National Pollutant Inventory

Emissions Estimation Technique Manual

for

Printing, Publishing, and Packaging

First published in August 1998

EMISSION ESTIMATION TECHNIQUES
FOR
PRINTING, PUBLISHING, AND PACKAGING

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1.0 Introduction

The purpose of all Emission Estimation Techniques (EET) Manuals in this series is to assist Australian manufacturing, industrial, and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in printing, packaging, and publishing activities.

The printing activities covered in this Manual apply to facilities primarily using the following printing methods :

• Rotogravure	Packaging, advertising, greeting cards, art books, catalogues, and directories
• Flexography	Packaging, advertising newspapers, books, magazines, financial and legal document directories
• Offset Lithography	Magazines, catalogues, and directories, newspapers, books, stationery, financial and legal documents, advertising, journals, packaging, food, beverage and aerosol cans
• Letterpress	Magazines, catalogues, and directories, newspapers, books, stationery, financial and legal documents, advertising, journals, packaging, food, beverage and aerosol cans
• Screen	Signs, electronics, wallpaper, greeting cards, ceramics, decals, banners, plastic bottles

EET MANUAL:	Printing, Publishing, and Packaging
HANDBOOK:	Printing, Publishing, and Services to Printing
ANZSIC CODE :	241 (including 2411, 2412, 2413), and 242 (including 2421, 2422, 2423)

This Manual was drafted by the NPI Unit of the Queensland Department of Environment on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities and key stakeholders, and has been considered by independent reviewers.

2.0 Process Description

2.1 Industrial Processes in the Printing, Publishing, and Packaging Industry

The printing and publishing activities covered in this Manual include the six basic processes of the printing and publishing industry as detailed in Section 1.0: rotogravure, offset lithographic, letterpress, flexography, screen, and plateless.

Printing can be conducted using coated or uncoated paper as well as other surfaces, including metals and plastic films. The material to receive the printing is called the substrate. The distinction between printing and paper coating, which may also employ rotogravure or lithographic methods, is that printing involves the application of ink using a printing press.

Printing inks vary widely in composition, but all consist of three major components: pigments, that produce the desired colours and are composed of finely divided organic and inorganic materials; binders are the components that lock the pigments to the substrate and which are composed of organic resins and polymers or, in some inks, oils and resins; and solvents or water, that disperse the pigments and binders. The solvents or water is evaporated from the ink during the drying process.

2.2 Rotogravure Printing

Gravure is a printing process in which an image is etched or engraved into the surface of a cylinder. It requires very fluid inks that flow from the cells to the substrate at high press speeds. Solvent-borne or water-borne ink systems can be used in gravure printing, but these ink systems are not interchangeable. Rotogravure printing is usually performed on a continuous web.

Rotogravure printing can be divided into publication and product/packaging segments. Publication gravure presses in Australia now use water-borne ink systems almost exclusively to reduce emissions of volatile organic compounds (VOCs) from the press. Rotogravure cylinder engraving is complex and expensive and therefore particularly suited to long-run printing jobs. Packaging and product gravure inks include nitrocellulose and solvent-based inks. The main inventory solvents used are ethanol, ethyl acetate, methyl ethyl ketone, toluene, and acetone.

The majority of presses are 8 or 9 colour machines, and allow all colours to be applied in one pass. Some of these printing presses are connected directly to adhesive laminators which allow another web to be applied to the printed web. The web to be printed is usually a film of paper, polyester, polypropylene, polystyrene, aluminium foil, cellulose, metallised polyester, metallised polypropylene, or some combination of these.

Materials other than inks, including adhesives, primers, coatings, and varnishes may be applied with rotogravure cylinders. These materials dry by evaporation as the substrate passes through hot air dryers. Figure 1 outlines the gravure printing process and highlights the likely emissions and emission points.

As there are only a small number of large printers in Australia that use the gravure technique, and the exact process in each facility is likely to be unique, you are encouraged to develop a flow diagram for your own operations detailing the input of materials and NPI listed substances, and the waste sources and emissions resulting from the operation of each process.

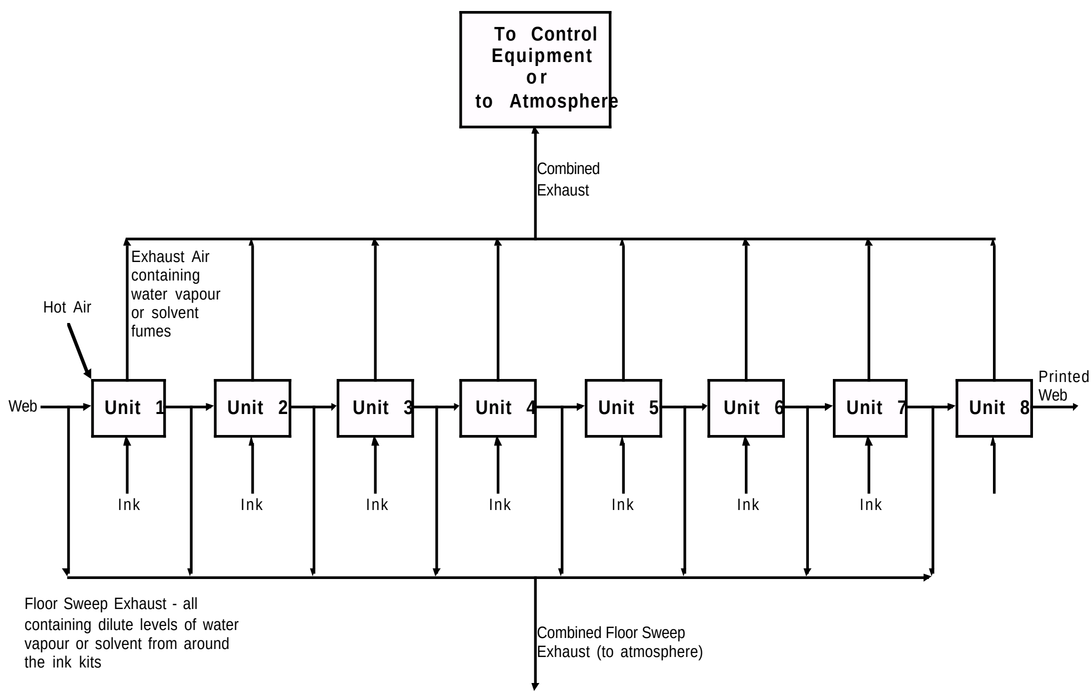

Figure 1. Flow Chart for a Typical 8-Colour Gravure Printing Press

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2.3 Flexographic Printing

In flexographic printing, the image area is raised from the surface of a plate - like a typewriter - with a polymer image carrier. Alcohol-based inks are generally used. The process is usually web-fed and used for medium or long multi-colour runs on a variety of substrates, including heavy paper, fibreboard, and metal and plastic foil. Almost all milk cartons and multiwall bags, and around half of all flexible packaging in Australia is printed by this process.

Solvent-based inks are used primarily in packaging and printing on plastic or metallic films. The solvent is usually an alcohol or an acetate such as ethanol, or ethyl acetate. The inks dry by absorption into the web or by evaporation, usually in high-velocity hot-air dryers at temperatures below 120°C. Most of the solvent-borne flexographic inks contain few or no hazardous air pollutants. As in rotogravure, the web is printed on only one side at a time.

2.4 Offset Lithographic Printing

Lithography is characterised by the use of a planographic image carrier; that is the image and non-image areas are on the same plane. The image area is ink wettable and water repellent, and the non-image area is chemically repellent to ink. The inks used in lithography are either heatset or non-heatset. In offset printing, the graphic image is applied from an ink-covered print plate to a rubber-covered ‘blanket’ cylinder and then transferred onto the substrate, hence the term ‘offset’ lithography (USEPA, 1993). The substrate in offset lithography can be either a web or sheet. A web substrate can be used with either heatset or non-heatset inks. Sheets are used with non-heatset only. Figure 2 outlines the offset lithographic process and shows potential emission points. Some offset presses print on both sides of the paper at the same time while others print on one side only, or two sides sequentially.

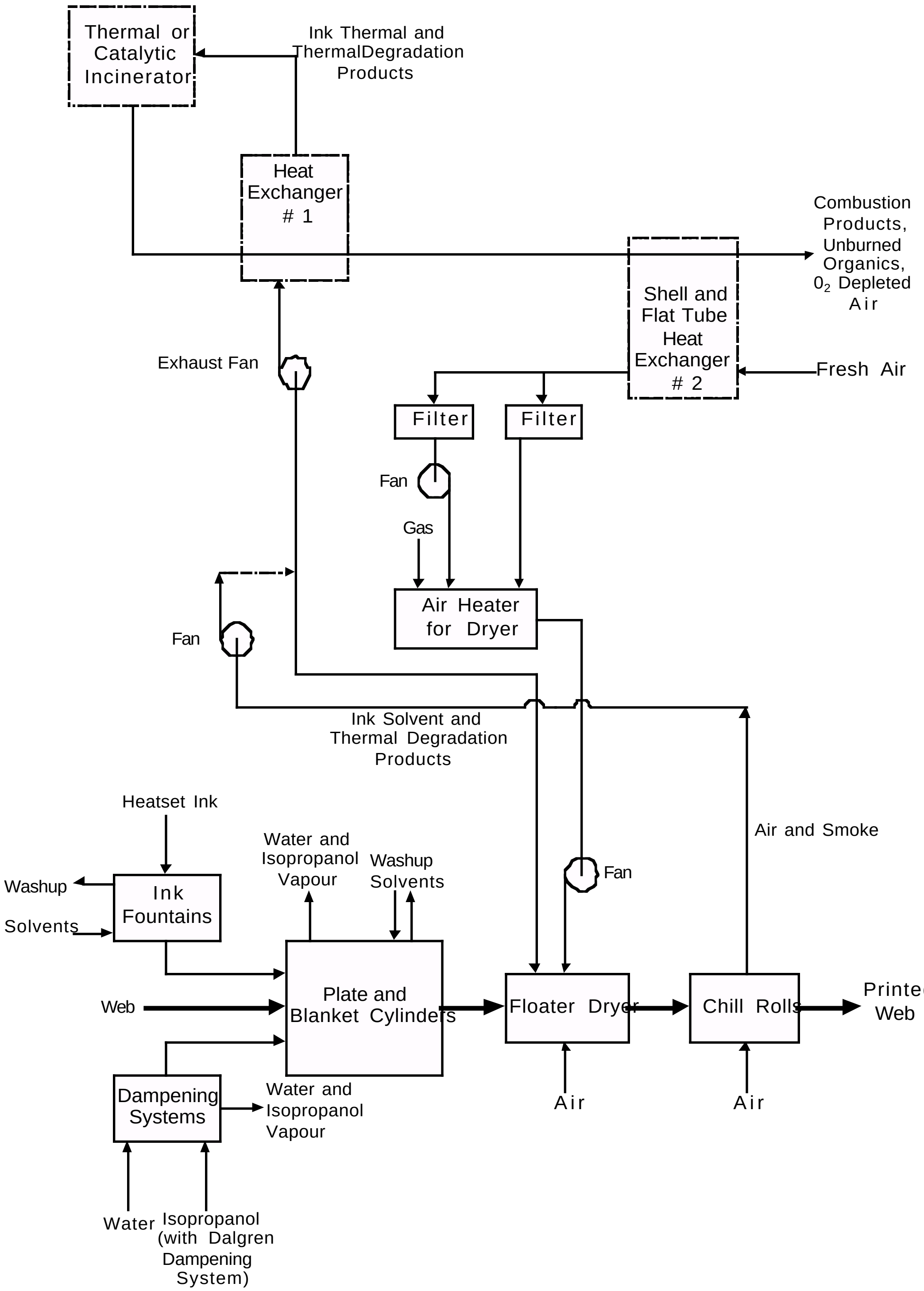

Figure 2. Offset Lithography Printing Line Emission Poi

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An aqueous solution of isopropyl alcohol is commonly used to dampen the non-image area on the plate, and is called the ‘fountain’ or ‘dampening’ solution. The fountain solution in offset lithographic printing has traditionally contained about 15 percent alcohol although there are times when up to 30 percent alcohol can be used. Because of environmental concerns, the use of isopropyl alcohol is decreasing. Fountain solutions containing less VOCs, or alcohol substitutes are gaining acceptance within the industry in Australia. The newspaper industry in particular is now predominantly using alcohol substitutes.

Offset lithographers also use cleaning solutions to clean the press and machine parts. These cleaning solutions have traditionally contained high solvent solutions (90 to 100 percent). Some lower or non-solvent cleaners are now becoming available, in which the solvent content ranges from zero to 30 percent.

2.5 Letterpress Printing

Letterpress printing is the oldest form of movable type printing. Like flexography, letterpress printing uses a relief printing plate and viscous inks similar to lithographic inks. Various types of letterpress plates are available. These plates differ from flexographic plates in that they have a rigid backing, - usually metal or plastic, and are not ‘flexible’. Both sheet-fed and web presses are in use. Web letterpress equipment uses heatset and non-heatset inks. Letterpress printing uses no fountain solutions, and the cleaning solvents are similar to those used in lithography. Letterpress printing once dominated periodical and newspaper publishing, however, the majority of newspapers in Australia have now converted to non-heatset web offset printing.

Letterpress printing uses a paper web that is printed on both sides (one side at a time), and uses heatset inks (usually of about 40 percent by volume solvent). The web is dried after each colour is applied. Heatset letterpress ink is similar to heatset lithographic ink. These inks contain resins dissolved in aliphatic hydrocarbons (alkenes), and are dried in hot-air ovens.

‘Moisture-set’ inks used in some packaging applications contain trimethylene glycol, which is a hazardous air pollutant. ‘Water-washable’ letterpress inks are sometimes used for printing paper and corrugated boxes, and these inks contain glycol-based solvents that may contain listed substances. Figure 3 shows the letterpress schematic and potential emission points along the printing line.

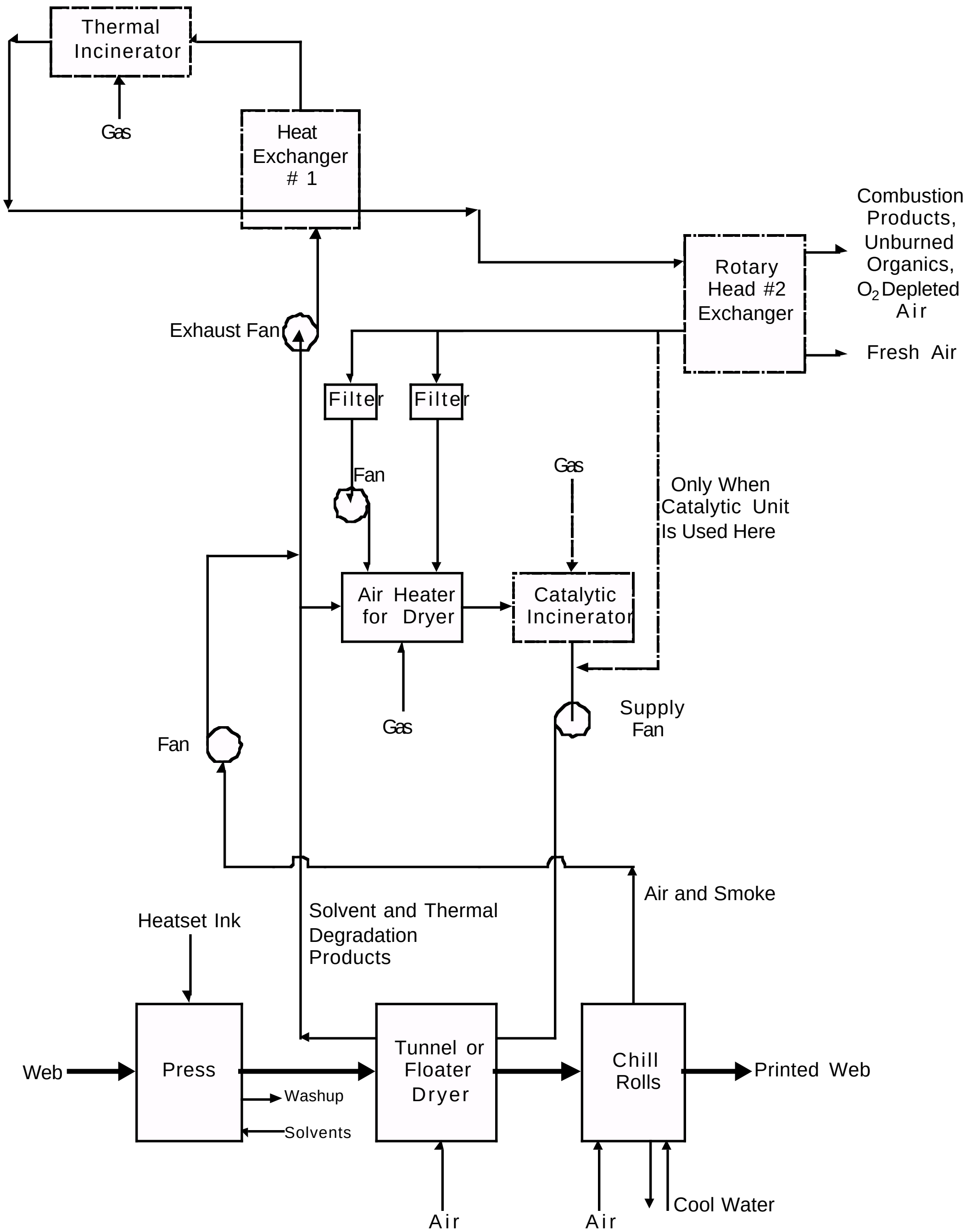

Figure 3. Letterpress Printing Line Emission Points

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2.6 Screen Printing

Screen printing involves forcing ink through a stencil in which the image areas are porous. The screens are generally made of silk, nylon, or metal mesh. Screen printing is used for signs, displays, electronics, wallpaper, greeting cards, ceramics, decals, banners, and textiles. Most screen printing work in Australia is conducted on textiles. Ink systems used in screen printing include ultra-violet cure, water-borne, solvent-borne, and plastisol (polyvinyl chloride), which is mainly used in textile printing. Solvent-based ink systems contain aliphatic, aromatic, and oxygenated organic solvents.

Both sheet-fed and web presses are used in screen printing. The substrate can be dried after each printing station or, in the case of absorbent substrates, after all colours are printed. Solvent and water-borne inks are dried in hot-air or infra-red drying ovens. Dryer gases are partially recycled and partially vented.

2.7 Plateless Printing

This technology is a relatively new process used primarily for short runs on paper substrates. Plateless printing processes include electronic (laser printing), electrostatic (photocopiers), magnetic, thermal (facsimile machines), and ink-jet printing. Plateless printing processes account for only a small fraction of printing activity. Electrostatic toners and ink-jet printer inks may contain listed substances.

3.0 Emission Sources In The Production Line

The predominant emissions from the printing industry are volatile organic compounds (VOCs) contained in the printing inks, fountain solutions, and cleaning solutions. Some of these VOCs are likely to be listed substances with emissions requiring NPI reporting. VOCs can also be emitted from binding and laminating operations.

In printing processes, the solvent or water evaporates from the ink into the atmosphere during a drying stage. Ultraviolet inks may be also used in printing operations, although no emissions are occurring in this case.

Emissions from proofing presses, cleaning operations, ink storage tanks, and ink mixing operations are relatively minor compared to the emissions that occur during a printing process, but they do contribute to overall emissions.

Other listed substances, including sulphur dioxide, carbon monoxide, and particulate matter, are emitted from combustion sources.

The *Combustion in Boilers* Manual should be available from your local State or Territory environmental authorities This Manual is designed to provide guidance on estimating emissions from combustion sources using a wide variety of fuels and combustion equipment including low-temperature ovens and driers.

The six printing processes identified in the previous Section have many common emissions, although there are emissions that are process specific. Table 1 identifies likely emissions of listed substances common to all processes, while Tables 2 to 6 outline potential emissions for each of the different printing processes.

Table 1. Substances Typically Emitted by Printing Activities

♦ acetone	♦ *n*-butyl alcohol
♦ ethyl acetate	♦ *n*-propyl alcohol
♦ ethanol	♦ phosphoric acid
♦ isopropyl alcohol	♦ styrene (ethyl benzene)
♦ methyl ethyl ketone	♦ toluene (methylbenzene)
♦ methyl isobutyl ketone	♦ xylenes (individual or mixed isomers)
♦ propyl acetate	♦ particulate matter (PM_{10})
♦ butanol	♦ 2-Butoxyethanol

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Table 2. Rotogravure Raw Material Inputs and Pollutant Outputs

Process	Inputs	Outputs
Imaging	Photographic processing solution	May contain volatile organic compounds and contribute to air emissions. Waste solutions.
	Wash Water	Used rinse water.
	Cleaning Solutions	Rags containing solvents (sent to laundry service, disposed of as hazardous waste, or treated on or off-site to recover solvents).
	Chemical Storage Containers	Empty containers (disposed of or returned to suppliers) containing residue listed substances.
Cylinder Making	Acid etching solution	Waste solutions containing listed substances to water or sewer.
Printing	Ink	Solvent-based inks (toluene-based for mass-circulation printing and alcohol-based for packaging) maintain the required low viscosity and contribute to air emissions. Waste ink disposed of as hazardous waste.
	Heat	Ovens are used to drive off the solvents to dry the ink. Ink solvents can be recaptured through abatement and control equipment.
	Cleaning Solutions	Solvents used to remove excess ink contribute to air emissions.
Finishing	Adhesives	Possible losses to the air.

Adapted from *Profile of the Printing and Publishing Industry*, USEPA 1995.

Table 3. Flexography Raw Material Inputs and Pollutant Outputs

Process	Inputs	Outputs
Imaging	Developer	May contain volatile organic compounds and contribute to air emissions. Spent developer (transferred to waste treatment).
	Fixer	May be volatile and contribute to air emissions. Silver from film is often electrolytically recovered from the fixer prior to transfer of spent fixer to sewer).
	Wash Water	Used rinse water.
	Cleaning Solutions	Rags containing solvents (sent to laundry service, disposed of as hazardous waste, or treated on or off-site to recover solvents).
	Chemical Storage Containers	Empty containers (disposed of or returned to suppliers) containing residue listed substances.
Platemaking	Plate mould	Used moulds, engravings and washes.
	Rubber plate	Used plates, defective plates and photopolymer.
	Etching and wash-out solutions	Waste solution and spent solvents.
Printing	Ink	Waste ink disposed of as hazardous waste. Solvent-based inks contribute to air emissions.
	Heat	Alcohol content of some inks contribute to air emissions as ink dries. Water-based inks are used for paper and some films.
	Cleaning Solutions	Solvents used to remove excess ink contribute to air emissions and hazardous wastes.
Finishing	Adhesives	Possible losses to the air.

Adapted from *Profile of the Printing and Publishing Industry*, USEPA 1995.

Table 4. Lithography Raw Material Inputs and Pollutant Outputs

Process	Inputs	Outputs
Imaging	Developer	May contain volatile organic compounds and contribute to air emissions. Spent developer transferred to waste treatment.
	Fixer	May contain volatile organic compounds and contribute to air emissions. Silver from film is often electrolytically recovered from the fixer prior to transfer of spent fixer to sewer.
	Wash Water	Used rinse water.
	Cleaning Solutions	Rags containing solvents (sent to laundry service or disposed of as hazardous waste).
	Chemical Storage Containers	Empty containers (disposed of or returned to suppliers) containing residue listed substances.
Platemaking	Water	Used rinse water (transferred to sewer).
	Developer	Spent developer (may contain alcohol; contributes to air emissions).
Printing	Fountain Solution	May contain VOCs and contribute to air emissions.
	Ink	Waste oil based ink disposed of as hazardous waste. Solvent-based inks contribute to air emissions.
	Cleaning Solutions	Solvents used to clean press and remove excess ink contribute to air emissions.
	Rags	Ink and solvent-laden rags (sent to laundry service, disposed of as hazardous waste, or treated on or off-site to recover solvents).
Finishing	Adhesives	Possible emissions to air.

Adapted from *Profile of the Printing and Publishing Industry*, USEPA 1995.

Table 5. Letterpress Raw Material Inputs and Pollutant Outputs

Process	Inputs	Outputs
Imaging	Developer	May contain volatile organic compounds and contribute to air emissions. Spent developer transferred to waste treatment.
	Fixer	May contain volatile organic compounds and contribute to air emissions. Silver from film is often electrolytically recovered from the fixer prior to transfer of spent fixer to sewer.
	Wash Water	Used rinse water.
	Cleaning Solutions	Rags containing cleaning solvents (sent to laundry service, disposed of as hazardous waste, or treated on or off-site to recover solvents).
	Chemical Storage Containers	Empty containers (disposed of or returned to suppliers) containing residue listed substances.
Platemaking	Plate developer solution	Waste solutions may contain listed substances.
Printing	Ink	Waste ink transferred as hazardous waste. Solvent-based inks contribute to air emissions.
	Cleaning Solutions	Solvents used to remove excess ink contribute to air emissions.
Finishing	Adhesives	Possible losses to the air.

Adapted from *Profile of the Printing and Publishing Industry*, USEPA 1995.

Table 6. Screen Printing Raw Material Inputs and Pollutant Outputs

Process	Inputs	Outputs
Imaging and Screen Making	Emulsion	Waste emulsion and out-of-date product.
	Photosensitisation solution (needed for unsensitised films only)	Waste solution.
	Developer	May contain volatile organic compounds and contribute to air emissions. Spent developer transferred to waste treatment.
	Fixer	May contain volatile organic compounds and contribute to air emissions.
	Chemical Storage Containers	Empty containers (disposed of or returned to suppliers) containing residue listed substances.
Printing	Ink	Waste ink usually disposed of as hazardous waste. Solvent-based inks contribute to air emissions of listed substances.
	Blockout	Removed during screen reclamation and disposed with screen reclaim chemicals.
	Screen Reclamation Chemicals	Screen reclamation chemicals and ink are disposed of in rags and in clean-up wastewater.
	Water	Water used for screen reclamation is transferred to sewer; sometimes it is filtered prior to transfer.
Finishing	Adhesives	Possible losses to the air.

Adapted from *Profile of the Printing and Publishing Industry*, USEPA 1995.

4.0 Factors Influencing Emissions

4.1 Process Operating Factors

The type of printing and ink used are the most important process operating factors for estimating emissions from printing operations. The next most important process operating factor affecting emissions is the production volume (ie. the amount of material printed as area times length), and this will be the determining factor in the relative magnitude of emissions. The amount of ink used per unit of substrate (ie. the relative amount of inked versus non-inked areas) is determined by the type of product (eg. newspaper, cereal box, birthday card, etc), and is another important factor

The following process variables relate to specific types of printing or operations common to all types.

4.2 Rotogravure Printing

In packaging rotogravure printing, the inks contain from 55 to 80 percent by volume low boiling-point solvent with low viscosities. It is important that the ink or other coating dries quickly between each colour, so the ink vehicle must be evaporated between stations. NPI listed organic solvents (including toluene and methyl ethyl ketone) and alcohols are commonly used as the volatile portion of the ink, but water-based inks are becoming more popular because of lower potential for worker and environmental harm. However, most presses are not compatible for use with both systems because water-based inks require a greater equipment drying capacity as well as a different cell design.

Although rotogravure inks already contain solvents, additional solvents may be mixed into the ink to obtain the desired viscosity.

4.3 Flexographic Printing

The ink used in flexography is of low viscosity because the ink must be fluid to print properly. Most flexographic printing (including all flexographic newspaper and corrugated carton printing) is done with water-borne inks, but alcohol or other low-viscosity, volatile liquids are also used as the ink base. Solvents used must be compatible with the polymeric plates, so aromatic solvents are not used. Some of the components of solvent-based flexographic ink include ethanol, *n*-propyl alcohol, isopropyl alcohol, and acetates.

When flexography is used to print corrugated board and most paperboard, water-based inks can be used. However, fast-drying inks are required for plastic films so that the web can be rewound or processed into the final product at the end of the press. When printing pressure-sensitive labels, the ink must dry quickly without penetration.

4.4 Offset Lithographic Printing

The solvents (high-boiling temperature petroleum oils >150°C) in heatset inks are driven away in a hot air or direct-flame dryer (150-200°C) to set the ink. Non-heatset inks dry by adsorption or oxidation and are not released from the substrate under normal conditions. Approximately 20 to 40 percent of the solvent remains in the substrate with heatset inks, increasing to 95 to 100 percent when using non-heatset inks.

Emissions from the fountain solution will depend on whether alcohol or non-alcohol additives are used. The concentration of VOCs in the fountain solution can vary from one facility another, and from one job to another within a facility.

Solvents used for press clean-up are usually kerosene-type high boiling-point hydrocarbons sometimes mixed with detergents. These materials can contain up to 100 percent VOCs. Low-VOC cleaning solutions are also in use in which the VOC content is less than 70 percent (and can be less than 30 percent VOCs).

4.5 Letterpress Printing

Only web presses using solvent-borne inks are sources of emissions in this industry. Letterpress newspaper and sheet-fed printing use oxidative drying inks and are not a source of emissions. Cleaning solutions are used with all letterpress operations.

4.6 Screen Printing

Ink systems used in screen printing include ultra-violet cure, water-borne, solvent-borne, and plastisol (polyvinyl chloride), with the latter used mainly in textile printing. Solvent-based ink systems contain aliphatic, aromatic, and oxygenated organic solvents.

4.7 In-Process Fuel

Fuels including natural gas, oil, and electricity are used to operate the dryers used in heatset offset lithography, heatset letterpress, gravure, and flexography. A boiler may be used to generate steam for steam and water-based flexography, and to regenerate the activated carbon beds used as control devices. Combustion byproducts include particulate matter (PM_{10}), sulphur dioxide, nitrogen oxides, carbon monoxide, and VOCs. These are all listed substances that require reporting. As previously mentioned, the *Combustion in Boilers* Manual will be available to assist in estimating emissions from fuel burning activities.

4.8 Storage Tanks

Printing operations may use storage tanks for inks, solvents, and other organic substances such as fuel. To assist you in estimating emissions from these sources, the *Fuel and Organic Liquid Storage* Manual will be available from your local environmental authority.

5.0 Emission Estimation

Estimates of emissions of listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in *The NPI Guide* at the front of this Handbook.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility. These are described in *The NPI Guide*. Select the EET, or mix of EETs, which is most appropriate for your purposes. If you estimate your emission by using any of these EET's, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of emission estimation techniques that are not outlined in this Handbook, your data will also be displayed as being of 'acceptable reliability'.

For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

You are able to use emission estimation techniques that are not outlined in this document. You must, however, seek the consent of your relevant environmental authority. For example, if you already undertake direct measurement, you may use this information for NPI reporting purposes (if you do not undertake direct measurement, the NPI does not require you to do so).

5.1 Emissions To Air

Air emissions may be categorised as :

Fugitive emissions

These are emissions that are not released through a vent or stack. Examples of fugitive emissions include dust from stockpiles, volatilisation of vapour from vats or open vessels, and material handling. Emissions emanating from ridgeline roof-vents, louvres, and open doors of a building as well as equipment leaks, and leaks from valves and flanges are also examples of fugitive emissions. Emission factor EETs are the usual method for determining losses through fugitive emissions.

Point source emissions

These emissions are exhausted into a vent or stack and emitted through a single point source into the atmosphere. An air emissions control device such as a carbon adsorption unit, scrubber, baghouse, or afterburner may be added to the stack prior to the atmospheric release.

5.2 Emissions To Water

Emissions of substances to water can be categorised as discharges to:

- Surface waters (eg. lakes, rivers, dams, and estuaries);
- Coastal or marine waters; and
- Stormwater.

The discharge of listed substances to a sewer or tailings dam does not require you to report to the NPI (See also Section 3.0 of *The NPI Guide*). The main source of wastewater from this industry is usually from air pollution control equipment such as wet scrubbers.

The most appropriate method for determining emissions to the environment via wastewater is to use direct measurement, however, you may use other EETs for the purposes of reporting to the NPI.

5.3 Emissions To Land

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids, and the use of chemicals to control various elements of the environment where these emissions contain listed substances. These emission sources can be broadly categorised as :

- surface impoundments of liquids and slurries
- unintentional leaks and spills.

5.4 Total VOC Emissions From The Press

The most appropriate method for estimating emissions of NPI listed substances from printing activities is a facility mass balance. Using industry-wide emission factors will not, in most cases, provide an accurate reflection of the actual emissions from any facility because of the wide range of operational practices within the industry. Operational activities that are process and facility-specific include :

- the range and mix of printing process activities that occur at a facility;
- the amount of inks, fountain solutions, and cleaning solutions used at the facility;
- the VOC content and weight percentage of listed substances in the inks, fountain solutions, and cleaning solutions used;
- the amount of ink that is recycled, but not reused, within the facility; and,
- the control equipment used, and the efficiency of this equipment.

In conducting a mass balance for a printing operation, it is important to factor into your equation that the amount of VOCs emitted during printing (the volatile fraction) is not always equivalent to the measured or estimated VOC content of the raw material. This is particularly relevant for offset lithographic printing processes. Although non-heatset lithographic inks may contain significant VOCs, only 2 percent of the total are emitted during printing, while the rest is retained in the substrate.

Equation 1 will assist you to estimate total uncontrolled emissions for each listed substance (S) contained in ink, fountain solution, or cleaning solution from each type of printing operation (P).

Equation 1. Emissions of Listed Substances From Uncontrolled Presses

$$\text{Total Uncontrolled Emissions}_S = \sum \left[\left(\text{Amount Ink Used}_P\right) \times \left(\text{Volatile Fraction}_{S,P}\right) - \left(\text{Amount Recycled}_P\right) \right]$$
$$+ \sum \left[\left(\text{Amount Fountain Solution Used}_P\right) \times \left(\text{Volatile Fraction}_{S,P}\right) - \left(\text{Amount Recycled}_P\right) \right]$$
$$+ \sum \left[\left(\text{Amount Cleaning Solution Used}_P\right) \times \left(\text{Volatile Fraction}_{S,P}\right) - \left(\text{Amount Recycled}_P\right) \right]$$

Equation 2 will assist you to estimate total controlled emissions for each listed substance (S) contained in ink, fountain solution, or cleaning solution from each type of printing operation (P).

Equation 2. Emissions of Listed Substances From Controlled Presses

$$\text{Total Controlled Emissions}_S = \sum \left[\left\{ \left(\text{Amount Ink Used}_P\right) \times \left(\text{Volatile Fraction}_{S,P}\right) - \left(\text{Amount Recycled}_P\right) \right\} \times \left(1 - CE_I \div 100\right) \right]$$
$$+ \sum \left[\left\{ \left(\text{Amount Fountain Solution Used}_P\right) \times \left(\text{Volatile Fraction}_{S,P}\right) - \left(\text{Amount Recycled}_P\right) \right\} \times \left(1 - CE_{FS} \div 100\right) \right]$$
$$+ \sum \left[\left\{ \left(\text{Amount Cleaning Solution Used}_P\right) \times \left(\text{Volatile Fraction}_{S,P}\right) - \left(\text{Amount Recycled}_P\right) \right\} \times \left(1 - CE_{CS} \div 100\right) \right]$$

where :

CE_I = Control efficiency (percent) for each ink (I) used;

CE_{FS} = Control efficiency (percent) for each fountain solution (FS) used; and

CE_{CS} = Control efficiency (percent) for each cleaning solution (CS) used.

5.5 Speciating Total VOC Emissions

The above mentioned mass balance equations can be used to estimate emissions of total VOCs from the press, or for listed substance contained in the ink, fountain solution, or cleaning solution.

For these purposes NPI reporting, you will need to separately list and report emissions of each listed substance contained in ink, fountain and cleaning solutions by first determining the weight percentage of listed substance in the products used.

This information is often available from your ink or solvent supplier or from the product Material & Safety Data Sheets. If this information provides listed solvent amounts in volume, then you will need to convert this volume amount to weight units as shown in Equation 3.

Equation 3. Converting Volume of Solvent to Weight Units

$$\text{Amount used in kilograms} = \left(\text{Amount of material (litres)}\right) \times \left(\text{Density factor (kg/litre)}\right)$$

Emission factors are not recommended for estimating emissions from the printing industry as the processes and practices used vary significantly. Appendix I contains emission factors for can coating and printing operations with accompanying uncertainty estimate codes for each emission factor provided. Section 6.0 contains a discussion of the reliability, or uncertainty, of the emission factor codes used.

6.0 Emission Factor Rating

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry Handbooks. They are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). Consequently, the ratings may not be directly relevant to Australian industry. Sources for all emission factors cited can be found in the references section of this document. The emission factor ratings <u>will not</u> form part of the public NPI database.

When using emission factors, you should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or category is not representative of the source type. These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor, and the target equipment/process from which the factor was derived.

The EFR system is as follows :

A - Excellent
B - Above Average
C - Average
D - Below Average
E - Poor
U - Unrated

Estimating your facility's emissions based on emission factors only, and without taking into account any control measures, may have an uncertainty as high as 100%.

Other EETs, such as release calculations based on mass balance of solvent consumption and without taking into account control measures, may have an uncertainty of 50%.

An EET based on an audit or direct measurement, and taking into account control measures, may have an uncertainty of 20%.

7.0 Control Technologies

As solvents are expensive, they may be recovered and reused for economic as well as environmental reasons. Solvent emissions can be controlled as part of the normal operating procedures in a printing or packaging facility. In addition, most manufacturing is undertaken inside facility buildings, where solvent losses must be minimised to protect the health of workers, and conform to occupational health and safety standards.

In recent years the printing industry in Australia has implemented several creative emission prevention and control techniques that improve efficiency and increase profits, while at the same time minimising environmental impacts. In many facilities, using alternative ink and cleaning products with reduced VOC emissions and lowering the VOC emissions, from printing and press clean-up, has been accomplished using vegetable oil-based or water-based inks rather than solvent-based inks. Other control technologies that have gained wide industry acceptance include :

- improving housekeeping and better operating practices, eg. covering reservoirs and containers, scheduling jobs according to the colour to be printed, and using wipes as long as possible;
- reducing ink vaporisation by using diaphragm pumps which do not heat ink to the same extent as mechanical vane pumps;
- recycling waste solvents on-site and off-site, as the segregation of solvents may allow for a secondary use such as equipment cleaning or ink thinning;
- recycling of certain waste inks where possible;
- eliminating the use of chromium(VI) containing fountain solutions;
- installing automatic viscosity controllers to keep ink conditions optimal;
- using automatic cleaning equipment which can often be retrofitted to existing presses and operations. Typically, lower volumes of cleaning formulations are applied with cleaning equipment, such that air contact, and thereby volatilisation is reduced, and most are designed to include recycling and reuse of cleaning solutions; and
- using fountain coolers to reduce evaporation from the dampening fountain.

It is difficult to make a quantitative estimate of the efficiency of each control method listed above as abatement largely depends on the process being controlled, and printing and packaging can involve hundreds of different processes. Incinerators, carbon adsorbers, and scrubbers have been reported to remove greater than 90 percent of the organics in the control equipment inlet stream. Condensers are limited because they can only reduce the concentration in the gas stream to saturation at the condenser temperature, and not below that level. Lowering the temperature will, of course, lower the concentration at saturation, but it is not possible to operate at a temperature below the freezing point of one of the components of the gas stream.

Table 7 provides expected control efficiencies for emissions to air on commonly used abatement equipment in the printing industry. In the absence of precise data on the efficiencies of control equipment at your facility, you should assume that any abatement equipment used reduces emissions by 90 percent. Therefore, to obtain an emission total from a controlled source, multiply the uncontrolled emission total by 0.1.

Table 7. Estimated Control Technology Efficiencies for Printing Lines

Method	Application	Reduction in Organic Emissions (%)
Carbon adsorption	Publication rotogravure operations	75[a 1]
Incineration[b]	Web offset lithography Web letterpress Packaging rotogravure printing Flexography printing	95[c 1] 95[c 1] 85[a 2] 95[c 2]
Biofiltration		65[a 2]
Water-borne inks[d]	Packaging rotogravure printing[e] Flexography packaging printing	70[a 1] 60[a 1]

[1] USEPA (1995)
[2] Campbell. H. (1998)
[a] Overall emission reduction efficiency (capture efficiency multiplied by control device efficiency).
[b] Direct flame (thermal) catalytic and pebble bed. Three or more pebble beds in a system have a heat recovery efficiency of 85%.
[c] Efficiency of volatile organic removal; does not consider capture efficiency.
[d] Solvent portion consists of 75 volume % water and 25 volume % organic solvent.
[e] With less demanding quality requirements.

8.0 References

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Written Communication and Attachments from Heather Campbell, Containers Packaging to Tim Powe Queensland Department of Environment, Brisbane Queensland, 21 January 1998.

Written Communication and Attachments from Dr Tony Wilkins, News Limited to Tim Powe Queensland Department of Environment, Brisbane Queensland, 23 January 1998.

Appendix I

Can Printing and Coating

1.0 Printing Process Description

Cans may be made from a rectangular sheet and two circular ends (3-piece cans), or they can be drawn and wall ironed from a shallow cup to which an end is attached after the can is filled (2-piece cans). While the printing of both can types is almost identical, there are major differences in coating practices, depending on the type of can and the packaged product. Figure 1 depicts a 3-piece can sheet printing operation.

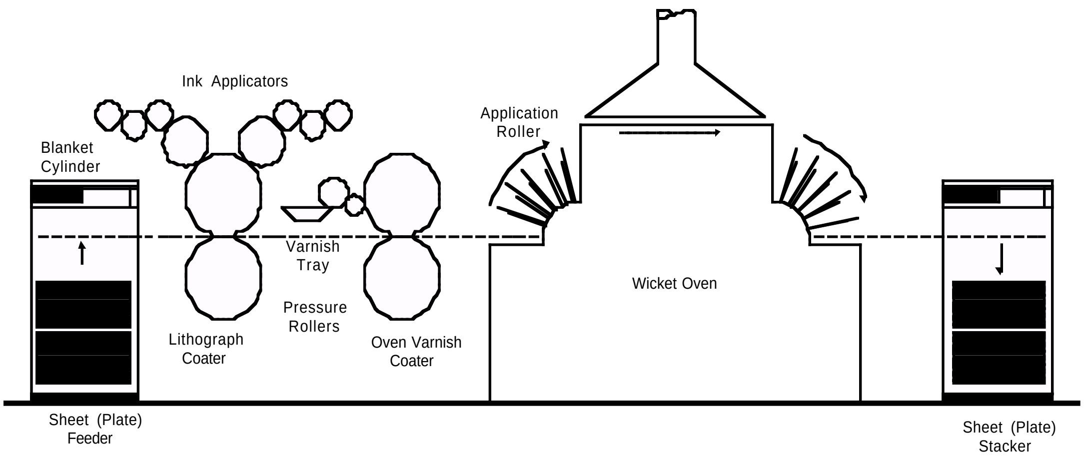

Figure 1. Three Piece Can Sheet Printing Operation
USEPA January 1995a. AP-42

Aluminium Can Decoration

The process of printing and coating aluminium cans has two stages: the internal spraying of the can, and then decoration and the application of lacquer to the outside surface of the can. Internal coatings over varnish and basecoat materials are water based, but can often contain a small percentage of the solvents butanol and butyl cellusolve. These solvents will evaporate in the curing ovens.

The actual printing process is letterpress offset which uses paste inks. The letterpress plate transfers the ink to a blanket which then prints the cans in the 'round' allowing over 1000 cans/minute to be printed on a six colour machine. Emissions from this printing process are negligible.

Flat Metal Decoration

The process of printing tinplate or aluminium sheets involves two major operations: firstly the precoating or lacquering of the plate, followed by printing, generally using the offset lithographic process. The final print is then given a coat of protective varnish using a machine identical to a pre-coater.

The process description of the use of plates, blankets, isopropyl alcohol, and clean-up solvents is described at Section 2.4 of this Manual. Inks may be alkyd resin, polyester or UV curable types, but more frequently are the resin-based. Hot air ovens are used to dry by means of heat oxidation. Inks contain very low levels of VOC and are unlikely to contain NPI listed solvents.

2.0 Coating Process Description

Emissions from can coating operations depend on the composition of the coating, the coated area, thickness of coat, and, the efficiency of application. Post-application chemical changes and nonsolvent contaminants, including oven fuel combustion products, may also affect the composition of emissions. All solvents used and not recovered can be considered potential emissions.

Sources of can coating VOC emissions include the coating area and the oven area of the sheet base and lithographic coating lines, the 3-piece can side seam and interior spray coating processes, and the 2-piece can coating and end sealing compound lines. Emission rates vary with line speed, can or sheet size, and coating type. On sheet coating lines where the coating is applied by rollers, most solvent evaporates in the oven. For other coating processes, the operation itself is the major source. Emissions can be estimated from the amount of coating applied and applying the emission factors in Table 1.

Incineration, and the use of water-borne and low solvent coatings, both reduce organic vapour emissions. Catalytic and thermal incinerators can also be used. Pimers, backers (coatings on the reverse, or backside of the coil), and some water-borne low to medium-gloss top-coats have been developed that equal the performance of organic solvent-borne coatings for aluminium. Other feasible control options, such as electrostatically sprayed powder coatings, are not yet available to the whole industry.

Available control technology includes the use of add-on devices like incinerators and carbon adsorbers and a conversion to low solvent and ultraviolet curable coatings. Thermal and catalytic incinerators can both be used to control emissions from 3-piece can sheet base coating lines, sheet lithographic coating lines, and interior spray coating. Incineration is applicable to a 2-piece can coating line. Carbon adsorption is most applicable to low temperature processes that use a limited number of solvents. Such processes include 2 and 3-piece can interior spray coating, 2-piece can end sealing compounds lines, and 3-piece can side seam spray coating.

Low solvent coatings are not yet available to replace all the organic solvent-borne formulations presently used in the can industry. Water-borne basecoats have been successfully applied to 2-piece cans. Powder coating technology is used for side seam coating of non-cemented 3-piece cans.

Ultraviolet curing technology is available for rapid drying of the first two colours of ink on 3-piece can sheet lithographic coating lines.

The efficiencies of various control technologies for can coating lines are present in Table 2.

3.0 Emission Factors for Can Coating

An emission factor is a tool that is used to estimate emissions to the environment. In this Manual, it relates the quantity of substances emitted from a source to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources, and are usually expressed as the weight of a substance emitted, multiplied by the unit weight, volume, distance, or duration of the activity emitting the substance. For example, kilograms of VOCs emitted per hour of can coating line operation.

Emission factors are used to estimate a facility's emissions by the general equation:

$$E = A \times T \times EF \times [1 - (CE / 100)]$$

where :

E = emissions;
A = activity rate;
T = time (or another variable)
EF = uncontrolled emission factor; and
CE = overall emission control efficiency, %.

Emission factors developed from measurements for a coating line or can oven dryer can sometimes be used to estimate emissions at other sites. For example, a company may have several units of similar model and size, such that if emissions were measured from one coating line or oven, an emission factor could be developed and applied to similar units. As recommended previously, it is advisable to have the emission factor reviewed and approved by your local environmental authority prior to its use for NPI estimations.

Table 1. VOC Emission Factors For Can Coating Processes [a]

Process	Typical Emissions from Coating Line [b] (kg/hr)	Estimated Fraction From Coated Area (%)	Estimated Fraction From Oven (%)	Typical Emissions of VOCs [c] (tonnes/ year)
3-piece can sheet sheet base coating	51	9 - 12	88 - 91	160
3-piece can sheet lithographic coating l	30	8 - 11	89 - 92	50
3-piece beer and beverage can - side seam spray coating	5	100	air dried	18
3-piece beer and beverage can - interior body spray coating process	25	75 - 85	15 - 25	80
2-piece can coating line	39	ND	ND	260
2-piece can end sealing compound line	4	100	air dried	14

[a] USEPA. 1977. *Control of Volatile Organic Emissions From Existing Stationary Sources, Volume II: Surface Coating of Cans, Coils, Paper Fabrics, Automobiles, And Light Duty Trucks*, EPA-450/2-77-008. United States Environmental Protection Agency. Research, Triangle Park, NC, USA.
[b] Organic solvent emissions will vary according to line speed, size of can or sheet being coated, and type of coating used.
[c] Based upon normal operating conditions. NPI reporting requires speciating total VOC emissions into individual listed compounds. To do this calculation, multiply the weight percentages of each individual listed substance in the inks by the total VOC weight emissions.

Table 2 provides expected control efficiencies for emissions to air on commonly used abatement equipment on can coating lines. To determine total emissions, multiply the emission obtained from using the emission factors in Table 1 by the reduction percentage from Table 2. For example, if the control efficiency relevant to your process is given as 90 percent, multiply the uncontrolled emission total (obtained from either using the emission factors in Table 1, a mass balance or another EET) by 0.1.

Table 2. Control Efficiencies for Can Coating Lines [a]

Affected Facility	Control Option	Reduction (%)
2-Piece Can Lines		
exterior coating	thermal and catalytic incineration	90
	waterborne and high solids coating	60 - 90
	ultraviolet curing	Û100
interior spray coating	thermal and catalytic incineration	90
	waterborne and high solids coating	60 - 90
	powder coating	100
	carbon adsorption	90
3-Piece Can Lines		
sheet coating lines		
exterior coating	thermal and catalytic incineration	90
	waterborne and high solids coating	60 - 90
	ultraviolet curing	Û100
interior spray coating	thermal and catalytic incineration	90
	waterborne and high solids coating	60 - 90
can fabricating lines		
side seam spray coating	waterborne and high solids coating	60 - 90
	powder (for uncemented seams)	100
interior spray coating	thermal and catalytic incineration	90
	waterborne and high solids coating	60 - 90
	powder (for uncemented seams)	100
	carbon adsorption	
End Coating Lines		
sealing compound	waterborne and high solids coating	70 - 95
sheet coating	carbon adsorption	90
	thermal and catalytic incineration	90
	waterborne and high solids coating	60 - 90

[a] USEPA. 1977. *Control of Volatile Organic Emissions From Existing Stationary Sources, Volume II: Surface Coating of Cans, Coils, Paper Fabrics, Automobiles, And Light Duty Trucks*, EPA-450/2-77-008. United States Environmental Protection Agency. Research, Triangle Park, NC, USA.

[b] Coil coating lines consist of coaters, ovens, and quench areas. Sheet, can, and end wire coating lines consist of coaters and ovens.

[c] Compared to conventional solvent base coatings used without any added thinners.