TO COLDLY GO...

AS INDUSTRIAL VEHICLES HEAD EVER FURTHER INTO INHOSPITABLE CLIMES, WHAT DEMANDS ARE PLACED ON THEIR ENGINES, AND HOW ARE THEY ADAPTED TO COPE?

As the quest for harvesting natural resources continues, more and more industrial vehicles are beginning to pitch up in cold and inhospitable environments. Fortunately, technology seems to be quite capable of keeping pace with these demanding environments.

Mercedes-Benz supplies power plants to a variety of excavators, wheeled loaders, trucks and the like across the globe. Director, classic engines and aftertreatment systems, Hans-Otto Herrmann, says, "The most important thing about the design of an engine for use in a cold climate is that initially the intake air must be heated, usually with a flame heater or a grid heater. We design based on the outside temperature, and this is ideal for -15° to -20°C. When the temperature is lower than that, say -30°C or colder, then we also recommend an externally-powered block heater."

There are other subtle material differences, depending on where the vehicle is destined to go. "Take the oil pan," Herrmann notes with a chuckle. "Plastic is perfectly safe to use down to about -40°C, but not in Siberia. That's because there, if the engine doesn't start, they light a fire under it…"

From a design perspective, where altitude is concerned, Mercedes-Benz places great emphasis on the turbocharger. Carefully optimized up to a specific height, power reduction is inevitable should this be breached. Herrmann adds, "Altitude also makes emission control slightly more challenging. Currently the legislation stops at -7°C and above 1,700m. AdBlue freezes at -11°C, so we use coolant-based heat exchangers to enable us to inject it again. It does not make a huge difference, but less oxygen in the intake charge does cause NOx and particulates to creep up."

As far as any future emissions legislation is concerned, Herrmann is adamant that this must proceed hand in hand with fuel quality, and he cites sulphur content in particular. "Also, there has been quite a lot of discussion about biofuels recently. Diversity in fuel is all well and good, but it seems to me the only reason to use it in the cost-driven commercial vehicle business is as a tax incentive. This will go away, and interest will wane. Diesel will still be the main fuel of choice in 20 years.

"Improvements will come with higher-pressure injection systems, and incremental efficiency increases, like with lubricants. Ultimately we need to learn how to make better use of an engine's waste heat."

Taking to the piste

Cummins Engines provides Kässbohrer Geländefahrzeug with QSL9 engines for the PistenBully 400. Made in Darlington, UK, the 8.9-liter turbocharged six-cylinder

MAIN IMAGE: **The PistenBully 400 relies on the 8-liter Cummins QSL9 to deliver 272kW and maximum torque of 1,519Nm** units produce 370hp, with a torque of 1,519Nm at 1,500rpm. As Steve Nendick, Cummins communications director, observes, "These engines differ from our normal engines as they have been specially adapted for the cold climate. As well as a block heater and a fuel heater, we specify low viscosity oils, such as 5W 30, instead of 15W 40."

Also unique is the control software, Nendick elaborates: "This includes several cold-start parameter changes, such as pre-heat time and fueling table changes. It's not only cold start, but cold start at high altitude."

Kässbohrer adds a few features to its machine as well; for example, during cranking there is alternator decoupling and pressure-relief valves in the hydraulics. For those vehicles destined for Antarctica, an oil pan heater is installed. Here, sometimes operators need to start up at -40ºC, but once the engine is running it usually won't be shut down again.

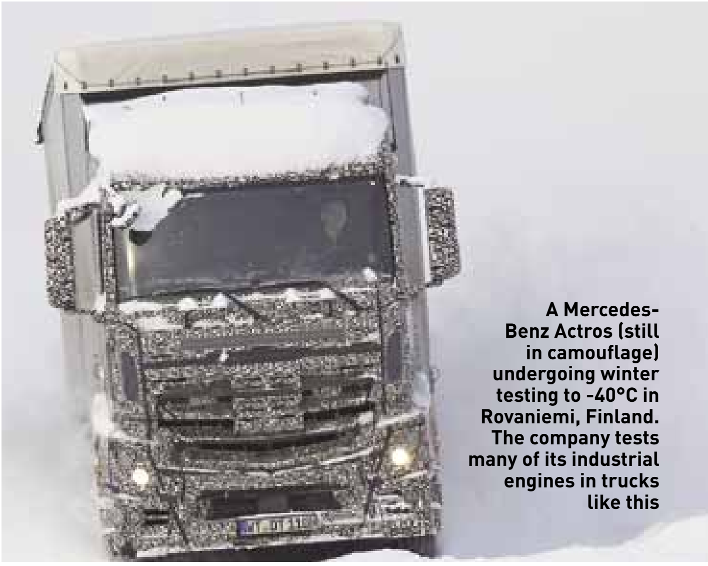
The PistenBully unit is compliant with Stage IIIA/Tier 3, but Nendick notes: "For Tier 4 Final, the use of SCR and AdBlue aftertreatment systems means additional components will be required to keep it working at low temperatures. There needs to be capable heating of the AdBlue. Electrical heaters on the lines as well as a coolant-based heater in the tank are the solution here."

In fact, Cummins has a long and interesting history when it comes to cold-weather innovation. It supplied a pair of its renowned H-6 units to the Antarctic Snow Cruiser, built in 1939, which featured an unusual twin engine and electric drive combination – as the feature on page 54 reveals.

The cold hard facts

Perkins also features cold-weather options for the majority of its range. Martin Parker, technical manager, notes, "Challenges not only include starting the engine, but thermal management of the aftertreatment; providing sufficient heat to the operator [the cab heater draws its heat from the engine] and the time it takes for the engine to warm up.

"Also we would mandate fluid changes – notably oil to cope with the viscosity change – and would advise heating various systems such as the DEF tank lines and breather. A cold-weather pack is also available, including ether start and cylinder block heaters."



A Mercedes-Benz Actros (still in camouflage) undergoing winter testing to -40°C in Rovaniemi, Finland. The company tests many of its industrial engines in trucks like this

While the control software stays the same, mechanical components such as batteries, starters, power cables and alternators are selected dependent on the application, as the machine's parasitic load will change with temperature.

Parker continues, "We design our engines with differing fuel qualities in mind, but not for additives. Looking forward, developments in the way we integrate the engine and the powertrain are likely."

SPARK OF INNOVATION

Diesel may be king in the industrial world, but petrol still has its place. Rotax has been installing its engines in snowmobiles since 1962, and currently the company makes 2- and 4-stroke engines for a variety of uses, including BRP's Ski-Doo and Lynx ranges, industrial ATVs and even the Sea-Doo wet bike.

Thomas Uhr, general manager at BRP-Powertrain, observes, "Designing engines for cold weather poses specific challenges. For snowmobiles, we design down to -40°C, so tolerances are smaller due to the different elongation factor of the materials, such as an aluminum crankcase versus a main bearing and crankshaft made out of steel. So if the calculations and matching of those components is not properly done and extremely accurate, it could lead to a seizure at low temperature."

Uhr points out that the machines must also be able to start at low temperatures without a battery if necessary, stressing the importance of using oil with an appropriate viscosity, especially on the 4-stroke units.

There are further design differences between the cold-weather engines and their ambient-temperature counterparts. Uhr continues, "One of the main differences between Ski-Doo engines versus, for example, the Can-Am ATV engine, is the coolant system.

"With the ATV radiators, as with car engines, ambient air passes through to cool the liquid. On the Ski-Doo, the aluminum body frame is used instead – the snow does the cooling."

Rotax has created a custom ECU to cope with the changes in altitude. Again in common with cars, both the 2- and 4-stroke systems use sensors measuring temperature, air density, throttle position, RPM, and so on, to govern what the injectors do.

Over the years, Rotax has tested various biofuels. Uhr notes, "With ethanol, there are problems due to the affinity of alcohol to water. This may lead to reduced performance in the short term, and excessive corrosion of fuel system components in the long term.

"We remain open minded, but in the short term the best way of handling emissions is by good design. For example, the modern Rotax 2-stroke snowmobile engines have been equipped with the state-of-the-art E-Tech direct fuel injection system which allows the engine to operate as lean as possible under all conditions."

"THE SIBERIAN KIT OPTION FOR VOLVO'S ARTICULATED HAULERS IS DESIGNED TO ALLOW MACHINES TO WORK IN TEMPERATURES DOWN TO -40°C"

Testing times

Part of Volvo CE's development process for new engine technology involves testing prototype machines in the far north of Sweden, where temperatures drop well below -30°C. The engine technology for its latest generation of machines was tested in the deepest point of winter at the Kiruna mine – perhaps the largest and most modern underground iron ore mine in the world.

Here, a Volvo customer who operates at the production site incorporated the prototype articulated haulers into his fleet. This meant that not only could Volvo engineers collect data and monitor performance in a real-life situation, but they were also able to understand how the new technology felt from the operator's point of view. Other tests included repeating standard working cycles and cold-start optimization.

Each winter testing expedition involves around 100 engine and machine engineers, who together carry out hundreds of tests over the month-long expedition. The expeditions and tests are repeated twice – the first time during the development phase and again later on in the process, for verification.

Taking it to the other extreme, these tests are also carried out in demanding applications in the punishing heat as well as at high altitudes. Testing is carried out in climate chambers and test rigs at Volvo facilities.

MAIN IMAGE: **Testing the latest generation of Volvo articulated trucks involved repeating standard working cycles and cold-start optimization at the Kiruna iron ore mine in Sweden**

ABOVE: **Henrik Amann, director engine and auxiliaries at Volvo CE: "Stored electrical power... could be used to help start the machine in freezing conditions"**

When asked about the differences between cold and ambient engine specs, Henrik Amann, director engine and auxiliaries at Volvo CE, notes, "As much as is possible, the engines are the same. However, there are some differences between cold and ambient engine specs, such as electric block heaters.

"The Siberian Kit option for Volvo's articulated haulers has been designed to allow machines to work in extremely low ambient temperatures, down to -40°C. The kit contains a variety of modifications to crucial sub-systems, including electrical equipment, batteries, the hood, fuel supply and the radiator."

Amann also sees securing engine startability in cold climates as an important design challenge to overcome, as well as material specification so that parts don't crack. "The latest generation of our machines equipped with Tier 4 Final/ Stage IV engines now incorporate SCR, so in cold climates the tank and hoses containing the liquid are heated so that dosing can start as soon as possible after a cold start, and so that the reduction agent remains in liquid form. This is one of the key design features for Volvo machines that was tested during the winter expeditions."

As a key part of the testing and validation process, prototypes are also tested at high altitudes. The latest generation of machines was tested 3,500m above sea level in Les Deux Alpes, France.

For fuel, Amann advises, "For operation in cold climates, it is essential to use fuel with a low cloud point. It is usually the case that the fuel sold in Arctic climates has these properties. Volvo CE does not recommend the use of aftermarket fuel additives; instead we advise the machine operator to speak with the fuel supplier to ensure they use the correct fuel for cold climate operation."

Building prototype machines commits a lot of time and resources, so the manufacturer is developing new methods to increase the amount of virtual testing and simulation that can be conducted. The aim of this is to shorten the development cycle and also ensure that when the prototypes are built, they are of a higher quality and much closer to the final product. In the future, Amann believes the company will be able to skip early prototypes and build a more mature model with a higher level of accuracy that's much closer to the final machine – saving both time and money.

He concludes, "Looking further ahead, I think we will see more electric hybrids on the market. The stored electrical power in these could be used to help start the machine in freezing conditions." **iVT**