Questions and Answers on Energy Saving and Reducing Emissions.
Questions and Answers on Emissions and the New Legislation

01. What are the key points of EU Stage III B concerning the legislation on reducing emissions?

Emphasis is on the reduction of particulate matter (PM) and nitrogen oxides (NOx). The exhaust emissions levels of hydrocarbons (HC) and carbon monoxide (CO) are also regulated.

02. What is particulate matter (PM)?

Particulate matter (PM) or particulates consist mainly of soot (carbon particles) and residues of lubricating oil.

03. What are nitrogen oxides (NOx)?

Nitrogen oxides consist of nitrogen monoxide (NO) and nitrogen dioxide (NO2). Nitrogen oxides are formed when the oxygen and nitrogen in air react under intense heat and high pressure during combustion.
What are hydrocarbons (HC)?

Hydrocarbons are a family of compounds composed of carbon and hydrogen, consisting basically of incompletely combusted fuel and oil residues. The concentration of hydrocarbons in diesel exhaust emissions is very low and can be further reduced through the use of high-quality fuels, an efficient combustion process and an exhaust gas treatment system.

What is carbon monoxide (CO)?

Carbon monoxide is a compound of carbon and oxygen formed by incomplete combustion in the presence of insufficient air. Diesel engines operate with a large excess of air and therefore normally only emit small quantities of carbon monoxide.

What is carbon dioxide (CO₂)?

Carbon dioxide is one of two natural end products of combustion; the other is water. CO₂ is not toxic and the quantity is directly proportional to the fuel consumption. CO₂ contributes to the so-called greenhouse effect which impacts the climate.
Are CO₂ emissions regulated?

No, CO₂ is not regulated in the case of mobile machines, but governments, political parties and international and national bodies are placing increasing demands on, for example, the automotive, construction and agricultural industries to supply products with ever-lower CO₂ emissions. The onus is also on the users of these products to operate their machines in the most fuel-efficient way.

How can CO₂ emissions from diesel engines be reduced?

The only way to reduce CO₂ is to lower the fuel consumption. Fuel-efficient engines and high-efficiency drive and hydraulic systems are therefore also important elements in the pursuit of lower CO₂ emissions.

What is the difference in the regulated emission levels of EU Stage IIIB/Tier 4 Interim compared to EU Stage IIIA/Tier 3?

EU Stage IIIB/Tier 4 Interim requires a reduction of PM by no less than 90 % and of NOₓ emission levels by 50 % compared to EU Stage IIIA/Tier 3 levels.
When did the EU Stage IIIB regulations come into effect?

On the 1st of January 2011. In this regard, the build date of the engine is the crucial factor, i.e. all engines manufactured on or after the given date of the new legislation coming into force, must comply with the new regulation.
**11 Will all new machines available for sale in 2011 and beyond, in the market areas concerned, be equipped with EU Stage IIIB-compliant engines?**

No, the regulation contains provisions (transition clauses) that permit a certain degree of flexibility in its enforcement in order to ensure an orderly, rational transition from EU Stage IIIA to EU Stage IIIB at manufacturer, distributor and end user levels. This will mean that new machines manufactured prior to 2011, fitted with EU Stage IIIA-compliant engines and still in stock at manufacturers or distributors, can continue to be sold to end users.

Also, "machine flexibility clauses" permit that, in special conditions, a limited quantity of EU Stage IIIA engines may be built after the year 2010, thus providing machinery manufacturers with another rational option for a smooth transition.

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**12 Are the regulated EU Stage IIIB and US (EPA) Tier 4 Interim emission limit values identical?**

Yes, the limits are in principle the same in both of these geographic areas, based on the power range in which the machinery operates.

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**13 Will there be further requirements imposed by governments at a future date regarding the reduction in diesel exhaust emissions from "non-road" machinery?**

Yes, one further step has already been decided in the case of Europe (EU) and North America. On the 1st of January 2014 new, even stricter emissions regulations will come into force, US (EPA) Tier 4 Final and EU Stage IV, requiring that non-road vehicles and machinery lower their emissions of NOX by 90% compared to EU Stage IIIA/Tier 3. By this time, both NOX and PM will have reached near zero levels.
After the EU Stage IIIIB has come into effect, will there be a requirement to upgrade existing, older generation machinery as far as NO\textsubscript{X} and PM emissions are concerned?

For Europe as a whole, it is unlikely that such a regulation would come into force. Some local regulations are, however, already in place; Switzerland is a case in point.

What technology options are available to meet the demands of EU Stage IIIIB regarding emission limits?

NO\textsubscript{X} and PM reduction can be achieved in several ways, each having both advantages and disadvantages.

For example, in-engine NO\textsubscript{X} reduction always leads to higher PM emission levels, and conversely, in-engine reduction of PM leads to high NO\textsubscript{X} emissions. Optimisation of fuel injection and air supply, including different EGR (Exhaust Gas Recirculation) configurations (cooled/non-cooled etc.), and various exhaust gas treatment technologies, including diesel particulate filters and SCR (Selective Catalytic Reduction) technology are all tools used for NO\textsubscript{X} and PM reduction.
How does the SCR technology work?...

Selective Catalytic Reduction (SCR) is a technology where a reagent is injected into the exhaust gas flow and mixed in a catalytic converter. This reduces the NO\textsubscript{X} to harmless nitrogen and oxygen. The reagent is a mixture of 32.5 % urea and 67.5 % water and in Europe is known commercially as AdBlue. Depending on the engine load factor, the urea usage corresponds to approx. 4 % of the diesel usage.

The basic engine must, in any case, be fine-tuned to minimise engine-out PM emissions as required by the EU Stage IIIB emission regulations.

... and the DPF technology?

The Diesel Particulate Filter (DPF) is a device in which the particulates are collected and then oxidised by passive or active regeneration. Advanced electronic control of the process is necessary to ensure effective PM removal in all engine duty cycles of any type.

In addition, the basic engine must be fine-tuned to minimise engine-out NO\textsubscript{X} emissions to meet the NO\textsubscript{X} levels required by law. Ultra-low sulphur fuels and low-ash lubricating oils are a must for these DPF technologies to function properly.

Will EU Stage IIIB solutions be based on the existing engine platforms or will a new design be required?

Mobile machines are generally powered by modern high-volume production engines. These engine platforms have from the outset been designed to cope with the higher internal loads arising from the new performance requirements of EU Stage IIIB. Some design changes will, however, be introduced in order to further enhance the performance of the engines.

It is important to mention here that the engine platforms that are normally used for EU Stage IIIB applications are used in road vehicles by prestigious manufacturers and have already undergone more than 2,000,000 km of real-world testing.

Are there any other factors that influence the design of the machines?

The larger space requirement of the additional systems in the exhaust system means that the existing space must be used very efficiently or new space must be created by reducing other components (e.g. tanks).
Practical Implementation of the Emissions Directive

By the end of 2010:
Tier 3 / EURO III

- Common rail system
- Single-stage turbocharging
- External EGR
  (Exhaust Gas Recirculation)

From 2011:
Tier 4 Interim / EURO IIIB

- Two-stage turbocharging with intercooler
- Diesel particulate filter

From 2014:
Tier 4 Final / EURO IV

- Common rail system
- Externally cooled EGR
- Two-stage turbocharging with intercooler
- SCR system: AdBlue

Development of costs

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<tr>
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Installation space required

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<td>+25 %</td>
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HYDAC’s answers to energy-saving, emissions reduction and additional space requirements

In its range of products HYDAC holds numerous answers to today’s questions on environmental protection, reduction of emissions, and energy and fuel-saving.

Whether in car, truck or construction machine – the demands made on the most up-to-date components and systems and their future development are practically identical.

HYDAC develops and supplies Components and Systems

... for Saving Energy and Reducing Emissions

- SCR Technology (Selective Catalytic Reduction) 20
- Diesel Filtration 21
- Gas Tanks (CNG/LPG) 22
- Diesel Particulate Filters 22
- Hydraulic Hybrid Technology 24
- Cooling Systems 27

... for Additional Space Requirements

- Tank/Filter/Cooler Combinations 28
- Plastic Tank Systems 29

Support / System Optimisation 32

... for Complete Energy Optimisation 34
HYDAC Components for ...

... SCR Technology

AdBlue shut-off valve

- Meets the highest sealing requirements
- $Q_{\text{max}} = 15 \text{ l/min}$
- $\Delta p_{\text{max}} = 0.1 \text{ bar at } 1 \text{ l/min}$
- $p_{\text{max}} = 10 \text{ bar}$

Deep-Bed Filter Element

- High contamination retention rate and contamination retention capacity due to innovative multi-layer filter media structure
- High strength and durable polymer fibre matrix due to thermoplastic bonding of the fibre structure
- Structural weak points eliminated (e.g. no seam)
- Low pressure drop
- Compact design

... Diesel Filtration

HYDAC Diesel PreCare

- Diesel filtration and 2-stage water separation
- Manual water discharge (BestCost design) – the conventional, operator-dependent solution
- Fully automatic discharge Plug&Play (HighTech design) – the innovative solution for fully automatic dewatering, independent of the operator, even during suction-side operation
- Suction side pre-filter
- Protects all the pumps and components in the fuel system from water and contamination
- Environmentally friendly due to incinerable filter elements
- Longer service life and increased machine availability
HYDAC Components for ...

... Gas Tanks

- **CNG shut-off valve**
  - Shut-off valve for CNG-powered (Compressed Natural Gas) vehicles

- **Mounting technology**
  - TÜV certified, patented gas tank mounting clamps with quick release fastenings.
  - "Multi" swivel bolt band console clamp (see next point)

... Diesel Particulate Filters

- **Mounting technology**
  - The continued development of the successful "Multi" swivel bolt band console clamp made from high-quality stainless steels. Specifically designed for high dynamic loads, thermal stresses, changes in diameter and the effects of strong forces – have been successfully tested by well-known manufacturers in the mobile industry.
HYDAC Components for...

...Hydraulic Hybrid Technology

Double piston accumulator

Innovative hydraulic accumulator for hydraulic hybrid drives

Efficiency gains due to the special system design:
  perfect energy balance,
  compact design,
  low weight

Hydraulic accumulator in lightweight design

Fuel savings due to low weight

Space-saving accumulator solutions for hydraulic hybrid retrofits

Energy Management Unit (valve block)

Customised design

More HYDAC products for hybrid drive concepts

Hydraulic accumulators in different designs (standard, high pressure, lightweight ...)

Accumulator accessories (safety and shut-off blocks, clamps ...)

Wide range of valve technology

Sensors (e.g. pressure sensors)

Product advantages

Hydraulic hybrid drives offer a host of possible advantages:

- Downsizing of the combustion engine
- Support of the combustion engine
- Operation of the combustion engine close to the maximum efficiency level
- Energy recovery
- Reduced fuel consumption
- Boost operation
Increased demands for energy efficiency and noise reduction on mobile machinery have pushed the cooling systems for these vehicles to their physical limits. Special design details lay the foundation for optimum cooling systems.

**Fan drives**

**Hydraulic:**
With an outboard bearing, a switching block for reversible operation and a proportional pressure relief valve PDB 08 PZ. The speed of the fan motor can be regulated steplessly with the aid of the proportional pressure relief valve.

**Electrical:**
PWM and analogue input, diagnostics output, very quiet, reversible

**Advantages:**
- Noise reduction
- Reduced fuel consumption
- Reduction in emissions
- Compact design
**Problem:** Smaller hydraulic tanks are a cause of air in oil

**HYDAC Support:** HYDAC offers a wide range of support to avoid air in the hydraulic system. (see page 32)

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**Additional Space Requirements**

**Tank/Filter/Cooler Combination**

Patented function integration FCI (Filter Cooler Industrial): combination of pump, motor, filter and cooler in a compact ready-to-install unit.

The motor-pump unit and cooling element are directly flanged to the filter which saves space by eliminating the need for pipework.

**Advantages:**

- Cost-effective, compact design, no pipework required between filter and cooler
- Guaranteed system cleanliness
- Indicator for optimum timing of element change
- Reliable heat regulation
- Easy to handle
- Optimum cooling performance with less cooling water usage
- When used in offline operation: continuous filtration and cooling of the contents of the tank
- Easy to service

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**Plastic Tank Systems**

Plastic tanks are used where installation space is limited. Frequently this means that, complex, customised designs are required in addition to our standard designs.

**Advantages for the customer:**

- Flexible tank design
- Patented spacer ring for the filter head flange mounting
- Built-in baffle (patented)
- Low weight
- No risk of corrosion
- Resistant to ageing
- Shock and impact-resistant
- Optimum price/performance ratio
- Fewer assembly and test requirements: system is supplied with all add-on components (return line filter, air breather filter, oil level gauge, standard fittings, clamping bands ...)
- Leak tested
- No need for time-consuming flushing processes due to high degree of cleanliness during manufacture
**The Problem:** Smaller hydraulic tanks are a cause of air in oil

Current requirements for mobile machines:
- Emission Standards
- Energy efficiency
- Power density
- Low life cycle cost
- Noise control
- Vibration protection in the workplace

Changes in the machine and hydraulic concepts

**RISK:** Air in the hydraulic system

Problems of installation space

Consequence: e.g., changes to hydraulic tank:
- Tank volume
- Tank geometry
- Dwell time

Performance problems

Effects of air in the hydraulic system
- Efficiency losses of pumps
- Cavitation damage to components
- Accelerated oil ageing/Micro-dieseling effect
- Dynamic operating problems/increased compressibility
- Noise generation
- Increase in temperature
HYDAC Support

Intelligent System Optimisation for Air Removal

We use the following tools to develop the best individual solutions for your system:

- Many years’ experience in the field of intelligent system optimisation for air removal and stimulating exchanges of information in this area
- Customised test rigs and measurement technologies to analyse the air removal on subsystems and to develop the optimum solution for your application
- Qualified engineers measure air removal from complete systems using field instruments
- Qualified engineers find and rectify any sources of air inclusion
- CFD flow simulations to find solutions
- Individual space-saving complete tank solutions (see also page 29) prevent air inclusion in your system

When it comes to system optimisation we concentrate on the following approaches:

- Optimisation of the Suction Area
- Optimisation of the Tank Design
- Optimisation of the Return Line

In the FluidCareCenter, 23 experienced fluid technology specialists are engaged on application-specific solutions.

Air content (1 = 100 %)

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<tr>
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<tr>
<td>10 s</td>
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<td>300 s</td>
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Multiphase bubble flow simulation in the tank

Example of the tank systems under analysis
Total Energy Optimisation

Pressure transmitters/pressure switches

In order to comply with the Directive on the reduction of engine exhaust emissions for mobile machines, hydraulic systems are today being developed with particular focus on the most efficient use of energy.

HYDAC is offering pressure transmitters and electronic pressure switches which have been specially designed for the tough conditions in mobile hydraulics. They are particularly suitable for the complex control tasks in such systems, e.g. positive control systems.

Advantages:
- Very robust sensor cell
- Small, compact construction
- Very small temperature error
- Accuracy:
  - ≤ ±0.25 % FS typ.
  - ≤ ±0.50 % FS typ.
- Excellent EMC characteristics

Universal Mobile Controller HY-TTC

The HY-TTC family meets all technical requirements for advanced automotive electronics in the off-highway sector. It is part of a complete and compatible product family and is protected by an extremely compact and robust housing specially designed for the off-highway vehicle industry.

Advantages:
- Robust die-cast aluminium housing
- Splash-proof 80-pin connector
- Pressure equalisation is via waterproof Gore-Tex® membrane
Load-sensing switching valve

Load-sensing generally refers to load-sensing hydraulic controls. In this case the block is designed to charge an accumulator in the brake circuit quickly. When the accumulator is full, the valve is closed and when it is drained, the valve to the pump opens and the full pump pressure acts on the pump’s LS line. The pump’s displacement angle now switches to maximum in order to charge the accumulator quickly. A built-in pressure relief valve protects the pump. An additional orifice dampens the load sense pressure signals.

Advantages:
- Pump protection built into the block
- Optimum damping of the system through use of bypass orifice
- Accumulator charging as required

Accumulator charging switch

HYDAC accumulator charging valves control the charging of the hydraulic accumulator within an adjustable switching range. The combination of accumulator and accumulator charging valve means that pumps and motors on oil-hydraulic systems where flow rate requirements fluctuate can be downsized. This saves money and energy, and unnecessary heat generation is also avoided. Accumulator charging valves are also used in brake circuits and emergency steering on mobile machines.

Advantages:
- System adaptation is easily achieved through the use of valves with various fixed switching pressures (12, 16, 21 %)
- Shut-off pressures are user-adjustable
- Low ∆p characteristics
- The accumulator cannot discharge unexpectedly because the poppet valves are leak-free
HYDAC Components for ...

... Total Energy
Optimisation

Brazed plate heat exchangers

Brazed plate heat exchangers are high performance components and provide a high level of efficiency combined with compact dimensions and low weight.

In construction machines they are used to transfer the transmission oil or axle losses to the hydraulic or water circuit.

Advantages:

The special moulding of the plates produces the required turbulent flow and provides the plate heat exchanger with a high level of mechanical strength.

The turbulent flow of the medium is necessary for effective heat transfer and also has a self-cleaning action: fluids passing through the narrow channels induce highly turbulent flow at the walls.

This results in a scrubbing action reducing contamination on the surfaces.
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