Hot under the collar on emissions technology

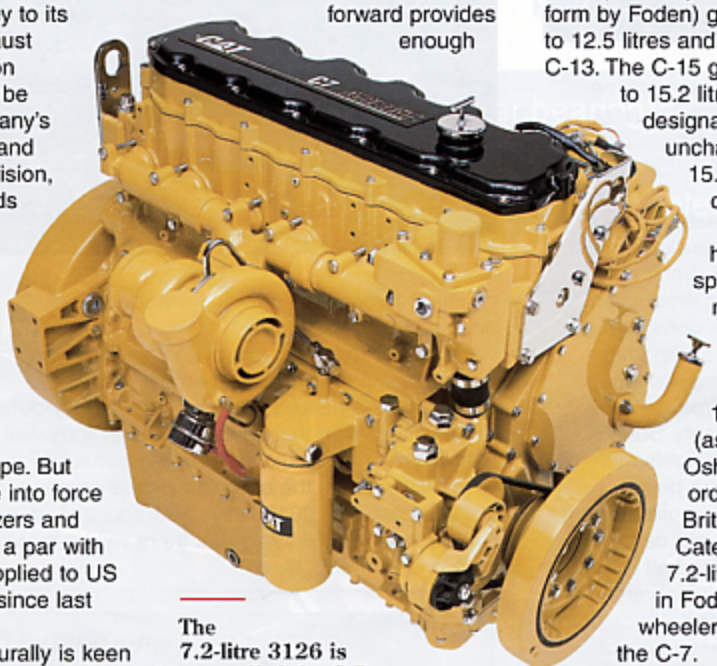
The exhaust-emissions-technology rift between Caterpillar and several rival manufacturers of heavy-duty diesel engines is widening as more information on the latest Cat engines begins to emerge.

Engineers at Detroit Diesel (the DaimlerChrysler subsidiary), Cummins, Volvo and Navistar all favour cooled exhaust gas recirculation (EGR) to cut emissions of oxides of nitrogen (NOX) on their North American engines. But Caterpillar is eschewing EGR in favour of its ACERT (advanced combustion emissions reduction technology) system (*Transport Engineer* February), full technical details of which have been kept under wraps longer than expected.

Some of Cat's rivals now believe that the key to its opposition to exhaust gas recirculation on truck engines can be found in the company's huge earthmover and industrial plant division, which also depends on diesel power. Current exhaust emission limits for such off-road machinery are much less stringent than those for on-road trucks in North America and Europe. But limits due to come into force in 2006 for bulldozers and excavators are on a par with those that have applied to US trucks and buses since last October.

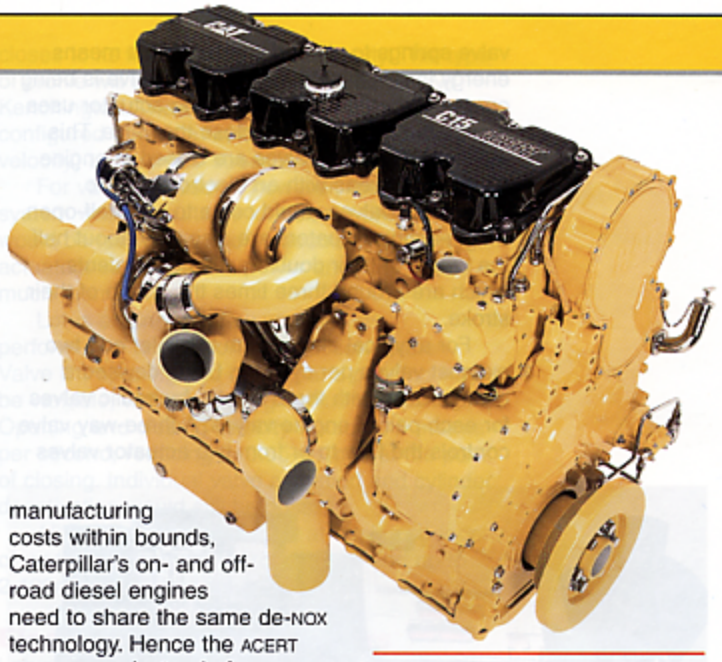
Caterpillar naturally is keen to rationalise its on- and off-highway diesel engines as much as possible. With exhaust gas recirculation, engine cooling would be an insurmountable hurdle, it is argued. Adding EGR to an engine increases its heat-rejection significantly, largely as a result of all the extra calories dumped into the cooling system by the EGR cooler – a gas/water heat exchanger typically mounted on the side of the rocker cover. The temperature of recirculated exhaust gas needs to be lowered to prevent it from nullifying much of the work done by an engine's main intercooler. Every Cat ACERT engine has two intercoolers, because durability depends critically on proper charge-cooling. Cat's belt-and-braces approach involves inlet air passing first through a European-style front-of-radiator air-to-air charge-cooler, and then through a US-style water-to-air charge-cooler, all in the interest of lowering the temperature and thus increasing the density of the fuel/air charge.

But one side-effect is that more heat has to be dissipated through the vehicle's main radiator. For a typical truck or bus with a large, thermally-efficient radiator and operating out on the open road, ram air as the vehicle moves forward provides enough cooling even for hot-running EGR engines. And on "conventional" bonneted US heavy trucks there is plenty of scope anyway for increasing radiator size.



The 7.2-litre 3126 is now called the C-7

But Caterpillar engineers privately admit that EGR could not be used on earthmovers and other off-highway plant because lack of ram air means the radiators would have to be "as big as barn doors". Yet to keep development and manufacturing costs within bounds, Caterpillar's on- and off-road diesel engines need to share the same de-NOX technology. Hence the ACERT programme instead of EGR.



The C-15 goes from 14.6 to 15.2 litres, courtesy of a longer stroke.

Stroke has been lengthened to increase swept volume on all Cat ACERT engines bigger than the C-9, to maintain established power and torque ratings without exceeding cooling-system temperature limits. The C-10 goes from 10.3 to 11.1 litres and is renamed C-11. The C-12 (currently fitted in Euro-3 form by Foden) goes from 11.95 to 12.5 litres and becomes the C-13. The C-15 goes from 14.6 to 15.2 litres but the designation is unchanged. The 15.8-litre C-16 is dropped. It was used only by a handful of specialist vehicle manufacturers. They are now being offered the 18.1-litre C-18 (as fitted in the Oshkosh trucks ordered by the British army). Caterpillar's ACERT 7.2-litre 3126 (used in Foden rigid six-wheelers) is renamed the C-7.

Twin (sequential) turbochargers with electronically-controlled/graduated wastegate valves are used on the C-11 and above. These are believed to be needed to get enough air into the combustion chambers to keep NOX emissions and smoke under control.

Despite its anti-EGR stance, condemning the notion of fresh intake air being polluted with dirty exhaust gas, Caterpillar incorporates in ACERT engines what MAN calls "internal EGR". Each valve bridge is equipped with an electro-hydraulic actuator which selectively alters valve timing. On the exhaust stroke the exhaust valve can be closed early. Some exhaust gas is thus trapped in the cylinder, ready to mix with incoming air on the next induction stroke, displacing some oxygen and damping down combustion, thereby reining back the peak temperatures which are critical in the formation of NOX. The smaller of the twin turbochargers provides additional boost pressure at low engine speed.

Caterpillar's ACERT truck engines are the only ones at present in the US relying on exhaust after-treatment to meet the US government's Environmental Protection Agency 2004 limits (in force since last October for most engine-makers). Cat's oxidation catalyst is thought to come from Johnson Matthey. Nobody at Caterpillar wants to talk about the chemistry of the ACERT oxicat, but it appears to be something novel, given a cost estimated by other engine-makers at between US$3,000 and $4,000. The oxicat's main job is to deal with volatile organic compounds (VOC) in particulate matter. Downstream PM control gives Caterpillar engineers scope for injection timing management to trade off PM against NOX.

The ACERT system makes additional demands on Caterpillar's two established in-house fuel systems: HEUI

(hydraulic electronic unit injector) used on the 3126/C-7 and C-9, and MEUI (mechanical electronic unit injector) originally developed and manufactured by Lucas's fuel-injection division (now part of Delphi) and used on Cat engines from the C-11 to the C-18. It is thought that ACERT requires up to five injection events per cycle to optimise valve-timing and turbo wastegate controls. The computing power of the HEUI electronic control module has had to be stepped up hugely to cope with this. Cat's original ACERT plan included adoption of HEUI on bigger engines. But it seems that in multiple-injection mode a bigger-than-normal HEUI system suffered pressure drops after pilot injection from which it could not recover rapidly enough to deliver the main fuel charge. So for engines bigger than 10 litres swept volume, MEUI has been upgraded to what Caterpillar calls MEUI-B, in effect a clone of the Delphi E3 unit-injector system now used by Volvo on its EPA 2004 12-litre engine. A second solenoid valve in each injector is used to open and close injector needles independently.

Luc Richard, Caterpillar's UK-based truck engine account manager, says selective catalytic reduction will be applied to Cat's Euro-4 truck engines within three years. Caterpillar engines with SCR are being tested in the US already, he says. But he stresses that SCR will complement rather than replace ACERT, though some of its features, such as the costly oxicat, may be left off in Europe.

But the hydraulic valve timing and internal EGR definitely will be retained, according to Mr Richard.

Cummins, Caterpillar's arch-rival in truck engines, recently unveiled in the US an EPA 2004 version of its 8.9-litre ISL engine embodying several ACERT-like features, and without cooled EGR. A form of valve-timing-controlled internal EGR is used, in combination with an oxicat. The thinking of Cummins engineers here is being shaped largely by the growing popularity of the ISL engine with American buyers of large "recreational vehicles" (better known as motorhomes in Europe) on which the engine installation makes fitment of bigger radiators difficult and where typical operation does not generate much cooling ram air.

The ISL and its 8.3-litre ISC stablemate will be fitted with a Bosch common-rail fuel system like that on the European Engine Alliance-developed one-litre-per-cylinder ISB. The CAPS (Cummins accumulator pressure system) fitted at present on ISL and ISC engines is being dropped. Cummins sources say this is because it cannot match the Bosch system on nozzle pressure – a critical factor for future emissions limits. ■

Bright future for cleaner US truck engines: but will they or won't they need exhaust gas recirculation?