VOLUME II:  CHAPTER 11

# PREFERRED AND ALTERNATIVE METHODS FOR ESTIMATING AIR EMISSIONS FROM PLASTIC PRODUCTS MANUFACTURING

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**DISCLAIMER**

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

ACKNOWLEDGMENT

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# 1

# INTRODUCTION

The purposes of the preferred methods guidelines are to describe emission estimation techniques for point sources in a clear and unambiguous manner and to provide concise example calculations to aid regulatory and non-regulatory personnel in the preparation of emission inventories.  This chapter describes the procedures and recommended approaches for estimating air emissions from plastic products manufacturing operations.

Section 2 of this chapter contains a general description of the plastic products manufacturing source category, identifies common emission sources, and contains an overview of available air pollution control technologies.  Section 3 of this chapter provides an overview of available emission estimation methods.  It should be noted that the use of site-specific emissions data is usually preferred over the use of industry-averaged data.  However, depending upon available resources, obtaining site-specific data may not be cost effective.

Section 4 presents the preferred emission estimation methods for plastic products manufacturing and Section 5 presents alternative emission estimation techniques.  Quality assurance and quality control procedures associated with the emission estimation methods are described in Section 6. Section 7 contains data coding procedures used for data input and storage.  Some states use their own unique identification codes, so non-regulatory personnel developing an inventory should contact individual state agencies to determine the appropriate coding scheme to use.  References cited in this document are provided in Section 8 and other useful information on this topic may be found in the references listed in Section 9 (Bibliography).  Appendix A contains an example data collection form for plastic products manufacturing sources and may be revised to fit individual user's needs.

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# 2

# SOURCE CATEGORY DESCRIPTION

## 2.1 PROCESS DESCRIPTION

Plastic products manufacturing involves molding, forming, shaping, or otherwise altering plastic resins or plastic materials to produce an intermediate or final product. This manufacturing industry is also commonly referred to as plastics processing or polymer processing. The manufacture of resins is not a part of plastic products manufacturing; however, some facilities manufacture resins at the same site as where the resins are processed.[1] This chapter will not address the manufacture of resins because it is not an activity inherent to plastic products manufacturing.

Solid and foamed plastic products are manufactured using plastic resins or solid plastic chips as the starting material. Most plastic products are manufactured by mixing plastic resins with additives, applying heat or pressure to the mixture, and shaping the mixture to form the desired product.

Section 2.1.1 describes the different types of plastics used by plastic products manufacturing facilities in the United States. Section 2.1.2 describes the major manufacturing techniques used to process plastic products.

### 2.1.1 TYPES OF PLASTICS

Plastic products can be fabricated into a solid or foam state. The basic properties of a plastic product are influenced and limited by the physical and chemical characteristics of the plastic resin from which it is made.

Plastic resins are generally defined by their rheology, or ability to flow under heat or pressure. Thermoplastic resins (or dry blends) and thermoset resins are the two major classes of resins that are used to manufacture plastic products. Although most resins fall into one of these two classes of resins, some resins can be classified as both a thermoplastic and thermoset resin.

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[1] A polymer is a high-molecular-weight organic compound, natural or synthetic, whose structure can be represented by a repeated small unit, the monomer. A resin is a solid or semisolid organic product usually of high molecular weight and no definite melting point. Most resins are polymers (The Society of the Plastics Industry, 1991).

### *Thermoplastics*

Thermoplastic resins (or thermoplastics) are plastic resins that will repeatedly become soft when heated and hard when cooled. Thermoplastics do not normally undergo a chemical change during forming. Plastic products manufacturing facilities usually purchase and use thermoplastics in solid pellet form for processing. An economic advantage of products made from thermoplastics is that they can be easily remanufactured or reprocessed.

Thermoplastics account for the major share of domestic polymer production. The following six thermoplastics are processed in the largest quantities in the United States:

- Low-density polyethylene;

- High-density polyethylene;

- Polyvinyl chloride;

- Polypropylene;

- Polystyrene; and

- Linear low-density polyethylene.

### *Thermosets*

Thermoset resins (or thermosets) undergo a chemical reaction and become permanently solid when heated, pressurized, or reacted with a hardening agent. Thermosets are usually available in liquid or powder form for processing. Unlike thermoplastics, thermosets cannot be easily remelted or refabricated. However, scraps from thermoset processing operations can be used as fillers for other products.

Some widely used thermosets include:

- Epoxy;

- Phenolic;

- Unsaturated polyester; and

- Urea.

### *Foamed Plastics*

Foamed plastics (or foams) have a unique cellular structure that is different from solid plastics. For this reason, foams are often called "cellular plastics." Foams, which are rigid, semi-rigid, or flexible, can be manufactured with thermoplastic or thermoset resins. Many of the manufacturing techniques used to fabricate solid plastic products are also used to make foam products. The process used to manufacture foams influences the properties of the final foam product.

Some typical foams include:

- Polystyrene foam;

- Polyurethane foam; and

- Polyethylene foam.

A detailed description of foam processing is provided in Section 2.1.2.

Table 11.2-1 lists ten plastics that are processed in the largest quantities in the United States (The Society of the Plastics Industry, 1991 and 1996). It also presents common applications and typical manufacturing techniques used for each plastic type.

## 2.1.2 MANUFACTURING TECHNIQUES

Solid and foamed plastic products are manufactured by a variety of methods. The choice of manufacturing techniques used to process a plastic product depends largely on whether the resin is a thermoplastic or thermoset, and the dimensions, shape, or physical qualities of the desired product.

This section describes the major manufacturing techniques used to fabricate intermediate and final plastic products. Extrusion is the most widely used processing technique, followed by injection molding, blow molding, and foam processing (Midwest Research Institute, 1993). These four manufacturing techniques, in addition to lamination, coating, and finishing operations, are described below.

### *Extrusion*

The extrusion process is a common technique used to form thermoplastic materials into long plastic shapes including pipes, tubes, coated wires, coated cables, rods, and continuous sheets

## TABLE 11.2-1

### COMMON APPLICATIONS AND MANUFACTURING TECHNIQUES FOR SELECTED PLASTICS

| Plastic Type | Common Applications | Typical Processing Methods | 1995 Production[a] |
|---|---|---|---|
| **Thermoplastics** | | | |
| Polyethylene | Packaging, housewares, toys and communications equipment | Extrusion, compression molding, injection molding, blow molding, foam processing | 25,097[b] |
| Polypropylene | Packaging, automotive, appliance, and carpeting | Extrusion, compression molding, injection molding, blow molding | 10,890 |
| Polystyrene | Consumer and institutional products (egg cartons, business machines, pallets), electrical/electronic uses, and building construction | General molding, compression molding, expandable bead molding, extrusion, injection molding | 5,656 |
| Polyvinyl Chloride | Building/construction, packaging, consumer and institutional products, and electrical/electronic uses | Extrusion, injection molding, calendaring, foam processing | 12,295 |
| Saturated Polyester | Packaging, automotive, electrical, and consumer markets | Film and sheet processing, blow molding, injection molding | 3,785 |
| **Thermosets** | | | |
| Epoxy | Protective coatings, bonding adhesives, building and construction, and electrical uses | Adhesive, bonding, lamination, transfer molding, injection molding, foam processing | 632 |
| Phenolic | Adhesives, casting resins, potting compounds, laminating resins, and electrical uses | Adhesive bonding, lamination, compression molding, transfer molding, foam processing | 3,204 |
| Polyurethanes | Automotive industry, transportation, carpet underlay, furniture (foam cushion), and construction markets | Flexible foam processing, rigid foam processing, reaction injection molding | 4,269[c] |
| Unsaturated Polyester | Transportation, appliances, electrical, and construction markets | Reinforced plastics processing, general molding | 1,577 |
| Urea-Formaldehyde | Laminates and chemically resistant coatings, rigid electrical and decorative products | Compression molding, transfer molding, lamination | 1,816 |

[a] Millions of pounds
[b] Low and high density
[c] Market data for 1994
Source:  The Society of the Plastics Industry, 1996 and 1991.

and films.  The types of extrusion methods are as diverse as the products that can be fabricated by extrusion.  Extrusion methods include blown film, sheet extrusion, cast film, extrusion coating, profile extrusion, pipe and tubing extrusion, wire and cable coating, and fiber extrusion.

In most extrusion operations, dry resin material is poured into a hopper, which directs the resin material into the feed throat of the extruding machine where the resin is heated.  A large continuously revolving screw encased in a long heating chamber then carries the heated resin down the length of the screw toward a die (orifice) at the end of the chamber.  The revolving screw forces the fluidized resin material through the die which has the shape of the cross section of the final plastic product.  After the resin material exits the die, it may be wound into a roll, or transported on rollers or a conveyer belt where it is cooled by air or water immersion.

### *Molding*

In most molding operations, the forming of the intermediate or final plastic product takes place in a closed mold.  Molding methods vary depending on resin type, raw materials, desired plastic product shape, and other factors.  Some of the more typical molding methods include injection, blow, general, rotational, transfer, reaction injection, and compression injection.  This section will describe the three most prevalent molding methods currently used in the United States.

**Injection Molding.**  Injection molding is one of the more common methods used to mold thermoplastics; however, this method can also be used to mold thermosets.  The injection molding process is similar to the extrusion method except that in injection molding, the molten material is injected into a mold rather than forced through a die.

Plastic pellets are fed into a heating chamber and are pushed along by a plunger until they are homogenized and fluidized.  The fluid plastic is then injected (forced under high pressure) through a nozzle into a relatively cold mold.  The fluid plastic conforms to the shape of the clamped mold, which is released once the plastic solidifies.  The reciprocating screw injection machine, which serves as both a plasticizer and injection ram, is the most common machine used for injection molding.

Reaction injection molding is a recently developed injection molding technology that mixes liquid plastic (i.e., polyols and isocyanates) at low temperatures before injecting the liquid plastic into a mold.  Unlike standard injection molding, an exothermic reaction takes place in reaction injection molding; therefore reaction injection molding requires substantially less energy than traditional injection molding (The Society of the Plastics Industry, 1996).

**Blow Molding.**  Blow molding is used to manufacture bottles and other hollow or lightweight objects. The basic technique of blow molding is to stretch and form plastic material against a mold, usually by air pressure.  The extrusion blow molding method extrudes fluid plastic into a

parison (a free-blown form shaped like a tube) before molding the final product. The parison is directed between two halves of a mold, then air pressure expands the parison and forces it to conform to the contour of the mold. The injection blow molding method is similar to extrusion blow molding, except that the parison is injection-molded rather than extruded.

**Compression Molding.** Compression molding is a common method for forming thermosets and is rarely used for thermoplastics, except with a few specialized processes. In compression molding, a premixed plastic mixture or preformed plastic part is placed in an open mold cavity. As the heated mold is closed, the plastic mixture spreads throughout the mold. The mixture in the mold is pressurized and heated until it undergoes a chemical change that hardens the mixture into the desired shape.

**Transfer Molding.** Transfer molding is a process similar to compression molding that is used for thermoplastics. However, unlike compression molding, a hydraulic plunger forces the heated plastic mixture into a closed hot mold where it solidifies.

### *Lamination*

Lamination is the binding and fusing of multiple layers with heat and pressure. All thermosets can be used as laminating binders; however, phenolic is the most common binder used in lamination.

Most laminating operations involve the following three basic steps: impregnation, drying, and pressing. First, a web of paper, fabric, or other material is impregnated with a resin solution by continuously feeding it through a dip tank. Next, excess resin is removed and the web is dried. The drying, which takes place in an oven, vaporizes the solvent and helps increase the molecular weight of the resin via additional chemical reactions. Usually the web sheeting is cut and placed in multiple layers. Finally, a hydraulic press compacts the layers of sheets at pressures ranging from 1,400 Kilopascals (kPa) to 12,000 kPa under temperature conditions of 140 to 180°C (EPA, 1978).

### *Coating*

A variety of methods are available to coat objects, web materials, and other substrates with plastic. Some of the more common methods are included in this discussion. For a detailed discussion on coating operations and estimating emissions from associated activities, please see Chapter 7 in this series, *Preferred and Alternative Methods for Estimating Emissions from Surface Coating Operations*.

Calender coating involves the production of plastic sheets that are then pressed between heated rollers against a web of material. The heat and pressure bond the plastic to the web substrate.

In dip coating, a part is dipped or immersed in a resin solution.  After the part is removed from the solution and excess coating is drained, the part is air-dried or baked.  This coating method is useful for irregularly shaped parts.  In flow coating, a method similar to dip coating, plastic coating is poured or sprayed on the part and allowed to drain by gravity.

Roll coating is another common method that is often used for web substrates.  A controlled amount of resin is applied to the web as it passes over and between a series of rollers.  In knife-over-roll coating, a coating knife controls the thickness of the coating that is applied to the web substrate as it passes over a roller.  The coating thickness is regulated by the distance between the coating knife edge and the surface of the web material.

### Foam Processing

Many of the same processes used to manufacture solid plastic products (i.e., extrusion and molding) are used to generate foamed plastic products.  However, unlike solid plastic products manufacturing, the manufacture of foamed plastic products requires a specialized stage where air, chemical, or physical blowing agents are incorporated into the plastic mixture to produce a cellular structure unique to foamed plastics.

Foamed plastics are divided into three major types: blown, syntactic, and structural.  Blown foam is an expanded matrix (resembles a sponge).  Syntactic foam is the encapsulation of hollow micro spheres in a plastic matrix.  Structural foam is a foamed core surrounded by a solid outer skin.

The following are some basic processes that are used in conjunction with standard molding and forming operations to produce blown and syntactic foam plastic:

- A chemical blowing agent that generates gas through thermal decomposition is incorporated into the polymer melt or pellet;

- Pressurized gas or liquid is injected into the melt and expands during pressure relief;

- A low-boiling-point liquid (i.e., hydrocarbons) is incorporated into the plastic compound and volatilized through the exothermic heat of reaction or the application of heat;

- Nonchemical gas-liberating agents, in the form of gas adsorbed on finely divided carbon, are added to the resin mix and released during heating;

- Air is dispersed by mechanical means within the polymer; or

- The external application of heat causes the expansion of small beads of thermoplastic resin containing a blowing agent.

Structural foam plastic is made by injection molding liquid resins that contain chemical blowing agents.  Less mixture is injected into the mold than is needed to mold a solid plastic part.  At first, the injection pressure is very high, causing the blowing agent to solidify against the mold without undergoing expansion.  As the outer skin is formed, the pressure is reduced and the remaining resin expands to fill the remainder of the mold (EPA, 1995).

### Finishing Operations

Many plastic products need finishing or machining after they have been processed to remove imperfections, repair defects, or decorate the plastic product.  Finishing operations include filing, grinding, sanding, polishing, painting, bonding, coating, engraving, and a number of other operations.  Some finishing operations, like bonding or grinding, can also be classified as major processes when they are a part of the operations employed to produce an intermediate product.

## 2.1.3 ADDITIVES

Additives are incorporated in plastic materials prior to processing to impart specific chemical or physical properties to the plastic.  Additives include lubricants, antioxidants, antistats, blowing (foaming) agents, colorants, plasticizers, heat stabilizers, flame retardants, and ultraviolet stabilizers.  Three common additives (plasticizers, antioxidants, and stabilizers) are discussed below.

### Plasticizers

Plasticizers are added to plastic materials to improve flexibility, workability, or extrudability.  Most plasticizers are used in the manufacture of flexible polyvinyl chloride (PVC).  Phthalates, adipates, and trimellitates are the most common plasticizers.

### Antioxidants

Antioxidants are added to plastic materials to inhibit the oxidation of plastic exposed to air.  Antioxidants minimize degradation during processing, storage, and service.  Hindered phenols are the class of compounds predominantly used to stabilize most polymers.

### *Stabilizers*

Stabilizers are used to prevent plastic materials from degrading when subject to heat or ultraviolet radiation.  For example, pure PVC degrades with the application of heat.  Therefore, incorporating stabilizers into the PVC material can help maintain the physical and chemical properties of the PVC material throughout processing and the life of the PVC material.

Ultraviolet stabilizers protect plastics from degrading when exposed to sunlight.  Hindered amine light stabilizers (HALS), benzotriazoles, benzophenones, and nickel compounds are typical light stabilizers (Midwest Research Institute, 1993).

## 2.2  EMISSION SOURCES

Emissions from plastic products manufacturing come from a variety of sources and are highly dependent upon the chemical makeup of the raw materials (resins, additives) and types of production processes used.  In addition, the diverse nature of these raw materials and manufacturing techniques results in a wide range of potential combinations of emission sources and pollutants.

The primary sources of emissions at plastic products manufacturing facilities are the pieces of equipment (e.g., extruder hopper, die head, sander) used to handle raw materials and produce the final product.  These are typically the locations where chemical reactions occur, liquid solvents and solvent blends are exposed to the atmosphere, solid resin is heated and melted, and additives are introduced.

In addition to emissions generated directly from primary production processes associated with plastic products manufacturing, there may be additional emissions produced by secondary processes at these facilities.  Emission sources from these secondary processes include storage tanks, equipment leaks, wastewater treatment, combustion sources, and cleaning and surface coating operations.  Chapter 2 of this volume addresses emissions from combustion in boilers, Chapter 4 addresses emissions from equipment leaks, Chapter 5 addresses emissions from wastewater collection and treatment, and Chapter 7 addresses emissions from surface coating operations.  In addition, Chapter 1 of this volume discusses general emission estimation approaches and includes useful references to other sources and tools for estimating emissions.

As explained earlier, there are multiple processes occurring at plastic products manufacturing facilities that give rise to a wide variety of pollutants.  Emissions from plastic products manufacturing may be generally classified as follows:

- Volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions resulting from the volatilization of free monomer or solvent in the primary polymer blend during processing;

- VOC and HAP emissions that result from secondary process materials, such as blowing agents, additives, and lubricants (mold release compounds);

- VOC, HAP, and particulate matter (PM) emissions that result from byproducts formed by chemical reactions or formed during heating of resins; and

- PM emissions generated during raw material handling and finishing operations.

The following discussion provides additional information on some of the specific pollutants emitted from plastic products manufacturing facilities and the specific processes giving rise to emissions.

## 2.2.1 FREE MONOMER/SOLVENT

Emissions of free monomer (a single molecule of a chemical used in a polymer) may occur when a solid resin is heated during extrusion, molding, or any of the other processes discussed in Section 2.1. For example, one recent study (Contos et al., 1995) found a monomer (styrene) to be the principle component of the emissions produced during the extrusion of acrylonitrile-butadiene-styrene (ABS) resins.

Emissions of free monomer would also be expected from resins used in solvent form. Some resins may be handled using a solvent medium to store and transport the resin prior to processing. In this case, emissions would also come from the solvent used to suspend the resin prior to the polymerization step. Thermoset resins are often handled in monomer form prior to solidifying under heat or pressure, or reaction with a hardening agent to generate a solid polymer. For example, when curing of thermosets is accomplished during processing or when processing involves polymerization (such as when thermoset polyurethane elastomers are processed using reaction injection molding), substantial emissions of monomers are likely to be generated (Midwest Research Institute, 1993).

## 2.2.2 SECONDARY PROCESS MATERIALS

In addition to the bulk polymer and additives used to form the plastic product, additional materials may be used to assist in lubrication, or, in the case of blowing agents used to manufacture foams, to decrease the density of the final product.

### Lubrication

Lubrication is used in molding and forming operations to prevent plastic material from sticking to mold surfaces. A mold release agent (lubricating or parting agent) is sprayed on a mold cavity surface in a thin waxy layer to facilitate the release or removal of the molded plastic form from the mold. Mold release agents contain carrier solvents (HAP-based and non-HAP based) that evaporate immediately when the mold release agent adheres to the mold cavity surface (EPA, 1996).

### Blowing Agents

Emissions also occur from blowing agents used to manufacture certain foams. In expanded polystyrene (EPS) bead manufacturing, the blowing agent is typically contained in the raw polymer beads as they come from the supplier. This causes the beads to expand when exposed to heat. There are three general classes of emissions from this type of foam production: manufacturing emissions; prompt foam cell losses, which are losses that typically occur during storage and shipping; and banked emissions, which are losses that occur through slow diffusion of blowing agents out of the foam over the life of the product (EPA, 1990).

Another type of polystyrene foam is extruded polystyrene foam sheet (PSF). Pentane is the predominant hydrocarbon blowing agent used to manufacture PSF. After extrusion, sheets of intermediate product are wound into rolls and aged for 3 to 5 days. After aging, the sheets are thermoformed into consumer products and packaged for shipment. Typically 50 percent of the blowing agent is lost during the manufacturing and reclaim operations and the remainder as fugitives during warehousing, transportation, and after the product is sold (EPA, 1990).

In the manufacture of polyurethane foams, large quantities of auxiliary blowing agents are used to reduce foam density. The use of these blowing agents (predominantly methylene chloride or chlorofluorocarbons) does not involve any chemical reactions, but is merely a change of the physical state of the blowing agent. Volatilization of the auxiliary blowing agent from liquid to gas provides the volume needed to increase the number and size of foam cells. One recent study estimates that approximately 60 percent of methylene chloride is lost within the first 10 minutes of the process and the remaining 40 percent is lost slowly by diffusion over the next 24 hours (Kaufman and Overcash, 1993). The initial bulk of emissions are typically released through

process vents located at the foaming equipment, while the remaining 40 percent of emissions are released fugitively while the foam is being transported and stored.

### 2.2.3 CHEMICAL REACTIONS/BYPRODUCTS

VOC and HAP emissions may be generated from chemical reactions occurring as a direct part of the process, as in the case of thermoset resins, or as an indirect result of the process environment. For example, pure PVC degrades with the application of heat to form hydrochloric acid (HCl) gas, which itself is a catalyst for further degradation.

Because many thermoplastic operations occur in heated environments, some amount of emissions occurs due to thermal degradation of additives as well as the actual polymeric material used to produce the final product.

### 2.2.4 PARTICULATE SOURCES

Particulate emissions from plastic products manufacturing are composed of solid particulates and hydrocarbon-based aerosols (EPA, 1978). The solid particulates are generated during grinding, cutting, and sawing of raw materials as well as finished products; and from the pneumatic and manual conveying and subsequent handling of polymeric materials and additives.

The level of particulate emissions is dependent on several factors. For example, one publication noted an increase in the level of particulate emissions with an increase in process temperature (Barlow et al., 1996). This may be due to the increased level of oxidation (smoking) the raw polymer undergoes at higher temperatures. Thermoplastic resins may be handled in a variety of forms, from solvent suspended solutions to pellets, beads, flake, or granular form. In general, materials handled in finely divided solid form (resins or flakes) are more likely emitted from handling operations than materials handled in larger solid form (chips) or in aqueous solution.

## 2.3 PROCESS DESIGN AND OPERATING FACTORS INFLUENCING EMISSIONS

### 2.3.1 PROCESS AND OPERATING FACTORS

As mentioned above, emissions from plastic products manufacturing facilities occur where solid resins are heated and melted, liquid solvents and solvent blends are exposed to the atmosphere, additives are introduced, and where chemical reactions occur. Therefore, it is expected that emissions are influenced by chemical makeup of the process materials, the physical makeup of the plastic processing equipment, and the conditions under which processing occurs.

For thermoplastic resins, one of the most important factors is the temperature at which the resin is melted and shaped into the final product. Those processes which occur at or near the melting point of the solid resin result in lower emissions than processes occurring at temperatures well beyond the melting point of the resin. For example, published emission factors indicate that for low-density polyethylene resin, there is an increase of over 400 percent in VOC emissions with a change of temperature from 500 to 600°F (Barlow et al., 1996).

Another important factor is the time interval during which the raw product (solid resin, solvent solutions) is exposed to air. Closed processes, such as enclosed mixing tanks or injection molds, result in lower emissions due to less direct contact with air and less opportunity for materials to volatilize. Conversely, large open tanks or air cooled extrusion processes are likely to lead to higher emissions. In addition to volatilization of organics and PM emissions from wind, increased exposure to the atmosphere would lead to increased chemical reactions as most polymers are subject to attack from oxygen in the air (Midwest Research Institute, 1993).

Recent testing data appear to indicate that the total surface area of the plastic product exposed to air may also affect emissions. For example, the surface area to mass ratio is greater for blown sheet than for extruded rod, allowing more contact with air and greater opportunity for emissions (on a mass basis). However, further research is needed to validate these conclusions.

## 2.3.2 CONTROL TECHNIQUES

Emissions from plastic products manufacturing may be reduced either through process modifications or by using add-on control devices. Process modifications include the use of alternative raw materials such as alternative blowing agents for foam or switching to non-HAP containing additives. Process modifications also refer to the use of modified equipment or operating practices such as covering storage piles. In addition, keeping the die temperature close to the resin melting temperature and reducing the residence time of the heated resin in air will help reduce emissions.

There are many types of add-on control devices that could potentially be employed at plastic products manufacturing facilities to control emissions of VOC, HAPs, and PM. These would typically be most appropriate for contained streams with pollutant concentrations high enough for add-on control devices to be cost effective. Unfortunately, there is little information available that indicates the types and extent of add-on control devices currently being used. It is expected that VOC and organic HAP emissions could be controlled by incineration, adsorption, absorption, or condensation. Incineration and carbon adsorption have been identified as technologies currently in use at polystyrene foam manufacturing facilities (EPA, 1990). PM emissions generated from finishing operations, including cutting and grinding, are typically controlled by cyclones or fabric filters.

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# 3

# OVERVIEW OF AVAILABLE METHODS

## 3.1 EMISSION ESTIMATION METHODS

Several methods are available for estimating emissions from primary processes at plastic products manufacturing facilities. The best method to use depends upon available data, available resources, and the degree of accuracy required in the estimate. In general, site-specific data that are representative of normal operations at a particular site are preferred over data obtained from other similar sites, or industry-averaged data.

This section discusses the methods available for calculating emissions from plastic products manufacturing operations and identifies the preferred method of calculation on a pollutant basis. Although preferred methods are identified, this document is not regulatory in nature and does not mandate any emission estimation method. Industry personnel using this manual should contact the appropriate state or local air pollution control agency regarding use of suggested methods. A comparison of the methods is also presented.

### 3.1.1 MATERIAL BALANCE

A material balance approach may be used to estimate emissions when the quantities of a material used, recycled, incorporated into a product, and disposed of are known. For example, in PSF sheet production, the amount of blowing agent entering the process is a known quantity. After manufacturing is completed, the blowing agent remaining in the product can be measured by gas chromatography or gravimetric methods. The difference between what was used and the residual left in the foam represents the total manufacturing emissions (Krutchen and Wu, 1988a, 1988b, 1988c).

For liquid applications, such as solvent use, usage figures would typically be in gallons. The difference (by mass) of the amount of a liquid used and the amount of the liquid recovered, disposed of, or converted to another form, is assumed to equal releases to the air.

### 3.1.2 SOURCE TESTS

Source tests provide a "snapshot" of emissions during the period of the test. Samples are collected using probes inserted into the stack, and pollutants are collected in or on various media and sent to a laboratory for analysis or analyzed on-site by continuous analysis. Pollutant concentrations are obtained by dividing the amount of pollutant collected during the test by the volume of the sample. Emission rates are then determined by multiplying the pollutant concentration by the volumetric stack flow rate.

EPA has published approved test methods for determining air emissions in Title 40 CFR Part 60, Appendix A. Methods that would be applicable to plastic products manufacturing would be Method 18 (speciated organics), Method 25 (total hydrocarbon [THC]), Method 5 (PM), Method 201 (PM-10), Method 202 (condensable PM) and Method 0030 (speciated organics). In order to obtain accurate results using source testing, state-of-the-art methods should be chosen which are specifically targeted for pollutants of interest.

### 3.1.3 EMISSION FACTORS

Emission factors are used to estimate emissions based on known relationships between process rates and emission rates. The use of emission factors to estimate emissions from plastic products manufacturing facilities is an appropriate approach. Development of an accurate emission factor would require detailed knowledge of the process conditions and chemical and resin usage rates during the time period for which emissions are known. Emission factors should be applied to similar-type processes utilizing similar or identical process recipes.

## 3.2 COMPARISON OF AVAILABLE EMISSION ESTIMATION METHODS

Table 11.3-1 identifies the preferred and alternative emission estimation approaches for the primary types of pollutants emitted at plastic products manufacturing facilities. The preferred method for estimating organic compound (VOC and HAP) emissions is dependent on how the material is used and the source of the emissions. For example, the preferred method for estimating emissions of methylene chloride used as a blowing agent is through the use of a material balance. Alternatively, the preferred method for estimating emissions of HAPs emitted during the heating of thermoplastics resins is the use of source testing since the extent of volatilization of the pollutant from the resin is unknown. In Table 11.3-1 these two cases are indicated as "Non-consumable VOC or HAP" and "Consumable VOC or HAP." "Consumable VOC or HAP" means chemical agents (such as monomers) used in the manufacturing process are chemically altered or bound and are consumed in the manufacturing process. For example, MDI (methylene di-para-phenylene isocyanate) is used in the manufacture of polyurethane. It reacts and becomes chemically bound in the final product. "Non-Consumable VOC or HAP" means chemical agents used in the manufacturing process that are not chemically altered or

bound and therefore are not consumed in the manufacturing process. For example, pentane is used as a blowing agent for polystyrene products to reduce density. Pentane is released throughout the manufacturing process. While some pentane remains in the product, overall it is chemically unchanged. It should be noted that for the material balance method to result in an accurate estimate, each fate of the chemical must be known when using this approach.

TABLE **11.3-1**

SUMMARY OF PREFERRED AND ALTERNATIVE EMISSION ESTIMATION METHODS FOR PLASTIC PRODUCTS MANUFACTURING OPERATIONS

| Pollutant | Preferred Emission Estimation Approach | Alternative Emission Estimation Approaches |
|---|---|---|
| Non-consumable VOC (Total and speciated) and non-consumable HAP | Material Balance | Source Testing Emission Factors |
| Consumable VOC (Total and speciated) and consumable HAP | Source Testing | Emission Factors Material Balance |
| Particulate Matter (Includes total PM, PM-10, PM-2.5) | Source Testing | Emission Factors |

Emission factors may not be based solely on site-specific data and should only be used if one of the preferred methods is not a viable option due to lack of data or resources. It is possible to obtain high-quality emissions estimates using emission factors, but only if they were originally developed using one of the preferred methods mentioned above.

### 3.2.1 MATERIAL BALANCE

A material balance approach is the preferred method for estimating emissions of VOCs, including specific HAPs (xylene, ethylbenzene, toluene, etc.) from solvent use and other solvent sources which are not consumed or expected to remain in the final product. These types of emittants are referred to as non-consumable VOC in Table 11.3-1. Examples of non-consumable VOCs including blowing agents and carrier solvents. This approach is suitable for these types of pollutants because they do not enter into chemical reactions. Also, their usage and waste rates may already be tracked for purchasing reasons as well as other non-air-related environmental reporting purposes.

For thermoplastic processing where blowing agents, solvents, or other liquids are not involved, a material balance technique is generally not the preferred method. For these processes, source testing or emission factors will generally give a more accurate estimate. Examples of these processes are discussed in Section 2 and include most thermoplastic processes where solvents are not added.

For other pollutants emitted at plastic products manufacturing facilities, a material balance may not be an appropriate primary emission estimate approach due to the uncertainty in the extent of chemical remaining in the product or generated as the result of chemical reactions. However, a material balance could be used as an alternative approach in cases where other methods are difficult or resource intensive and where a finite number of assumptions would result in a complete mass balance equation.

## 3.2.2 SOURCE TESTS

The standard EPA test methods mentioned in Section 3.1.2 can be used to obtain emission estimates from plastic products manufacturing processes for specific classes of compounds. In general, stack tests result in an accurate assessment of emissions when performed at the point of emissions generation and when the emissions can be directly correlated to a process activity for use in developing a site specific emission factor.

However, many of the emissions generating processes found at plastic products manufacturing facilities are not specifically vented or hooded, resulting in emissions being released as fugitives (through building openings such as windows, doors, and ventilation ducts) rather than through discrete emission points (such as process vents or stacks).

The former scenario would not be conducive to the use of source testing for estimating emissions. Source testing is best applied to contained gas streams originating at a specific emission generating process such as process vents or sanding and finishing stations.

## 3.2.3 EMISSION FACTORS

Emission factors may also be used to estimate emissions from plastic products manufacturing. However, because of the highly variable nature of the plastic products manufacturing process, emission factors should be determined using site-specific data whenever possible. There are three principal ways to derive emission factors for plastic products manufacturing operations: through the use of emissions test data; a material balance approach; or engineering judgement.

Once derived, these factors may be applied to estimate emissions based on production rates or other appropriate parameters such as usage rates of a particular chemical. This approach provides an alternative method of estimating emissions over a longer term or for a different

processing scenario based on short-term emission estimates (i.e., during the time of the test) obtained from individual process steps.  Also, emission factors for one process or chemical may be appropriate to use for estimating emissions from similar processes occurring within a facility or at other similar facilities.

The Society of the Plastics Industry (SPI) recently began a testing program with the cooperation of several resin suppliers to characterize emissions and develop emission factors for a variety of resin types and manufacturing techniques.  Initial results from these testing programs have been published in several recent journal articles (Barlow et al., 1996; Barlow et al., 1997; Contos et al., 1995).  The types of resins addressed in these studies include polyethylene, ABS, polypropylene, PVC, polystyrene, polycarbonate, and Nylon.

Emission factors for plastic products manufacturing are also presented in *AP-42*;  *Source Assessment: Plastics Processing, State of the Art* (EPA, 1978); and the Factor Information and Retrieval (FIRE) System database.  The emission factors presented in *Source Assessment: Plastics Processing, State of the Art* were developed in the mid 1970's and appear to be several orders of magnitude higher than emission factors based on recent testing.  The report acknowledges "...that the accuracy of the data in this table (Table 5-Emission Factors) is unknown."  The reader should consult with their local air pollution agency to determine which emission factors are acceptable for a particular application.

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# 4

# PREFERRED METHODS FOR ESTIMATING EMISSIONS

The preferred method for estimating non-consumable VOC emissions (including HAPs) from plastic products manufacturing processes is the use of a material balance. This approach can be used to estimate emissions from solvent use and coating application for pollutants not involved in chemical reactions. As mentioned in Section 3, material balance uses the raw material usage rate and material disposal rate (present in product or waste streams) to estimate emissions; therefore, a detailed knowledge of each fate of the chemical is needed.

The preferred method for estimating PM and consumable VOC (including HAPs) emissions is the use of source testing. This is also the preferred method for estimating emissions of pollutants generated as a result of chemical reactions, thermal degradation, or pollutants with uncertain fates or origins.

It should be noted that for many processes both consumable and non-consumable chemicals are used. As the preferred methods are chemical specific and not process specific, several estimation techniques may be preferred for an individual operation.

The equations and examples in this section present how material balance and source testing data may be used to estimate VOC, speciated organic, speciated inorganic, and particulate emissions. Table 11.4-1 lists the variables and symbols used in the following discussions.

## TABLE 11.4-1

### LIST OF VARIABLES AND SYMBOLS

| Variable | Symbol | Units |
|---|---|---|
| Material entering the process | $Q_{in}$ | gal/hr |
| Material leaving the process as waste, recovered material, or in product | $Q_{out}$ | gal/hr |
| Concentration of pollutant x at standard temperature, pressure | $C_x$ | parts per million by volume dry (ppmvd) or lb/gal |
| Concentration of pollutant x in raw material entering a process | $X_{in}$ | parts per million by volume dry (ppmvd), lb/gal or lb/lb |
| Concentration of pollutant x in material exiting a process | $X_{out}$ | parts per million by volume dry (ppmvd), lb/gal or lb/lb |
| Percentage by weight of speciated pollutant x in material | $wt\%_x$ | % |
| Density of material | d | lb/gal |
| Temperature correction for differences in temperature during test | $K_t$ | dimensionless |
| Pressure correction for differences in pressure during test | $K_p$ | dimensionless |
| Average concentration of pollutant x during test | $C_{a,x}$ | ppmvd |
| Molecular weight of pollutant x | $MW_x$ | lb/lb-mole |
| Stack gas volumetric flow rate | V | dry standard cubic feet per hour (dscf/hr) |
| Molar Volume | M | 385.5 scf/lb-mole @ 68°F, 1 atm |
| Annual emissions of pollutant x | $E_{an,x}$ | ton/yr |
| Hourly emissions of pollutant x | $E_{hr,x}$ | lb/hr |
| Operating hours | OH | hr/yr |

## 4.1 EMISSIONS CALCULATION USING MATERIAL BALANCE

Material balance is the preferred method for estimating emissions of VOCs and organic HAPs used in materials such as solvents, cleaners and blowing agents where the VOC or HAP is not incorporated into the final product. In order to use this approach, some information about the material is needed. Information such as material density, VOC content, and pollutant concentration can usually be found on the manufacturer's technical specification sheet or the material safety data sheet (MSDS).

If the pollutant concentration in a material is known, non-consumable VOC and HAP emissions from plastic products manufacturing may be estimated using a material balance approach by applying Equation 11.4-1:

$$E_{hr, x} = Q_{in} * X_{in} - Q_{out} * X_{out} \tag{11.4-1}$$

where:

$E_{hr, x}$ = Hourly emissions of pollutant x (lb/hr)
$Q_{in}$ = Material entering the process (gal/hr)
$Q_{out}$ = Material leaving the process as waste, recovered material, or in product (gal/hr)
$X_{in}$ = Concentration of pollutant x (lb/gal) in raw material entering a process
$X_{out}$ = Concentration of pollutant x (lb/gal) in raw material exiting a process

The term $Q_{out}$ may actually involve several different "fates" for an individual pollutant. This could include the amount recovered (or recycled), the amount leaving the process in the product, the amount leaving the process in the wastewater, the amount being converted to another compound, or the amount of material shipped off-site as hazardous waste. A thorough knowledge of the different fates for the pollutant of interest is necessary for an accurate emissions estimate. Example 11.4-1 illustrates the use of Equation 11.4-1.

Example 11.4-1

This example shows how non-consumable VOC emissions may be calculated using
Equation 11.4-1.

In a given 1-hour period, a facility uses 2 gallons of a cleaning solvent containing 7.5
lb VOC/gal.  At the end of the 1-hour period, 1.5 gallons of solvent remain.  Based on
hazardous waste profiles for this application you know the spent solvent contains 6.0
lb VOC/gal.  Using the variables defined above, this information may be  presented as:

$Q_{in}$ = 2.0 gal/hr
$Q_{out}$ = 1.5 gal/hr
$X_{in}$ = 7.5 lb VOC/gal
$X_{out}$ = 6.0 lb VOC/gal

From Equation 11.4-1, VOC emissions are calculated as follows:

$$E_{hr, VOC} = Q_{in} * X_{in} - Q_{out} * X_{out}$$
$$= 2.0 \text{ (gal/hr)} * 7.5 \text{ (lb VOC/gal)} - 1.5 \text{ (gal/hr)} * 6.0 \text{ (lb VOC/gal)}$$
$$= 6.0 \text{ (lb VOC/hr)}$$

If the pollutant concentration in a material is unknown, but material density and the percentage,
by mass, of a pollutant in material is known, a material balance approach may also be used.  In
this case, non-consumable VOC and HAP emissions may be estimated by using
Equation 11.4-2:

$$E_{hr, x} = (Q_{in} - Q_{out}) * d * (wt\%_x)/100 \qquad (11.4-2)$$

where:

$E_{hr, x}$ = Hourly emissions of pollutant x (lb/hr)
$Q_{in}$ = Material entering the process (gal/hr)
$Q_{out}$ = Material leaving the process as waste, recovered material, or in
product (gal/hr)
d = Density of material (lb/gal)
$wt\%_x$ = Percentage by weight of speciated pollutant x in material (%)

Example 11.4-2 illustrates the use of Equation 11.4-2.

---

<u>Example 11.4-2</u>

This example shows how toluene emissions may be estimated for a cleaning process using toluene-containing cleaner given the following data:

$Q_{in}$ $\quad$ = $\quad$ 2 gal/hr
$Q_{out}$ $\quad$ = 1.5 gal/hr
d $\quad\quad$ = 7.5 lb/gal
$wt\%_x$ $\quad$ = 25% toluene

$E_{hr, toluene}$ = $\quad$ $(Q_{in} - Q_{out}) * d * (wt\%_{toluene})/100$
$\quad\quad\quad\quad$ = (2 gal/hr - 1.5 gal/hr) * 7.5 lb/gal * 25/100
$\quad\quad\quad\quad$ = 0.94 lb toluene/hr

---

## 4.2 EMISSIONS CALCULATION USING SOURCE TEST DATA

Stack sampling test methods can be used to estimate PM, consumable VOC, and inorganic HAP emission rates from plastic products manufacturing. Most sampling methods provide pollutant concentration data through grab sampling followed by laboratory analysis. Concentration data are used with exhaust flow rate measurements to determine an emission rate. Volumetric flow rates can be determined from flow rate meters or from pressure drops across a critical orifice (e.g., EPA Method 2). A detailed discussion of the applicability of stack sampling test methods for selected pollutants may be found in Chapter 1 of this volume.

Stack sampling test reports often provide chemical concentration data in parts per million by volume dry (ppmvd). For gaseous pollutants, the concentration of a pollutant ($C_x$) at standard temperature and pressure can be determined using Equation 11.4-3:

$$C_x = K_t * K_p * C_{a,x} \quad\quad\quad (11.4-3)$$

where:

$C_x$ $\quad$ = Concentration of pollutant x at standard temperature, pressure (ppmvd)
$K_t$ $\quad$ = Temperature correction for differences in temperature during test (dimensionless)
$K_p$ $\quad$ = Pressure correction for differences in pressure during test (dimensionless)
$C_{a,x}$ $\quad$ = $\quad$ Average concentration of pollutant x during test (ppmvd)

If the concentration is known, an hourly emission rate can be determined using Equation 11.4-4:

$$E_{hr,x} = (C_x * MW_x * V)/(M * 10^6)$$ (11.4-4)

where:

$E_{hr,x}$  =  Hourly emissions of pollutant x (lb/hr)
$C_x$  =  Concentration of pollutant x at standard temperature, pressure (ppmvd)
$MW_x$  =  Molecular weight of pollutant x (lb/lb-mole)
V  =  Stack gas volumetric flow rate (dscf/hr)
M  =  Molar volume; i.e., volume occupied by 1 mole of ideal gas at standard temperature and pressure (385.5 scf/lb-mole at 68°F and 1 atm)

Emissions in tons per year can be calculated by multiplying the hourly emission rate (lb/hr) from Equation 11.4-4 by the number of operating hours (as shown in Equation 11.4-5 below).

$$E_{an,x} = E_{hr,x} * OH * 1 \text{ ton}/2,000 \text{ lb}$$ (11.4-5)

where:

$E_{an,x}$  =  Annual emissions of pollutant x (ton/yr)
$E_{hr,x}$  =  Total hourly emissions of pollutant x (lb/hr)
OH  =  Operating hours (hr/yr)

Example 11.4-3 illustrates the use of Equations 11.4-3 through 11.4-5.

Concentration data obtained from source testing may come in a variety of units, including parts per million (ppm) or grams per dry standard cubic feet (g/dscf), and in a variety of conditions, such as wet, dry, or excess oxygen ($O_2$). This may require conversion of concentration data to consistent units for compatibility with the equations given above.

Example 11.4-3

This example shows how annual hydrogen chloride (HCl) emissions can be calculated using the data obtained from a stack test. The concentration of HCl is calculated using Equation 11.4-3, hourly emissions are calculated using Equation 11.4-4, and annual emissions are calculated using Equation 11.4-5.

Given:

$K_t$      = 1.0
$K_p$      = 0.8
$C_{a,HCl}$ = 15.4 ppmvd (obtained from stack test data)
$MW_{HCl}$   =      36.46 lb/lb-mole of HCl
$V$         = 20,500 dscf/hr
$OH$        = 1,760 hr/yr
$M$         = 385.5 $ft^3$/lb-mole

The concentration of HCl ($C_{HCl}$) is calculated from Equation 11.4-3:

$$
\begin{aligned}
C_{HCl} &= K_t * K_p * C_{a,HCl} \\
&= 1.0 * 0.8 * 15.4 \text{ ppmvd} \\
&= 12.32 \text{ ppmvd}
\end{aligned}
$$

Hourly emissions are calculated using Equation 11.4-4:

$$
\begin{aligned}
E_{hr,HCl} &= (C_{HCl} * MW_{HCl} * V)/(M * 10^6) \\
&= 12.32 \text{ ppmvd} * 36.46 \text{ lb/lb-mole} * 20,500 \text{ dscf/hr}/(385.5 \text{ } ft^3/ \\
&\quad \text{lb-mole} * 10^6) \\
&= 0.02 \text{ lb/hr}
\end{aligned}
$$

Annual emissions are calculated using Equation 11.4-5:

$$
\begin{aligned}
E_{an,HCl} &= E_{HCl} * OH * 1 \text{ ton/2,000 lb} \\
&= 0.02 \text{ lb/hr} * 1,760 \text{ hr/yr} * 1 \text{ ton/2,000 lb} \\
&= 0.02 \text{ ton/yr}
\end{aligned}
$$

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# 5

# ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

Source testing, material balance, and emission factors are all alternative methods for estimating organic compound emissions (including VOC and HAP) and inorganic compound emissions from primary processes at plastic products manufacturing facilities. Emission factors may be used as an alternative method for estimating emissions of PM.

The following equations and examples present how source test data, emission factors and material balance may be used to estimate PM, VOC (consumable and non-consumable), speciated organic, and speciated inorganic emissions. Table 11.5-1 lists the variables and symbols used in the following discussions.

## 5.1 EMISSIONS CALCULATION USING SOURCE TEST DATA

Various stack sampling test methods can be used to estimate non-consumable VOC and speciated organic emission rates from plastic products manufacturing (e.g., EPA Method 25). Volumetric flow rates can be determined from flow rate meters or from pressure drops across a critical orifice (e.g., EPA Method 2).

Stack sampling test reports often provide chemical concentration data in parts per million by volume dry (ppmvd). For gaseous pollutants, the concentration of a pollutant ($C_x$) can be determined from Equation 11.5-1:

$$C_x = K_t * K_p * C_{a,x} \tag{11.5-1}$$

TABLE 11.5-1

LIST OF VARIABLES AND SYMBOLS

| Variable | Symbol | Units |
|---|---|---|
| Concentration of pollutant x  at standard temperature, pressure | $C_x$ | ppmvd or lb/gal |
| Temperature correction for differences in temperature during test | $K_t$ | dimensionless |
| Pressure correction for differences in pressure during test | $K_p$ | dimensionless |
| Average concentration of  pollutant x during test | $C_{a,x}$ | parts per million by volume dry (ppmvd) or lb/gal |
| Hourly emissions of pollutant x | $E_{hr,x}$ | lb/hr |
| Molecular weight of pollutant x | $MW_x$ | lb/lb-mole |
| Stack gas volumetric flow rate | $V$ | dry standard cubic feet per hour (dscf/hr) |
| Molar volume | $M$ | cubic feet $(ft^3)$/lb-mole |
| Concentration of pollutant x in material entering a process | $X_{in}$ | parts per million by volume dry (ppmvd), lb/gal, lb/lb |
| Concentration of pollutant x in material exiting a process | $X_{out}$ | parts per million by volume dry (ppmvd), lb/gal, lb/lb |
| Annual emissions of pollutant x | $E_{an,x}$ | ton/yr |
| Operating hours | OH | hr/yr |
| Emission factor for pollutant x | $EF_x$ | lb/units |
| Activity factor | AF | units/hr |
| Material entering the process | $Q_{in}$ | typically gal/hr or lb/hr |
| Material leaving the process as waste, recovered material, or in product | $Q_{out}$ | typically gal/hr or lb/hr |

where:

$C_x$ = Concentration of pollutant x (ppmvd) at standard temperature, pressure
$K_t$ = Temperature correction for differences in temperature during test (dimensionless)
$K_p$ = Pressure correction for differences in pressure during test (dimensionless)
$C_{a,x}$ = Average concentration of pollutant x (ppmvd) during test

If the concentration is known, an hourly emission rate can be determined using Equation 11.5-2:

$$E_{hr,x} = (C_x * MW_x * V)/(M * 10^6) \qquad (11.5\text{-}2)$$

where:

$E_x$ = Hourly emissions of pollutant x (lb/hr)
$C_x$ = Concentration of pollutant x (ppmvd)
$MW_x$ = Molecular weight of pollutant x (lb/lb-mole)
$V$ = Stack gas volumetric flow rate (dscf/hr)
$M$ = Molar volume; i.e., volume occupied by 1 mole of ideal gas at standard temperature and pressure (385.5 ft$^3$/lb-mole at 68°F and 1 atm)

Emissions in tons per year can be calculated by multiplying the average hourly emission rate (lb/hr) from Equation 11.5-2 by the number of operating hours (as shown in Equation 11.5-3 below) or by multiplying an average emission factor (lb/gal) by the total annual amount of material used (gal).

$$E_{an,x} = E_{hr,\ x} * OH * 1 \text{ ton}/2{,}000 \text{ lb} \qquad (11.5\text{-}3)$$

where:

$E_{an,x}$ = Annual emissions of pollutant x (ton/yr)
$E_{hr,x}$ = Hourly emissions of pollutant x (lb/hr)
$OH$ = Operating hours (hr/yr)

Example 11.5-1 illustrates the use of Equations 11.5-1 through 11.5-3.

Concentration data obtained from source testing may come in a variety of units, including parts per million (ppm) or grams per dry standard cubic feet (g/dscf), and in a variety of conditions, such as wet, dry, or excess $O_2$.  This may require conversion of concentration data to consistent units for compatibility with the equations given above.

Example 11.5-1

This example shows how annual methyl ethyl ketone (a non-consumable VOC) emissions can be calculated using data obtained from a stack test.  The concentration of methyl ethyl ketone (MEK) is calculated using Equation 11.5-1, hourly emissions are calculated using Equation 11.5-2, and annual emissions are calculated using Equation 11.5-3.

Given:

$K_t$ = 1.0
$K_p$ = 0.8
$C_{a,MEK}$ = 9 ppmvd (obtained from stack test data)
$MW_{MEK}$ = 72.11 lb/lb-mole of MEK
V = 30,200 dscf/hr
OH = 1,760 hr/yr
M = 385.5 ft$^3$/lb-mole

The concentration of MEK ($C_{MEK}$) is calculated from Equation 11.5-1:

$C_{MEK}$ = $K_t * K_p * C_{a,MEK}$
= 1.0 * 0.8 * 9 ppmvd
= 7.2 ppmvd

Hourly emissions are calculated using Equation 11.5-2:

$E_{hr, MEK}$ = $(C_{MEK} * MW_{MEK} * V)/(M * 10^6)$
= 7.2 ppmvd * 72.11 lb/lb-mole * 30,200 dscf/hr/(385.5 ft$^3$/lb-mole * 10$^6$)
= 0.04 lb/hr

Annual emissions are calculated using Equation 11.5-3:

$E_{an, MEK}$ = $E_{hr, MEK}$ * OH * 1 ton/2,000 lb
= 0.04 lb/hr * 1,760 hr/yr * 1 ton/2,000 lb

## 5.2 EMISSIONS CALCULATION USING EMISSION FACTORS

Emission factors may be used to estimate PM, VOC (consumable and non-consumable), organic HAP, and inorganic HAP emissions from plastic products manufacturing operations using Equation 11.5-4:

$$E_{hr,x} = EF_x * AF \qquad\qquad (11.5\text{-}4)$$

where:

      $E_{hr,\,x}$   =   Hourly emissions of pollutant x (lb/hr)
      $EF_x$  =  Emission factor for pollutant x (lb/units)
      AF   =   Activity factor (units/hr)

Example 11.5-2 illustrates the use of Equation 11.5-4. It should be noted that at this time, there is not a comprehensive listing of emission factors for all plastic products manufacturing processes, and emission factors will need to be developed for each pollutant and process or operation of interest.

---

Example 11.5-2

This example shows how PM emissions can be calculated for a high-density polyethylene (HDPE) blow molding process using an emission factor[a] and Equation 11.5-4 given the following data:

    $EF_{PM}$  =  19.6 lb PM/million lb HDPE (at 380°F)
    AF     =  2,000 lb HDPE/hr

    $E_{hr,\,PM}$   =  $EF_{PM} * AF$
               =  $(19.6 \text{ lb PM}/1 * 10^6 \text{ lbs HDPE}) * (2{,}000 \text{ lb HDPE/hr})$
               =  $3.92 * 10^{-2}$ lb PM/hr

---

[a] The emission factor used in this example comes from the SPI study mentioned previously (Barlow et al., 1996).

## 5.3 EMISSIONS CALCULATION USING MATERIAL BALANCE

Consumable VOC emissions from plastic products manufacturing may be estimated using a material balance approach by applying Equation 11.5-5:

$$E_{hr,x} = Q_{in} * X_{in} - Q_{out} * X_{out} \qquad (11.5\text{-}5)$$

where:

$E_{hr,x}$ = Hourly emissions of pollutant x (lb/hr)
$Q_{in}$ = Material entering the process (gal/hr or lb/hr)
$Q_{out}$ = Material leaving the process as waste, recovered material, or in product (gal/hr or lb/hr)
$X_{in}$ = Concentration of pollutant x (lb/gal) in raw material entering a process
$X_{out}$ = Concentration of pollutant x (lb/gal) in raw material exiting a process

The term $Q_{out}$ may actually involve several different "fates" for an individual pollutant. This could include the amount recovered (or recycled), the amount leaving the process in the product, the amount leaving the process in the wastewater, the amount being converted to another compound or the amount of material shipped off-site as hazardous waste. A thorough knowledge of the different fates for the pollutant of interest is necessary for an accurate emissions estimate. Fates of pollutants should include pollutants created through chemical degradation or re-polymerization. Example 11.5-3 illustrates the use of Equation 11.5-5.

Example 11.5-3

This example shows how to calculate emissions evolving from blowing agents used in foam production. Most blowing agents contain VOCs that immediately volatilize during foam processing; however, depending on the blowing agent used, some of the blowing agent remains in the product after processing.

Over a 30 day period a polystyrene packaging plant manufactures consumer products using pentane as a blowing agent. Using a mass balance approach, calculate the emissions for the facility for the last month (30 days). Assume the blowing agent leaves the facility only as product or as emissions.

Given:

$Q_{in}$ = 66,500 lbs of pure pentane
$X_{in}$ = 1 lb pentane/lb pentane
$Q_{out}$ = 1,000,000 lbs of polystyrene product
$X_{out}$ = 3.6% pentane, measured by GC or gravimetric methods

Solution:

$$E_x = Q_{in} * X_{in} - Q_{out} * X_{out}$$

Note that $Q_{in}$ is known and equals 66,500 lbs of blowing agent, so:

$E_{pentane} = Q_{in} - Q_{out} * X_{out}$
$E_{pentane}$ = 66,500 lbs - 1,000,000 lbs product * 3.6 (lb pentane/100 lbs product)
$E_{pentane}$ = 30,500 lbs of pentane emitted in 30 days

 or

$E_{pentane}$ = 30,500/(30 days * 24 hr/day) = 42.36 lbs/hr

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# 6

# QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance (QA) and quality control (QC) are essential elements in producing high quality emission estimates and should be included in all methods used to estimate emissions. QA/QC of emissions estimates are accomplished through a set of procedures that ensure the quality and reliability of data collection and processing. These procedures include the use of appropriate emission estimation methods, reasonable assumptions, data reliability checks, and accuracy/logic checks of calculations. Volume VI of this EIIP document series, *Quality Assurance Procedures*, describes methods and tools for performing these QA/QC procedures.

In addition, Chapter 1 of this EIIP Point Sources Volume, *Introduction to Point Source Emission Inventory Development,* provides QA/QC guidance for preparing point source emission estimates. The following sections discuss QA/QC considerations that are specific to the emission estimation methods presented in this chapter for estimating emissions from plastic products manufacturing.

## 6.1 QA/QC FOR USING MATERIAL BALANCE

The material balance method for estimating emissions may use various approaches, so the QA/QC considerations will vary and may be specific to an approach. Generally, the fates of all materials of interest are identified, and then the quantity of material allocated to each fate determined. Identifying these fates, such as material contained in a product or material leaving the process in the wastewater, is usually straightforward. However, estimating the amount of material allocated to each fate is sometimes complicated and is the prime QA/QC consideration in using the material balance approach. Amounts obtained by direct measurement are more accurate and produce emission estimates of higher quality than those obtained by engineering or theoretical calculations. QA/QC of an emissions estimate developed from a material balance approach should include a thorough check of all assumptions and calculations.

## 6.2 QA/QC FOR USING EMISSION FACTORS

When using emission factors to estimate emissions from plastic products manufacturing, the applicability and representativeness of the emission factor are the first criteria to consider. To assess applicability, the reviewer needs to examine how closely the process of interest matches

the process for which the emission factor is available.  Similarly, the reviewer should look at how well the range of conditions on which the available emission factor is based compares to the conditions of interest.  For example, an emission factor that is based on a strand extruder process may be appropriate for a conservative estimate of emissions from heavy sheet and profile extrusion (as well as closed mold operations such as injection molding) and thermoforming, but may not be the best emission factor for a film process.

## 6.3  QA/QC FOR USING SOURCE TEST DATA

In reviewing stack sampling data, the first consideration is whether the method measures the pollutant of interest or can only be used as a surrogate.  For example, if particulate matter concentration in a hood exhaust is measured, PM-10 emissions could be estimated only after assuming all, or a given percentage, of the particulate is present as PM-10.  Next, the reviewer should determine whether the sampling conditions represent the operating conditions of interest for the emission estimate.  For example, if the data are to be used to estimate emissions during typical operations, then sampling should have been done during typical operating conditions. Parameters that should be evaluated in QA/QC of stack sampling data and the acceptance criteria for stack sampling are presented in Chapter 1 of this volume and in the individual test methods.

## 6.4  DATA ATTRIBUTE RATING SYSTEM (DARS) SCORES

One measure of emission inventory data quality is the DARS score.  Chapter 4 of Volume VI, *Quality Assurance Procedures*, and the QA/QC section in Chapter 1 of this volume provide a complete discussion of DARS.  DARS assumes activity data and factor data are used to generate an inventory and provides criteria that are used to assign a numerical score to each data set.  The activity score is multiplied by the factor score to obtain a composite score for the emissions estimate.  The highest (best) possible value for an individual or composite score is 1.0.  The composite score for the emissions estimate can be used to evaluate the quality and accuracy of the estimate.

DARS was used to evaluate the methods for estimating emissions that are presented in this document to provide an idea of the relative quality of each method.  This was accomplished by assuming an inventory was developed using each method and using DARS to score each inventory.  Because the inventories are hypothetical, it was necessary to make some additional assumptions.  The first three assumptions were that emissions are for a 1-year period, from one process or from one facility, and for normal operating conditions.  Also, all material usage data used were assumed to be reasonably accurate.  Some scores are expressed as a range, with the lower value representing an estimate developed from low- to medium-quality data and the upper value representing an estimate based on relatively high-quality data.  Tables 11.6-1 through

11.6-3 present the DARS scores for the different emission estimation methods presented in this chapter.  It should be noted that the DARS scoring is currently applied manually, but the system will eventually be publicly available as an electronic tool.

Comparing the scores for the different methods, the preferred methods (material balance and source testing) received higher scores and the alternative method (emission factors) received the lowest.  The material balance method for estimating emissions received the highest DARS score (0.98), as shown in Table 11.6-1.  Note that the score is based on the assumption that the factor data were measured continuously during the year (the inventory period) and that the pollutant is a non-consumable VOC.  Also, note that if factor data and activity data are measured continuously over the year, a perfect score (1.0) is possible for an emissions estimate when using material balance.  Table 11.6-1 assumes the pollutant being estimated is a non-consumable VOC.

The source testing approach received the next highest overall score (0.78-0.93), as shown in Table 11.6-2.  As indicated by the scores, the major parameters affecting the quality of stack sampling data are the number of tests (range of process rates; number of tests performed over the year) and the frequency of measurement of activity data (intermittent or continuous).  A high DARS score for an emissions estimate based on stack sampling data is possible if the factor data are the result of numerous tests performed during typical operations and the emission activity data are the result of continuous measurements over the inventory period.

In using DARS to score the emission factor approach, the example provided shows how the representativeness (or quality) of an emission factor may vary and how emission factor quality affects emission estimates.  The example shown in Table 11.6-3 assumes the emission factor was developed from a process that is similar, if not identical, to the process for which the emissions estimate was made.  Because the emission factor represents a process similar to the inventory process, a high score is assigned.  Assuming the activity data were measured continuously, a composite score of 0.83 to 0.90 results.  The lower value reflects the score assigned to an estimate based on a lower-quality emission factor and the upper value reflects an estimate based on a higher-quality emission factor.  As shown by the scores in Table 11.6-3, the quality of an emissions estimate developed from emission factors is directly affected by the quality of the emission factors and can vary greatly.  The scores also indicate that a source-specific emission factor may produce an emissions estimate of higher quality than an estimate developed from a factor developed for a similar process.

The examples provided in the tables are given as an illustration of the relative quality of each estimation method.  If DARS was applied to actual inventories developed using the preferred and alternative methods and data of reasonably good quality were used for each method, the scores could be different; however, the relative ranking of the methods would be expected to remain the same.

TABLE 11.6-1

DARS SCORES: MATERIAL BALANCE DATA[a]

| Attribute | Factor Score | Activity Score | Emissions Score | Factor Assumptions | Activity Assumptions |
|---|---|---|---|---|---|
| Measurement/Method | 0.9 | 1.0 | 0.9 | Factor is based on accurate data | Direct, continuous measurement of activity |
| Source Specificity | 1.0 | 1.0 | 1.0 | Factor developed specifically for the intended source | Activity data represent the emission process exactly |
| Spatial Congruity | 1.0 | 1.0 | 1.0 | Factor developed for and specific to the given spatial scale | Activity data developed for and specific to the inventory area (one process) |
| Temporal Congruity | 1.0 | 1.0 | 1.0 | Factor developed for and applicable to the same temporal scale | Activity data specific to 1 year |
| Composite Score | 0.98 | 1.0 | 0.98 | | |

[a] The "activity" is the amount of material (pollutant) used in a year and is directly measurable. The "factor" is the fraction of material used that is emitted to the atmosphere. The fraction is based on engineering calculations and is assumed to remain constant over the year. Example assumes pollutant being scored is a non-consumable VOC.

TABLE 11.6-2

DARS SCORES:  SOURCE TEST DATA

| Attribute | Factor Score | Activity Score | Emissions Score | Factor Assumptions | Activity Assumptions |
|---|---|---|---|---|---|
| Measurement/Method | 0.7 - 0.9 | 0.9 - 1.0 | 0.63 - 0.9 | Lower score reflects a small number of tests at typical process rates; upper score represents numerous tests over a range of process loads | Lower score reflects direct, intermittent measurement of activity; upper score reflects direct, continuous measurement of activity |
| Source Specificity | 1.0 | 1.0 | 1.0 | Factor developed specifically for the intended source | Activity data represent the emission process exactly |
| Spatial Congruity | 1.0 | 1.0 | 1.0 | Factor developed for and specific to the given spatial scale (one process) | Activity data developed for and specific to the inventory area (one process) |
| Temporal Congruity | 0.7 - 0.9 | 0.7 - 0.9 | 0.49 - 0.81 | Lower score reflects factor developed for a shorter time period with moderate to low temporal variability; upper score reflects factor derived from an average of numerous tests during the year | Lower score reflects activity data representative of short period of time with low to moderate temporal variability; upper score reflects activity data measured numerous times during the year |
| Composite Score | 0.85 - 0.95 | 0.90 - 0.98 | 0.78 - 0.93 | | |

# TABLE 11.6-3

## DARS SCORES: SOURCE-SPECIFIC EMISSION FACTOR DATA[a]

| Attribute | Factor Score | Activity Score | Emissions Score | Factor Assumptions | Activity Assumptions |
|---|---|---|---|---|---|
| Measurement/Method | 1.0 | 0.9 - 1.0 | 0.9 -1.0 | Continuous or near-continuous measurement of pollutant | Lower scores reflect direct, intermittent measurement of activity; upper scores reflect direct, continuous measurement of activity |
| Source Specificity | 0.8 | 1.0 | 0.8 | Factor developed for a similar category; low variability | Activity data represent the emission process exactly |
| Spatial Congruity | 0.9 | 1.0 | 0.9 | Factor developed from a process of similar size; low variability | Activity data developed for and specific to the inventory area (one process) |
| Temporal Congruity | 1.0 | 0.7 - 0.9 | 0.7 - 0.9 | Factor developed for and applicable to a period of 1 year | Lower score reflects activity data representative of short period of time with low to moderate temporal variability; upper score reflects activity data measured numerous times during the year |
| Composite Score | 0.93 | 0.90 - 0.98 | 0.83 - 0.90 | | |

[a] Assumes emission factor was developed from an identical or similar facility and is of high quality.

# 7

# DATA CODING PROCEDURES

This section describes the methods and codes available for characterizing emission sources at plastic products manufacturing facilities. Consistent categorization and coding will result in greater uniformity among inventories. In addition, the procedures described here will assist the reader who is preparing data for input to the Aerometric Information Retrieval System (AIRS) or a similar database management system. The use of the Source Classification Codes (SCCs) provided in Table 11.7-1 is recommended for describing various plastic products manufacturing operations. Refer to the Clearinghouse for Inventories and Emission Factors (CHIEF) web site (www.epa.gov/ttn/chief) for these codes and any additional codes that may be added to describe plastic products manufacturing operations.

## 7.1 SOURCE CLASSIFICATION CODES

SCCs for various processes occurring at plastic products manufacturing facilities are presented in Table 11.7-1.

## 7.2 AIRS CONTROL DEVICE CODES

Control device codes that may be applicable to plastic products manufacturing operations are presented in Table 11.7-2. These should be used to enter the type of applicable emission control device into the AIRS Facility Subsystem (AFS). The "099" control code may be used for miscellaneous control devices that do not have a unique identification code.

TABLE 11.7-1

SOURCE CLASSIFICATION CODES FOR PLASTIC PRODUCTS
MANUFACTURING PROCESSES

| Source Description | Process Description | SCC | Units |
|---|---|---|---|
| Plastic Production | Extruder | 30101809 | Tons Product |
| | | 30101814 | Tons Product |
| | | 30101863 | Tons Product |
| | Conveying | 30101810 | Tons Product |
| | Storage | 30101811 | Tons Product |
| | Pellet Silo | 30101815 | Tons Product |
| | Transferring/Handling/Loading/Packing | 30101816 | Tons Product |
| | Extruding/Pelletizing/Conveying/Storage | 30101821 | Tons Product |
| | Resin Storage Tank | 30101840 | 1000 Gallons Thinned-Resins Stored |
| | Pellet Silo/Storage | 30101864 | Tons Product |
| | Transferring/Conveying | 30101865 | Tons Product |
| | Packing/Shipping | 30101866 | Tons Product |
| | Blowing Agent: Freon (Polyether Resins) | 30101871 | Tons Product |
| | Blowing Agent: Freon (Polyurethane) | 30101881 | Tons Agent Used |
| | Blowing Agent: Methylene Chloride (Polyurethane) | 30101882 | Tons Agent Used |
| | Transferring/Conveying/Storage (Polyurethane) | 30101883 | Tons Product |
| | Packing/shipping (Polyurethane) | 30101884 | Tons Product |
| | Raw Material Storage | 30101893 | Tons Raw Material |
| | Solvent Storage | 30101894 | Tons Solvent |
| | Plastic Production - Others Not Specified | 30101899 | Tons Product |
| Rubber & Misc. Plastics Products - Fiberglass Resin Products | Plastic Machining: Drilling/Sanding/Sawing, etc. | 30800701 | Tons Processed |
| | Mould Release | 30800702 | Tons Product |
| | Solvent Consumption | 30800703 | Tons Solvent |
| | Adhesive Consumption | 30800704 | Tons Adhesive |
| | Wax Burnout Oven | 30890001 | Tons Was Burned |

**TABLE 11.7-2**

**AIRS CONTROL DEVICE CODES FOR PLASTIC PRODUCTS MANUFACTURING**

| Control Device | Code |
|---|:---:|
| Centrifugal Collector - High Efficiency | 007 |
| Centrifugal Collector - Medium Efficiency | 008 |
| Centrifugal Collector - Low Efficiency | 009 |
| Fabric Filter - High Temperature | 016 |
| Fabric Filter - Medium Temperature | 017 |
| Fabric Filter - Low Temperature | 018 |
| Activated Carbon Adsorption | 048 |
| Single Cyclone | 075 |
| Miscellaneous Control Device | 099 |

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# APPENDIX A

# EXAMPLE DATA COLLECTION FORMS AND INSTRUCTIONS - PLASTIC PRODUCTS MANUFACTURING

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## EXAMPLE DATA COLLECTION FORMS INSTRUCTIONS -
## PLASTIC PRODUCTS MANUFACTURING FACILITIES

1.    These forms may be used as worksheets to aid the plant engineer in collecting the information necessary to calculate emissions from plastic products manufacturing facilities. The information requested on the forms relates to the methods (described in Sections 3, 4, and 5) for quantifying emissions.  These forms may also be used by the regulatory agency to assist in area wide inventory preparation.

2.    The completed forms should be maintained in a reference file by the plant engineer with other supporting documentation.

3.    If the information requested is unknown, write "unknown" in the blank.  If the information requested does not apply to a particular unit or process, write "NA" in the blank.

4.    If you want to modify the form to better serve your needs, an electronic copy of the form may be obtained through the EIIP on the Clearinghouse for Inventories and Emission Factors (CHIEF) web site.

5.    Collect all Material Safety Data Sheets (MSDSs) for all materials containing potential air contaminants that are used at the facility.

6.    The plant engineer should maintain all material usage information and MSDSs in a reference file.

**EXAMPLE DATA COLLECTION FORM**

**FORM A:  GENERAL INFORMATION**

Facility/Plant:

SIC Code:

SCC:

SCC Description:

Location

       County:

       City:

       State:

Parent Company Name and Address:

Plant Geographical Coordinates

       Latitude:

       Longitude:

       UTM Zone:

       UTM Easting:

       UTM Northing:

Date of Initial Operation:

Source ID Number:

Type of Plant:

Permit Number:

Permitted Hours of Operation (Per Year):

Actual Hours of Operation (Per Year):

    Hours/Day:

    Days/Week:

    Weeks/Year:

Contact Name:

Title:

Telephone Number:

## EXAMPLE DATA COLLECTION FORM

**FORM B:  SOURCE INFORMATION** **(complete a separate form for each process unit)**

Unit ID:

Permit No.:

Location:

Unit Description:

Source ID Number:

Manufacturer:

Date Installed:

Date Modified:

Operating Schedule:

  Hours/Day:

  Days/Week:

  Weeks/Year:

Raw Material Used:

| Material Name[a] | Constituents | Mass % | Annual Usage[b] | Reclaim[b] |
|---|---|---|---|---|
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[a]  For resins, specify resin type
[b]  Document annual usage and reclaim quantities with appropriate units (i.e., tons,  gallons).

**EXAMPLE DATA COLLECTION FORM**

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**FORM C:  CONTROL DEVICE INFORMATION** (complete a form for each control device)

Unit ID:

Permit No.:

Location:

Pollutant Controlled:

Control Efficiency (Indicate source of information):

Type of Control Device:

☐ Baghouse
☐ Thermal Incinerator
☐ Other (indicate type) _____

Manufacturer:

Date Installed:

Date Modified:

Operating Schedule:

   Hours/Day:

   Days/Week:

   Weeks/Year:

Source(s) Linked to this Control Device:

**EXAMPLE DATA COLLECTION FORM**

**FORM D:  STACK INFORMATION** (if applicable)

Stack ID:

Unit ID:

Stack (Release) Height (ft):

Stack Diameter (inch):

Stack Gas Temperature ($^{o}$F):

Stack Gas Velocity (ft/sec):

Stack Gas Flow Rate (dscf/hr):

Source(s) Linked to this Stack:

## EXAMPLE DATA COLLECTION FORM

**FORM E:  MATERIAL DATA FORMS** (to be completed for each material used)

Manufacturer Name:

Material Description or Brand Name and Number:

Typical Units (Check one):

[   ] Gallons     [   ] Pounds    [   ] Cubic Feet   [   ] Other _____

Density:  _____          lb/gal          or          _____          lb/ft$^3$

Volatile Organic Compound  (VOC) Content: _____     lb/gal          or
_____     wt % VOC in the material

Solids Content:          _____     wt % solids in the material

True Vapor Pressure   _____   psia
@ 70°F:

Boiling Point:          _____   °F

Antoine's Coefficients:

A_____                B_____
C_____                Ref_____

Molecular Weight:          _____ lb/lb-mole

Fuels:  Heat Content _____          Btu usage/unit _____

**EXAMPLE DATA COLLECTION FORM**

**FORM F:  MATERIAL DATA FORMS** **(to be completed for each raw material used) (cont.)**

| Component Name | CAS#[a] | Wt % in Material | ppmv in Material |
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[a] Provide Chemical Abstract Service number if applicable.

**EXAMPLE DATA COLLECTION FORM**

## FORM G: FACILITY-WIDE PRODUCTION INFORMATION          Calendar Year _____

| Product Name | Process Method Used to Manufacture Product | Amount Produced (lb, ton or other units) |
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## EXAMPLE DATA COLLECTION FORM

## FORM H:  FACILITY-WIDE RESIN USAGE

**Calendar Year** _____

| Resin Name | Constituents | Mass % | Amount Used |
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## EXAMPLE DATA COLLECTION FORM

### FORM I: FACILITY-WIDE SOLVENT USAGE

**Calendar Year** _____

| Solvent Name | Constituents | Mass % | Amount Used |
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**EXAMPLE DATA COLLECTION FORM**

SCC Name: _____

SCC: _____

**FORM J:  ANNUAL FACILITY-WIDE EMISSION ESTIMATES[d]** **(this form must be completed for each SCC)**

| Pollutant[a] | Emission Estimation Method[b] | Emissions Value | Units of Emissions | Emission Factor[c] | Emission Factor Units | Comments |
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[a] Pollutants include VOCs, PM/PM-10, and HAPs (list individually).

[b]    Use the following codes to indicate which emission estimation method is used for each pollutant:

Emission Factor = EF          Stack Test = ST
Material Balance = MB          Emission Model = EM
Other Method (indicate) = O

[c]    Where applicable, enter the emission factor and provide full citation of the reference or source of information from where the emission factor came.  Indicate edition, version, table and page numbers if *AP-42* is used.

[d]    Emissions must be calculated for all process activities (i.e., process unit operations, process vessel cleaning, spills, material handling, solvent reclamation, etc.)

Please copy the blank form and attach additional sheets, as necessary.

## EXAMPLE DATA COLLECTION FORM

## FORM K:  ANNUAL FACILITY-WIDE EMISSION SUMMARY

| Pollutant | Emission Value | Emission Units (tons) |
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