National Pollutant Inventory

Emission Estimation Technique Manual

for

Motor Vehicle Manufacturing

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EMISSION ESTIMATION TECHNIQUES
FOR
MOTOR VEHICLE MANUFACTURING

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MOTOR VEHICLE MANUFACTURING MANUAL

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1.0 Introduction

The purpose of all Emission Estimation Technique (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 motor vehicle manufacturing.

The motor vehicle manufacturing activities covered by this Manual include facilities primarily engaged in the manufacture of motor vehicles, trucks, buses, caravans, and parts, accessories, and components used in the assembly of these vehicles.

EET MANUAL:	Motor Vehicle Manufacturing
HANDBOOK:	Motor Vehicle Manufacturing
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This Manual was drafted by the Queensland Department of Environment and Heritage on behalf of the Commonwealth Government. The Manual 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

This section specifically contains a description of commonly used production processes, associated raw materials, the by-products produced or emitted, and the materials containing NPI-listed substances that are either recycled or transferred off-site. This description, coupled with schematic drawings of the identified processes, provides a concise description of where emissions and wastes may be produced in the process. This section also describes the potential fate, that is to air, water, or land of these emissions and wastes. This section does not attempt to replicate published engineering information that is available for this industry.

The Australian motor vehicle and motor vehicle equipment industry produces a range of diverse products from ambulances and motor vehicles to the cylinder heads, ball joints, and horns that go into these vehicles.

The motor vehicle and motor vehicle equipment industry is organised into four primary areas based on the types of product produced. These areas are:

(1) passenger cars and light trucks;
(2) medium and heavy duty trucks;
(3) truck trailers; and
(4) motor vehicle parts and accessories.

The motor vehicle parts industry is further broken down into two sectors, original equipment suppliers and aftermarket suppliers. Original equipment suppliers provide parts directly to motor vehicle manufacturers while aftermarket suppliers provide parts exclusively to the replacement parts market. The original equipment market accounts for approximately 80 percent of all motor vehicle parts and accessories consumed in Australia, with the remaining 20 percent accounted for by the aftermarket.

There is no single production process for motor vehicle manufacturing. Instead, numerous processes are employed to manufacture motor vehicles and motor vehicle equipment. This section will focus on the significant production processes including those used in the foundry, metal shop, assembly line, and paint shop. More detailed descriptions of these processes are contained in the *Ferrous Foundries, Non-Ferrous Foundries, Electroplating*, and *Galvanising* EET Manuals and the reader should also consult these documents for additional detail on emission estimation techniques for these processes.

Motor vehicle parts and accessories include both finished and semi-finished components. Approximately 8 000 to 10 000 different parts are ultimately assembled into around 100 major motor vehicle components, including suspension systems, transmissions, and radiators. For some makes and models, these parts may be transported to a motor vehicle manufacturing plant for final assembly from the parts manufacturer, for other models, the component parts may be fully imported.

Component material selection plays a vital role in the production process. Materials are ultimately selected based on factors such as performance (strength versus durability, surface finish, corrosion resistance), cost, component manufacturing, consumer preference, and competitive responses.

Historically, car manufacture in Australia used parts composed primarily of iron and steel. Steel has remained a major vehicle component because of its structural integrity and ability to maintain dimensional geometry throughout the manufacturing process.

In response to increasing demands for more fuel efficient cars, the past ten years have seen changes in the composition of materials used in motor vehicles. Iron and steel use has steadily decreased, while plastics and aluminum has steadily increased. Aluminum and plastics are valuable car components not only for their lighter weight, but also because of their inherent corrosion resistance. Although the use of plastics in the vehicle industry is increasing, expansion in this area is finite because of limitations in current plastics materials.

The manufacturing processes used to produce the thousands of discrete parts and accessories vary depending on the end product and materials used. Different processes are employed for the production of metal components versus the production of plastic components. Most processes, however, typically include casting, forging, moulding, extrusion, stamping, and welding. Figure 1 lists major motor vehicle parts and the primary materials and production processes used to manufacture them.

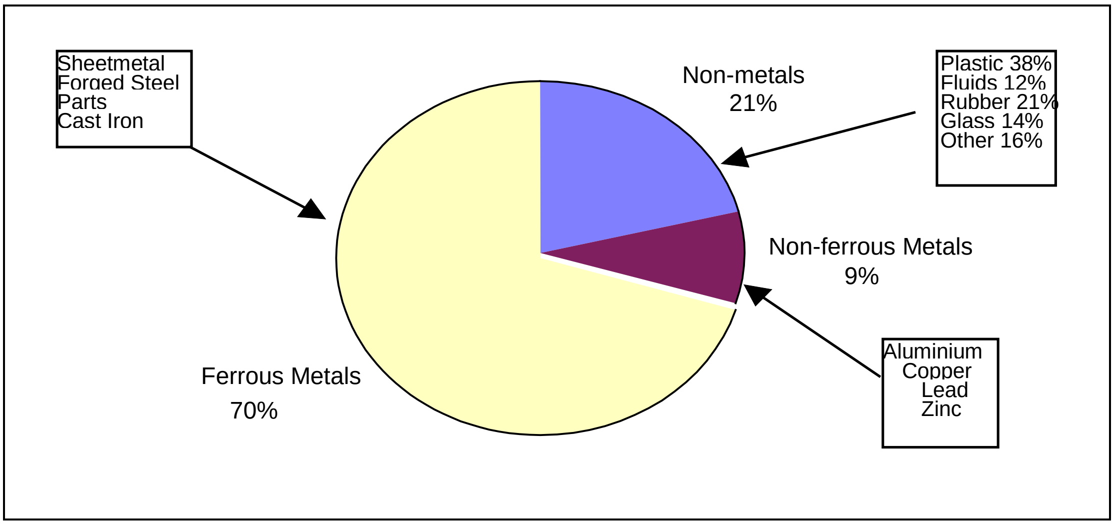

Figure 1 - Motor Vehicle Composition and Disposition
Adapted from USEPA *Office of Compliance Sector Notebook Project, 1995*

2.1 Foundry Operations

Foundries, whether they are integrated with motor vehicle assembly facilities or independent shops, cast metal products which play a key role in the production of motor vehicles and motor vehicle equipment. As discussed previously, even though aluminum and other metals are used increasingly in the production of motor vehicles and their parts, iron and steel are still the major metal components in any Australian car. Figure 2 illustrates a motor vehicle foundry operation and highlights the emission points.

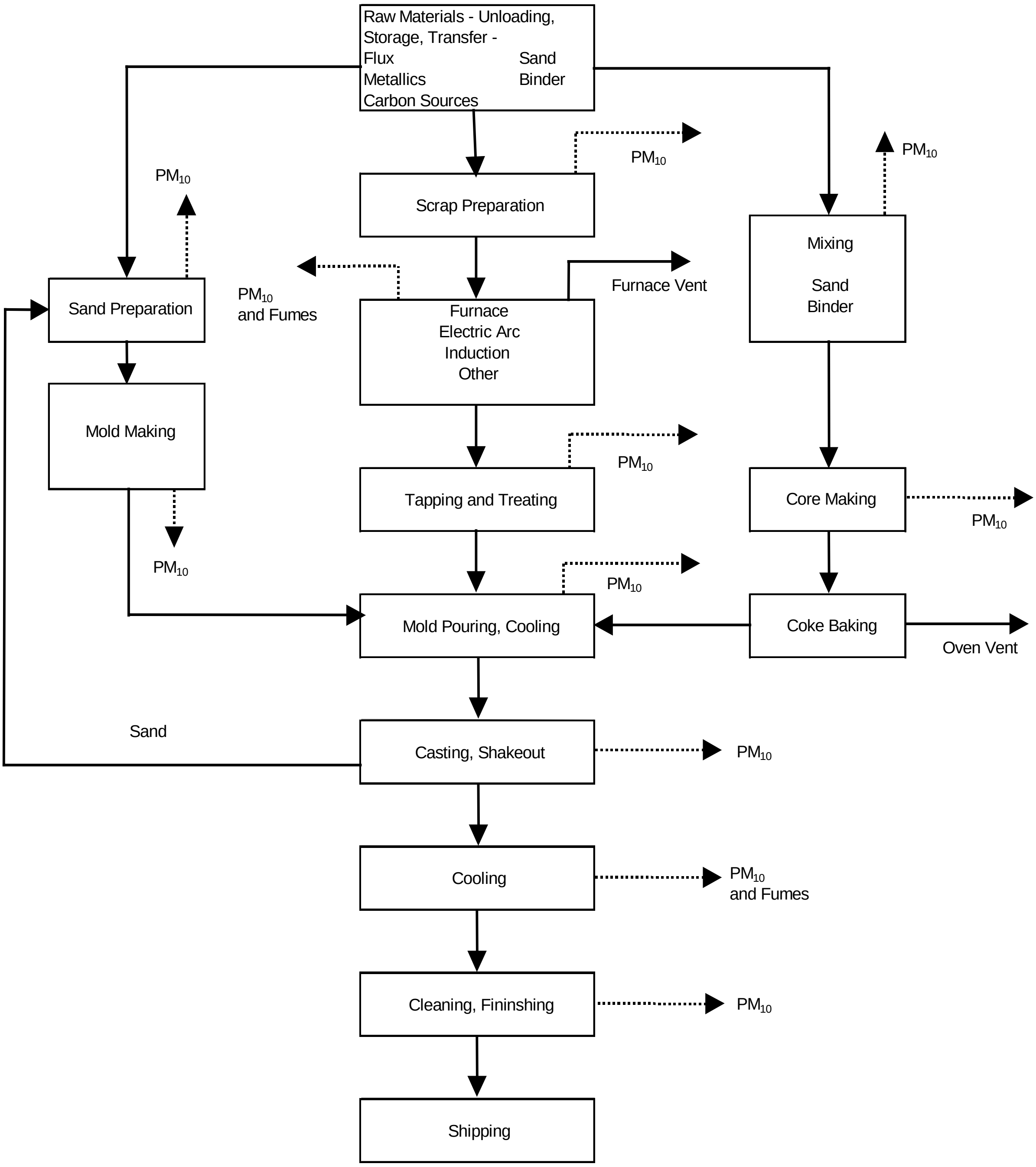

Figure 2 - General Motor Vehicle Foundry Flow Diagram
Adapted from: USEPA *Office of Compliance Sector Notebook Project,* 1995

2.2 Metal Shaping and Machining

Another major process in the manufacturing of motor vehicle parts is metal shaping and machining. Shaping and machining involves the shaping of metal components. Many vehicle parts, including bumper bars, hubcaps, and body parts are manufactured in metal galvanising and electroplating shops. A typical large-scale production of these items starts with molten metal (ferrous or non-ferrous) containing the correct metallurgical properties. Once the metal has been produced, it is cast into a shape that can enter the rolling process. Shearing and forming operations are then performed to cut materials into a desired shape and size and bend or form materials into specified shapes.

Once shearing and forming activities are complete, the material is machined. This entails shaping or forming a workpiece by removing material from pieces of raw stock with machine tools. The principal processes involved in machining are hole-making, milling, turning, shaping/planing, broaching, sawing, and grinding.

2.3 Metal Coating

Numerous methods are used to finish metal products. However, prior to applying the finishing application, the surface must be prepared. One of the most important aspects of a finished product is the surface cleanliness and quality. Without a properly cleaned surface, even the most expensive coatings will fail to adhere or prevent corrosion.

Pickling and salt bath processes are used to finish steel products by chemically removing oxides and scale from the surface of the steel. Most carbon steel is pickled with sulfuric or hydrochloric acid, while stainless steel is pickled with hydrochloric, nitric, and hydrofluoric acids. Steel generally passes from the pickling bath through a series of rinses. Alkaline cleansers are used to remove mineral oils and animal fats and oils from the steel surface. Common alkaline cleaning agents include: caustic soda, soda ash, alkaline silicates, and phosphates. Electrolytic cleaning as well as various abrasive methods, such as sand blasting, is also commonly used to remove surface oxides.

Steel products are often coated to inhibit oxidation and extend the life of the product. Coated products can also be painted to further inhibit corrosion. Common coating processes include galvanising, tin coating, chromium coating, and terne coating (lead and tin). An example of a coated motor vehicle part is the radiator, which is usually spray painted with a chromium coat to prevent corrosion; some water-based coats are now being utilised. Rinse water from the coating process may contain zinc, lead, cadmium, or chromium and this water may be recycled or transferred off-site to sewer or wastewater treatment.

Metal finishing and electroplating activities are performed on a number of metals and serve a variety of purposes: the primary purpose being protection against corrosion. This is particularly important to the motor vehicle industry because of the harsh weather and road conditions to which motor vehicles may be subjected. Metal finishing and electroplating are also performed for decorative purposes. These plating processes involve immersing the article to be coated or plated into a bath consisting of acids, bases, or salts.

The metals used in electroplating operations (both common and precious metal plating) include cadmium, lead, chromium, copper, nickel, zinc, gold, and silver. Cyanides are also used extensively in electroplating solutions and in some stripping and cleaning solutions. All of these metals can end up in wastes transferred to landfill, hazardous waste disposal, or recycler. All of these metals and many of the acids used are NPI-listed substances.

Electroless plating is the chemical deposition of a metal coating onto a metal object, by immersion of the object in an appropriate plating solution. In electroless nickel plating, the source of nickel is a salt, and a reducer is used to reduce the nickel to its base state. A complexing agent is used to hold the metal ion in the solution. Immersion plating produces a metal deposit by chemical displacement.

Immersion plating baths are usually formulations of metal salts, alkalies, and complexing agents (typically cyanide or ammonia).

Etching is the process used to produce specific design configurations or surface appearances on parts by controlled dissolution with chemical reagents or etchants. Etching solutions are commonly made up of strong acids or bases with spent etchants containing high concentrations of spent metal. The solutions include ferric chloride, nitric acid, ammonium persulfate, chromic acid, cupric chloride, and hydrochloric acid.

Anodising uses the piece to be coated, generally with an aluminum surface, as an anode in an electrolytic cell. Anodising provides aluminum parts with a hard abrasion- and corrosion-resistant film. This coating is porous, allowing it to be dyed or to absorb lubricants. This method is used both in decorative applications, including motor vehicle trim and bumper systems, and in engineering applications such as aircraft landing gear struts. Anodising is usually performed using either sulfuric or chromic acid often followed by a hot water bath, though nickel acetate or sodium potassium dichromate seal may also be used. Many of the mixtures and compounds used in motor vehicle plating and anodising process contain NPI-listed substances.

2.4 Motor Vehicle Assembly

Although techniques used to assemble motor vehicles vary from manufacturer to manufacturer, the first major step in assembly is the body shop. At this stage the car begins to take shape as sides are welded together and then attached to the underbody of the car. The underbody is composed of three primary pieces of galvanised steel that include the floor pan and components for the engine and chassis. After the underbody has been welded together by robotics, it is tested for dimensional and structural accuracy. It is then joined together in a tab-slot fashion with the side frame and various other side-assemblies. A worker then taps tabs into slots, and a robot clamps the tabs. Roof supports, and the roof, are now ready for installation. The car is now ready for final welding. Approximately 3 500 to 4 000 spots require welding. Robots perform most of the welding, with human workers doing only spot jobs. Chassis lids and bonnets are then installed.

2.5 Motor Vehicle Painting and Finishing

Motor vehicle finishing is a multi-step process subdivided into three categories:

(1) anti-corrosion operations, consisting of cleaning applications, a phosphate bath, and a chromic acid bath;

(2) priming operations, consisting of an electrodeposition primer bath, an anti-chip application, primer-surfacer application and joint sealant application; and

(3) finishing operations, consisting of a colour coat application, a clear coat application, and any painting necessary for two-tone colour or touch-up applications.

The stages of the motor vehicle finishing process are illustrated in Figure 3.

After the vehicle body has been assembled, anti-corrosion operations prepare the body for the painting and finishing process. Initially, the body is sprayed with and immersed in a cleaning agent, typically consisting of detergents, to remove residual oils and dirt. The body is then dipped into a phosphate bath, typically zinc phosphate, to prevent corrosion. The phosphate process also improves the adhesion of the primer to the metal. The body is then rinsed with chromic acid, further enhancing the anti-corrosion properties of the zinc phosphate coating. The anti-corrosion operations conclude with another series of rinsing steps.

Priming operations further prepare the body for finishing by applying various layers of coatings designed to protect the metal surface from corrosion and assure good adhesion of subsequent coatings. As illustrated in Figure 4, a primer coating is applied to the body using an electrodeposition method, creating a strong bond between the coating and the body to provide a more durable coating. In electrodeposition, a negatively charged car body is immersed in a positively charged bath of primer for approximately three minutes. The coating particles, insoluble in the liquid and positively charged, migrate toward the body and are, in effect, plated onto the body surface.

Although the primer bath is mostly water-based with only small amounts of organic solvent (less than ten percent), fugitive emissions consisting of volatile organic compounds (VOCs) can occur. However, the amount of these emissions is quite small. In addition to solvents and pigments, the electrodeposition bath contains lead, although the amount of lead used has been decreasing over the years.

Prior to baking, excess primer is removed through several rinsing stages. The rinsing operations use various systems to recover excess electrodeposited primer. Once the body is thoroughly rinsed, it is baked for approximately 20 minutes at 130°C to 180°C. VOC emissions may result from the baking stage at both motor vehicle and motor vehicle parts facilities. VOC emissions are generally minimised by incineration of the oven exhaust gases, usually at approximately 760°C.

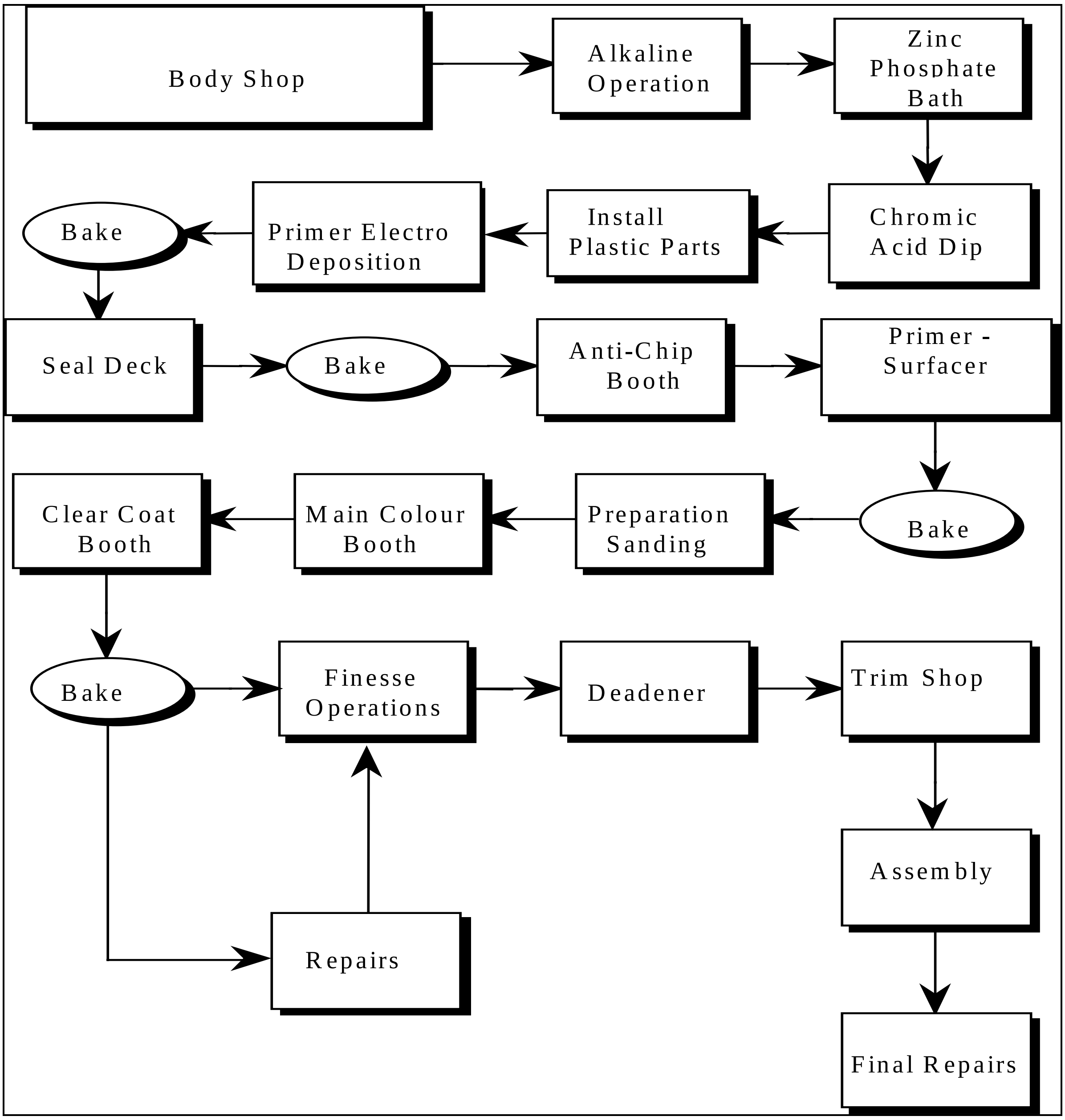

Figure 3 - Schematic of a General Motor Vehicle Painting Process
Source: Ford Motor Company of Australia, 1998
* Assembly line processes vary between plants.

Next, the body is further water proofed by sealing spot-welded joints of the body. Water-proofing is accomplished through the application of a paste or putty-like substance. This sealant usually consists of polyvinyl chloride and small amounts of solvents. The body is again baked to ensure that the sealant adheres thoroughly to the spot-welded areas and again emissions of solvents could be expected. Alternatively, this process can be carried out in the primer surfacer bake oven.

After water-proofing, the vehicle body proceeds to the anti-chip booth. Here, a substance usually consisting of a urethane, vinyl plastisol, or an epoxy ester resin, in conjunction with solvents, is applied locally to certain areas along the base of the body, such as the rocker panel or the front of the car. This anti-chip substance protects the lower portions of the body from small objects, such as rocks, which can fly up and damage vehicle finishes.

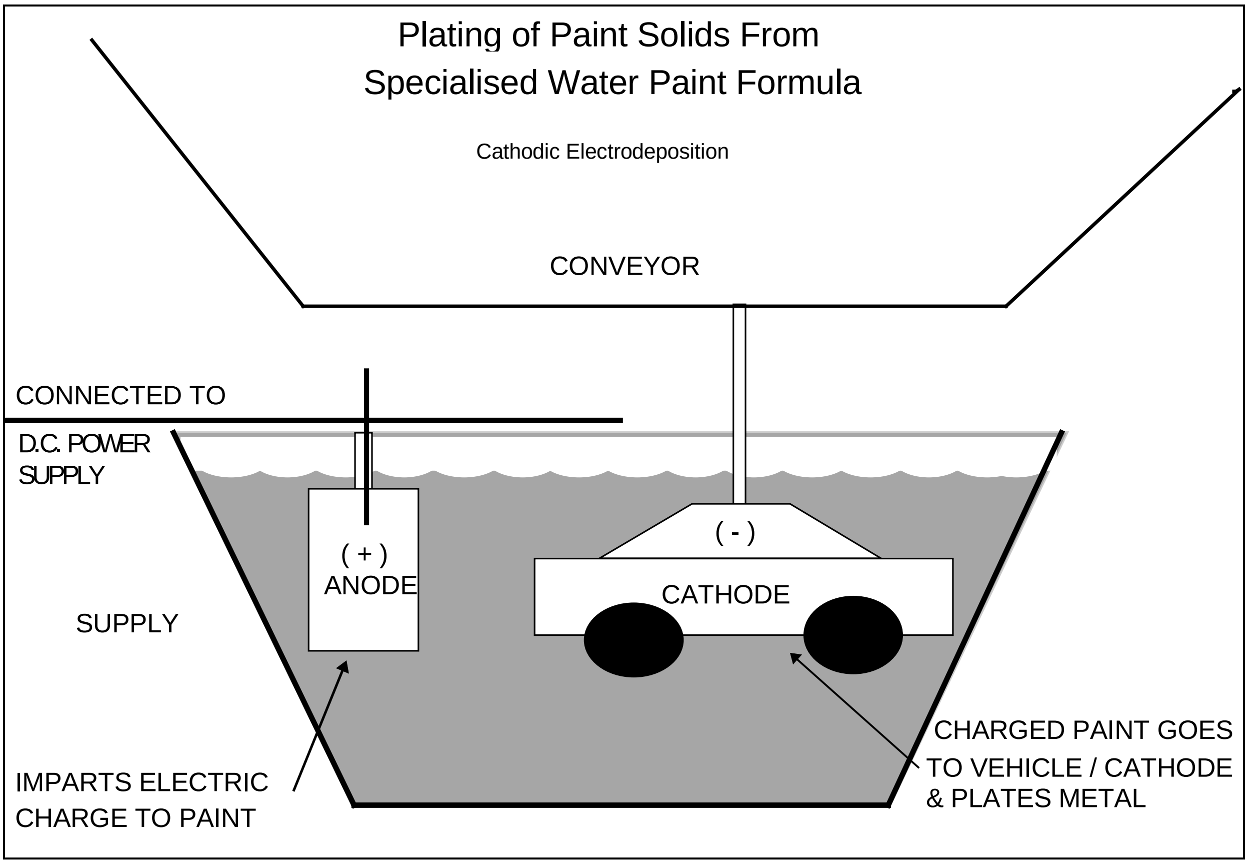

Figure 4 - Plating of Paint Solids from Specialised Water Paint Formula
Adapted from: USEPA, September 1995.

The primer-surfacer coating, unlike the initial electrodeposition primer coating, is applied by spray application in a water-wash spray booth, usually via automatic profile – tracking rotary atomisers. The primer-surfacer consists primarily of pigments, polyester or epoxy ester resins, and solvents. Due to the composition of this coating, the primer-surfacer creates a durable finish that can be sanded. The pigments used in this finish provide additional colour layers in case the primary colour coating is damaged. The water-wash spray booth is generally 30 to 70 metres long and applies the primer-surfacer in a constant air stream through which the vehicle body moves. A continuous stream of air, usually from ceiling to floor, is used to transport airborne particulates and solvents from primer-surfacer over-spray. The air passes through a water curtain that captures a portion of the airborne solvents for transfer and treatment at a wastewater facility. Efforts have been made by Australian car makers to recycle this air to further reduce VOC emissions.

After the primer-surfacer coating is baked, the body is then sanded, if necessary, to remove any dirt or coating flaws. This is accomplished using a dry or moist sanding technique. The primary environmental concern at this stage of the finishing process is the generation of particulate matter.

The next step of the finishing process is the application of the primary colour coating. This is accomplished in a manner similar to the application of primer-surfacer. One difference between these two steps is the amount of pigments and solvents used in the application process. VOC emissions from primary colour coating operations can be double that emitted from primer-surfacer operations. In addition to the pigments and solvents, aluminum or mica flakes can be added to the primary colour coating to create a finish with unique reflective qualities. Instead of baking, the primary colour coat is allowed to *flash off,* or in other words, the solvent evaporates and is emitted to air with the application of heat below the bake temperature.

Pigments, used to formulate both primers and paints, are an integral part of the paint formulation, which also contains other substances. The pigmented resin forms a coating on the body surface as the solvent dries. The chemical composition of a pigment varies according to its colour, as illustrated in Table 1.

Table 1 - Typical Chemical Components of Pigments Found in Paint

Pigment Colour	Chemical Components
White	Titanium dioxide, white lead, zinc oxide
Red	Iron oxides, calcium sulfate, cadmium selenide
Orange	Lead chromate-molybdate
Brown	Iron oxides
Yellow	Iron oxides, lead chromate, calcium sulfide
Green	Chromium oxide, copper, phosphotungstic acid, phosphomolybdic acid
Blue	Ferric ferrocyanide, copper
Purple	Manganese phosphate
Black	Black iron oxide
Metallic	Aluminum, bronze, copper, lead, nickel, stainless steel, silver, powdered zinc

Source: USEPA, July 1995

After the primary colour coating is allowed to air-dry briefly, the final coating, a clear coat, is applied. The clear coat adds lustre and durability to the vehicle finish. This coating generally consists of a modified acrylic or a urethane and is baked for approximately 30 minutes at 140°C to 150°C.

Following the baking of the clear coat, the body is inspected for imperfections in the finish. Operators finesse minor flaws through light sanding and polishing and without any repainting. Repairs of major flaws are carried out by repeating the sanding process and reprocessing the bodies in either a repair booth or a spot repair facility. The latter uses small amounts of catalysed paint applied with hand guns, followed by a lamp bake.

Once the clear coat is baked, a coating known as *deadener* is applied to certain areas of the motor vehicle underbody. Deadener, generally a solvent-based resin of tar-like consistency, is applied to areas such as the inside of wheel wells to reduce noise. In addition, anti-corrosion wax is applied to other areas, (eg. the inside of doors), to further seal the vehicle body and prevent moisture damage. This wax contains aluminum flake pigment and is applied using a spray wand.

After painting and finishing, two types of trim are installed - hard and soft. Hard trim, such as instrument panels, steering columns, weather stripping, and body glass, is installed first. The car body is then passed through a water test where, by using phosphorus and a black light, leaks are identified. Soft trim, including seats, door pads, roof panel insulation, carpeting, and upholstery, is then installed. The only VOC emissions resulting from this stage of the process originate from the use of adhesives to attach items, such as seat covers and carpeting.

Next, the motor vehicle body is fitted with the following: gas tank, catalytic converter, muffler, tail pipe, and bumpers. Concurrently, the engine goes through a process known as *dressing*, which consists of installing the transmission, coolant hoses, the alternator, and other components. The engine and tyres are then attached to the body, completing the assembly process.

The finished vehicle is then rigorously inspected to ensure that no damage has occurred as a result of the final assembly stages. If there is major damage, the entire body part is replaced. However, if the damage is minor, such as a scratch, paint is taken to the end of the line and applied using a hand-operated spray gun. Because the vehicle cannot be baked at temperatures as high as in earlier stages of the finishing process, the paint is catalysed prior to application to allow for faster drying at lower temperatures.

Generally, spray and immersion finishing methods are, to a certain extent, interchangeable, and the application method for various coatings varies from facility to facility. The same variance applies to the number and order of rinsing steps for cleaning, phosphating, and electrodeposition primer operations. Spray rinsing the body prior to immersion rinsing decreases the amount of residues deposited in the bath and allows for greater solvent recovery.

In addition to the above-mentioned uses of solvents as ingredients of coatings, solvents are often used in facility and equipment clean-up operations. Efforts have been made at several facilities to reduce the amount of solvent used for this purpose, thereby reducing fugitive VOC emissions, and to reuse these solvents when preparing batches of coatings used in certain stages of the finishing process.

The expanded use of alternative coating methods, such as electrostatic powder spray, is being researched. Powder coatings are being used instead of solvent-based coatings for some initial coating steps, such as the anti-chip and the primer-surfacer process.

3.0 Inputs and Emissions of NPI-Listed Substances

The many different production processes employed to manufacture a motor vehicle require a vast amount of material inputs and generate large amounts of waste and considerable emissions. The outputs resulting from the various stages of production, range from air emissions from foundry operations to spent solvents from surface painting and finishing. Many of material inputs and emissions are of NPI-listed substances.

Table 2 highlights the production processes, the material inputs, and the various emissions and wastes resulting from these operations. Process waste emissions are treated or neutralised before emission.

Table 2 - Material Inputs and Pollutant Outputs

Process	Material Input	Emissions to Atmosphere	Emissions to Water or Solid Waste	Emissions via Solid Waste
Metal Shaping				
Metal Cutting and/or Forming	Cutting oils, degreasing and cleaning solvents, acids, and metals	Solvent wastes (acetone, xylene, toluene, etc.)	Acid/alkaline wastes (eg. hydrochloric, sulfuric and nitric acids) and waste oils	Metal wastes (eg. copper, chromium and nickel) and solvent wastes (acetone, xylene, toluene, etc.)
Heat Treating	Acid/alkaline solutions (eg. hydrochloric and sulfuric acid), cyanide salts, and oils		Acid/alkaline wastes, cyanide wastes, and waste oils	Metal wastes (eg. copper, chromium, and nickel)
Surface Preparation				
Solvent Cleaning	Acid/alkaline cleaners and solvents	Solvent wastes (eg. acetone, xylene, toluene, etc.)	Acid/alkaline wastes	Ignitable wastes, solvent wastes, (acetone, xylene, toluene, etc.) and still bottoms
Pickling	Acid/alkaline solutions		Acid/alkaline wastes	Metal wastes

Table 2 - Material Inputs and Pollutant Outputs cont'

Process	Material Input	Emission to Atmosphere	Emissions to Water or Solid Waste	Emissions via Solid Waste
Surface Finishing				
Electroplating	Acid/alkaline solutions, metal bearing and cyanide bearing solutions		Acid/alkaline wastes, cyanide wastes, plating wastes, and wastewater	Metal wastes, reactive wastes, and solvent wastes
Surface Finishing	Solvents	Solvent wastes (acetone, xylene, toluene, etc.)		Metal paint wastes, solvent wastes, ignitable paint wastes, and still bottoms
Facility Clean-up	Solvents	Solvent wastes (acetone, xylene, toluene, etc.)		Solvent wastes and still bottoms

Source: Queensland Department of Environment and Heritage, 1998.

The description of pollutant emissions from motor vehicle manufacturing follows the same format as the description of the manufacturing process in Section 2, *viz*; foundry operations; metal fabricating; metal finishing; assembly; and painting and coating.

3.1 Foundry Operations

Iron and aluminium foundries create a number of emissions of NPI-listed substances. Gaseous and particulate emissions are a concern throughout the casting process. Particulate matter (PM_{10}) created during sand preparation, moulding, and shakeout is of concern due to the carcinogenic potential of the crystalline silica in the sand. Gases containing lead and cadmium and other particulate matter and sulfur dioxide are also created during foundry operation, especially during the melting of iron.

The wastewater generated during foundry operations may also contain NPI-listed substances. Wastewater is generated primarily during slag quenching operations (water is sprayed on the slag to both cool it as well as pelletise it) and by the wet scrubbers employed as air pollution control devices connected to furnaces and sand and shakeout operations. Due to the presence of cadmium and lead in iron, these metals may both be present in wastewater.

Lead and cadmium would also be expected in wastewater sludges and baghouse dust. Foundries may also use NPI-listed organics and mineral acids for cleaning, which when spent, may be collected and recycled on-site or transferred off-site to a recycling contractor.

Information on emissions from foundry processes can be found in the EET Manuals for *Ferrous* and *Non-Ferrous Foundries*, which are included in this Handbook.

3.2 Metal Shaping and Machining

Each of the metal shaping processes can result in emissions and wastes containing listed substances (depending on the metal being used). In general, there are two categories of emissions and wastes generated in metal shaping operations: scrap metal, and metalworking fluids.

Scrap metal may consist of metals removed from the original piece (eg. steel or aluminum). Quite often, scrap is reintroduced into the process as a feedstock. Metals not used as a feedstock, are transferred off-site to a metal recycler or to landfill.

In general, metalworking fluids can be petroleum-based, oil-water emulsions, or synthetic emulsions that are applied to either the tool or the metal being tooled to facilitate the shaping operation. Metalworking fluids typically become contaminated and spent with extended use and reuse. When disposed, these oils may be contaminated with several NPI-listed substances, including metals (cadmium, chromium, and lead). Many fluids may also contain chemical additives such as chlorine, sulfur, and phosphorus compounds, phenols, cresols, and alkalines. In the past, such oils have commonly been mixed with used cleaning fluids and solvents (including listed chlorinated solvents). Air emissions may result through volatilisation during storage, fugitive losses during use, and direct ventilation of fumes.

Surface preparation operations generate emissions of solvents and metals depending on the type of cleaning operation. Concentrated solvent-bearing wastes and emissions may arise from degreasing operations. Degreasing operations may result in solvent-bearing wastewater, air emissions, and materials in solid form. Solvents may be rinsed into wash waters and/or spilled into floor drains. Although contamination of the wastewater is possible, procedures are in place at most Australian facilities to prevent such emissions in the first place. Air emissions may result through volatilisation during storage, fugitive losses during use, and direct ventilation of fumes. Any solid wastes (eg. wastewater treatment sludges, still bottoms, cleaning tank residues, machining fluid residues, etc.) generated by the operation, may be contaminated with listed solvents and also require inventory reporting.

Chemical treatment operations can result in wastes that contain listed metals. Alkaline, acid, mechanical, and abrasive cleaning methods can generate waste streams such as spent cleaning media, wastewater, and rinse waters. Such wastes consist primarily of the metal complexes or particles, the cleaning compound, contaminants from the metal surface, and water. In many cases, chemical treatment operations are used in conjunction with organic solvent cleaning systems. As such, many of these wastes may be cross-contaminated with solvents containing listed organics.

The nature of the emission will depend upon the specific cleaning application and manufacturing operation. Emissions from surface preparation operations may contribute to commingled waste streams such as wastewater discharged to on-site or off-site treatment. Further, such operations can result in direct emissions such as fugitive emissions and easily segregated wastes such as cleaning tank residues; all containing listed substances.

3.3 Metal Finishing

Surface finishing and related washing operations account for a large volume of wastes associated with motor vehicle metal finishing. Metal plating and related waste account for the largest volumes of metal (eg. cadmium, chromium, copper, lead, mercury, and nickel) and cyanide-bearing wastes.

Electroplating operations can result in solid and liquid waste streams that contain listed substances. Liquid wastes result from workplace rinses and process clean-up waters. Most surface finishing (and many surface preparation) operations result in liquid waste streams. Centralised wastewater treatment systems are common, and can result in solid-phase wastewater treatment sludges. In addition to these wastes, spent process solutions and quench bathes are discarded periodically when the concentrations of contaminants inhibit proper function of the solution or bath. When discarded, process bathes usually consist of solid- and liquid-phase wastes that may contain high concentrations of the constituents of concern, especially cyanide (both free and complex).

Plating operations generate mists due to the evolution of hydrogen and oxygen gas. The gases are formed in the process tanks on the surface of the submerged motor vehicle or on anodes or cathodes. As these gas bubbles rise to the surface, they escape into the air and may carry considerable liquid with them in the form of a fine mist. The rate of gassing is a function of the chemical or electrochemical activity in the tank and increases with the amount of work in the tank, the strength and temperature of the solution, and the current densities in the plating tanks. Air sparging also can result in emissions from the bursting of air bubbles at the surface of the plating tank liquid.

Emissions are also generated from surface preparation steps, such as alkaline cleaning, acid dipping, and vapour degreasing. These emissions are in the form of alkaline and acid mists and solvent vapours. The extent of acid misting from the plating processes depends mainly on the efficiency of the plating bath and the degree of air sparging or mechanical agitation. For many metals, plating baths have high cathode efficiencies so that the generation of mist is minimal. However, the cathode efficiency of chromium plating baths is very low (10 to 20 percent), and a substantial quantity of chromic acid mist is generated.

Related operations, including all non-painting processes, can contribute emissions of listed substances, including scrap metals, cleaning wastewater, and other solid materials. The nature of these emissions will depend on the specific process, the nature of the workplace, and the composition of materials used in the process.

3.4 Motor Vehicle Assembly

Due to advances in technology, well designed operating procedures, and the implementation of strategies to limit emissions from assembly, few emissions of NPI-listed substances are generated during the actual assembly of a motor vehicle (with the exception of painting and finishing which is discussed in the following section).

The majority of emissions generated during assembly are solid wastes resulting from parts packaging. Advances in packaging design, changes in purchasing, and the elimination of unneeded materials have greatly reduced the amount of expendable waste generated.

Emissions of NPI-listed substances generated from assembly operations may be limited to general plant operations and cleaning and maintenance and include solvents, ammonia, listed acids, and chlorine.

3.5 Motor Vehicle Painting and Finishing

Many of the emissions of NPI-listed substances generated during motor vehicle production are the result of painting and finishing operations. These operations result in air emissions, as well as the generation of solid and liquid wastes.

Air emissions, primarily VOCs, result from the painting and finishing application processes (paint storage, mixing, applications, and drying) as well as cleaning operations. These emissions are composed mainly of organic solvents that are used as carriers for the paint. Solvents are also used during clean-up processes to clean spray equipment between colour changes, and to clean portions of the spray booth. Xylenes and butanol are most common along with lesser amounts of butyl acetate and mixed aromatics (often including dimethyl-benzene, 2-Pranone, 4-methyl-2-pentanone, butyl ester acetic acid, light aromatic solvent naphtha, styrene (ethyl benzene), hydro-treated heavy naphtha, 2-butanone, toluene, and methyl ethyl ketone). Of these hydrocarbons, only styrene, toluene, methyl ethyl ketone, and acetic acid are listed individually on the NPI, although all are VOCs and require reporting under this category.

Various solid and liquid waste streams and emissions may be generated throughout painting operations and are usually the result of the following operations:

- Paint application - paint over-spray caught by emissions control devices (paint booth collection systems, ventilation filters);
- Paint drying - ventilated emissions as paint carriers evaporate;
- Clean-up of equipment and in the paint booth area; and
- Disposal - transfer and recycling of unused paint as well as containers used to hold paints, paint materials, and over-spray.

Solid and liquid wastes may also contain NPI-listed metals from paint pigments. These metals, and their associated pigment, are shown in Table 1.

4.0 Emission Estimation Techniques

Numerous processes are employed to manufacture motor vehicles and motor vehicle equipment with many of these processes, such as the foundry, metal shaping and machining activities, and the electroplating shop, common to many other industry sectors. Emission estimation techniques (EETs) for calculating emissions from these other more generic industrial processes are not repeated in this EET Manual. Other EET Manuals in this series that are available to assist in estimating emissions from motor vehicle and vehicle equipment manufacture include:

- Combustion Engines;
- Combustion in Boilers;
- Electroplating and Anodising;
- Ferrous Foundries;
- Fuel and Organic Liquid Storage;
- Galvanizing;
- Non-Ferrous Foundries; and
- Sewage and Wastewater Treatment.

This section focuses on providing EETs for motor vehicle painting and finishing activities. Emissions arising from auxiliary painting and coating activities, such as from the loading of paint and other coatings into vessels, coating spills, and solvent cleaning and degreasing of coating application equipment, are covered in the *Surface Coating* EET Manual.

The greater the quantity of VOC in the paint or coating composition, the greater will be the emissions. Lacquers, having 12 to 18 volume percent solids, are higher in VOCs than enamels that have 24 to 33 volume percent solids. Emissions are also influenced by the area of the motor vehicle or vehicle parts being coated, the coating thickness, the configuration of the part, and the application technique. However, the emission factors, presented in Section 4.1, provide a technique for estimating VOC emissions expected from a vehicle paint shop irrespective of these influences. A speciation profile of VOCs in motor vehicle coatings is also provided to enable reporting of individual NPI-listed substances. Calculating site-specific emissions requires that these external factors are considered in the estimation technique, which is discussed in Section 4.2.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility.

The four types described in *The NPI Guide* are:

- sampling or direct measurement;
- mass balance;
- fuel analysis or other engineering calculations; and
- emission factors.

Select the EET, (or mix of EETs), that is most appropriate for your purposes. 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.

If you estimate your emission by using any of these EETs, 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 EETs that are not outlined in this handbook, your data will also be displayed as being of ‘acceptable reliability’.

This Manual seeks to provide the most effective emission estimation techniques for the NPI substances relevant to this industry. However, the absence of an EET for a substance in this handbook does not necessarily imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains if reporting thresholds have been exceeded.

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 your company has developed site-specific emission factors, you may use these if approved by your relevant environmental authority.

You should note that the EETs presented in this manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (eg. spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, ie. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

The **usage*** of each of the substances listed as Category 1 and 1a under the NPI must be estimated to determine whether the 10 tonnes (or 25 tonnes for VOCs) reporting threshold is exceeded. If the threshold is exceeded, **emissions** of these Category 1 and 1a substances must be reported for all operations/processes relating to the facility, even if the actual emissions of the substances are very low or zero.

* Usage is defined as meaning the handling, manufacture, import, processing, coincidental production or other uses of the substances.

4.1 Using Emission Factors

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 divided by the unit weight, volume, distance, or duration of the activity emitting the substance. For example, kilograms of VOCs emitted per motor vehicle coated. Equation 1 is the general emission factor equation and Example 1 illustrates its application.

Equation 1

$$E_{kpy,i} = [A * OpHrs] * EF_i * [1 - (CE_i/100)]$$

where :

$E_{kpy,i}$ = emission rate of pollutant i, kg/yr
A = activity rate, t/hr
$OpHrs$= operating hours, hr/yr
EF_i = uncontrolled emission factor of pollutant i, kg/t
CE_i = overall control efficiency for pollutant i, %.

Calculating VOC emissions from representative conditions can be undertaken using the emission factors shown in Table 3, Table 4, and Table 5.

Emission factors are not available for final topcoat repair, clean up (except for solvent degreasing which can be found in the *Surface Coating* EET Manual), coating of small parts, and application of sealants.

Example 1 - Calculating VOC Emissions Using Emission Factors

A motor vehicle manufacturer averages 35 vehicles an hour through the paint shop facility utilising the latest water-borne coating technology. The booth is fitted with an incinerator that reduces VOC emissions by 95 percent. VOC emissions can be calculated using Equation 1 and the emission factors from Table 3 (by adding the emission factor for each coat being applied). It is assumed the paint shop is operational for 2 750 hours per year.

$$E_{kpy,i} = A * OpHrs * \Sigma EF_i * [1 - (CE/100)]$$

$$E_{kpy,VOC} = 2\ 750 \text{ hr/yr} * 35 \text{ vehicle/hr} * (0.21 + 0.68 + 2.25) \text{ kg/vehicle} * [1 - (95 /100)]$$

$$= 2\ 750 \text{ hr/yr} * 35 \text{ vehicle/hr} * 3.14 \text{ kg/vehicle} * 0.05$$

$$= 15\ 111 \text{ kg/yr}$$

Use either Table 3, Table 4 or Table 5 to determine VOC emissions. Choose the table that best meets your available data: Table 3 shows VOC emissions per vehicle or per hour, while Table 4 and Table 5 show VOC emissions per vehicle surface area covered.

Table 3 - Emission Factors for Motor Vehicle and Light Duty Truck Surface Coating Operations[a b]

Coating	Motor Vehicle (kg of VOCs)		Light Duty Truck (kg of VOCs)	
	per vehicle	per hour	per vehicle	per hour
Prime Coat				
Solventborne spray	6.61	363	19.27	732
Cathodic electrodeposition	0.21	12	0.27	10
Guide Coat				
Solventborne spray	1.89	104	6.38	243
Waterborne spray	0.68	38	2.3	87
Topcoat				
Lacquer	21.96	1208	ND	ND
Dispersion lacquer	14.50	798	ND	ND
Enamel	7.08	390	17.71	673
Basecoat/clear coat	6.05	333	18.91	719
Waterborne	2.25	124	7.03	267

Source: USEPA, January 1995.

[a] All non-methane VOC. Factors are calculated using the equation in Section 4.2 and the typical values of parameters are presented in Table 7 and Table 8.

[b] All emission factors are rated C (see section 5.4).

ND = no data.

Table 4 - Emission Factors for Vehicle Coating - Passenger and Non-Commercial

Vehicle Surface Area (m^2) [a,b]	VOC Emission Factors Solid Paint (kg/m^2) [b]	VOC Emission Factors Metallic Paint (kg/m^2) [b]	Factor Rating Code
55	0.1599	0.1836	U
65	0.1890	0.2170	U
75	0.2046	0.2299	U
85	0.2202	0.2428	U
95	0.2357	0.2557	U
105	0.2513	0.2685	U
115	0.2669	0.2814	U
125	0.2960	0.3114	U
135	0.3286	0.3456	U

Adapted from European Environment Agency data EMEP/ CORINAIR 1996.

[a] Units expressed as m^2 of car surface to be coated.

[b] Units expressed as kg of solvent per m^2 of surface area coated.

[c] Vehicle surface area includes total areas coated, eg. the inside of doors and under bonnet.

Table 5 - Emission Factors for Vehicle Coating - Commercial Vehicles

Vehicle Type and Surface Area (m^2)[a]	VOC Emission Factors (kg/m^2)[b,c]	Rating
Trucks -cabins (60-75) -boxes (80) -axles (4-8) -chassis (11-25)	0.12	E
Buses -bodies (220-280) -chassis (18-25)	0.5	E
Vans (120)	0.12	E

Adapted from European Environment Agency data EMEP/ CORINAIR 1996.

[a] Units expressed as m^2 of surface to be coated.

[b] Units expressed as kg of solvent per m^2 of surface area coated.

The VOC emission estimate, calculated from applying Equation 1 and the emission factors above, requires speciating into individual NPI-listed organics for reporting purposes. Equation 2 shows the technique for calculating any NPI-listed organic contained in vehicle coatings using the speciation profile in Table 6. Example 2 illustrates the application of Equation 2.

Equation 2

$$E_{kpy,i} = E_{kpy,VOC} * Wt_i/100$$

where:

$E_{kpy,i}$ = emissions of speciated pollutant i, kg/yr

$E_{kpy,VOC}$ = emissions of total VOCs, kg VOC/yr

Wt_i = weight of pollutant i in total VOCs, %

Example 2 - Estimating Speciated Organic Emissions

A motor vehicle manufacturer estimates that VOC emissions from the paint facility are 15 111 kg VOC/yr. Emissions of xylenes can be estimated using Equation 2. Assume the xylenes weight percentage in total VOCs is 33%.

$E_{kpy,i}$ = $E_{kpy,VOC}$ * Wt_i/100

$E_{kpy,xylenes}$ = 15 111 kg VOC/yr * 33 / 100

= 4 987 kg xylenes/yr

Table 6 - Speciation Profile for VOCs - Vehicle Coatings

CASR No.	**Substance**	**Weight %** **(total = 100%)**
141-78-6	Ethyl acetate	2
1330-20-7	Isomers of xylene	33
78-93-3	Methyl ethyl ketone	17
108-10-1	Methyl isobutyl ketone	3
108-88-3	Toluene	29
	(Other VOCs not listed)	(16)

Source: Queensland Department of Environment and Heritage, 1998.

4.2 Using Site-Specific Equations

The emission factors presented earlier in Section 4.1 were calculated using the typical value of parameters present in Table 7 and Table 8. These typical values for the various parameters for motor vehicles and light duty trucks represent average conditions existing in the motor vehicle industry in the US in 1980. A more contemporary and site-specific emissions estimate, and one perhaps relevant to Australian conditions, can be calculated using the equations in this section.

Equation 3 can be used to obtain emission factors relevant to a specific facility's coating operation or coating line within a facility. Example 3 illustrates the application of Equation 3.

Equation 3

$$E_V = \frac{A_v \, c_1 \, T_F \, V_c \, c_2}{S_C \, e_T}$$

where:

E_V = uncontrolled emission factor for total VOC, kg/vehicle
A_V = area coated per vehicle, m^2/vehicle
c_1 = conversion factor, 0.001m/mm
T_F = thickness of the dry coating film, mm
V_C = VOC content of coating as applied, less water, kg VOC/L coating, less water
c_2 = conversion factor, 1 000 L/m^3
S_C = solids in coating as applied, volume fraction, L solids/ L coating
e_T = transfer efficiency fraction, fraction of total coating solids used that remains on the coated parts

The transfer efficiency (fraction of the solids in the total consumed coating that remains on the part) varies with the type of application technique. Transfer efficiency for typical air atomised spraying ranges from 20 to 50 percent. The range for electrostatic spraying, an application method that uses an electrical potential to increase transfer efficiency of the coating solids, is from 60 to 100 percent. Both air atomised and electrostatic spray equipment may be used in the same spray booth.

Example 3 illustrates the application of Equation 3.

Example 3 - Calculating a Site or Process Specific Emission Factor

Annual emissions of VOCs, or speciated organics, can be estimated from Equation 3 from a cathodic electrodeposited prime coat. The following data is given at Table 7:

A_v = $79m^2$

T_f = 0.015mm

V_c = 0.144 kg VOC/L-H_2O

S_c = 0.84 L/L-H_2O

e_T = 100%

$$E_V = \frac{A_v \; c_1 \; T_F \; V_c \; c_2}{S_C \; e_T}$$

$$= (79m^2) * (0.001m/mm)\ (0.015mm) * (0.144\ kg/L\text{-}H_2O) * (1\,000L/m^3) / (0.84\ L/L\text{-}H_2O) * (1.00)$$

= 0.2 kg VOC/vehicle

Table 7 - Parameters for Motor Vehicle Surface Coating[a]

Application	Vehicle Area Coated (m^2)	Film Thickness (mm)	VOC Content (kg/L-H_20)	Volume Fraction Solids (L/L-H_20)	Transfer Efficiency (%)
Prime Coat					
Solventborne Spray	42	0.02	0.683	0.22	40
Cathodic Electrodeposition	79	0.015	0.144	0.84	100
Guide Coat					
Solventborne Spray	19	0.02	0.599	0.30	40
Waterborne Spray	19	0.02	0.336	0.62	30
Topcoat					
Solventborne Spray					
Lacquer	22	0.064	0.743	0.12	40
Dispersion Lacquer	22	0.064	0.695	0.17	40
Enamel	22	0.064	0.599	0.30	40
Basecoat/Clear Coat[b]	22	0.064	0.563	0.33	40
Base Coat	22	0.025	0.671	0.2	40
Clear Coat	22	0.038	0.479	0.42	40
Waterborne Spray	22	0.056	0.336	0.62	30

Source: USEPA, January 1995.

[a] All values for coatings as applied except for VOC content and volume fraction solids that are for coatings as applied minus water. Low VOC (high solids) base coat/clear coats are still undergoing testing and development.

[b] Composite of base coat and clear coat.

Table 8 - Parameters for Light Duty Truck Surface Coating[a]

Application	Vehicle Area Coated (m^2)	Film Thickness (mm)	VOC Content (kg/L-$H_2$0)	Volume Fraction Solids (L/L-$H_2$0)	Transfer Efficiency (%)
Prime Coat					
Solventborne Spray	81.3	0.03	0.683	0.22	40
Cathodic Electrodeposition	102	0.015	0.144	0.84	100
Guide Coat					
Solventborne Spray	62.7	0.02	0.599	0.30	40
Waterborne Spray	62.7	0.02	0.336	0.62	30
Topcoat					
Solventborne Spray					
Enamel	69.7	0.051	0.599	0.30	40
Basecoat/Clear Coat [b]	69.7	0.065	0.563	0.33	40
Base Coat	69.7	0.025	0.671	0.2	40
Clear Coat	69.7	0.038	0.479	0.42	40
Waterborne Spray	69.7	0.056	0.336	0.62	30

Source: USEPA, January 1995.

[a] All values for coatings as applied except for VOC content and volume fraction solids that are for coatings as applied minus water. Low VOC (high solids) base coat/clear coats are still undergoing testing and development.

[b] Composite of base coat and clear coat.

5.0 Emission Estimation Techniques: Acceptable Reliability and Uncertainty

This section is intended to give a general overview of some of the inaccuracies associated with each of the techniques. Although the NPI does not favour one emission estimation technique over another, this section does attempt to evaluate the available emission estimation techniques with regards to accuracy.

Several techniques are available for calculating emissions from motor vehicle manufacturing facilities. The technique chosen is dependent on available data, available resources, and the degree of accuracy sought by the facility in undertaking the estimate. In general, site-specific data that is representative of normal operations is more accurate than industry-averaged data.

5.1 Direct Measurement

Use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from motor vehicle manufacturing facilities. However, collection and analysis of samples from facilities can be very expensive and especially complicated where a variety of NPI-listed substances are emitted, and where most of these emissions are fugitive in nature. Sampling data from a specific process may not be representative of the entire manufacturing operation, and may provide only one example of the facility’s emissions.

To be representative, sampling data used for NPI reporting purposes needs to be collected over a period of time, to and cover all aspects of vehicle production.

In the case of continuous emissions monitoring (CEMs), instrument calibration drift can be problematic and uncaptured data can create long-term incomplete data sets. However, it may be misleading to assert that a snapshot (stack sampling) can better predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and the corresponding emissions data.

5.2 Mass Balance

Calculating emissions from a motor vehicle manufacturing facility using mass balance appears to be a straightforward approach to emission estimation. However, it is likely that few Australian manufacturing facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking or other activities inherent in each material handling stage can often result in large deviations of total facility emissions. Because emissions from specific materials are typically below 2 percent of gross consumption, an error of only ± 5 percent in any one step of the operation can significantly skew emission estimations.

5.3 Engineering Calculations

Theoretical and complex equations or *models* can be used for estimating emissions from a variety of motor vehicle manufacturing processes.

Use of these emission equations to estimate emissions from manufacturing facilities is a more complex and time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors but they do provide an emission estimate that is based on facility-specific conditions.

5.4 Emission Factors

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 Section 6.0 of this Manual. The emission factor ratings will not 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

6.0 References

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USEPA. July 1996. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, fifth edition, AP-42. Section 12.20 Electroplating.* United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.

Written communication between Ford Motor Company of Australia, Campbellfield, Victoria and Queensland Department of Environment and Heritage, Brisbane, Queensland, 20 July 1998.

The following Emission Estimation Technique Manuals referred to in this Manual are available at the NPI Homepage (*http://www.npi.gov.au*) and can be obtained from your local environmental protection agency (see the front of the *NPI Guide* for details):

- Emission Estimation Technique Manual for Ferrous Foundries;
- Emission Estimation Technique Manual for Non-Ferrous Foundries;
- Emission Estimation Technique Manual for Combustion in Boilers;
- Emission Estimation Technique Manual for Combustion Engines;
- Emission Estimation Technique Manual for Fuel & Organic Liquid Storage;
- Emission Estimation Technique Manual for Galvanizing;
- Emission Estimation Technique Manual for Electroplating and Anodising; and
- Emission Estimation Technique Manual for Surface Coating.