissions must be captured and contained for discharge through a control device.
[b]Total area of NDO's is not to exceed 5 percent of total surface area.
[c]Access doors and windows should be closed during normal operation.
[d]The average inward face velocity across all NDO's must be at least 3,600 m/hr (200 ft/min).
[e]All sources of emissions within the enclosure should be at least 4 equivalent diameters away from each NDO.
[f]These plants' exhaust systems were designed around the PTE concept, but one was not yet complete and the other shut down before the examination could be completed during our visits.
[g]The Amko plant uses waterborne inks so these criteria are not applicable.

TABLE 8. SUMMARY OF OVERALL CONTROL EFFICIENCIES

Plant	Capture efficiency	Destruction/ removal efficiency	Overall control efficiency for compliance purposes
Package Products Charlotte, NC	PTE (100)	99.5	99.5
Tarkett Whitehall, PA	PTE (100)	98.0	98.0
Maxwell Graphics Richmond, VA	-	-	94[a]
Advanced Printing Technology Morgantown, PA	PTE (100)	99.3	99.3
Morrill Press Fulton, NY	PTE (100)	97.0	97.0
Amko Plastics Cincinnati, OH			66.7[b]
CMS Gilbreth-Bristol Croydon, PA[c]			
CMS Gilbreth-Bensalem Bensalem, PA[c]			

[a]Overall control efficiency obtained from material balances performed from records kept on solvent used and solvent recovered in carbon adsorption system.

[b]Based on emission reductions reported by Amko from 1983 to 1989. The calculated reduction does not include a correction for the increased production that occurred over the 6-year period. If this could be done, Amko's emission reduction would be larger than presented on the table.

[c]These plants' exhaust systems were designed around the PTE concept, but one was not yet complete and the other shut down before the examination could be completed during our visits.

extensive data that confirm that these control devices are capable of achieving very high efficiencies. These control devices are capable of routinely achieving efficiencies of 95 percent or greater. In fact, the control efficiencies documented from our visits ranged from 97 to 99.5 percent. Overall control efficiencies ranged from 94 to 99.5 percent for those facilities using add-on controls.

The information gathered in the course of this study leads to the conclusion that capture and control systems have been demonstrated to be effective and reliable in controlling greater than 90 percent of the VOC emissions from graphic arts facilities. This level of control is not limited to new facilities. Only one of the facilities visited during this study was a totally new facility. The other facilities, including the facility using water-based inks had all been retrofitted with the technology to reduce VOC emissions. In addition, recent information reported to EPA indicates that other facilities have adopted capture and control systems that achieve greater than 90 percent VOC emission reductions.

The information contained in this report serves to demonstrate that VOC control efficiencies of 90 percent and greater are obtainable and previously accepted VOC emission reductions of 65 percent may no longer serve as a practical upper bound for control of these sources. States should be cognizant of the demonstrated control efficiencies obtained in these and other graphic arts facilities and apply this information in future BACT/LAER and RACT determinations.

6.2 WATER-BASED INKS

The use of water-based inks as an alternative to reducing VOC emissions in flexible packaging printing operations has been demonstrated by Amko Plastics in Cincinnati, Ohio. Some of the advantages to water-based inks include:

1. Water-based inks are noncombustible and are not subject to special storage requirements;

2. Water evaporates more slowly than solvent, resulting in less fluctuation of the ink viscosity during printing that affects product quality; and

3. Ambient press room air is virtually free of solvent vapors. The conversion from solvent-based inks to water-based inks requires that presses be altered and dryers redesigned to accommodate the greater drying capacity needed to dry water-based inks. Appropriate pigment systems have to be developed, which requires close coordination between pigment and coating manufacturers as well as buyer awareness programs. In addition, the polyethylene film must be custom blended for use with water-based inks. The EPA should consider whether further VOC reductions are possible if consumers can be educated about the environmental and worker health and safety benefits of conversion to water-based coatings.

6.3 OTHER TOTAL ENCLOSURE CONSIDERATIONS

6.3.1 Differential Pressure Controllers

Some plants are equipped with differential pressure sensors/controllers that activate a variable speed forced makeup air fan to adjust the amount of forced makeup air that is being sent to the enclosure. Usually, the differential pressure controllers are set to maintain a specified pressure drop between the inside of the enclosure and the ambient air outside of it. Door openings and disturbances within the enclosure affect the pressure in the enclosure, which may result in a change in the forced makeup air rate. Since the design of the automatically controlled system means that knowledge of actual average airflow rates is unnecessary and is difficult to determine, plant personnel are generally not able to provide information on the average airflow rate of the makeup air fan. The alternative, using maximum design values for the makeup air fan, can overestimate actual face velocities through NDO's. Consequently, it is difficult to calculate whether the enclosure satisfies the average face velocity requirement of Criteria 4.

An alternate means of complying with Criteria 4 is to establish a minimum static pressure drop across the NDO of about 1.0 Pa (0.004 in. water). This pressure drop results in inward face velocities of least 3,600 m/hr (200 ft/min). Therefore, maintaining a minimum acceptable differential pressure across the NDO's will ensure reasonable compliance with the 3,600 m/hr (200 ft/min) face velocity requirements regardless of the changing NDO areas caused by the opening of doors and other disturbances.

The EPA personnel involved in inspecting or permitting facilities that use differential pressure controllers should confirm two pieces of information, however. First, if the controller controls supply air only, it is possible that a low exhaust flow rate could result in the controller switching off the supply fan. In this case, there is no assurance that an adequate pressure drop will be maintained. It should also be noted that the differential pressure readings must be taken across the NDO's and not necessarily with respect to atmospheric pressure (unless the NDO leads directly to the outside). Enclosures with exhaust fans may effectively reduce the pressure of an entire facility relative to atmospheric pressure, making it necessary to measure static pressure differences across NDO's that open to other areas of a plant.

6.3.2 Worker Exposure and Safety Considerations

Attaining a high level of capture efficiency is only one of the design criteria that facilities consider when they design or retrofit total enclosures. Issues of worker exposure to concentrated solvent vapors and the ability of workers to quickly exit from the enclosure in the event of a sudden hazard must be addressed, just as they were in the design of the initial plant. Personnel at several facilities which have total enclosures confirmed that worker exposure is not a problem at their facilities; they report that solvent levels in their enclosures are approximately 30 to 50 percent of those allowed by OSHA and at least one plant is reported to have altogether eliminated the characteristic solvent odor so ubiquitous to printing facilities. Worker exit requirements were also specifically addressed in our discussion with plant personnel. None of the facilities believed that the enclosures had increased safety problems in any respect.

7.0 REFERENCES

1. The Printing Ink Handbook, National Association of Printing Ink Manufacturers, Inc., Harrison 1988. pp. 39-47.

2. Memorandum. Vaught, C., MRI, to Catlett, K., EPA:CPB. Trip Report: Package Products Company in Charlotte, North Carolina, on November 30, 1989.

3. Telecon. Shine, B., MRI, with Warlick, T., Engraph. June 26, 1989. Discussion about control levels and technologies at Engraph facilities.

4. Memorandum. Vaught, C., MRI, to Catlett, K., EPA:CPB. Trip Report: Tarkett, Inc. in Whitehall, Pennsylvania, on December 6, 1989.

5. Telecon. Friedman, B., MRI, with Switzer, W., Tarkett, Inc. December 18, 1990. Discussion about total enclosure.

6. Memorandum. Vaught, C., MRI, to Catlett, K., EPA:CPB. Trip Report: Maxwell Graphics in Richmond, Virginia, on January 16, 1990.

7. Telecon. Friedman, B., MRI, with Kontny, D., Maxwell Graphics. December 17, 1990. Discussion about enclosures.

8. Memorandum. Vaught, C., MRI, to Catlett, K., EPA:CPB. Trip Report: Advanced Printing Technology in Morgantown, Pennsylvania, on December 5, 1989.

9. Memorandum. Vaught, C., MRI, to Catlett, K., EPA:CPB. Trip Report: Morrill Press in Fulton, New York, on April 6, 1990.

10. Memorandum. Vaught, C., MRI, to Catlett, K., EPA:CPB. Trip Report: Amko Plastics, Inc., in Cincinnati, Ohio, on January 18, 1990.

11. Memorandum. Vaught, C., MRI, to Catlett, K., EPA:CPB. Trip Report: CMS Gilbreth Packaging Systems in Croydon and Bensalem, Pennsylvania, on July 19, 1990.

12. Telecon. Friedman, B., MRI, with Nash, J., CMS Gilbreth Packaging Systems. December 17, 1990. Discussion about enclosures.

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16. ABSTRACT

The Graphic Arts Industry is a source of volatile organic compound (VOC) emissions. This study was conducted to document the reported overall control efficiency for VOC at a number of rotogravure and flexographic printing facilities.

The primary conclusions form this study are: (1) the use of capture and control systems and the use of water-based ink systems have been demonstrated to be effective and reliable in achieving greater than 90 percent overall VOC reduction rotogravure and flexogrpahic printing facilities; (2) facilities can be retrofitted to achieve 90 percent VOC reductions; and (3) permanent total enclosures meeting EPA criteria have been successfully installed and operated at rotogravure and flexographic printing facilities.

17. KEY WORDS AND DOCUMENT ANALYSIS

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