New generation of MTU Series 4000 engines meets EPA Tier 4 without exhaust gas aftertreatment

In 2015, MTU will introduce the Tier 4 final version of its successful Series 4000 engines for the mining industry. The new engine generation was developed to meet the most stringent emissions mandates from the Environmental Protection Agency (EPA) – without the use of any exhaust gas aftertreatment.

Continuous improvement has long been key to the success of MTU’s Series 4000 engines. This series is one of the company’s most popular product families, with more than 26,000 units sold since its launch in 1996. The Series 4000 is a proven performer in power generation, marine, oil and gas, and rail and mining applications. In mining, these engines power vehicles like haul trucks, wheel loaders and excavators.

To meet increasing demands from customers and rigorous emissions legislation, MTU has continuously built on its leadership in emissions control technologies for diesel engines. The Series 4000 technology package includes high-pressure common rail fuel injection and two-stage turbocharging with adjustable high-pressure stage and exhaust gas recirculation. Together, these technologies deliver very low-particulate and low-nitrogen oxide (NOx) emissions – without requiring aftertreatment, additives or related infrastructure. Simply put, tomorrow’s Series 4000 engines achieve low emissions/pollutant levels using only technology built into the engine.

For OEMs and mine operators, powering their vehicles without aftertreatment improves their bottom line. Lower weight and volume, less complicated maintenance and highly-efficient fuel consumption minimize costs. Together, these factors make the Series 4000 the best solution for mining equipment requiring Tier 4 final emissions levels.
Preparing the way for Tier 4 final

These Tier 4 final engines are built on a foundation of MTU’s successful Series 4000 Tier 2 engines. They benefit from in-house expertise for all key diesel engine technologies. MTU started pre-testing new technologies on the test stand and in field tests, as early as 2004, with an eye on meeting future requirements ahead of regulations. For example, at that time, MTU installed an 8-cylinder Series 4000 rail engine with cooled exhaust gas recirculation (EGR) in a diesel locomotive. Within the next two years, the engine operated approximately 5,500 hours, while consistently maintaining operational data values throughout the field test.

Building on this experience from testing rail engines – which are based on the same technology as mining engines – MTU significantly advanced the development of the next generation mining engine.

In the years that followed, engineering trials included the prototype testing of the tribological system for a Tier 4 engine. In 2009, MTU took a Series 4000 engine with high-cylinder peak pressure and put it to work in a Liebherr mining truck. In just six months, it logged over 3,000 hours of operation at an altitude of 3,200 meters (10,500ft) above sea level in Chile, with a load factor of 45%. MTU has started testing Tier 4 final prototype engines in mining equipment in 2012 – three years before the start of series production. In the same year, series production of the Tier 4i engine has begun for oil & gas applications. With some internal modifications, the Tier 4i engine will fulfill Tier 4 final regulations. Consequently, MTU will have gained real-world experience with the Series 4000 – three years before series production begins in 2015.

Substantial benefits of the new Series 4000

Over the years, MTU has consistently incorporated product requirements from major mining OEMs and input from the field in its development of the Series 4000. As a result, all operating and torque characteristics are specifically geared to power mining equipment. These engines are robust, reliable and cost effective workhorses, able to run continually at full...
capacity – in huge, dusty, open-pit operations, with high/low ambient temperature and high-altitude flexibilities.

Intensive dialogue with OEMs helped MTU clearly define requirements for its new engines. The priorities: meeting future emissions requirements while minimizing the impact on the equipment. For example, in terms of installation space and radiator size, the Tier 2 and Tier 4 engines have nearly the same dimensions. At the same time, the power output per cylinder increases to 155kW (208bhp), while fuel consumption will be reduced up to Tier 1 levels. Beginning in 2015, MTU will offer a complete family of Series 4000 engines with 8, 12, 16 and 20 cylinders. Each will provide more power than previous models. For special projects, the Tier 4i or final-compliant engines will be available even before 2015.

**Emissions-reducing technologies**

MTU leveraged a low-emissions combustion strategy to develop the Series 4000. This internal engine solution required that all key technologies affecting combustion be perfectly matched, in order to optimize results.

**Exhaust gas recirculation (EGR)**

EGR is one of the principal methods used to reduce nitrogen oxide emissions from diesel engines. During the EGR process, exhaust gas is cooled and then redirected into the charge air. This reduces the combustion temperature, producing less nitrogen oxide. MTU has engineered a very compact design that permits all the exhaust gas recirculation components to be integrated within the engine. Therefore, the new components have relatively little impact on space requirements.

Consequently, it is now much easier for customers to upgrade their mining vehicles to comply with a new emissions standard. This is especially true when compared with an engine requiring an aftertreatment system. Because exhaust gas recirculation doesn’t require consumables to reduce nitrogen oxide levels, it eliminates the cost of additional fluids,
tanks and piping and dosing infrastructure and of course additional mine infrastructure. Customers also benefit from reduced handling and maintenance costs.

**High-pressure common rail fuel injection system**

Besides EGR, the fuel injection system also plays a major role in MTU’s strategy to achieve clean fuel combustion through enhancements strictly within the engine. MTU’s design injects fuel at high pressure – at precisely the right moment and in precisely the right quantity – in order to create the conditions required for low-emissions combustion inside the cylinder. All engine and turbocharging functions are centrally controlled by MTU’s powerful engine management system: the Advanced Diesel Engine Control (ADEC) – ECU9. The improved engine management, map control and system control enable a very precise regulation of fuel volume delivery at high pressure. This results in lower exhaust emissions and improved transient behavior, as well as dramatically reduced fuel consumption with consequent CO₂ emission reduction.

That’s why MTU strategically abandoned conventional mechanical injection systems and embraced the flexible, electronically-controlled common rail system. The company made this decision very early on, with a vision to produce more economical engines. In 1996, the Series 4000 was the first large diesel engine to be equipped with a common rail system as a standard feature by MTU. Other engine manufacturers followed about a decade later, MTU sees that as a compliment. Since then, MTU has continuously improved the injection process and raised the maximum injection pressure. Today’s third-generation common rail systems are able to inject fuel with peak pressures of more than 2,000 bar – or 2,000 times greater than atmospheric pressure at sea level.

**Two-stage, intercooled turbocharging system**

Adding turbocharging can improve the performance of an internal combustion engine. Exhaust gas from the combustion process drives the
turbocharger. MTU produces this key technology in-house for its high-performance Series 4000 and equips all Tier 2 and Tier 4 mining engines with an MTU two-stage turbocharging system. The turbochargers supply the engine with combustion air and ensure maximum performance and engine dynamics even with sudden load changes. They compress the air so that more oxygen flows into the combustion chamber. In this way, more fuel can be injected without increasing soot emissions. The power output of the engine also increases. Intercoolers lower the temperature of the air, which further increases its density. So, greater air mass, and thus more oxygen, enters the cylinder. As a result, the new engines constantly deliver high performance across the entire engine operating range, from sea level to high altitudes, and from low to extremely high ambient temperatures. Because the turbochargers are specifically configured to meet mining engine specifications, they are easily integrated into the overall engine package. This makes the engines very compact – a decisive advantage in mining applications where weight and installation space are at a premium.

Smart solutions for the future
For the mining industry, the Series 4000 is the solid platform to ensure customers’ current and future success, offering the best solution for excavators, loaders, drills and trucks. MTU has not changed any major Series 4000 engine features that customers consider crucial. These include:

- best power-to-weight ratio
- low fuel consumption
- compact physical dimensions
- thermal protection function

In order to keep maintenance to a minimum, MTU will offer intelligent electronic features for remote diagnosis and status monitoring. In the event of problems, these technologies enable rapid reaction times, effective fault prevention and flexible response options. MTU will supply
engines for mining applications with full EPA Tier 4 certification, so customers can integrate MTU drive systems quickly, simply and economically.

In short, with the next generation of the Series 4000, MTU offers the best mining engine, designed to exceed even the most stringent emissions requirements without the need for aftertreatment. And the Series 4000 engines will continue to deliver on and improve their global reputation – for the same high performance, reliability and fuel efficiency customers have come to appreciate over the years.

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