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SELECTIVE CATALYTIC REDUCTION OF PACCAR TRUCKS

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ABSTRACT

This paper presents involvement of Paccar Inc. in protection and preservation of the environment through the MX engines that have achieved near-zero emissions of NOx. The Selective Catalytic Reduction (SCR) and in-cylinder Exhaust Gas Recirculation (EGR) are the two emissions technologies presented. The Diesel Exhaust Fluid is used. Also the integration of Selective Catalytic Reduction equipment on the vehicle chassis is illustrated and its benefits are underlined.

Keywords: selective catalytic reduction, emission technology, catalyst, truck, engine

1. Introduction

What counts in the automotive industry is whether a vehicle suits the needs or expectations of the potential customers. Characteristics such as costs, design, comfort, functionality, agility, reliability or sustainability are the main factors in the purchasing decision. Knowledge of the legal and personal requirements and their interdependencies, the design approaches to meet them is a prerequisite for successful automotive design.

In no other area of complete vehicle characteristics does legislation pose such a technical and economic challenge to carmakers as in vehicle emissions. To be able to do the R&D required to continuously fulfil the legal requirements, car makers need to be exactly aware of coming changes in legislation [3]. With both fuel consumption and tailpipe emissions being caused by the combustion of fossil fuel, most conceptual measures for efficiency and design for absence of emissions serve both targets. Today, design for fuel-efficiency is mainly related to the introduction of advanced and alternative technologies such as electric engines, fuel cells, or bio-fuels. But with individual mobility being a necessity in most parts of the world rather than only convenience, the long-term move towards alternative propulsion concepts must also respect today's reality in terms of motorized traffic and the related industry [2]:

• The worldwide fleet of passenger cars that is mainly propelled by combustion engines,

• The automotive industry that has its main resources deployed to produce vehicles with combustion engines,

•The oil industry that runs worldwide infrastructure to supply individual vehicles with the necessary fuel.

Worldwide the Environmental Protection agencies are establishing new generations of emissions standards for gasoline – and diesel – powered passenger cars, light-duty trucks, heavy duty trucks and busses. These emissions standards define the emission control strategies. The next generation of emission control employs a systems approach combining advanced engine and fuel delivery technology, advanced emission control technology and low sulfur fuel [1]. Advanced catalyst-based technology will play a central role in the emission control system of the future.

2. The MX Engine and the Emission Technologies

The PACCAR MX engine brings a new level of innovation through industry-leading quality, exceptional reliability and proven performance [5]. It combines maximum power with outstanding fuel efficiency to optimize performance in virtually any application. For more than 50 years, PACCAR has delivered over 1 million engines globally providing innovative solutions and an unwavering commitment to superior customer service and support. PACCAR's core commitment to quality is evident by the integration of systems and the use of the highest quality materials available that results in long-term customer value. Superior fuel economy is achieved using precise fuel management controlled by the PACCAR Electronic Control Module.

The MX features low operational engine speeds with excellent torque characteristics, as well

as individual injection pumps that produce over 36,000 psi injections and advanced dual valve controls, resulting in precise spray patterns. The outcome is an optimum combustion process with excellent fuel efficiency.

The MX is the only commercial diesel engine to use Compacted Graphite Iron (CGI) in both the cylinder block and head. CGI is lighter and stronger than traditional gray iron and offers weight sensitive users excellent horsepower-to weight ratio to optimize payload. The distinctive MX crankshaft reduces weight and increases power for quicker acceleration and smoother overall operation. The integrated lubrication module of the MX combines filters, a thermostat and an oil cooler joined directly to the engine without external lines to maintain oil quality and extend service intervals.

The MX features a fully encapsulated wiring harness mounted directly to the block that protects wiring from the elements and removes stress from connectors. This results in a dependable electrical system that is serviced in a non-invasive manner to keep trucks in operation.

The MX utilizes fractured cap technology in both the connecting rods and main bearing caps to provide high shearing strength that result in a wide horsepower range and longer torque and power curves for more efficient operation. A rear mounted gear train and a floating oil pan reduces engine vibrations and noise to provide drivers a quieter operating environment.

MX offers a long term value proposition through its technologically advanced designs with lightweight materials that achieve excellent performance and leading fuel economy. The fully integrated systems with modular components reduce design complexity resulting in longer service intervals, increased uptime, lower operating costs and higher resale value.

The volatility of fuel prices and the potential of explicit CO_2 emission control regulations have caused aerodynamic performance to become a critical component of heavy vehicle development.

Concern about clean air and environmental regulations impact all of us. The protection and preservation of the environment is a core value at PACCAR. From 2010 all PACCAR engines have achieved near-zero emissions of NOx, a greenhouse gas and smog causing compound.

Selective Catalytic Reduction (SCR) and in-cylinder, Exhaust Gas Recirculation (EGR) are the two emissions technologies available now. By evaluating the two technologies it was demonstrated that SCR provides the most fuel efficient and cost-effective solution to nowadays regulations. The SCR system operates downstream from the engine, removing much of the stress and heat rejection related to EGR-only engines to improve reliability and increase fuel economy.

3. Selective Catalytic Reduction Emission Technology

The SCR system has four major components, which integrated into the exhaust system (Figure 1):

- Diesel Exhaust Fluid (DEF) tank,
- DEF doser,
- SCR catalyst
- ammonia (NH3) catalyst.

In order to produce nitrogen gas and water vapour, small amounts of DEF are injected into the catalyst. After mixing it reacts with the NOx that is found in the exhaust. Then, nitrogen gas and water vapour are released into the atmosphere through the vehicle's tailpipe.

The benefits of SCR are improvement of engine fuel economy and increased engine reliability. In order to meet EPA 2010 NOx limits the engines using SCR after treatment do not require significant increases in EGR flow rates if one compares 2007 emissions technology with the EPA 2010 NOx limits. After treatment, an engine with SCR operates more efficient, cleaner and cooler than engines with higher EGR levels. This happens due to the fact that within the exhaust stream the pollutants are reduced to near-zero levels.

Engines equipped with SCR technology provide fuel economy up to 5% improvement compared with other engines. This improvement is greater when compared such an engine to a 2010 non-SCR engine. Also the reliability is greater because the engine is cooler.

SCR technology has been tested for a number of years in different applications from extreme climates and various industries including trucking, marine and stationary power applications [6]. More than 150 000 engines manufactured by Paccar are successfully performing with SCR technology. Engines that are utilizing high EGR flow rates are not very well tested. This is a new concept that is not actually used by any engine manufacturer. In order to deal with the increased EGR levels the high output EGR, engines require significantly higher heat rejection, leading to lower fuel economy comparing to actual designs.

A non-toxic solution of 67% purified water and 33% urea is called Diesel Exhaust Fluid (DEF). Urea is a natural compound produced from natural gas that is commonly used in everyday products such as fertilizer. DEF can be stored, dispensed and handled in bulk and smaller quantities.

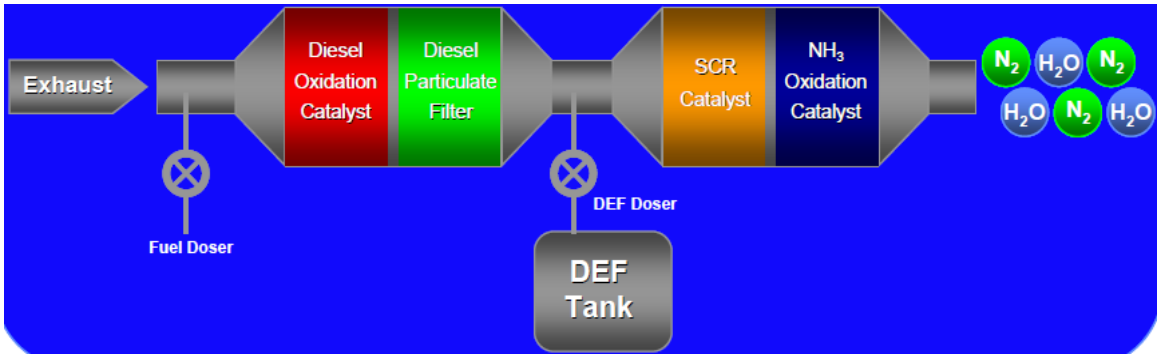

Figure 1: The SCR System

It is used in a small quantity approximately 2% of diesel fuel so on-vehicle the DEF tank is substantially smaller than the fuel tank. DEF is available to a range of bulk volumes, to small containers easily to carry on the vehicle. In Europe many fleets purchase bulk tanks for additional availability of DEF which is also available at DEF distributors: at truck stops and other fuelling outlets.

Figure 2: Catalyst integration on the vehicle chassis

In a wide range of climates DEF has proven to be very reliable in different places in the world. DEF freezes at -11°C. It thaws easy without degradation. DEF remains operational at -15°C during normal vehicle use without requiring a heating element in the system. Usually it is used heat generated from the engine to ensure the solution remains at operational consistency when temperatures are low.

When DEF is stored at high temperatures for an extended period of time it will slowly degrade. In order to keep product quality at all temperatures it is recommended to rotate the stock within a year.

In order to monitor operational performance the SCR system comprises sensors. The driver is informed by warning indicators of items requiring attention. For example, a number of indications are displayed when the DEF tank approaches empty. It provides the time to refill the tank before it becomes empty.

So far the biggest problem has been finding the proper space required accommodating the equipment. This is a big issue for some fitters who want open areas behind the truck cabs and along the frames as not to interfere with mounting the bodies.

The SCR system is integrated on the vehicle chassis. As shown in figure 2, the SCR catalyst is most likely be positioned within the toolbox mounted under the cab. The DEF tank, noted in green is mounted on the chassis in front of the fuel tanks where refilling is simple.

In figure 3 is shows a catalyst, on each component perform a specific function:

1. Diesel Particulate Filter – is used to reduce particulate matter.

2. SCR Catalyst - facilitates the chemical conversion of NOx to Nitrogen gas and water vapour.

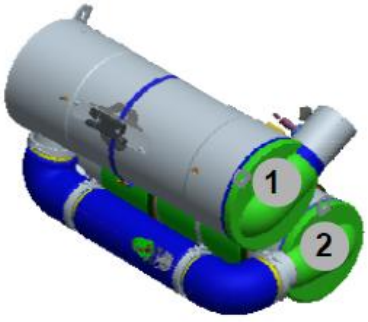

Figure 3: Catalyst

The tank and injection components, illustrated in figure 4, each perform a specific function in the after treatment process:

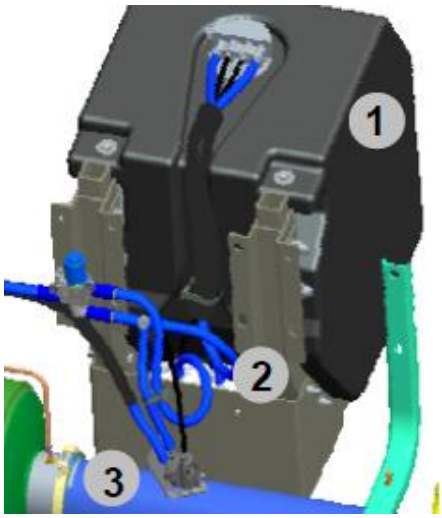

Figure 4: Tank and injection components

1. DEF Tank – store the DEF solution on the vehicle and be available in a range of sizes dependent upon total vehicle diesel fuel volume.

2. Dosing Pump – provides pressure to send the DEF solution from the tank to the doser.

3. DEF Doser – delivers the DEF into a mixing pipe where it is combined with the exhaust gas exiting the Diesel Particulate Filter (DPF).

In line with these changes, the air-intake system has been refined by integrating it into the hood and simplifying the intake piping to reduce any intake restriction, allowing the engine to breath easier.

As well, an improved seal stops the engine's heat seeping into the intake system, enhancing the delivery of cold ambient air-flow to the engine for optimal performance.

The PACCAR higher horsepower models with EGR engines employ an integrated Cummins-designed diesel particulate filter – a self-cleaning filter that also replaces the conventional muffler and is designed to last the life of the engine.

The Cummins diesel particulate filter is designed to capture the carbon scot within the walls of the filter, using a chemical reaction to neutralise the nitrogen oxides. The carbon is then naturally oxidised by heat in a second stage, which regenerated the filter.

This particular diesel filter has three different installations. Each installation type has been specifically designed to suit different applications.

The first is a horizontally mounted in-chassis location, which is suited to applications requiring full fuel capacity and/or maximum trailer lengths.

The second option is also a horizontal mounting, on the driver's side taking the place of the right-hand fuel tank. This installation is designated for operators who do not need to carry maximum fuel but may need to utilise the area at the rear of the chassis for ancillary equipment. The filter is covered by the front tank fairing on the aero models and by a step arrangement on the traditional range.

For applications that require full fuel, while allowing access to area underneath the chassis, there is the third option to vertically mount the particulate filter behind the cab. This lends itself to accommodating shorter trailer lengths with the swing clearance at the back.

4. Benefits of SCR Equipment

The SCR equipment added to the trucks increases the fuel mileage up to 9% or 1.8 mpg. In today's economy that can make a huge difference. Having the SCR placed in all trucks may also increase the productivity of most trucking companies, which will then increase their profitability. It is anticipated that SCR will reduce NOx output to near zero. SCR is one of the only emissions reduction technologies that is as good for business as it is for the environment, and the reach of SCR is broad. The goal of most any business is to make a profit.

When it comes to making the decision on whether or not to add the SCR equipment to the current truck models that are already out on the road, it's all a matter of opinion. Starcevic [4] reports that if she were to have that choice, at all costs not detrimental to the company, in her opinion option would be to add the fuel saving, production is increasing, money making SCR equipment.

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