Vehicle coating
Solvent use and BAT in motor vehicle paint shops

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ACEA

IN THE NEXT 20 MINUTES...

• Environmental relevance of vehicle paint shops
• What has been done in the last 10 years
• Rounded off by a 5 min crash course in vehicle painting
MOTOR VEHICLES

Passenger cars

Vans

Trucks and truck-cabins

cargo body or customized equipment is assembled after the chassis is coated, generally in separate facilities by specialized equipment manufacturers

Buses

MOTOR VEHICLE PAINTING OBJECTIVES

Customer requirements

Appearance

Design / Fashion:
- 2 tones
- metallic, pearlescent

Lightweight designing:
- multimaterial body

Quality:
- anti rust guarantee

Environmental protection

Manufacturing:
- cost efficiency

Workplace health & safety

© VW

© Renault

© MAN

© FIAT
COATING PROCESS

**Coats**

- Surface
  - CC – clear coat
  - BC – base coat
  - PR – primer
  - EC – electro coat
  - PHO – phosphate

- Metallic body
  - 0.6 – 1.2 mm

- Seams & Underbody
  - 2 – 4 mm
  - SD – sealer, damping

**Processes**

- **Pretreatment & e-coat line**
  - Body shop
  - PT cleaning, phosph.
  - EC E-coat
  - EC-Oven

- **Sealing & damping line**
  - PT
  - sanded/repaired
  - SD spray
  - SD-Oven

- **Primer line**
  - PT
  - PR primer
  - PR-Oven
  - sanding

- **Top coat line**
  - PT
  - BC spray
  - Intern. dry
  - CC spray
  - CC clear coat
  - TC-Oven

- **Finish & wax line**
  - FI
  - Finish, repair
  - CP Cavity wax

- **Assembly**

**NM VOC EMISSIONS 2012 IN THE EUROPEAN UNION**

Total anthropogenic emission: 9 817 Gg

- 3 A 2 Industrial Coating: 539 Gg = 5.8 %

1 Gg = 1000 tons

Comparison of ACEA data for motor vehicle coating and published data from national emissions inventories show that less than 0.5 % of NMVOC emissions are caused by vehicle coating.

http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emepdatabase/
VOC EMISSIONS OF EU PASSENGER CAR PAINT SHOPS

Determination of total emissions: mass flow $E_{\text{mass}}$ in kg/a:

- **Direct method**: Measurements at all fugitive and point sources.

- **Indirect method**: Consumption of solvents.

  - VOC destroyed or transferred in waste.

$$O_1 + \text{Fugitive} = E_{\text{mass}} = C - O_5 - O_6$$

Moderate costs, use of available data, reliable. Generally applied in the automobile industry.

**Determination of electro-coat surface** $A_{EC}$ in m²/a

$$A_{EC, \text{veh}} \times n_{\text{veh}} = A_{EC}$$

$A_{EC}$ surface is a reference surface (not the painted surface).

**Calculation of total emissions in g/m²**

$$E = E_{\text{mass}} / A_{EC}$$
FACTORS THAT INFLUENCE SOLVENT CONSUMPTION AND VOC EMISSIONS

- **Product requirements**
  Painted surface, custom requirements on appearance and fashion (special effect colours, 2-tone), availability of water based paints (fleet colours)

- **Paint shop design, application techniques and abatement measures**
  Consumption of solvents and emissions of VOC depend on the
  - application of many different techniques,
  - which might be different in each process step or paint shop line
  - and cannot be combined arbitrarily

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VOC REDUCTION MEASURES

**Spray subprocess (PR, BC, CC)**

<table>
<thead>
<tr>
<th>Secondary (end of pipe)</th>
<th>abate</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC (Overspray)</td>
<td></td>
</tr>
<tr>
<td>Spray booth</td>
<td></td>
</tr>
<tr>
<td>dryer (50-80 °C)</td>
<td></td>
</tr>
<tr>
<td>oven (120-160 °C)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary (process-integrated, optimisation)</th>
<th>avoid, reduce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray subprocess (PR, BC, CC)</td>
<td></td>
</tr>
</tbody>
</table>

**Paint concept** (choice of paint systems and paint shop design)
PRIMARY MEASURES (PROCESS-INTEGRATED)

- **High first run rate**
  - Clean room spray cabins
  - Air-locks with body dusting

- **High paint transfer efficiency**
  - Automation
  - Rotary atomisers (bells) with electrostatic charging

- **Low loss colour changers and cleaning techniques**
  - Capturing of cleaning solvents / paint at colour changes

- **Reduction of VOC content in coatings and solvents/cleaners**
  - High solid paints
  - Replacement of solvent cleaners by detergents

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PRIMARY MEASURES (PROCESS-INTEGRATED)

- **Driving forces: product quality, cost per unit**
- **Environmental benefit without or with acceptable additional cost**
- **Achieved VOC reduction in the last 10 years: (10 ± 5) g/m², depending on local conditions**
- **Can be retrofitted in existing paint shops, but limitations of applicability must be taken into account**
- **Standard for new installations**
SECONDARY MEASURES (END-OF PIPE)

- **Waste gas treatment (WGT) of VOC in dryer oven waste gases**
  - E-coat → EC-Oven → Sealing/drying → SD-Oven → Primer → PR-Oven → Base coat → Dryer → Clear coat → TC-Oven
  - Oxidisers with internal energy recovery (recuperative or regenerative)
  - Low volume flows
  - Often used (if high VOC raw gas concentrations)

- **Waste gas treatment (WGT) of VOC in spray booth waste gases**
  - E-coat → EC-Oven → Sealing/drying → SD-Oven → Primer → PR-Oven → Base coat → Dryer → Clear coat → TC-Oven
  - Mostly in combination with external accumulation of VOC (adsorption wheels)
  - Mostly oxidisers with internal energy recovery (recuperative or regenerative)
  - Seldom used (very high waste gas volumes with low/medium VOC concentrations, high energy consumption)

SECONDARY MEASURES – END OF PIPE

- **Driving forces: environmental protection**
- **Additional invest and running cost**
- **Achievable VOC reduction depends on raw gas mass flow**
- **Cross media effect: energy consumption, NOx and CO emissions**
- **Dryer oven waste gas treatment standard in new paint shops**
  (exceptions for low raw gas mass flows)
PAINT CONCEPTS: PAINT SHOP FAMILIES

- In a paint shop usually 3 - 4 paint layers are applied in successive steps
- Depending on solvent composition three paint shop families have been evolved in the last 30 years

<table>
<thead>
<tr>
<th>Family</th>
<th>% EU</th>
<th>Primer</th>
<th>Base coat</th>
<th>Clear coat</th>
</tr>
</thead>
<tbody>
<tr>
<td>SB</td>
<td>15</td>
<td>SB</td>
<td>SB</td>
<td>Oven (opt.*)</td>
</tr>
<tr>
<td>SB-Mix</td>
<td>29</td>
<td>WB</td>
<td>SB</td>
<td>WB</td>
</tr>
<tr>
<td>WB</td>
<td>56</td>
<td>WB</td>
<td>WB</td>
<td>Oven</td>
</tr>
</tbody>
</table>

**SB** = Solvent based (35 – 89 % VOC)
**WB** = Water based (5 – 17 % VOC)

*) = not for integrated processes (IP), IP is an umbrella term for several new paint processes introduced since ~2000 and actually used in ~18 % of all paint shops

SUBSTITUTION IS A FUNDAMENTAL CHANGE

<table>
<thead>
<tr>
<th></th>
<th>Solvent based</th>
<th>Water based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spray coating system:</td>
<td>Solvent based</td>
<td>Water based (except clear coat)</td>
</tr>
<tr>
<td>Intermediate dryer between base coat and clear coat</td>
<td>Short flash-off zone (not in all cases)</td>
<td>Intermediate dryer (with T = 50 – 80 °C, t = 5 – 10 min) and in/out air-locks necessary, typical length: 35 – 55 m (+ 75 % of total length of a top coat line).</td>
</tr>
<tr>
<td>Primer dryer oven heating curve</td>
<td>No temperature hold below 100 °C</td>
<td>5 – 10 min. temperature hold necessary to evaporate water before surpassing the boiling point temperature.</td>
</tr>
<tr>
<td>Construction material for paint booths</td>
<td>Standard galvanised steel</td>
<td>Stainless steel for all parts in contact with paint</td>
</tr>
<tr>
<td>Use of electrically charged bells</td>
<td>Automatic application</td>
<td>Automatic application. Electrically disjoined paint supply system necessary</td>
</tr>
<tr>
<td>Paint window</td>
<td>Broader than for water based paints</td>
<td>Restrictions in range of humidity. Depending on local climate conditions additional equipment for air conditioning</td>
</tr>
</tbody>
</table>
CHOICE OF PAINT CONCEPTS

- The choice of the coating system entails fundamental and mostly irreversible differences in the design of the paint shop.
- In existing sites such a fundamental change can be done only if
  - there is room to build a second paint shop (or paint shop line) in parallel without interrupting the existing one,
  - and where the new paint shop can be linked to the body and to the assembly shop.
  - if production can be interrupted for a longer time (> 4 weeks), which is normally not the case in the vehicle industry.
- Each production line is normally dedicated to only one single model of the product range of a company.
- Due to these constraints such a transformation is very expensive and is rarely made.
- A decision for a certain paint concept is usually made for new paint shops.

EVALUATION OF VOC REDUCTION MEASURES

<table>
<thead>
<tr>
<th>Measure</th>
<th>Implementation time</th>
<th>Costs</th>
<th>Potential tradeoffs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Short - long</td>
<td>• High invest</td>
<td>• Quality / Appearance loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• long pay back</td>
<td>• Run up difficulties</td>
</tr>
<tr>
<td>Secondary</td>
<td>Short</td>
<td>• High invest</td>
<td>• More energy use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• high operational cost</td>
<td>• more CO₂ emissions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• no payback</td>
<td>• additional emissions of dust, NOₓ, CO</td>
</tr>
<tr>
<td>Paint concept</td>
<td>Long (new or major</td>
<td>• Can reduce operational costs</td>
<td>• Quality loss</td>
</tr>
<tr>
<td></td>
<td>refurbishment)</td>
<td></td>
<td>• Appearance loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Run up difficulties</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Longer interruption not acceptable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Production losses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Site layout constraints</td>
</tr>
</tbody>
</table>
SUMMARY AND CONCLUSION

• VOC emissions have been halved in the last 10 years.
• The contribution of motor vehicle paint shop emissions to anthropogenic NMVOC emissions in the EU has been reduced to below 0.5%.
• This has been achieved by a combination of
  o Primary measures (process optimisation),
  o Secondary measures (waste gas treatment),
  o Introduction of paint concepts with low VOC paints (mainly in the context of startup of new plants).
• The applicability of each measure has to be evaluated case by case.
• Achievable emission reductions are different for existing and new installations
• Further reduction of VOC emissions will be slow and very expensive.
PAINT SHOP FOR COATING OF PASSENGER CARS

Typical line: 30 u/h, 85 000 m² floor, line length 1.5 km; processing time 6 – 11 h:
### KEY ENVIRONMENTAL ISSUES

**Ressource consumption**
- Solvents / Paints
- Energy
- Water

**Releases into air**
- VOC: volatile organic compounds
- PM: particulate matter
- NOx, CO: Nitrogen oxides, Carbon monoxide
- CO2: Carbon dioxide

**Releases into water**
- COD: Chemical oxygen demand
- Metals: (Heavy) metals, Ni, Zn

**Waste**
- Paint sludge / paint filter dust
- Solvent
- Phosphate sludge

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### EMISSION REDUCTION 1987 – 2014 - EXAMPLE FRANCE

[Graph showing Emission Reduction](source: CITEPA)

- 77% in 27 years
Supplementary information

VOC EMISSIONS OF EU PASSENGER CAR PAINT SHOPS 2012

PAINT SHOP SOLVENT BALANCE (SOLVENT MANAGEMENT PLAN)

Determination of total emission E:

\[ E = O_1 + O_2 + O_4 = C - O_5 - O_6 \]

direct method
going indirect method

Example: paint shop without spray booth VOC abatement
High first run rate

- Dusting
  - Airlocks at spray cabins with dusting equipment for bodies:
    - ionised air blow-off stations
    - rotating feathers
    - robot-operated suction brushes
- Clean room conditions
  - Particle filters in spray cabin AHU
  - Special work-clothes
  - Airlocks for operators and maintenance personnel

TRANSFER EFFICIENCY

- Manual application
  - Only with air-spray
  - Exterior until 2000
  - Hard to reach areas
  - Special cases
- Airspray (HVLP)
  - Automatic & manual
  - Exterior: until 2000
  - Interior: until 2012
  - Still applied in special cases
  - Transfer efficiency: 25 – 45 %
- Paint machines
  - Air-spray or bells
  - Many spray-heads
  - Interior: not applicable
- Rotary atomiser (Bell)
  - Only automatic
  - With internal or external electrostatic charging
  - Exterior since 2000
  - Interior: since 2012, ongoing
  - Transfer efficiency: 50 – 85 %
- Robots
  - Mainly bell atomisation
  - Interior: 2010 - ongoing

Supplementary information
COLOUR CHANGE / PURGING

A. Pigging systems
Reclamation of color from piping systems at colour changes

B. Integration in robot arm

C. Low loss technology

D. Collection of purge solvents

C1. Colour changer old
Paint reservoir must be purged at colour change
Loss:
- Paint: 25 ml
- Solvent: 250 ml

C2. Colour changer new
Direct coupling of supply line to feed line with rotational or linear valve skid
Loss:
- Paint: <10 ml
- Solvent: 150 ml

WASTE GAS TREATMENT - DRYER OVEN

Regenerative or recuperative thermal oxidation

- Raw gas volume from dryer oven: 8 000 – 20 000 Nm³/h
- Dedicated to each dryer oven or centralised waste gas treatment plant
- Reduction effect depends on raw gas mass flow
- Crossmedia effects: energy consumption, NOx, CO emission, ....
- Invest and running cost

Example: combined recuperative postcombustion with dryer heating (schematic)
VOC accumulation and incineration

- Raw gas mass flow:
  - without cabin air recirculation: 80,000 - 300,000 m³/h (large adsorption wheels necessary)
  - with cabin air recirculation: 20,000 - 50,000 m³/h (not possible in combination with wet paint overspray scrubbers)
- Reduction effect depends on raw gas mass flow
- Crossmedia effects: high energy consumption, NOx-, CO emission, ....
- Very high invest and running cost