Guidance on VOC Substitution and Reduction for Activities Covered by the VOC Solvents Emissions Directive (Directive 1999/13/EC)

Guidance 7:

Coil coating

European Commission - DG Environment

Contract ENV/C.4/FRA/2007/001

Content

1 Introduction 149

2 Summary of VOC substitution/reduction 150

3 Description of the activity and related industry sectors 150

4 Technical process description 151

4.1 Process flow and relevant associated VOC emissions 151

4.2 Process description 153

4.3 Coatings used in the coil coating industry 154

5 Solvent use, emissions and environmental impact 156

5.1 Solvents used 156

5.2 Solvents consumption and emission levels 156

5.3 Key environmental and health issues 157

6 VOC Substitution 158

6.1 VOC-free systems 158

6.2 VOC-reduced systems 159

7 Other VOC emission prevention measures and abatement techniques 161

7.1 Process improvements 161

7.2 Abatement technologies/End of pipe measures 161

8 Summary of VOC emission reduction measures 162

9 Good practice examples 163

9.1 Example 1: Use of Reduced-Solvent Polyester Paints 163

9.2 Example 2: Use of water Reducible Epoxy Backer 164

10 Emerging techniques and substitutes under development 165

10.1 UV/EB radiation curing 165

10.2 Development of VOC-free or VOC reduced products 165

11 Information sources 166

1 Introduction

This guidance addresses coil coating and the related cleaning of equipment, presenting options to substitute or reduce the use of VOC and its resulting emissions.

Table 1: Scope definition of the VOC Solvent Emission Directive (SE Directive)

SE Directive – Scope definitions (Annex I)
The activity 'coil coating' is defined as 'any activity where coiled steel, stainless steel, coated steel, copper alloys or aluminium strip is coated with either a film forming or laminate coating in a continuous process.' The SE Directive covers installations in which this activity is taking place with an annual organic solvent consumption greater than 25 tonnes.

The SE Directive lays down the following activity specific emission limit values for coil coating:

THE SE DIRECTIVE APPLIES TO COIL COATING IF A SOLVENT CONSUMPTION OF 25 TONNES PER YEAR IS EXCEEDED

Table 2: Emission limit values of the SE Directive

SE Directive - Emission limit values (ELVs) (Annex II A – activity No. 7)				
Activity	**Solvent consumption threshold [tonnes/year]**	**ELVs in waste gases [mg C/Nm³]**	**Fugitive emission values [% of solvent input]**	**Total ELVs**
Coil coating	>25	50*	new installations: 5 existing installations:10	-
Special provisions: *For installations which use techniques which allow reuse of recovered solvents, the emission limit shall be 150.				

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[1] as well as for halogenated VOCs which are assigned the risk phrases R40 or R68[2]. There is a general obligation to replace CMR substances– as far as

1 CMR substances – carcinogenic (R45, R49), mutagenic (R46), or toxic to reproduction (R60, R61)
2 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. Untilthe SE Directive is adapted to this change, a final decision on which version applies can only be given by the European Court

possible – by less harmful substances or preparations within the shortest possible time. In the case of a mass flow ≥10 g/h for VOC classified as

CMR substances or ≥100 g/h for halogenated[3] VOC with R40/R68 the ELVs in waste gases are 2 and 20 mg/Nm³ respectively, and these also apply when a reduction scheme is being used.

National legislation may define lower thresholds for solvent consumption, stricter ELVs or additional requirements.

2 Summary of VOC substitution/reduction

In the coil coating industry VOC emissions arise from the application and the subsequent drying of solvent-based coatings. In general, there has been a trend away from solvent-based paints towards solvent reduced systems with a solvent content of 30-45%.

VOC REDUCED PAINT SYSTEMS ARE THE MOST RELEVANT VOC REDUCTION MEASURES AT PRESENT

Low VOC systems, such as high solid coatings or water-based systems, are available but the shift to these systems has been slow, either because of technical limitations or product requirements. The only VOC-free technology currently in use in coil coating is powder coating, although this is severely limited by economic and technical factors.

Where it is not possible to avoid using solvent-based systems then improved process equipment, air extraction, and end-of-pipe abatement are the most effective measures of reducing the emissions arising from the coating and drying process and the associated handling, storage and mixing of solvents.

3 Description of the activity and related industry sectors

Coil coating takes place in specialised production lines. In many cases coil coaters are part of large aluminium or steel companies [BREF STS 2007]. There are also specialised service centres or coaters of narrow strips providing customized products. The annual production volume of individual plants in the sector varies from 5 to more than 40 million m² coated product.

The main substrates which are pre-coated are either cold rolled, zinc or zinc alloy coated steel (82%) or aluminium (18%) [ECCA 2008].

In 2007 around 5,700 kilo tonnes of steel and 440 kilo tonnes of aluminium have been pre-coated in Europe[4], amounting to over 1,500 million m² of coated product [ECCA]. In total, there are 158 coil coating production lines in Europe[5] [BREF STS 2007, ECCA 2008].

CURRENTLY ONLY AROUND 5 % OF THE PRODUCTION LINES USE VOC-FREE POWDER COATINGS

Out of all the production lines, 7 use solvent-free powder coatings, the others use coatings with a varying degree of solvent content (see also Table) [ECCA 2008].

3 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.
4 based on latest 2007 statistics for ECCA members shipments
5 EU 15 and Czech Republic, Hungary, Poland, Slovak Republic

Coil coated products (also named pre-coated products) are used in a wide range of applications, as Figure 1 shows:

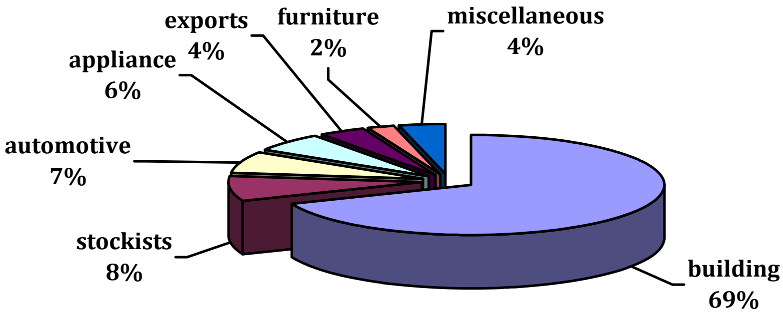

Figure 1: Application areas of pre-coated material in 2006 [source: ECCA DE]

THE BUILDING SECTOR IS THE MOST IMPORTANT APPLICATION AREA FOR COIL COATED MATERIALS

Within the building sector pre-coated metal sheets are mainly used for wall cladding (~ 75%), metal roofing and other outdoor applications (~18%) and indoor applications (~8%) [ECCA 2008, ECCA DE].

An increasing demand of pre-coated products is expected for the future.

4 Technical process description

4.1 Process flow and relevant associated VOC emissions

The following flow chart of a typical coil coating process provides an overview of possible VOC emissions. The pre-treatment, primer and coating application might take place on one or on both sides of the metal strip.

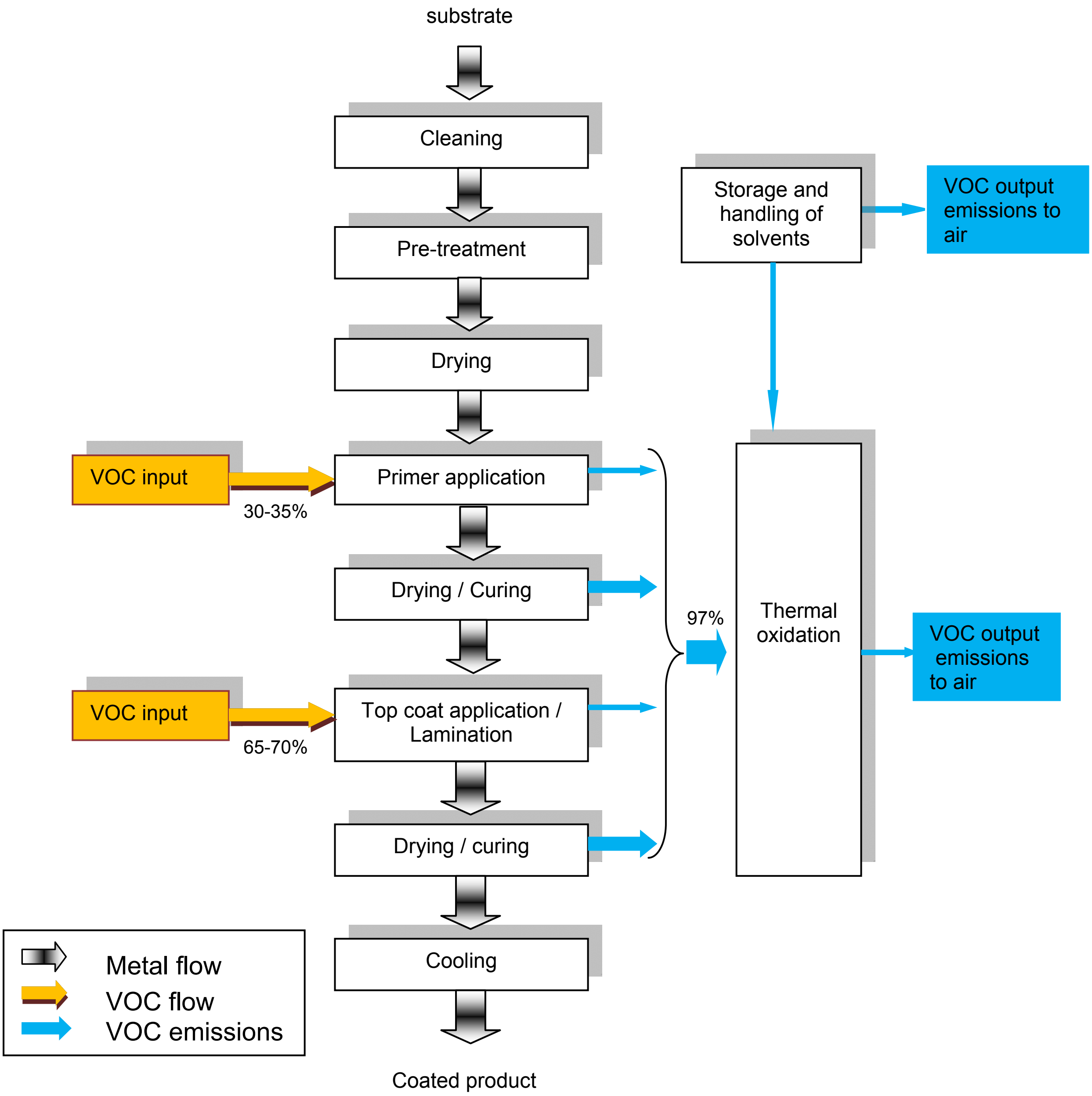

Figure 2: The possible VOC emission sources in a typical solvent based coil coating process

The drying / curing phases contribute the most to VOC emissions to air. Depending on the number of colour changes and the subsequent clean-downs of the equipment, the top-coat accounts for approximately 65-70% of the VOC emissions while 30-35% of emissions are from the primer (standard 25 µm top paint system with 5 µm primer, at the typical solvent loadings given in Table).

Around 97% of all the VOC emissions from the whole coil coating process can be captured. Fugitive VOC emissions make up the remaining 3%. [BREF STS 2007]

4.2 Process description

Coil coating is a continuous process. All production steps, from the winding of the substrate, through pre-treatment and coating application, through to the recoiling of the coated product, are carried out as a continuous sequence. Figure 33 presents an overview of a complete production line.

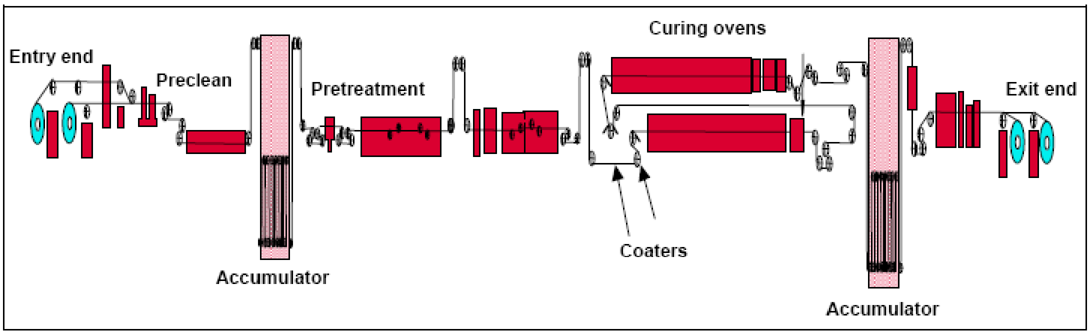

Figure 3: Schematic overview of a complete coil coating production line [ECCA 2008]

In the following the VOC relevant process steps of a typical coil coating production line are described.

Primer coat application

A primer coat is applied, by a roller coater, on one or both sides of the strip. The roller coater is adjusted to give the required primer thickness. Modern application systems are enclosed and the VOC emissions occurring are extracted and vented to the thermal oxidation unit.

PRIMERS ARE APPLIED EITHER ON ONE OR BOTH SIDES OF THE STRIP

After the primer application, the strip enters the drying oven where volatile compounds are evaporating. The metal strip is then cooled, by air or water based cooling systems or, in some instances, by both. The VOC containing air of the oven is also directed to the thermal oxidation unit.

Finishing coat (top coat) application

For the application of the finishing coat, the strip passes to a second roller coater machine. The top coat may be applied on one or on both sides.

In state-of-the-art plants, the application unit for the top coat is also enclosed and the air containing solvents is extracted and vented to the thermal oxidation unit.

After the metal strip has passed the coating area, it enters into a drying oven where the paint cures. The solvent laden exhaust gas from the oven is then passed to the thermal oxidation unit.

After the application of the top coat, the metal strip is cooled down and passed to the accumulator stack and to the recoiling unit.

IN THE LAMINATION PROCESS VOC EMISSIONS MAY RESULT FROM THE USE OF ADHESIVES OR SPECIAL BASE COATS

Lamination

Lamination means the application of thin laminate films on an adhesive layer or special coating layer, instead of a coating. The lamination process can be carried out at the same production line as the paint coating.

In case of laminate films, the adhesive or special coating required for the application can be applied with either of the roller coater heads. The thin polymer film is laid on the hot coating or adhesive layer by roll pressure, followed by a quenching and a drying step. In the lamination process, VOC emissions may result from the use of adhesives or special base coats. The; lamination film itself does not cause VOC emissions.

Cleaning activities

Organic solvents are also used for the clean-down of the equipment before a system or colour change. Generally, clean-down is much more frequent when applying the top-coat than for the primer. The cleaning of the equipment takes place in the area where off-gases are extracted, so solvent emissions are abated.

Cleaning solvents are in most cases collected and treated (usually off-site) so that they can be re-used, either as cleaning solvent again, in paint formulation or for other solvent applications. The solvent used for cleaning is generally not the same as used in the paint formulation because a very low-boiling solvent is required for cleaning while a relatively high-boiling solvent is required in paints.

4.3 Coatings used in the coil coating industry

Nearly all (> 99%) of the coatings used for coil coating are solvent based [ECCA 2008]. Powder coating systems are the only solvent-free applications commonly used in the coil coating industry. Although 7 powder coating lines exist in Europe, the overall consumption of powder coatings is marginal compared to the large amounts of solvent based products used by big production lines. Powder coating lines are typically very small with very limited capacities.

The film thicknesses that can be achieved with powder coatings are limited. It is currently not possible to achieve uniformity at less than 30 microns and so powder coating cannot be used to produce the thin films that can be achieved with conventional solvent based systems:

Solvent-based paint system (50 wt-%):	32-53 g/m² coil
Powder coating system:	60-80 g/m² coil

In addition the range of powder coatings that can meet the specific requirements of high speed coil coating production is still very limited.

Plastic laminates (representing 6% of coil-coating activities) also contain no solvent but their application is not solvent-free, since in almost every case, they require a solvent containing liquid base coat or adhesive layer for the lamination.

Table 3 below gives an overview of commonly used coil coating systems.

Table 3: Overview of coating systems typically used in the coil coating industry [BREF STS 2007, ECCA 2008]

Coating	Dry film thickness (µm)	Resin types	Solvent content (%)	Solvent types	Curing temperature (°C)
Primer					
Primers (conventional)	4-20	Epoxy/urea, Epoxy/ melamine, Polyester/melamine, Polyurethane, Acrylic	50-70	High boiling aromatics, alcohols, glycol ethers/esters, high boiling esters	210-230
Primers [42] (high build)	12-25	Polyester/melamine, Polyurethane	40-50		
Back coats					
Back coats	2-15	Polyester/melamine, Epoxy/ melamine, Epoxy/ phenolic, Alkyd/melamine	50-70	High boiling aromatics, alcohols, glycol ethers/esters,	180-250
Top coats					
Polyester	17-26	Saturated polyesters cross lined with melamine formaldehyde resins	35-55	High boiling aromatics, glycol ethers/esters, high boiling esters	210-230
SMP (silicone modified polyester)	18-25	As above except for silicone modification in the polyester resin	45-55		210-230
Polyurethane	18-30	Saturated polyesters with urethane cross-linking	30-50		220-240
PVDF PVF2	15-25	Polyvinylidene difluoride + acrylic polymer	40-65	High boiling aromatics, glycol ethers/esters, high boiling ketones	240-260
PVC plastisol	100-200	Polyvinyl chloride + plasticisers	< 10	High boiling esters, high boiling aliphatics	190-210
Water-based products (includes some primers and back coats)	1-25	Acrylic/melamine	5-15	High boiling esters, glycol ethers/esters	220-230
Non-stick bakeware coatings	12-15 (2-coat 7+7)	Polyether-sulphone PTFE	65-80	N-methlypyrrolidone, butyrolactone, high boiling aromatics	350-370
Laminate film coatings	15-120	PVC, PVF (polyvinyl fluoride), PET (polyethylene terephthalate), acrylic, polypropylene	0	None in film, but used in primer/adhesive	lamination at 180-230
Powder coating	35-100	Polyester/epoxy polyurethane	0	-	200-250

5 Solvent use, emissions and environmental impact

5.1 Solvents used

Various VOC containing products are used for coil coating (see section 4.3) and they commonly contain the solvents listed in Table 4.

SOLVENTS WITH SPECIFIC R-PHRASES ARE MOSTLY PHASED OUT IN THE COIL COATING INDUSTRY

Table 4: Overview of solvent types typically used for coil coating industry

Type of solvent	Some examples
alcohols	diacetone alcohol
glycol acetates	propylene glycol methyl ether acetate, ethyl diglycol acetate
glycols	butyl diglycol, propylene glycol monomethyl ether
high boiling esters	dibasic esters (DBE), mixtures of refined dimethyl esters of adipic, glutaric and succinic acids
ketones	isophorone
petroleum hydrocarbons	commercial aromatic fractions, xylol

Solvents with a specific R-phrase which are restricted by the SE Directive have been mostly phased out in the coil coating industry, namely those classified as R45, R46, R49, R60 and R61 or as halogenated R40. [ECCA 2008]

5.2 Solvent consumption and emission levels

In 2007 the coil coating industry consumed 200.000 tonnes of coating products. Assuming an average solvent loading of the coatings of 40-50%, the total solvent consumption from the paint used in the coil coating industry in the EU was 80 – 100 kilo tonnes in 2007.

Solvent is also used for cleaning apparatus, particularly during product changes. On some lines with frequent product changes the solvent for cleaning can amount to up to one third of the total solvent use.

Water based products and powder coatings make up less than 1% of the total products used.

An overview of the specific VOC emissions for the different systems is shown in Table 5 below.

Table 5: Specific VOC emission for different systems (average coating thickness: 55µm) [BREF STS 2007] [ECCA 2008]

Coating system	Specific VOC emission (g/m² coated coil)	Abatement technique
Solvent-based (50 wt-%)	28 – 29[1]	None
Solvent-based	<2.5	Thermal oxidation connected to oven
Powder coating	0 – 0.8[2]	None

[1]Emission levels with no further abatement of the air stream (compliance with SE Directive limit values has to be checked)
[2]VOC emissions relate to curing reactions rather than solvent use

With the installation of a thermal oxidiser the specific VOC-emissions per m² coated coil can be reduced significantly (< 2.5 g/m² coated coil), independent of the solvent content of the paint system.

Both paint and solvent consumption has increased steadily over the last years. ECCA estimates that in 2007 over 90% of installations had secondary VOC abatement technologies in place (some form of oxidiser). This could imply that although solvent use has increased (with total paint use) total VOC emissions will not necessarily have matched this. [ECCA 2008].

5.3 Key environmental and health issues

In coil coating industry a broad range of different solvents are used in the different paint systems as well as for cleaning activities.

VOC emissions, 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

- prime and top coating application

- drying processes

- cleaning operations

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

The process generates waste containing solvents which need to be disposed of in such a way that emissions to air, soil and groundwater are prevented or limited.

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 Powder coatings

Powder coatings are typically based on polyester resins and are 100 % VOC free. Powder coating is suitable for both steel and aluminium substrates, but it is not applicable for all end uses.

Powder coat particles are electrostatically charged either in a spray gun or in a cloud chamber and they are attracted to the earthed metal substrate. The subsequent drying or curing step is typically carried out by a combination of infrared and circulating hot air at temperatures of 180-250°C (during 1.5 to 2 minutes). For comparison, typical residence times in conventional coil-coating ovens are 15-30 seconds.

At present, powder coatings can only be applied to one side of the substrate and with only one layer. The typical layer thickness is 50 to 60 µm.

Powder coating is used for the painting of pre-formed items such as sanitary cabins, computer enclosures and for small volume and niche products. It does not generally provide the ‘heavy duty’ performance needed for coil-coated products that are subject to outdoor exposure. Powder coating of flat metal substrate is used primarily where small batch sizes and flexible colour changes are important.

No VOC emissions occur with the application of powder coatings, but odorous reaction products can occur during the curing process which might still require appropriate abatement technologies.

SLOWER LINE-SPEEDS AND RESTRICTION RELATED TO THE THICKNESS OF THE COATING ARE THE MAIN CONSTRAINTS RELATED TO POWDER COATINGS

Powder coating lines generally have a lower capacity than liquid applying coating lines because they run at a lower line speed (limited to 15 m/min). Typical capacity figures of powder coating lines are 4-8 kilo tonnes/year compared to 20-200 kilo tonnes/year of the liquid coating lines.

The production costs are higher than those of liquid coating processes due to slower line-speeds and to achieve a thin coating, (more expensive) powder is required with very small and tightly controlled particle size.

This cost penalty has prevented the widespread adoption of powder coating where traditional coil-coating can be used. It is not feasible to convert an existing liquid application production line to powder coating.

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 High solid coatings

The high solid coating systems, most typically used in coil coating processes, have a solids content of 70-95%. The most frequently used products use PVC plastisols with a solvent content of less than 10%.

THE MOST IMPORTANT HIGH SOLID PRODUCTS IN THE COIL COATING INDUSTRY ARE PVC PLASTISOLS

High solid coatings such as plastisols are typically applied with a higher film thickness (100-200 µm dry film thickness) than other solvent based paints (15-30 µm dry film thickness, average solvent content 50%). Therefore total quantity of solvent used (and so VOC emitted) per m² coated coil is often similar for both systems. For this reason, the use of high-solids coatings in the coil coating industry is generally not that effective related to the overall solvent emissions reduction.

High solid products can be applied using the same production lines as conventional solvent-based products. In general, high-solid coatings are less expensive per kg, but as they are applied at higher thickness, their application is often more expensive. They are only used if they provide the best way of achieving the required properties. A general switch from conventional products to high solid products is not possible.

Equipment maintenance costs might be higher for high solid coatings as the application places higher stress on the application rolls. The electrical energy needed to drive the coater might also be higher.

6.2.2 Reduced solvent coatings

REDUCED SOLVENT COATINGS WITH A SOLVENT CONTENT BETWEEN 30-40% ARE THE MOST PROMISING VOC REDUCED PRODUCTS FOR THE COIL COATING INDUSTRY

Reduced solvent coatings can offer a genuine reduction in the quantity of solvents used for the majority of coatings.

There are several drivers that prompted a reduction of the average solvent loading in recent years. These include reducing the cost of the solvent used, reducing the VOC emissions, and allowing faster line-speeds without increasing the solvent levels in drying ovens. However, standard paint systems still have solvent loadings in the range 30 – 40%.

Reducing the solvent loading in coatings can have an impact on paint flow and the rheology of the coating and so it must be done in a carefully controlled manner.

The operational costs of the equipment are similar to the conventional solvent-based coil coating but the costs for the coatings can be less.

6.2.3 Water based coatings

Water-based products used in the coil coating industry typically contain up to 25% of organic solvents.

Currently water based top coats are only suitable for a very limited range of end products. Water based coats are mainly applied as primer, backing or ground coating. The main difficulty is the switching between water-based and solvent-based systems. As water-based paints are not suitable for all applications, it is required to have both solvent and water products in place at the same installation.

Water-based products typically require higher energy for the drying process. In addition VOC abatement technologies are often still necessary due to the organic solvent content of the products.

Apart from the energy costs, the other operational costs of water based coatings are similar to conventional solvent based coatings. Problems might occur with corrosion in storage, pumping and application equipment. Therefore it may be necessary to replace existing equipment with stainless steel parts.

Amines are used for pH stabilisation of water based systems and some of these substances have a significant toxicity.

6.2.4 Laminate film coatings

Laminate films are solvent-free, solid polymer films that are applied to the substrate to achieve specific requirements such as stain resistance, hardness or decorative effects. Although the laminate films are solvent free, in almost all cases an adhesive or liquid coat layer is required as the basis for the film. For co-laminates (clear laminates over a liquid base coat) the base coat is often a solvent-based polyester coating. Compared to conventional solvent based products only one layer with VOC containing adhesives is required compared to at least two layers in case of conventional solvent based products with a primer and at least one layer of top coat.

The film is applied by a pressure roll onto a preheated metal strip with an appropriate base coat / adhesive (see also chapter 4.2).

LAMINATED FILMS ARE GENERALLY MORE EXPENSIVE THAN CONVENTIONAL COATING SYSTEMS

The use of laminate film coatings is generally more expensive than conventional liquid coatings and therefore they are only used as alternatives in case of very specific end use properties. Laminates are widely used in domestic appliances where their greater flexibility and toughness can allow more extreme metal forming. They are also still used extensively for applications such as external partition walls in shipbuilding. The decorative properties of laminates are often a feature of office furniture.

The cost of the film depends on factors such as thickness, colour and complexity of patterning or design. Laminate production lines also tend to have slower line-speeds than production lines for liquid coatings. In addition increased scrap levels are reported resulting in increased process costs.

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 in the coil coating industry:

7.1 Abatement technologies / End of pipe measures

7.1.1 Thermal oxidation (recuperative / regenerative)

Two types of thermal oxidiser are in common use in the coil coating industry - regenerative and recuperative. Both destroy VOCs by burning (oxidation). Regenerative oxidation tends to be more efficient than recuperative thermal oxidation as it uses the recovered energy to pre-heat incoming process air to oxidation temperatures (~ 800 °C). Consequently its operating costs are significantly lower than for recuperative oxidation systems. However, the capital cost of a regenerative oxidiser is significantly higher than for a recuperative system and for small installations, this additional investment cannot be recouped through reduced energy costs. Regenerative thermal oxidation systems are particularly effective for process streams with low solvent loading but their operating costs depend highly on the efficiency of the heat exchanger.

REGENERATIVE AS WELL AS RECUPERATIVE THERMAL OXIDIZERS ARE IN USE IN THE COIL COATING INDUSTRY

Recuperative systems are mainly used for small flow rates. At higher rates the systems are not cost effective.

Regenerative thermal oxidation systems are widely used because they are relatively insensitive to the composition and the concentration of the solvents in the process air. Thermal oxidation systems are used for concentration rates of 1-20 g/Nm³. Thermal oxidation efficiency rates of up to 99.9% are possible.

Thermal oxidation systems use the calorific content of the effluent stream VOCs. Therefore, after a warm up phase, regenerative oxidisers can run efficiently with little or no additional fuel for the oxidation process. The minimum VOC concentration for an autothermic oxidation process is 1-2 g VOC/Nm³.

Catalytic oxidation is an alternative to thermal oxidation that is sometimes applied for coil-coating. Whether catalytic oxidation is a viable option depends on the flow rate, solvent concentration and chemical composition of the waste stream feeding it. Since catalysts are vulnerable to poisoning, catalytic oxidation should only be used if the exhaust air does not contain catalyst poisons such as sulphur, halogens, polymers or heavy metals. The consequence is that the system cannot be applied for all painting systems.

DEPENDING ON THE WASTE GAS PARAMETERS, IN SOME APPLICATIONS CATALYTIC THERMAL OXIDIZERS ARE IN USE

7.2 Process improvements

The most effective process improvement measure for emission reductions is to enclose the system and to fit seals to the entrance and the exit of the ovens/driers. VOCs arising from the coating preparation should be extracted and vented to the waste gas treatment.

8 Summary of VOC emission reduction measures

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

Table 6: Measures for VOC substitution and VOC reduction in coil coating processes

Objectives	Description	Applicability
VOC-free Systems	Use of powder coatings	Limited applicability due to economic and performance factors
VOC-reduced Systems	Use of high solid coating systems	Only suitable for specific end-uses
	Reduced solvent coatings	Widely applicable in most cases
	Use of water-based coating systems	Limited applicability due to economic and performance factors
	Use of lamination systems	Only suitable for specific end-uses
Process Improvements	Enclosure and air extraction of coating preparation area for waste gas treatment	Applicable in all cases
Abatement Technologies	Recuperative thermal oxidation	Widely applicable but not as effective as regenerative
	Regenerative thermal oxidation	Restricted to larger installations due to capital cost
	Catalytic thermal oxidation	Restricted to installations with well defined and constant waste gas parameters and catalyst poisoning free exhaust gases

9 Good practice examples

9.1 Example 1: Use of Reduced-Solvent Polyester Paints

One major paint supplier has been working with four coil coaters to reduce the solvent content of polyester paints. Of all the paint types used, polyesters account for over 50% of top-coats and the vast majority of backing coats, so modifications to polyesters can make a very significant difference. New generations of polyester resins and careful choice of solvents have allowed solvent loadings to be reduced without having a detrimental effect on viscosity and flow properties.

The principal drivers for these developments have been to reduce total paint cost and to increase running speeds where line-speed is limited by VOC concentrations in the curing ovens. The efficiency of the abatement used on most coil coating installations means that these reductions in solvent usage have not had a significant effect on overall VOC emission rates.

The minimum permissible solvent levels in a polyester paint will depend on many factors including the colour, pigmentation, viscosity requirements and line running conditions. Reduced solvent paints will not be applicable on all lines, but across four major customers, it was found that an average reduction in solvent usage of over 6% can be achieved. The table gives more data on this.

Coating type	Volume of paint supplied [t/a]	Solvent content prior to change	Solvent content after change	Solvent saved [t/a]
Customer A	363	45%	38%	25
Customer B	168	41%	36%	8.5
Customer C	75	42%	36%	4.5
Customer D	36	45%	37%	2.5

In 2007, nearly 79,000 tonnes of polyester paint were used in the coil coating industry. Assuming that for half of this paint a reduction in solvent content could be achieved which is similar to the one illustrated here, this could lead to overall savings of over 2,000 tonnes of solvent usage per year in this sector.

[BASF 2008]

9.2 Example 2: Use of Water Reducible Epoxy Backer

The use of a water reducible backer (back coat) has been applied on aluminium substrates in at least one coil coating line in Europe. The water reducible backer (solvent content 20%) substituted solvent based coatings containing 50% solvent. In total the water reducible backer constituted approximately 5% of the site's total paint usage resulting in a total VOC reduction of 3%.

Water backers typically contain less than 20% solids and less than 20% solvent, with the remainder being water. The solvent is required to ensure that the polymer within the paint remains miscible in water.

There are numerous important limitations associated with the processing and end uses of this backer, these being, in summary:

- The coating offers no weathering resistance and no corrosion resistance so it cannot be used e.g. on steel.
- The coating is only suitable for thin film applications, where the dry film thickness required is not more than five microns. This is due to the fact that the wet film thickness requirement is approximately five times that of the dry film (based on 20% solids content) and wet film thicknesses of over 25 microns with 80% volatile material would cause processing problems on coil coating lines such as solvent boil.
- Widening the usage of water containing coatings at a line built for organic solvent coating may result in processing (equipment) problems such as flash rusting of ovens and flue liners.
- The availability of resins for water-based systems is limited.
- Only water miscible solvents are suitable for use in water containing coatings. These tend to be glycols, as opposed to aromatic hydrocarbons and esters. The glycols are more hazardous from the safety perspective and hence tend to have lower workplace exposure limits.

[ECCA 2008]

10 Emerging techniques and substitutes under development

10.1 UV/EB radiation curing

This technology uses paints that are cured with ultra violet / electron beam (UV/EB) radiation. This results in a solvent-free process with a relatively low energy penalty. Currently no commercial applications are known for coil coating. There are significant technical challenges still to overcome and radiation-cured coatings may not be suitable for all applications. Moreover, it is unlikely that existing installations would switch, due to the high capital cost of curing technology. [ECCA 2008]

10.2 Development of VOC-free or VOC reduced products

There is continuing technical progress in increasing the solids content of coil coatings.

The technical feasibility of powder coatings has been proven in major coil coating lines but its economic viability is not yet proven. It is continuously under review.

[ECCA 2008], [BASF 2008]

11 Information sources

[SE Directive 1999]
Council Directive 1999/13/EC of 11 March 1999 on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations

[BASF 2008]
BASF, UK, personal communication, 2008

[BREF STS 2007]
EU Commission: Reference Document on Best Available Techniques on Surface Treatment using organic solvents, August 2007

[DEFRA 2004]
DEFRA, Department for Environment, Food and Rural Affairs, Scottish Executive, Secretary of State's Guidance for Coil Coating, Process Guidance Note 6/13 (04)

[EGTEI Synopsis Sheet]
Coil Coating– Synopsis sheet, prepared in the framework of EGTEI, 04. Sept. 2006
http://www.citepa.org/forums/egtei/18-Synopsis-sheet-coil-coating-30-09-05.pdf

[ECCA 2008]
ECCA, European Coil Coating Association, Belgium, personal information, 2008 Mr. Graeme Peacock, http://www.eccacoil.com

[ECCA DE]
ECCA-Gruppe Deutschland e.V., http://www.ecca.de/

[Henkel 2008]
Henkel AG & Co. KGaA, 2008 http://www.henkel.de/