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Graphic Design STAR Srl, Italy
THE STAGE V CHALLENGE

Technological excellence and product innovation for FPT Industrial represent the truly determining factor and part of its primary strategic mission. The company has focused its research and development activities in order to become the innovation leader in the agriculture and construction powertrain field and a reference provider of the most cost efficient powertrain solutions for Tier 4B/Stage IV.

FPT Industrial complies with emission legislations ensuring a minimal impact on the vehicle architecture and the lowest possible increase in cost, an objective that is achieved through HI-eSCR technology. The breakthrough patented technology, based on an experience of more than 11 years and 500,000 engines produced, allows our engines to meet Tier 4B/Stage IV guaranteeing a very high NOx conversion efficiency (over 95% versus 80-85% of best competitors), without resorting to ec-EGR and DPF.

To comply with future Stage V emissions, FPT Industrial confirms its long-term SCR-only strategy. It’s one of the few manufacturers to retain an Exhaust Gas Recirculation (EGR) free solution, continuing the competitive advantages achieved with HI-eSCR, such as best in class in fuel economy and best in class in power and torque density.
During the combustion process, inside a Diesel engine, the chemical energy is transformed into a mechanical one. Because of the chemistry of combustion, several toxic substances are produced, of which the most harmful are Nitrogen Oxides (NOx) and Particulate Matter (PM).

Since 2011, when Tier 4A/Stage IIIA came into force, many efforts have been made to reduce pollutants that are damaging the environment.

Tier 4B/Stage IV compliance, introduced in 2014, implied a further significant reduction of NOx (-80% vs. Tier 4A/Stage IIIA levels), while PM is not affected by further reduction, having already reached a 90% abatement in the previous step.

A further step in European legislation is under discussion: based on current EU Commission Proposal, the new Stage V emission standard is expected to be introduced for non-mobile machinery starting from January 2019/2020, depending on engine power level.

According to the proposal, Stage V regulation will tighten limits on PM emissions, by further reducing the admitted quantity of PM by 40%, and introducing a limitation also on the number of emitted particles (Particle Number Limit, PN).

In addition, Stage V regulation will involve power ranges currently with lighter or no legislation at all (power range below 37 kW and above 560 kW).
After the introduction of Tier4B / Stage IV emission limits in 2014-2015, a further regulation re-enforcement is under discussion for European Non-Road applications; new Stage V regulation is expected to be introduced in 2019 or 2020 depending on power levels.

Emission Durability Period: 8000 hours, 10 years

No new type approval in Europe for existing emission stage permitted in the year before new emission stage introduction

NE: no emission regulation in Europe for P < 19 kW and P ≥ 560 kW
### STAGE IIIB / TIER 4A INTERIM

<table>
<thead>
<tr>
<th></th>
<th>CO g/kWh</th>
<th>HC g/kWh</th>
<th>NOₓ g/kWh</th>
<th>PM g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>P ≥ 560 kW</td>
<td>3.5</td>
<td>0.40</td>
<td>3.5</td>
<td>0.10</td>
</tr>
<tr>
<td>130 ≤ P &lt; 560 kW</td>
<td>3.5</td>
<td>0.19</td>
<td>2.0</td>
<td>0.02</td>
</tr>
<tr>
<td>56 ≤ P &lt; 130 kW</td>
<td>5.0</td>
<td>0.19</td>
<td>3.3</td>
<td>0.02</td>
</tr>
<tr>
<td>37 ≤ P &lt; 56 kW</td>
<td>5.0</td>
<td>4.7</td>
<td>0.02</td>
<td>0.015</td>
</tr>
<tr>
<td>19 ≤ P &lt; 37 kW</td>
<td>5.5</td>
<td>7.5</td>
<td>0.6</td>
<td>1 x 10¹²</td>
</tr>
</tbody>
</table>

### STAGE IV / TIER 4B FINAL

<table>
<thead>
<tr>
<th></th>
<th>CO g/kWh</th>
<th>HC g/kWh</th>
<th>NOₓ g/kWh</th>
<th>PM g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>P ≥ 560 kW</td>
<td>3.5</td>
<td>0.19</td>
<td>3.5</td>
<td>0.04</td>
</tr>
<tr>
<td>130 ≤ P &lt; 560 kW</td>
<td>3.5</td>
<td>0.19</td>
<td>4.0</td>
<td>0.02</td>
</tr>
<tr>
<td>56 ≤ P &lt; 130 kW</td>
<td>5.0</td>
<td>0.19</td>
<td>4.0</td>
<td>0.02</td>
</tr>
<tr>
<td>37 ≤ P &lt; 56 kW</td>
<td>5.0</td>
<td>0.19</td>
<td>4.0</td>
<td>0.015</td>
</tr>
<tr>
<td>19 ≤ P &lt; 37 kW</td>
<td>5.5</td>
<td>0.19</td>
<td>4.0</td>
<td>1 x 10¹²</td>
</tr>
</tbody>
</table>

### STAGE V EU COMMISSION PROPOSAL

<table>
<thead>
<tr>
<th></th>
<th>CO g/kWh</th>
<th>HC g/kWh</th>
<th>NOₓ g/kWh</th>
<th>PM g/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>P ≥ 560 kW</td>
<td>3.5</td>
<td>0.19</td>
<td>3.5</td>
<td>0.045</td>
</tr>
<tr>
<td>130 ≤ P &lt; 560 kW</td>
<td>3.5</td>
<td>0.19</td>
<td>4.0</td>
<td>0.015</td>
</tr>
<tr>
<td>56 ≤ P &lt; 130 kW</td>
<td>5.0</td>
<td>0.19</td>
<td>4.0</td>
<td>1 x 10¹²</td>
</tr>
<tr>
<td>37 ≤ P &lt; 56 kW</td>
<td>5.0</td>
<td>0.19</td>
<td>4.0</td>
<td>1 x 10¹²</td>
</tr>
<tr>
<td>19 ≤ P &lt; 37 kW</td>
<td>5.0</td>
<td>0.19</td>
<td>4.0</td>
<td>1 x 10¹²</td>
</tr>
</tbody>
</table>

**Legend:**
- CO: Carbon Monoxide
- HC: Hydrocarbons
- NOₓ: Nitrogen Oxides
- PM: Particulate Matter
- PN: Particle Number

**Emission Durability Period:** 8000 hours, 10 years

1. In Europe, no emission regulation for P > 560 kW until introduction of Stage V
2. In Europe, Stage IIIA in force for 19 < P ≤ 37 kW until introduction of Stage V
FPT Industrial Engines

By way of continuous technical advances our state of the art engine range allows our customers to have class leading features, such as minimized total cost of ownership and outstanding performance. Key to the optimization of combustion efficiency is high cylinder pressure and high injector nozzle pressures: engines adopting the latest generation of Common Rail system feature peak nozzle pressures of up to 2200 bar.

To achieve these targets, crankcase and cylinder head design has been improved to ensure increased structural stiffness. An Electronic Control Unit manages engine parameters and guarantees an accurate control of the after-treatment system.

In addition, since the engine only breathes clean filtered air, rather than re-circulated exhaust gases, engine wear is low and oil service intervals are up to 600h, without the need of an increased oil sump capacity. This brings further advantages in terms of operating costs and reduced downtime for scheduled maintenance.
FPT Industrial’s Engine Advantages

- Increase vehicle productivity thanks to better transient response
- No additional turbocharger’s complexity while ensuring outstanding performance
- Low operating costs thanks to high combustion efficiency and long service intervals (up to 600h, depending on the mission)
- Engine lean design
- Lean technology improving durability and reliability
- No additional cooling requirements on both radiator dimensions or fan drive
Due to the opposite reaction to combustion temperature, the reduction of either of the combustion products (NO\textsubscript{X} or PM) necessarily implies the increase of the other one. In order to further reduce NO\textsubscript{X}, as required by Tier 4B/Stage IV, it is necessary to work both on combustion management and exhaust gas treatment system.

This means that Tier 4B/Stage IV emission limits can be reached only through the use of SCR (Selective Catalytic Reduction), either with or without EGR. The use of an EGR system reduces the NO\textsubscript{X} emissions in the combustion chamber, lowering combustion temperature through exhaust gas recirculation which however increases formation of particulate matter (PM) and reduction in combustion efficiency.

FPT Industrial has chosen to increase the combustion efficiency, reducing the PM without using EGR, thus allowing engines to work at their performance best point; NO\textsubscript{X} is then reduced in the SCR system, preserving fuel efficiency and overall system reliability.

**TIER 4B/STAGE IV:**

FPT Industrial’s patented HI-eSCR system is able to reduce the NO\textsubscript{X} levels more than 95%, offering best-in-class conversion efficiency; moreover, thanks to no DPF, the FPT solution is maintenance free and requires no regeneration, improving productivity by avoiding downtime during operation for filter cleaning or replacement.

**STAGE V:**

Maintaining the advantages of the unique & unbeaten HI-eSCR technology FPT Industrial will integrate a maintenance-free filtering device on its SCR catalyst, thus allowing to comply with tightened limits on PM emissions within a compact package.

The second generation HI-eSCR 2 will maintain the same after-treatment dimension of the current Tier 4B/Stage IV applications, requiring no machine redesign nor layout changes for easier upgrade to next emission level; thanks to the EGR-free combustion, performance and operating costs are optimized confirming the FPT Industrial’s competitive advantage.
Patents

“Closed” loop control through NO$_x$ and Ammonia sensors to provide accurate monitoring of exhaust gas composition; adaptive dosing system to reduce AdBlue

*Thermally insulated high turbulence mixer, to allow homogeneous hydrolysis of urea, ensuring correct distribution in exhaust gas flow*

*Improved exhaust gas temperature control to speed up SCR light-off in the cold part of emission cycle through an electronically-controlled exhaust flap*

All after-treatment components are packaged in a compact and fully enclosed structure, providing flexible layout options to simplify installation on machines.
Main Components

HI-eSCR 2 main components are:

- The DEF/AdBlue Supply Module
- The DEF/AdBlue Dosing Module
- The Disel Oxydation Catalyst (DOC)
- The DEF/AdBlue Mixer
- The Selective Catalytic Reduction (SCR) on filter
- The Clean Up Catalyst

The whole system is fitted with a network of integrated sensors to control, among others, the NO\textsubscript{x} and any excess of NH\textsubscript{3} (ammonia) produced.

Exhaust gas flow coming from the engine enters the DOC, where NO is oxidised to NO\textsubscript{2}, in order to maximize SCR catalyst’s efficiency conversion.

The ECU (Engine Control Unit), the brain behind the HI-eSCR 2 system, checks, through integrated sensors network, the amount of Water-Urea (DEF/AdBlue) solution to be injected in the exhaust pipe. To increase the durability of the injector, Dosing Module is cooled by the engine coolant.

The HI-eSCR 2 after-treatment system adopts a filtering device on its SCR catalyst. At the same time as trapping and oxidizing the Particulate Matter, the catalyst converts NO\textsubscript{x} into Nitrogen (N\textsubscript{2}) and water (H\textsubscript{2}O) thanks to the chemical reaction of Ammonia (NH\textsubscript{3}) generated from DEF/Adblue. In the end, the integrated CUC eliminates the remaining Ammonia (NH\textsubscript{3}). The result is a reduction of NOx superior to 95% and the PM levels within Stage V emission limits.
1 **DIESEL OXIDATION CATALYST**
   NO → NO₂
   HC, CO and PM oxidation

2 **AdBlue® / DEF INJECTION**
   Hydrolysis → NH₃ + CO₂

3 **SELECTIVE CATALYTIC REDUCTION ON FILTER**
   NO and NO₂ reduction by NH₃ to N₂ and H₂O
   PM oxidation with NO₂

4 **CLEAN-UP CATALYST**
   Residual NH₃ oxidation

*AdBlue® / DEF = CO(NH₂)₂ + H₂O

**LEGEND**
- PM Particulate Matter
- HC unburnt Hydrocarbons
- NOₓ Nitrogen Oxides
- CO Carbon Monoxide
- N₂ Nitrogen
- CO₂ Carbon Dioxide
- H₂O Water
Why choose HI-eSCR 2

**FPT’s STAGE V SOLUTION**

**THE SECOND GENERATION HI-eSCR**

- EGR free
- Active regeneration free
- Maintenance free

ENSURING:

|   | **HIGH PRODUCTIVITY & SAFETY** | Best in class power & torque density.  
Lowest after treatment temperature: no need of heat protection against active regeneration peak temperatures.  
Maximising uptime: no need to stop equipment for regeneration. |
|---|--------------------------------|---------------------------------------------------------------------------------------------------|
| 2 | **LOW OPERATING COSTS**        | Best in class fluid consumption cost*.  
After treatment system for life: based on particle number reduction experience with over 3.5 billion hours in field. |
| 3 | **EASE OF INSTALLATION**       | Same engine cooling package from stage IIIa to stage v.  
Smallest overall packaging**.  
Multiple off-the-shelf configurations available: more than 20 different layout available for each power node. |

* compared to competitor average using EGR & active regeneration  
** when considering a packaging including cooling system, engine & after-treatment system
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