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Shedding Tiers

C&A

engines

The subject of engine emissions has dominated construction equipment development - both on and off road - for the past decade or more. It was thought that there might have been a 'breather' after Tier 4 was introduced for off road equipment a year or so ago, but with Stage V looming, the whole industry is once again going to have to ramp up to deal with yet another stricter regulation. We take a look at the detail and do our best to clarify it.

Emission legislation in Europe (although this constant upgrading is not limited to Europe) is controlled by the Non-Road Mobile Machinery (NRMM) directive 97/68/EC - which dates back to 1997 - together with five amendments, the latest being 2012/46/EU in 2012. These standards outline gradually more stringent levels or tiers known as Stage I to Stage V. The first four stages are regulated by 97/68/EC and its amendments, however for Stage V - a new regulation currently under discussion - will be introduced from 2019. The earlier standards have followed or mirrored those in the USA, however Stage V is European driven and will mean that Europe has the strictest legislation of all the low emission countries - at least for a while.

USA standards

The first standards (Tier 1) in the US for off-road diesel engines were adopted in 1994 and applied to engines with an output of more than 37kW. This was phased in from 1996 to 2000 with increasingly stringent Tier 2 and Tier 3 standards introduced from 2000 to 2008. Tiers 1 to 3 were met through improved engine design with limited use of exhaust after-treatment. However,

Stage 5 legislation will be introduced from 2019.

in 2004 the US Environmental Protection Agency (EPA) launched Tier 4 - introduced from 2008 to 2015 - which did require Particulate Matter and NOx to be reduced by a further 90 percent. This could only be achieved using exhaust gas after-treatment. Although the sulphur content of off-road diesel fuels was not limited by environmental regulations at Tier 1 to 3, Tier 4 off-road engines were subject to reductions of 15 ppm - requiring ultra-low sulphur diesel - which came into effect in 2010.

European standards

Stage III and IV standards were adopted in 2004. Stage III was further divided into IIIa and IIIb and phased in from 2006 to 2013 with Stage IV from 2014. Stage III and IV legislation only applied to new vehicles and equipment - replacement engines for machinery already in use only had to comply with the rules in force when it was delivered.

What is mobile machinery?

But what is meant by non-road mobile machinery? The US is clearer on this than Europe. If it moves or is on wheels then it is mobile - if the equipment does not move for more than 12 months it is not. In the EU it is more a design intent so if the equipment is built into the basement of a building it is not moving or

A single module after treatment.



going to move and therefore not covered by the regulation. But anything that is designed to be moved - even a cracking rig which may stay in one place for three years but then move - is classified as mobile. This also includes temporary or mobile generators.

Why Stage V?

According to EU figures, engines on Non-Road Mobile Machinery contribute significantly to air pollution and are responsible for roughly 15 percent of the nitrogen oxide (NOx) and five percent of the particulate matter emissions in the EU. Several technical reviews have concluded that in its current form the legislation has shortcomings, particularly by leaving out some engine categories. Also new emission stages were last introduced when it was amended in 2004 and no longer reflect the current state of technology.

Finally, there is recent conclusive evidence on the adverse health effects of diesel exhaust emissions and especially particulate matter (i.e. diesel soot). One of the main findings is that the size of the particles is a crucial factor and this can only be addressed limiting values that are based on a particle number count. Therefore, in-line with developments in the car and truck sector, Stage V will target particle number limits in addition to particle mass limits. The objective is to progressively reduce the emissions and to phase out polluting equipment.

The Commission adopted the 'Proposal for a Regulation on requirements relating to emission

limits and type-approval for internal combustion engines for non-road mobile machinery' on 25 September 2014. The proposed measures will cut emissions of major air pollutants from engines in non-road mobile machinery and will cut the complexity of the legal framework in the sector. The new regulation will replace 28 national laws and will repeal the current extremely complex directive that comprises 15 Annexes and has been amended eight times since its adoption in 1997.

Development since Stage III

Since 2011 off-highway engines have required after-treatment of some sort or another, depending on the power output. The industry has been nervous of the introduction of after-treatment with many saying it would be a disaster for the construction equipment industry. Tier IIIa engines before after-treatment were highly fuel-efficient and robust and customers were happy. However the new engines with after-treatment had to be introduced to comply with Tier IV interim and Tier IV final yet still need to be reliable, durable and fuel efficient.



A retro-fitted DPF



Engine manufacturer Cummins has carried out numerous engine comparisons, more than 10,000 hours of medium duty applications, measuring 230 parameters both with and without after-treatment. It has found that a Stage IIIa (2011) engines improved efficiency by five percent and the 2014 after-treatment engines improved overall efficiency by eight to 10 percent with a much improved - up to 40 percent - improvement in fuel efficiency. Engines have more power and use less fuel and there is no difference in reliability before and after, even when adding in all the complexity.

The legislative proposal for Stage V started in September 2014 and is currently going through the political and legal process and so may well change. But why is Europe pushing for Stage V when the US is currently not planning to do more? According to Richard Payne, Cummins off-highway regulatory affairs director, Europe it is because virtually all European Union member states have air quality problems.

"At least 17 are facing infractions - legal action, because air quality is not meeting European environmental standards," he said. "Those member states are pushing to bring in legislation. Passenger cars and trucks have improved with Euro 6 and the contribution of construction equipment to air quality problems - particularly in cities - is increasing. So member states want to see this solved, in particular a reduction in particulate matter and specifically the relatively small equipment that tends to be prevalent in cities."

As mentioned earlier, the size of the particulate is a crucial factor and this can only be addressed reducing the particle number count (ie PN limit). Stage V plans to target particle number limits in addition to particle mass limits. Experience with cars and trucks has shown that it is difficult to measure particulate matter by conventional means and this is made easier when identifying the number of particles. This rule

however will force the use of a diesel particulate filter (DPF). The EU would never mandate this, however changing from the mass of particulates coming out of the engine to the number count method means that there is currently no other way of achieving it.

The limits are also being reduced from 0.25 to 0.15 grammes per kW/hour - not a huge drop but it will result in a small benefit and still a realistic level to measure on a filter. The end result would be the same because when fitted with a DPF a figure of around 0.0015 would be achieved. There is also a focus on smaller particles - 2.5 microns rather than 10 microns - as the smaller particles have been identified as more damaging to health. With the latest DPF engines the amount of particulates being emitted from the engine is about the same as the background count which means that when driving in a polluted city the engine actually cleans the air.

What is a DPF?

As exhaust gases flow through Diesel Particulate Filter, the filter captures soot and particulates and converts them, in a process called regeneration, into harmless CO₂ and that goes out of the system through a Selective Catalytic Reduction (SCR) which creates a secondary catalytic reaction. There are two types of regeneration processes - Passive through normal operating temperatures and Active which occurs at higher temperatures and requires the dosing of diesel exhaust fluids. This happens less than one percent of the operating time and has no impact on the equipment or need any input from the operator. Tier 4 and Tier 4 final engines with DPFs are generally compliant with Stage V

Using a DPF and the technology available today will capture all particulate matter and meet Stage V limits. However, engine manufacturers will use the latest legislation as an opportunity to take the technology further. Proposed introduction dates of Stage V is January 2019, with engines between 56-130kW coming a year later.

Main changes?

While some of the detail (or even the main points) may change or be amended as the legislation is 'discussed' by the various member



As part of the London Best Practice Guidance which affects NRMM (Non Road Mobile Machinery), it is a requirement that most machines operating in London are fitted with an emissions after-treatment device such as a DPF

states, the main points are currently as follows:

- All engines are included in Stage V from 0 to infinity power output rather than the 19kW to 560kW currently required
- No older engines will be allowed to be built as regulators were unhappy with the amount of older engines coming on the market
- OEMs will not be allowed to stockpile older technology engines for use at a time in the future.
- Engines must be installed within one year of purchase and sold within six months.
- Particulate matter is measured by particle count rather than mass
- A reduction in the complexity of the legal framework

The move to include small diesel engines brings the EU regulations in line with the US Tier 4. Stage IIIa and Stage IIIb will move to Stage V. As with all new EU legislation what is proposed is not necessarily what will be implemented. There are various aspects of Stage V that will trigger major discussions. One deals with replacement engines, which under the new proposals would have to be upgraded to the latest requirements and not be rebuilt. Currently if the engine stays the same it can retain the older technology. However, there is a big lobby trying to get this changed. One of the big problems will be the engine reconditioning businesses. For owners and operators it would have severe consequences if they cannot buy a new 'old tech' engine for existing equipment, while rebuilds take longer than an engine change. Fixed speed engines such as generators at stage IIIa will also have to catch up with variable speed engines.

Finally, there is the low emissions world - currently North America, Europe, Japan and Korea - and the rest of the world. The low emissions world has tended to have roughly the same emissions legislation and if anything North America has up to this point led the way. However, this looks set to change with Stage V with Europe driving the latest regulations.

Possible user implications?

But what will Stage V mean to the man in the street? Well when buying a new machine there should be little difference in real world operation. Obviously the engine will be more fuel efficient and emit less pollutants, but as with all the other engine legislation changes machines will need to have at least as a good performance, in this case that might be achieved within the existing power units, rather than requiring a move to a larger engine. Whether Stage V engines will be more expensive with the addition of DPFs and the new technology remains to be seen, but early indications oddly suggest not.

For OEMs this will mean another redesign to accommodate at least a bulky DPF or other after-treatment paraphernalia. With the latest legislation affecting lower output engines this will be particularly challenging on small compact machines, such as spider lifts and spider cranes etc. Whether this will spur the move towards more battery powered and hybrid machines, remains to be seen. And with familiar technology being used for Stage V to that of Tier 4 and Tier 4a, the technical knowledge for maintenance and servicing should be no more cumbersome than the current requirements. Hopefully as manufacturers perfect their Stage V engines reliability and maintenance should also be as good if not better. If past experience is anything to go by the need to incorporate a new engine will also spur on other new developments to the equipment.

So all in all the outcome for the end user could be much more positive than first indications suggest.

A cutaway of a DPF



A Liebherr engine with gas after treatment system.

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