Emission Techniques and Related SCR Systems by Ecocat and Albonair

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- Ecocat and Albonair collaboration
- V-SCR catalyst
- Urea dosing technology
- Optional elements
  - Hydrolizing catalyst
  - Ammonia slip catalyst
- Summary
Ecocat Oy ("Ecocat") is a leading emission technology company operating in the growing market for catalytic converters

- Leading industry pioneer with market presence since 1985
- Ecocat is ISO-TS16949 and ISO14001 certified.

Broad range of application areas in the global markets for
- Passenger & light commercial vehicles
- Heavy commercial vehicles (trucks, buses)
- Off-road (agricultural, rail, marine)
- Industry (stationary engines, VOC incinerators)

Capabilities for complete delivery of catalytic converters from substrate to canning
- In-house manufacturing of durable metallic substrates
- Coating expertise for both metallic and ceramic substrates
  Canning capabilities for different catalyst types
Ecocat Group

- Approximately 290 employees in five countries
- Sales agents close to customers
Ecocat's Products are Organized Around Four Business Areas

Passenger and Light Commercial Vehicles

Heavy Commercial Vehicles

Industry

Off-Road
Albonair - Company Overview

Development of Albonair

2007
Albonair is founded as part of Hinduja's Automotive Sector 100% privately owned by Hinduja Group

2008
Albonair delivers first prototypes of SCR-Systems to customers

2009
Albonair India is founded to set up a production facility for a local customer

2010
SOP of exhaust aftertreatment solutions for the Indian market
Albonair moves into a new headquarter in Dortmund, Germany

2012
SOP of EURO VI-UDS for an European OEM
<table>
<thead>
<tr>
<th></th>
<th><strong>ECOCAT</strong></th>
<th><strong>Albonair</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast growing European company, OEM supplier status</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>High-class technology for diesel exhaust aftertreatment</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Flexibility and intimacy to solve customers' challenges</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Focusing on the key projects</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Global presence with covering customer interface</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Localized production sites and competence centers to serve customers</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>All the catalytic elements available, substrates and coatings together with canning</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>All the SCR urea dosing system dosing components and system integration know-how available</td>
<td></td>
<td>✓</td>
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</tbody>
</table>

Two companies matching perfectly to enhance own success together by providing complete customized and well-integrated solutions
Complete diesel aftertreatment system

Based on application, normally only some of above are needed

Ecocat has the whole range of catalysts in portfolio; substrates and coatings

Together with partners, the complete systems tailored to fulfill customers requirements
Vanadia-based SCR catalyst
Reactions in SCR systems

PreOxicat: \( NO + O_2 \rightleftharpoons NO_2 \)

Hydrolysis: \( CO(NH_2)_2 CO + H_2O \rightarrow 2 NH_3 + CO_2 \)

SCR catalyst

- Standard SCR: \( 4 NO + 4 NH_3 + O_2 \rightarrow 4 N_2 + 6 H_2O \)
- Fast SCR: \( NO + 2 NH_3 + NO_2 \rightarrow 4 N_2 + 3 H_2O \)
- \( NO_2 \)-SCR: \( 4 NH_3 + 3 NO_2 \rightarrow 3.5 N_2 + 6 H_2O \)

PostOxicat: \( 4 NH_3 + 3 O_2 \rightarrow 2 N_2 + 6 H_2O \)

Optimization of DOC together with H-kat and SCR needed:
- \( NO_2 \) formation, backpressure, temperatures and costs
SCR activity by engine experiments

Criteria NO$_x$ conversion at 280°C

NH$_3$ slip $<20$ ppm

$\rightarrow$ 98% NO$_x$ conversion
SCR activity by engine experiments
Engine 6.9 L; Catalyst 12.8L, 500 cpsi

NOx conversion curve

NOx conversion, %
(NH3 < 20 ppm)

Temperature, °C

200 250 300 350 400 450 500 550

28.000 h⁻¹
465 ppm NOₓ

61.000 h⁻¹
1170 ppm NOₓ

57.000 h⁻¹
990 ppm NOₓ

16.500 h⁻¹
1420 ppm NOₓ

51.000 h⁻¹
930 ppm NOₓ

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Effect of NH₃ slip criteria limit

Urea-SCR engine results - MAN 6.9L, 15 h aged
KSCR2, 500 cpsi, 12.7L

→ No significant changes in performance
→ without any additional NH3 slip catalyst
Effect of cell density (surface area)

- Ecocat 220 cpsi
- Ecocat 350 cpsi
- Ecocat 500 cpsi

Target conversions:
- Euro 6/US2010
- Euro 5
- Euro 4

Graph showing the effect of temperature on criteria NOx conversion for different cell densities.
Ecocat SCR: the first EPA and CARB approval for V-SCR (off-road)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF TRANSPORTATION AND AIR QUALITY
WASHINGTON, DC 20460

CERTIFICATE OF CONFORMITY
2010 MODEL YEAR

Manufacturer: AGCO SISU POWER INC.
Engine Family: ASIDL08.4H6A

<table>
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<tr>
<th>MODEL YEAR</th>
<th>ENGINE FAMILY</th>
<th>DISPLACEMENT (liters)</th>
<th>FUEL TYPE</th>
<th>USEFUL LIFE (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>ASIDL08.4H6A</td>
<td>8.4 &amp; 9.8</td>
<td>Diesel</td>
<td>8000</td>
</tr>
</tbody>
</table>

SPECIAL FEATURES & EMISSION CONTROL SYSTEMS
Direct Diesel Injection, Turbocharger, Charge Air Cooler, Engine Control Module and Smoke Puff Limiter, Selective Catalytic Reduction

TYPICAL EQUIPMENT APPLICATION
Tractor
The reasons to develop improved V-SCR for high-temperature applications

- The SCR chemistry need to be durable for high-temp applications, too
  - Of-road full-load drivings
  - Need to be applicable for the usage together with DPF (Euro5 and beyond)
  - Cu-zeolite limitations (N$_2$O formation, sulphur sensitivity, NO$_2$ sensitivity)
Laboratory results

- HT700/20h
- Inlet: NO 1000 ppm, NO₂ 0 ppm, NH₃ 1000 ppm, O₂ 10 %, H₂O 8 %, N₂ bal.
- 600 cps, SV = 50 000 h⁻¹
Laboratory results

- HT700/20h
- Inlet: NO 600 ppm, NO\textsubscript{2} 400 ppm, NH\textsubscript{3} 1000 ppm, O\textsubscript{2} 10 \%, H\textsubscript{2}O 8 \%, N\textsubscript{2} bal.
- 600 cpsi, SV = 50 000 h\textsuperscript{-1}
Urea dosing and control units for complete systems
Albonair Product Portfolio

<table>
<thead>
<tr>
<th>Diesel Particulate Filter</th>
<th>Selective Catalytic Reduction System</th>
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<tr>
<td>Diesel Oxidation Catalyst</td>
<td></td>
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<tr>
<td>DPF / DOC</td>
<td>Urea Tank</td>
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<td></td>
<td>ACU &amp; UDS</td>
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<tr>
<td></td>
<td>SCR-Muffler &amp; Nozzle</td>
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</table>

» Albonair offers complete exhaust aftertreatment systems
Urea Dosing Units for Different Markets

EURO 4 (e.g. Emerging Markets)

EURO 6 (e.g. Europe)

Tier 4 Final (e.g. Off-Road vehicles)

EURO 6 Passenger Car (e.g. Europe, USA)
Concept of Albonair's SCR System

Schematics

- Urea level
- Urea temperature
- Air pressure
- Urea pressure
- Urea temperature
- CAN
- Engine ECU

**Engine Coolant**

**AdBlue Tank**

**Dosing System**

**Electronics (ACU)**

**Air Supply** (vehicle air or electrical air pressure)

**SCR Muffler with Injection Nozzle**

- Temp. Sensor
- Nozzle
- NOx sensor
- Temp. Sensor

**Exhaust stream**
<table>
<thead>
<tr>
<th>System</th>
<th>Spray Formation</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Atomizer (Airless)</td>
<td><img src="image1.png" alt="Pressure Atomizer Diagram" /></td>
<td>» Energy for atomization from the liquid pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Increase of pressure leads to improved spray quality</td>
</tr>
<tr>
<td>Twin Fluid Atomizer with internal mixing (Air Assisted)</td>
<td><img src="image2.png" alt="Twin Fluid Atomizer Diagram" /></td>
<td>» Energy for atomization from air pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Typically high air consumption</td>
</tr>
<tr>
<td><strong>Albonair’s Concept is based on:</strong></td>
<td><img src="image3.png" alt="Albonair Diagram" /></td>
<td>» Energy for atomization mainly from air pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» Low air consumption</td>
</tr>
<tr>
<td></td>
<td></td>
<td>» No contact between AdBlue and air in the dosing system / nozzle to avoid crystallization and deposits</td>
</tr>
</tbody>
</table>

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Technical Background
Evaporation Rates for Different Droplet Distributions

@Exhaust velocity 50 m/s and Low temperature (300 °C)

Even at 300 °C small droplets of SMD 21 μm evaporate completely within 600 mm
Very poor evaporation for big droplets SMD 96 μm
**Technical Background**

NH$_3$ and HNCO decomposition improve with Albonair UDS

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**Test Conditions:**
HD Dieselengine 12l, Hydrolyse Tube 600mm, Measurement HNCO and NH$_3$ using FTIR

- Significant increase of AdBlue Hydrolysis
- Better Nox-Conversion at the SCR Catalyst
- Less deposits in the exhaust system
Catalyst Efficiency improved at low Exhaust Mass Flow
Little NH₃-Slip

Low Exhaust Mass Flow
200 - 250 kg/h

High Exhaust Mass Flow
600 - 1000 kg/h
The importance of proper urea distribution

Proper design is an essential part of SCR technology to ensure that urea is well distributed and decomposed to ammonia before SCR catalyst.
Optional elements for SCR technology

Hydrolizing catalyst
Ammonia slip catalyst
Urea hydrolysis

Thermal or catalytic hydrolysis of urea important in the limited space of exhaust lines at low temperatures

$$\text{(NH}_2\text{)}_2\text{CO} \rightarrow \text{NH}_3 + \text{HNCO} \quad >200^\circ\text{C}$$  \hspace{1cm} \text{thermolysis}

$$\text{HNCO} + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{CO}_2 \quad >200^\circ\text{C}$$  \hspace{1cm} \text{hydrolysis}

→ enhancement with EcoXcell mixers in particular at low temperatures
→ possible to have good mixing, urea nozzle near to SCR and combinatory properties
Metallic substrate for mixers and H-catalysts

**EcoXcell®**
- Welded, mixer-type structure for coated catalysts having efficient 3D mass and heat transfer
- EcoXcell 20° for SCR applications
  → **Hydrolysis catalyst coating**
  → **SCR catalyst coating**
How to utilize H-cat in SCR?

1) Combination of SCR catalyst coated EcoXcell mixer-catalyst and SCR catalyst
   Optimized mixing and total SCR catalyst amount

![Diagram]

2) Small EcoXcell substrate (25 cpsi) as urea dosing mixer: to enhance hydrolysis
catalyst reactions to avoid any urea accumulation

![Diagram]

Note: also inlet tube (and cone) surfaces can be coated by H-Cat, to avoid any accumulation and corrosion
H cat only
laboratory experiments

Product distribution with blanco substrate
Nominal inlet: 1000 ppm NO, no NO₂, 500 ppm Urea, 10 % O₂, 8 % H₂O, N₂ balance
SV = 100 000 h⁻¹

~25 % of urea unreacted, no additional NH₃
H cat only
laboratory experiments

Product distribution with HT700 KH1.1+KH2.2 (good adhesion/improved selectivity)
Nominal inlet: 1000 ppm NO, no NO₂, 500 ppm Urea, 10 % O₂, 8 % H₂O, N₂ balance
SV = 100 000 h⁻¹
The enhancing effect of H-kat at low temperature

Significant effect on SCR activity by utilising H-kat in front of SCR obtained Studied by 4.9 l engine (H-kat size D105 x L 100 mm)
The role of ASC, NH3 slip control

Effect of ASC

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SUMMARY

- Ecocat-Albonair combination provides unique, one source solution
- All the elements available for meeting Euro6 requirements
- SCR chemistry proven to be extremely durable
- Competitive and cost-efficient urea dosing systems
- Clear technical benefits for NOx performance
- H-CAT and ASC elements available for the most challenging targets