
Guidance 6 – Part 1:
Vehicle coating and vehicle refinishing

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1 Introduction

This guidance addresses vehicle coating with an annual solvent consumption of less than 15 tonnes and vehicle refinishing and the related cleaning of equipment, presenting options to substitute or reduce the use of VOC and its resulting emissions.

<table>
<thead>
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<th>SE Directive – Scope definitions (Annex I)</th>
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<tbody>
<tr>
<td><strong>Vehicle coating</strong> is defined by the SE Directive as ‘any activity in which a single or multiple application of a continuous film of a coating is applied to vehicles as listed below:’</td>
</tr>
<tr>
<td>- new cars, defined as vehicles of category M1 in Directive 70/156/EEC (1), and of category N1 in so far as they are coated at the same installation as M1 vehicles,</td>
</tr>
<tr>
<td>- truck cabins, defined as the housing for the driver, and all integrated housing for the technical equipment, of vehicles of categories N2 and N3 in Directive 70/156/EEC,</td>
</tr>
<tr>
<td>- vans and trucks, defined as vehicles of categories N1, N2 and N3 in Directive 70/156/EEC, but not including truck cabins,</td>
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<tr>
<td>- buses, defined as vehicles of categories M2 and M3 in Directive 70/156/EEC.’</td>
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<tr>
<td><strong>Vehicle refinishing</strong> is defined by the Directive as ‘any industrial or commercial coating activity and associated degreasing activities performing:’</td>
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<td>- the original coating of road vehicles as defined in Directive 70/156/EEC(^1) or part of them with refinishing-type materials, where is carried out away from the original manufacturing line, or</td>
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<tr>
<td>- the coating of trailers (including semi-trailers) (Category O)’</td>
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This guidance document only addresses vehicle coating in installations with a solvent consumption between 0.5 and 15 tonnes/year.

Vehicle coating in installations exceeding this solvent consumption and other metal coating, exceeding a solvent consumption of 5 tonnes/year, are covered by the SE Directive but addressed in separate guidance documents: for vehicle coating > 15 tonnes/year see guidance no. 6 part 2, and for other metal coating see guidance no. 8.

Before 2004, the definition of vehicle refinishing given in the SE Directive also included ‘coating of road vehicles\(^2\), or parts of them, carried out as part

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\(^1\) Article 1: ‘For the purposes of this Directive, “vehicle” means any motor vehicle intended for use on the road, with or without bodywork, having at least four wheels and a maximum design speed exceeding 25 km/h, and its trailers, with the exception of vehicles which run on rails and of agricultural tractors and machinery.’

\(^2\) as defined in Directive 70/156/EEC, see footnote above
of vehicle repair, conservation or decoration outside of manufacturing installations'. However, these processes have been excluded from the Directive 2004/42/EC and the products used for them are now regulated under the Paints Directive.

The SE Directive lays down the following activity specific emission limit values for vehicle coating with an annual solvent consumption of less than 15 tonnes and for vehicle refinishing:

Table 2: Emission limit values (ELVs) of the SE Directive

<table>
<thead>
<tr>
<th>Activity</th>
<th>Solvent consumption threshold [tonnes/year]</th>
<th>ELVs in waste gases [mg C/Nm³]</th>
<th>Fugitive emission values [% of solvent input]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle coating</td>
<td>&gt; 0.5 - 15</td>
<td>50 *</td>
<td>25</td>
</tr>
<tr>
<td>Vehicle refinishing</td>
<td>&gt; 0.5</td>
<td>50 *</td>
<td>25</td>
</tr>
</tbody>
</table>

Special provisions:
* Compliance in accordance with Article 9 (3) should be demonstrated based on 15 minute average measurements

Instead of complying with the above ELVs, operators may choose to use a reduction scheme, following the specifications of Annex II (B) of the SE Directive.

Specific requirements apply for VOCs classified as CMR substances\(^3\) as well as for halogenated VOCs which are assigned the risk phrases R40 or R68\(^4\). There is a general obligation to replace CMR substances – as far as possible – by less harmful substances or preparations within the shortest possible time. In the case of a mass flow $\geq 10$ g/h for VOC classified as CMR substances or $\geq 100$ g/h for halogenated\(^5\) VOC with R40 the ELVs in waste gases are 2 and 20 mg/Nm³ respectively, and these also apply when a reduction scheme is being used.

\(^3\) CMR substances – carcinogenic (R45, R49), mutagenic (R46), or toxic to reproduction (R60, R61)

\(^4\) After the implementation of the SE Directive a revision of the R-phrase R40 took place. The original wording of R40 was: ‘Possible risk of irreversible effects’. The new wording is: ‘Limited evidence of a carcinogenic effect’. In the ‘old’ version mutagenity (cat 3) was included. This mutagenic effect is now covered separately under R68: ‘Possible risk of irreversible effects’. This new risk phrase does not include carcinogenicity. The new version of R40 is obviously less restrictive than the old version. Until the SE Directive is adapted to this change, a final decision on which version applies can only be given by the European Court

\(^5\) Halogenated organic solvents are hydrocarbons with one or more of the following halogens: fluorine, chlorine (e.g. trichloroethylene), bromine (e.g. n-propyl bromide) or iodine.
National legislation may define lower solvent consumption thresholds, stricter emission limit values or additional requirements.

2 Summary of VOC substitution/reduction

The most important sources of solvent related VOC emissions depend on the solvent content of the products used for the coating and refinishing of vehicles.

VOC emissions can be reduced by using more effective application techniques (thus reducing overspray and the total amount of solvent used).

Lower emissions may also be achieved by reducing the solvent content in the coatings and fillers (use of ‘high-solids’ products) or by a change of the coating system (e.g. from conventional coatings with a solvent content of about 70% to water based products with a solvent content of about 4 - 15%).

In some cases, VOC emissions can be totally eliminated with the substitution of solvent-based application techniques by powder coating.

3 Description of the activity and related industry sectors

In Europe there are about 500 sites, producing commercial vehicles, which have a solvent consumption not exceeding 15 t/a. [DuPont-1 2008]

Vehicle coating activities involving vans, trucks and buses where VOC consumption is between 0.5 and 15 t/a are likely to include operations for manufacture of special purpose vehicles (ambulances, fire engines, money transporters, camper vans, etc.).

If original coating of passenger cars is carried out away from the original manufacturing line and refinishing-type materials are used, these coating activities are classified as vehicle refinishing (> 0.5 t/a). This is typically done to meet special customer needs e.g. for coating of a car fleet for an individual customer.

The same category of ‘vehicle refinishing’ applies if coating of original parts of any vehicle is carried out away from the original manufacturing line with refinishing-type materials. Examples of parts treated in this way, in installations with < 15 t/a solvent consumption, are switches and other small parts used in serial production as well as parts like buffers or rims coated in special colours.

All coating of trailers (e.g. freight trailers, animal trailers and tippers), including semi-trailers, is classified as vehicle refinishing.

Vehicle coating and refinishing processes must both deal with the following technical challenges:

- Coating of complex three-dimensional objects

6 as defined by Directive 70/156/EEC, see footnote above
- Coating of multiple substrates (steel, cast metal, aluminium, magnesium, zinc, wood, thermoplastics, duroplastics, fibre-enforced plastics)

- Need for coating systems easy to apply under the conditions of small and medium sized enterprises (e.g. coating by both automatic and manual techniques, drying without automatic drying ovens)

- High quality is required in all stages of pre-treatment, coating application and finishing operations

- Coating systems need to perform well in a number of different ways including providing good protection from physical and chemical attack, good adhesion and elasticity, etc.

- A large range of fleet and individual colours are required both on car bodies and add-on parts

Refinishing-type coatings can meet all of these requirements. There are two important differences between vehicle refinishing-type coatings and those coatings used for serial production of vehicles.

Firstly, while serial-type coating systems have a drying temperature of about 140°C, refinishing-type coatings are (typically 2-component) paints with a drying temperature of 20 - 80°C so drying requirements are much lower.

Secondly, any colour that is required may be easily mixed on site in the case of refinishing-type coatings, whereas this is not feasible for serial-type coatings (more details are given in chapter 5.1)

4 Technical process description

4.1 Process flow and relevant associated VOC emissions

Spraying with solvent-based coatings is the most commonly used application technique for both refinishing and small-scale vehicle coating. The following flow chart gives an overview of the typical process steps, and the VOC emissions that can occur, assuming the use of conventional spray coating techniques applying a solvent-based coating with a solid content of 50 %, and further assuming 50% overspray.

In practice, conventional spray coating may have a coating efficiency between 5% and 60%, depending on the geometry of the work piece (plane surface or lattice-like) and the skill of the sprayer.

A change of the coating efficiency (e.g. due to a change of spraying technique) or the solvent content of the coating would have a corresponding impact on the VOC flows shown in the flow chart.
Figure 1: Exemplary VOC emissions from spray application with conventional technology

Based on [DFIU 2002]
4.2 Process description

Coating processes can differ significantly due to the fact that a wide range of products are used. Typical process steps and coating application techniques are described below.

4.2.1 Degreasing

In cases where special purpose vehicles are given original coatings they (or the parts of them to be coated) are sandblasted, in most cases, and further degreasing is not necessary. The same is also true for trailer chassis. In cases of local contamination e.g. with oil from final drilling or cutting activities, these areas of the work piece would usually be cleaned manually by brushing or wiping. Degreasers used for this type of application would usually have a high VOC content, from about 50% up to 100%.

Typically, smaller vehicle parts will be pre-cleaned either with a water-based cleaning liquid using a pressure washer or with solvent containing cleaners applied by spraying. [VDL 2008]

For further details of degreasing see guidance no. 4/5 on surface cleaning.

4.2.2 Application techniques

Coating systems - and therefore the application techniques - differ depending on the products coated. In practice three main groups of coated products need to be distinguished [DuPont -1, 2008]:

Coating of special purpose vehicles: The choice of coating system depends not only on the requirements of the work piece (e.g. the corrosion resistance to be achieved) but also on the size, available equipment and core business of the paint shop or company performing the coating.

Generally, for the coating of special purpose vehicles, 1- or 2-layer-coating systems applied via spray coating are dominant.

Electrophoretic dipping is a major technique for applying the primer systems for the coating of trailers. Even small, niche, producers of specialised trailers use standard chassis pre-treated in this way. Various types of spray coating are then used for subsequent coating layers in the case of small scale or specialised trailer production, whereas for large scale production powder coatings are typically used.

In some instances, trailers are not coated at all, but are instead either galvanized or left as bare aluminium.

Coating of parts of road vehicles: Parts, including buffers, condenser grills, roof luggage rails and door handle claddings are made of a variety of materials have a wide range of work piece geometries. Nevertheless, the application techniques are usually the same: either conventional spray coating, electrostatic or electrostatic assisted spray coating or conventional dipping.
Conventional high and low pressure spraying

Coating material is ejected from the nozzle of a spray gun using compressed air. The air transports the particles of the coating material onto the surface of the work piece.

The higher the pressure of the air, the finer the particles of the coating material. Fine particles increase the quality and the smoothness of the coated surface. On the other hand, the finer the particles, the greater the ease with which they are deflected by the airflow from the coated surface and this leads to increased coating waste (overspray). Conversely, if the pressure is too low, the coated surface is of poor quality (e.g. an ‘orange peel’ effect is created).

The coating efficiency varies between 5 % (for lattice-like work pieces) up to 30 – 60 % (for work pieces with large and plane surfaces).

Conventional spray coating is applicable for any surface and is used in particular for topcoats because of its ability to achieve high quality finishes and special surface effects (e.g. metallic or pearl look). [DFIU 2002] [BREF STS 2007]

High volume low pressure spraying (HVLP)

For high volume low-pressure spraying (HVLP), the atomising pressure is decreased from the conventional 3 – 6 bar down to 0.7 bar. Compared to high-pressure spray coating, up to 20 % overspray can be avoided and the coating efficiency is about 40 - 80 %.

Due to the larger particles of coating material created by HVLP sprays, the quality of finish may not match that achieved with conventional, high pressure, air guns. However, improvements in HVLP gun design are such that the most modern designs are able to match the quality of finish achieved by high-pressure guns. [DFIU 2002] [BREF STS 2007]

Airless spraying

In airless spray coating, the paint is forced through very small metal nozzles (< 2 mm) with a pressure of 80 to 250 bar. The paint jet strikes the stationary air outside the nozzle and is broken up in fine particles due to the force of this impact.

The paint is delivered to the nozzle using high-pressure pumps and this prevents quick colour changes. However, a high throughput of coating is possible. Airless spray coating is cheap and fast and can be used for 1-component and 2-component paint.

Airless spray coating gives a rough finish that needs to be sanded before finer coatings can be applied. This introduces an additional process stage compared with the use of high pressure air spraying. However, optimisation of the spraying can improve finish quality to close to that achieved with HVLP guns, especially with primer coatings. Operator training is essential in order to maximise the performance of airless spraying systems.

This spraying technique may be used either manually or automatically. Material efficiency for airless spray coating is about 5 % (lattice-like work pieces) up to 40 – 75 % (large surfaces). [DFIU 2002] [BREF STS 2007]
Electrostatic spray coating

An electric field is created between the work piece and the coating material, these having opposite polarity. Coating material is atomised and sprayed; the particles are attracted to the work piece. The process halts when the film thickness is nearly equal on all surfaces and edges. Cathodic coating is the most widely used technique as anodic work pieces tend to corrode.

In general, the efficiency of electrostatic spray coating is from 95 % up to 100 %. Compared to conventional spray coating, electrostatic spray coating is more time and material efficient and easier to automate. Less waste residues are generated and spray booths require less cleaning.

For electrostatic spraying to work, the work piece has to be conductive. This limits the substrates and coatings that can use the technique (e.g. it is not possible to recoat existing coatings). In addition geometries that act as Faraday cages have to be avoided because the coating is applied to them unevenly.

Electrostatically assisted compressed air, airless and air assisted spraying

These techniques combine paint material atomisation similar to regular compressed air or airless spraying with the electrostatic charging of paint particles

For compressed air, the material flow is up to 1000 ml/min, for airless or assisted airless techniques the material flow can be up to 3000 ml/min. The material efficiency is up to 85 %.

Compared to conventional spraying, less overspray is generated and spray booths are less polluted. Therefore, less cleaning agents are needed.

With electrostatically assisted spraying more complex geometries can be coated than with electrostatic spray coating.

[BREF STS 2007]

Conventional dipping

Work pieces are either dipped manually or transported and dipped via conveyor systems. Dipping into water-based paints might produce foam. Water-based paints are only stable over a small range of pH levels and, therefore, very sensitive to contamination that might be introduced from the pre-treatment processes.

This technique is quite cost effective and can achieve a material efficiency of up to 100%, [BREF STS 2007]

The finish quality for this coating technique is low. It is used for coating of small parts for the commercial vehicle sector. This technique is not applicable for coating of open-cell surface structures. [VDI 2008]

Electrophoretic dipping

In the process of electrophoretic dipping, a direct electric current is made to flow between the work piece and the electrodes of opposite polarity installed in a tank.
Cathodic (work piece loading) systems are commonly used, because they offer better resistance against corrosion than do anodic systems.

Electrophoretic dipping is only used with water-based coatings with a solvent content between 1 – 4 %.

Electrophoretic dipping is an efficient application technique that produces high quality coatings. However, it is a cost intensive system (investment and material costs), and requires a high level of maintenance of the paint tanks for quality assurance. [BREF STS 2007].

In the scope of this guidance, this technique is usually only used for the priming of trailers. As the work piece has to be conductive and has to be able to withstand temperatures of approx. 180°C, this technique cannot be applied for wooden trailer parts. Primer coats applied by electrophoretic dipping are usually followed by a powder coated topcoat.

**Application of powder coatings**

Powder coatings are applied and then melted and cured by heating the work piece at 200°-250°C [BREF STS 2007].

*Powder coating – electrostatically assisted spraying:* The powder particles are electrostatically charged and sprayed onto the work piece using compressed air. Spray booth and application tools can be cleaned by vacuum cleaning or by blowing with compressed air. There are no solvent emissions associated with this spraying process.

Material efficiency is about 80 – 95 %. [BREF STS 2007]

*Powder sintering:* The work piece is heated above the melting temperature of the powder coating before coatings are applied. As soon as the powder is in contact with the surface, sintering and merging takes place.

A high material efficiency can be achieved. [BREF STS 2007]

Powder coating is subject to similar restrictions as is electrophoretic dipping. The working piece has to be able to withstand the high temperatures used to melt and cure the powder. Therefore, this technique cannot be applied e.g. for plastic parts.

**4.2.3 Drying**

After the application, the coating has to dry.

In general, the refinishing-type coatings used in this activity have the ability to dry at ambient air temperatures in the workshop or outside. (see chapter 5, solvents used).

The drying time can be reduced by the use of additional drying units (ovens). Spray booths may also function as ovens.

The drying time depends on the object or substrate, the type of coating and the coating thickness, and varies from a few seconds to one hour.

For the drying of water-based coatings or a pre-drying step of wet-on-wet layer constructions, dehumidified air is used, with convection driers and an additional dehumidification step. Due to the removal of water in this manner, the drying times can be significantly reduced. [BREF STS 2007]
4.2.4 Cleaning

Cleaning needs to be undertaken in all application techniques: for work pieces, for work place environment, coating equipment and parts thereof. A range of cleaning techniques can be used, from manual cleaning to automatic cleaning (e.g. for spray guns and parts), using closed systems with solvent recovery. Solvent cleaners are used (and sometimes heated for higher efficiency) as well as water. Cleaning with water is possible when water-based coating systems are used and when the cleaning is performed before paints have dried.

Cleaning needs to be effective and fast. Cleaning intensity varies according to the nature of colour changes and is also dependent on whether the contamination is semi-dry or dry.

[BREF STS 2007]

Spray booths are usually cleaned with cleaners with a low VOC content. An alternative approach is the use of a film or a strippable varnish, applied to the walls of the booth. [VDI 2008]

5 Solvent use, emissions and environmental impact

5.1 Solvents used

Coating systems for the activities covered by this guidance in most cases consist of two layers, a primer and a top-coat.

The primer is used for the first treatment of the metal surface, providing an anticorrosive function and helping to increase bonding of the subsequent coating.

A typical conventional primer for metal surfaces is based on polyvinylbutyral resin. These primers have a total solvent content of 55-65 % w/w. More modern systems are either epoxy based (with a solvent content of about 40 % w/w) or polyester based (solvent content of about 20% w/w). Primers for larger-scale trailer production are applied by electrophoretic dipping, and are water-based with a solvent content of < 5%.

For most products top-coating is performed with a single layer system. This single layer coating has to provide both the colour/appearance and protection against chemical or other attack (sunlight, mechanical impact, etc).

The single layer coating may either be a 1-component system with a typical solvent content of about 45 - 55 % w/w or a 2-component system with solvent content of about 25-35% w/w. As an alternative, water based systems may be used with a VOC content of about 10-15% w/w.

In cases where very specific colour effects need to be achieved (e.g. on some components for passenger cars) two- or multi-layer systems are used. The two coat systems consist of a basecoat providing colour, followed by sealing with a clear topcoat. For multi-layer systems, an additional colour -coat is applied (intermediate coat). [VDI 2008]
All coatings are of the vehicle refinishing-type, drying at between 20°C – 80°C. The coatings can be produced in a wide range of colours and are mixed, often on-site, but also off-site by the coating supplier from 30 ‘basic’ colours. This colour-flexibility is of great importance to the vehicle coating & refinishing sector, particularly for trailer coating and coating of cars for special purposes.

Solvents in conventional solvent-based coatings (solvent content > 40 % w/w) are mainly mixtures of organic hydrocarbons (xylene, toluene and white spirit), although alcohols, esters and ketones are also used. [DFIU 2003]

In high-solid coatings (solvent content < 35 % w/w) the following solvents are used: xylene, white spirit, aromatic hydrocarbon mixtures, butyl acetate, alcohols, and glycol ethers. Ketones and toluene do not play a significant role in Europe.

Water-based coatings in most cases contain organic solvents (solvent content 10-15 % w/w) as a solubiliser and to improve the properties of the wet film layer. The main solvents used are glycol ethers and alcohols. Most glycol ethers are alkyl ethers of ethylene glycol (e.g. 2-butoxyethanol) propylene glycol. The latter are used in place of the toxic ethers 2-ethoxyethanol and 2-methoxyethanol.

Powder coatings are VOC-free.

5.2 Solvent consumption and emission levels

General data on solvent consumption and emission levels are difficult to obtain due to the variety of vehicles and parts coated as well as the variety of application processes used. For small-scale vehicle coating less automation of processes is typical, and more difficult product geometries and sizes have to be coated. These factors both result in less efficient application and thus higher emission rates than achieved with large-scale vehicle coating.

Installations coating special purpose vehicles often need to meet individual customer requirements, and make more frequent use of metallic colours (which are applied as solvent-based coatings) than large-scale car coating installations. The higher range of colours used leads to increased cleaning requirements. [BREF STS 2007]

Conventional solvent based coatings for cabins are, typically, associated with VOC emissions of 193 – 233 g VOC/m², while for buses the emissions are approximately 225 g/m². [BREF STS 2007]

VOC emissions from conventional coating systems for aluminium rims/wheels are reported to be about 66 g/wheel; while with water-based coatings, 4 g/wheel is achieved. [BREF STS 2007]

Cleaning

Cleaning processes with organic solvents account for about 20 % of total VOC emissions from paint shops. [BREF STS 2007]

Emissions from cleaning can be reduced to < 20 g/m² by using good practice in housekeeping, cleaning and substitution techniques. [BREF STS 2007]
5.3 Key environmental and health issues

In vehicle coating and refinishing a broad range of different solvents is used for coating materials and cleaners.

Process emissions of solvents, together with NOx emissions, are precursors of ground level ozone formation in the presence of sunlight. Existing occupational workplace limits should be taken into consideration.

Emissions of VOC to air may occur from:
- the storage of the solvents
- the process
- cleaning operations

Spills and leaks from storage areas may result in emissions to soil and groundwater.

6 VOC Substitution

The following sections describe potential substitutes for VOC (using VOC-free and VOC-reduced systems). There are also descriptions of the application technologies or special conditions needed and the advantages and disadvantages compared to systems that use solvents with a high VOC content.

6.1 VOC-free systems

This section describes the ways that VOC-free products or systems can be used to replace the organic solvents currently used.

6.1.1 Substitution by powder coating systems

Powder coatings can substitute for solvent-based coatings in many processes addressed here, provided that the work piece can be heated in order to cure the coating.

A change to powder coating requires a change to a new application technique and the need for a drying oven entailing additional costs. In addition, powder coatings are more expensive per unit weight than conventional coatings.

Conversely, each unit weight of powder coating is made up entirely of the material used to coat, unlike liquid coatings where some of the weight is solvent. Therefore, a tonne, for example, of powder coating would be able to coat a greater area than a tonne of solvent-based coating, assuming that both types of coating resulted in layers of equal thickness.
Application of powder coatings is also much more efficient. The combination of these factors usually means that the substitution to powder coatings is cost neutral. [DuPont 2008] Additional financial benefits occur where waste gas treatment systems can be avoided.

6.1.2 Substitution of VOC cleaners

Components and sub-assemblies can be degreased and cleaned in vats using water-based cleaning or degreasing techniques based on detergent systems that substitute solvent based systems.

Detergent systems can also be used for cleaning of equipment and parts when water based coating systems are used.

These systems combine detergents with alkalis and other substances, depending on the substrates and the materials to be removed. However, cleaning may take longer than with solvent-based systems.

Water based cleaning systems may also require additional heating and subsequent wastewater treatment. [BREF STS 2007]

6.2 VOC-reduced systems

If the complete substitution of organic solvents is impractical then changing to systems with a reduced VOC content, such as those described in this section, can decrease emissions.

6.2.1 Reduction of solvent content in coating systems

Often the most significant reduction in VOC emissions can be achieved by changing from conventional solvent based systems to high solid coatings or water-based systems. Total emission reductions of about 30 – 55 % can be achieved in this way. [DFIU 2000]

In the case of high-solid coatings, the higher price per unit weight for the coating is outweighed by the higher efficiency of the product (higher solid content per unit weight). [DuPont 2008]

In the case of water based systems, the change of application system requires stainless steel equipment to be used and also increases drying times. Adjusting the dryer, using heated air and increasing exchange rates, can provide the additional drying requirement. A case-by-case calculation, including energy costs, needs to be made in order to determine how costs will be affected by switching to water based coatings.

For water based coating systems for electrophoretic dipping, there are costs associated with new equipment and additional costs for additional maintenance required by this sort of application system. Here, as a rough estimate, it can be assumed that the turnover time for the coating solids in the bath volume needs to be < 1 year to achieve an economic situation. [DuPont 2008]
7 Other VOC emission prevention measures and abatement techniques

Preventive measures, process improvements and abatement techniques can be used to reduce VOC emissions if VOC substitution as described in section 6 is not possible. The following measures are commonly applied for vehicle coating with an annual solvent consumption of less than 15 tonnes and for vehicle refinishing:

7.1 Process improvements

Because conventional spray coating is the dominant application process for this sector, process improvements to reduce VOC emissions that have been applied in other sectors can also be applied here [EPA 2005].

It is essential that spray booths are used for all spraying in order to reduce fugitive emissions.

Spray booth walls do not necessarily have to be cleaned with solvent containing cleaners but instead can be coated with a paper, film or a strippable varnish, which may then be removed and disposed from time to time (see chapter 4.2.4). Emissions from cleaning are thereby reduced.

There are enclosed containers readily available on the market that can be used for locally dispensing thinners, pre-cleaners, degreasers, etc. These can be small plunger cans that dispense small amounts of solvents onto a cloth, or containers with sealed nozzles. These containers reduce emissions from material handling.

Enclosed paint mixing equipment that reduces the release of VOC is available on the market. As refinishing-type coatings are often mixed on-site (see chapter 5.1), emissions from paint mixing are often relevant.

Spillages also lead to emissions, and failure to keep containers closed increases emissions. All containers of degreasers, pre-cleaners, cleaners and thinners should be kept closed when not in use and during handling/transport around the premises.

Lids should be tight fitting. Containers that do not seal properly, e.g. that are damaged or dented, should not be used.
7.2 Improvement of application techniques

7.2.1 General application process improvements

General measures to reduce VOC emissions by improving the application of spray coating are [according to BayLFU 2005]:

- Limiting spraying distance to the coated surface
- Keeping the spray jet vertical to the surface
- Adjusting the width of the spray jet to the work piece’s width
- Applying precise contour coating
- Keeping air pressure as low as possible, but adequate for quality requirements
- Reducing the number of coating layers

7.2.2 Change to increased efficient application technique

High volume low-pressure (HVLP) spray equipment has a coating efficiency approximately 20 % better than conventional spray coating. Not only does such equipment significantly reduce emissions it also improves the finish quality and reduces paint costs - due to overspray reduction.

The typical cost of a high quality HVLP spray gun is € 400 [DFIU 2000]. These spray guns can be connected to the existing conventional pressurised air supply systems.

Typically VOC emissions can be reduced by replacing application techniques by other more efficient techniques (see table 3 below).

When changing to more efficient spray application techniques it should be remembered that operator training is likely to be necessary. Training will help operators to use spray gun types to optimum effect, thus maximising the efficiency achieved, thereby saving both emissions and money.

Improved colour mixing can reduce the amount of waste generated and help to avoid unnecessary VOC emissions. Electronic scales can improve the accuracy of batch preparation and automated data logging can be used for generating information for the solvent management plan. [EPA 2005]
### Table 3: Efficiency of application techniques

<table>
<thead>
<tr>
<th>Method</th>
<th>Degree of efficiency [%]</th>
<th>Suitable varnish system</th>
<th>Geometry of the work piece</th>
<th>Other restrictions</th>
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<tr>
<td>Compressed air spraying</td>
<td>20 – 65</td>
<td>1- and 2-component systems</td>
<td>No limitation</td>
<td>-</td>
</tr>
<tr>
<td>Airless</td>
<td>40 – 80</td>
<td>1- and 2-component systems</td>
<td>Large, simple shapes</td>
<td>-</td>
</tr>
<tr>
<td>Airmix</td>
<td>35 – 75</td>
<td>1- and 2-component systems</td>
<td>Large, simple shapes</td>
<td>-</td>
</tr>
<tr>
<td>HVLP</td>
<td>45 – 65</td>
<td>1- and 2-component systems</td>
<td>No limitation</td>
<td>-</td>
</tr>
<tr>
<td>Electrostatic assisted compressed air spraying</td>
<td>50 – 80</td>
<td>1- and 2-component systems</td>
<td>Not suitable for shapes that act as Faraday cages</td>
<td>Electrically conducting materials are necessary</td>
</tr>
<tr>
<td>Electrostatic assisted airless spraying</td>
<td>45 – 85</td>
<td>1- and 2-component systems</td>
<td>Not suitable for shapes that act as Faraday cages</td>
<td>Electrically conducting materials are necessary</td>
</tr>
<tr>
<td>Electrostatic assisted airmix spraying</td>
<td>40 – 80</td>
<td>1- and 2-component systems</td>
<td>Not suitable for shapes that act as Faraday cages</td>
<td>Electrically conducting materials are necessary</td>
</tr>
<tr>
<td>Flooding</td>
<td>85 – 95</td>
<td>1-component systems</td>
<td>Non-scooping parts</td>
<td>High solvent loss</td>
</tr>
<tr>
<td>Dipping</td>
<td>75 – 90</td>
<td>1-component systems</td>
<td>Non-scooping parts</td>
<td>High solvent loss</td>
</tr>
<tr>
<td>Powder with electrostatic spray technique</td>
<td>50 – 95</td>
<td>Powder</td>
<td>No limitation</td>
<td>Electrically conducting temperature resistant materials are necessary</td>
</tr>
</tbody>
</table>

[DFIU 2003, p.207]
7.2.3 Reduction of VOC emissions from cleaning

The following measures reduce the amount of solvents used for cleaning: [BayLFU 2005] [DFIU 2000] [BREF STS]

- No cleaning of equipment used for base coatings or coatings with low optical requirements
- Consecutive coating of same coloured work pieces
- Draining of the supply lines before cleaning, e.g. spraying until the line is empty
- Using a pig-clearing method7 to avoid residues remaining in pipes
- Immediate cleaning of parts, leaks, spillages and working environment before coating material is dried
- Regular inspections of storage areas and working environment to ensure appropriate handling procedures are being followed
- Minimising the surface area of any solvent containing materials at the working station.
- Using systems that allow back-flow of solvents to a closed container. For example, cleaners can be pumped through a tap or sprayed onto the object in a partially enclosed work area above a storage drum. The work area allows surplus solvent to flow back through coarse filters into the drum.

Automatic washing machines can clean parts to be coated as well as coating equipment. In these machines the solvents are contained and collected for reuse. Some emissions can still occur when opening the machine to remove cleaned equipment. These emissions can be treated using a solvent recovery system. These systems can achieve up to 80 – 90 % solvent recovery. Problems may occur with 2-component clear coat materials, however, which can lead to clogging of recovery tank pipes. A typical system costs 0.4 million Euros for a single spray booth [BREF STS 2007, p. 481]

Spray gun should be cleaned in enclosed equipment and this way 80 % of the solvent emissions from cleaning can be reduced. Such systems cost between 150 and 3000 Euros – both manually operated and automated equipment are readily available on the market. [EPA 2005, BREF STS 2007]

7 ‘Pigs’ are pieces of plastic, propelled by compressed air, that scour any residual coating from pipes and force it back to the storage tank. The system is only applicable, where paints are delivered to machinery through pipes and different colours are sent through the same pipe.
7.2.4 Examples of process improvements

Windscreen wipers are usually coated with water-based coatings (often using high rotation bells) but may also be coated with powder coating. [DFIU 2002]

Radiators can be effective coated with water-based coatings using manual electrostatic spray coating - even though they have a complex geometry parts made of both metal and synthetic materials. The system can be combined with overspray recovery whereby the recovered lacquer is mixed with fresh coating material to adjust the viscosity.

The combination of water based coatings and recovery of waste material can lead to a significant VOC emission reduction. Also UV cured powder coatings are increasingly used (due to the material mix of metal and plastics and related heating sensitivity). [DFIU 2002]

Automatic electrostatic application systems, using high rotation bells, can have high coating efficiencies and are suitable for axles and chassis. HVLP spraying and water based systems can be used for manual application. [DFIU 2002]

7.3 Abatement technologies / End of pipe measures

If emission values are likely to be exceeded and primary measures cannot be applied then VOCs may be destroyed by thermal oxidation, biological treatment or decomposition by thermal plasma. Biological and plasma treatments are mainly used for low concentrations of VOC (< 1 gC/m³).

Thermal oxidisation can achieve VOC reduction efficiencies of > 99.9 %, biological treatment generally has a lower efficiency but also lower investment and operating costs.

Adsorption onto activated carbon or zeolite materials, followed by controlled desorption, may be used to concentrate a dilute effluent for subsequent treatment. Concentrated gas streams must be monitored to ensure that the carbon content never exceeds 25 – 50 % of the lower explosion limit.

Thermal oxidation can be used if concentrations are above 1 mgC/m³. Consequently, low and varying carbon concentrations may require additional fuelling with natural gas to maintain a constant flame temperature. Autothermic combustion can be achieved with total carbon concentrations of about > 2 g/m³.

Recuperative oxidation systems recover waste heat from the combustion, via heat exchangers, to pre-heat incoming waste gas or for process operations such as dryers, or for room heating.

Regenerative oxidation systems are more efficient than recuperative systems. The hot exhaust gas is passed through chambers containing heat retentive honeycomb-like material. When a chamber has achieved its full heat loading the exhaust gas is routed to another chamber. Cool incoming waste gas is heated by passage through the hot honeycomb-like material before it enters the combustion chamber. The regeneration of waste heat decreases the energy demand of the process significantly.

Catalytic oxidation may be used if no ‘catalyst poisons’ are present; since catalysed oxidation occurs at a relatively low temperature the energy demand is reduced.
8 Summary of VOC emission reduction measures

The following table summarizes the various approaches to substitute or reduce VOC emissions as described in chapters 6 and 7:

Table 4: Measures for VOC substitution and VOC reduction in vehicle coating and vehicle refinishing

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Substitutes/ Solvent free processes</strong></td>
<td></td>
</tr>
<tr>
<td>VOC Substitution by changing the application system</td>
<td>Use of powder coatings</td>
</tr>
<tr>
<td>Substitution of VOC cleaners</td>
<td>Use of VOC-free cleaners e.g. water based cleaners for degreasing and cleaning of equipment and parts</td>
</tr>
<tr>
<td><strong>Reduction of the solvent content</strong></td>
<td></td>
</tr>
<tr>
<td>Reduction of the solvent content in coating systems</td>
<td>Changing from conventional coating systems to high solid and water based coating systems</td>
</tr>
<tr>
<td><strong>Process Improvements</strong></td>
<td></td>
</tr>
<tr>
<td>Improvement of application techniques</td>
<td>Optimising the spraying technique, reducing the number of coating layers, improving or replacing application techniques by those with a higher efficiency</td>
</tr>
<tr>
<td>General process improvements</td>
<td>Use spray booths for all spraying Use of enclosed paint mixing equipment Ensuring all containers with solvents are kept closed whenever possible.</td>
</tr>
<tr>
<td><strong>Abatement Technologies</strong></td>
<td></td>
</tr>
<tr>
<td>Destruction of VOC</td>
<td>Biological treatment, adsorption and/or thermal/catalytic oxidation.</td>
</tr>
</tbody>
</table>
9 Good practice examples

9.1 Coating of aluminium wheel rims

An installation coating aluminium wheel rims with conventional coating techniques used to have a VOC emission of about 66 g/wheel rim. This was reduced to 4 g/rim by changing to water based and powder-based technologies.

The conventional coating was a three-step process - a solvent free powder base coat followed by a solvent-based metallic effect base coating and a solvent-based clear top-coat. In the new system, the top-coat is powder and the metallic effect base-coat is water-based; the solvent free powder base coat remains unchanged.

The following table shows the reduction/substitution effects for each coating layer.

Table 5: Illustration of measures for VOC substitution and VOC reduction in wheel rim coating

<table>
<thead>
<tr>
<th>Input of coating per coated aluminium rim</th>
<th>Conventional process</th>
<th>New process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paint consumption</td>
<td>Solid application</td>
<td>Paint consumption</td>
</tr>
<tr>
<td>1. Coating/basic layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basic powder</td>
<td>80 – 100 g</td>
<td>80 – 100 g</td>
</tr>
<tr>
<td>Application efficiency</td>
<td>98 %</td>
<td>98 %</td>
</tr>
<tr>
<td>2. Metallic-basis layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvent-based wet paint</td>
<td>&lt; 60 g</td>
<td>12.5 g (approx.)</td>
</tr>
<tr>
<td>Water-based wet paint</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Application efficiency</td>
<td>50 – 60 %</td>
<td>80 %</td>
</tr>
<tr>
<td>3. Coating clear coat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvent-based clear coat</td>
<td>&lt; 60 g</td>
<td>15 g</td>
</tr>
<tr>
<td>Powder</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Application efficiency</td>
<td>50 – 60 %</td>
<td>98 %</td>
</tr>
</tbody>
</table>

[BREF STS 2007]
In total, paint material consumption decreased from 210 g/rim to 170 g/rim - with a constant coating thickness. Despite the use of additional powder coating, energy consumption did not increase. [DFIU 2002]

9.2 Coating of trailers

A body shop replaced its conventional coatings with high solid products. Application techniques were changed to HVLP technique and the material supply lines were shortened (from 27 m to 10 m) - thereby saving cleaning agent and effort.

The cost increase of about 15 – 20% per kilo high solid coating material is offset by the lower overall consumption of coating material. [BayLFU 2005]

Table: 6 Measures for VOC substitution and VOC reduction in coating of trailers and superstructures

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>Afterwards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stopper</td>
<td>3622</td>
<td>15.5</td>
</tr>
<tr>
<td>Wash primer</td>
<td>780</td>
<td>71.2</td>
</tr>
<tr>
<td>Primer</td>
<td>44</td>
<td>59.4</td>
</tr>
<tr>
<td>Filler</td>
<td>9255</td>
<td>31</td>
</tr>
<tr>
<td>Topcoat</td>
<td>13910</td>
<td>44.5</td>
</tr>
<tr>
<td>Basecoat</td>
<td>1406</td>
<td>77.2</td>
</tr>
<tr>
<td>Clear coat</td>
<td>779</td>
<td>52.2</td>
</tr>
<tr>
<td>Hardener</td>
<td>9958</td>
<td>62.9</td>
</tr>
<tr>
<td>Thinner</td>
<td>3932</td>
<td>100</td>
</tr>
<tr>
<td>Special prod.</td>
<td>50</td>
<td>32</td>
</tr>
<tr>
<td>Cleaner</td>
<td>2670</td>
<td>100</td>
</tr>
<tr>
<td>Total</td>
<td>46406</td>
<td>53</td>
</tr>
</tbody>
</table>

[BayLFU 2005]
9.3 Coating of brake pads

At a plant carrying out the spray coating of brake pads, a reduction of VOC consumption of about 50 % was achieved by optimizing the arrangement of the work pieces on their hangers. This led to increased application efficiency because the gaps between the discs, and overspray, were reduced.

By this simple measure the capacity of the installation was doubled and the paint consumption per brake pad decreased by more than 50%. Beside the environmental benefits the measure lead to notable economical savings.

[BayLFU 2005]

9.4 Cleaning of equipment

In a paint shop coating trailers, manual cleaning of a spraying gun consumed 480 ml of solvent cleaning agent per gun. Now, with automatic washing machines, the solvent consumption has reduced to 80 ml/gun and the used solvent is captured and recycled for reuse. Consequently the total VOC emissions from spray gun cleaning were reduced by 98%

The automatic spray gun washing machine required an investment of 2500 Euro but this investment was outweighed by a timesaving for the cleaning operation of more than 75% (from about 12 to less than 3 minutes per gun)

Figure 2: Automatic pistol washing machine

[Ökopol 2008]
10 Emerging techniques and substitutes under development

UV curing coatings are an emerging technology particularly suitable for the coating of smaller parts (this restriction is due to the size and cost of the UV curing unit). UV curing coatings may significantly improve the scratch resistance of the coated surface. [ISACOAT 2005]

Water based top coats with less than 10 % solvent content are being developed for large-scale vehicle coating and may also become more widely applicable in the future for small scale vehicle coating. [DuPont 2008]

11 Information sources

[SE Directive 1999]

[BayLFU 2005]

[BREF STS 2007]

[CHRIST et al. 2005]
Christ, U./Fugmann, B., VOC Leitfaden, Frei Lacke, 2005

[EPA 2005]

[DFIU 2000]
Deutsch-Französisches Institut für Umweltforschung (German-French Institute for Environmental Research), Leitfaden zum Einsatz von Wasserlacken in der KFZ-Reparaturlackierung (Guidance on the use of water-based coatings for vehicle refinishing), Ministerium für Umwelt und Verkehr Baden-Württemberg, 2000

[DFIU 2002]

[DuPont-1 2008]
DuPont, Mr. May, customer related environmental affairs, personal communication, 2008.

[EGTEI 2003]

[Envirowise 2003]

[IBU 2008]
ISACOAT 2005
ISACOAT- Network on Integrated Scenario Analysis of Metal COATing, research project under the fifth framework program under coordination of LEIDEN University.
Work package 3: Process models, Description of specific categories: reference cases and development options, Sector 1: Automotive OEM coating (small installations).

Ökopol 2008
Ökopol GmbH, data collection at paint producers, vehicle coating installations and vehicle refinishers, 2008.

UK Guidance 2004

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UK Guidance 2008
Integrated Pollution Prevention and Control (IPPC) - Secretary of State’s Guidance for the A2 Surface Treatment using Solvents Sector, Sector Guidance Note IPPC SG 6, Department for Environment, Food and Rural Affairs (DEFRA), London, 2008.

VDI 2008
VDI 3456 Pre draft no. 06, Emission Control (Re-)finishing cars and commercial vehicles (Small Enterprises), VDI, 2008