EXECUTIVE *Report*

A Hard Look at New Cooling Systems for Clean Diesel Engines

OEMs Face Significant Changes, Aggressive Deadlines

Engine makers are converging on workable solutions for reducing harmful emissions from diesel engines, in accordance with stringent regulations taking effect in the United States, Europe and Japan in the next few years.

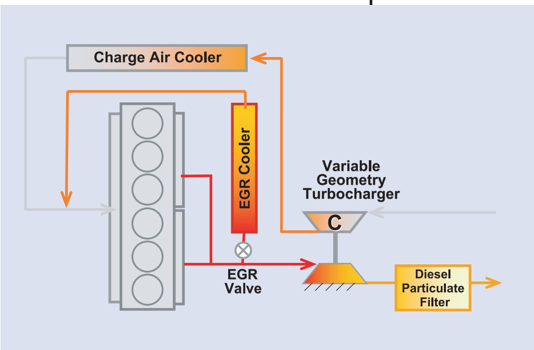
The U.S. Environmental Protection Agency (EPA) and Ford Motor Company recently announced a second phase of their technology partnership to develop a new diesel emission technology called Clean Diesel Combustion (CDC), which holds promise for providing a pathway for diesel engines to meet stringent emission levels for nitrogen oxides (NO_x) [1]. CDC technology involves improvements in diesel fuel injection system performance, re-optimization and refinement of air management and turbocharging systems, and an improved combustion system [2,3]. The stated program goal is to meet the upcoming diesel emissions standards without additional NO_x after treatment. A similar partnership between the EPA and International Truck and Engine Corporation was announced last year [4].

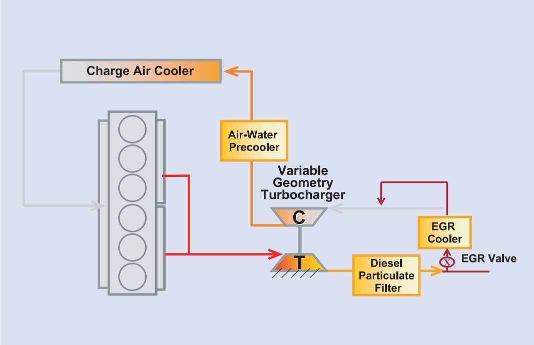
Earlier Cummins, Caterpillar, International and Detroit Diesel Corporation announced intentions to meet the 2007-2009 NO_x requirements using technologies generally based on various forms of exhaust gas recirculation (EGR) [5,6].

Hasse Johansson, the group vice-president for R&D at Scania, outlined similar developments in engine technology at a symposium "Future Environmental Challenges for the Automotive Industry," which was devoted to broad issues relating to new clean air regulations [7]. Johansson identified EGR as Scania's preferred solution, because it attacks emissions at the source rather than rely on after treatment [8]. Scania is the world's fourth largest truck brand for heavy trucks above 16 tons, behind Volvo, Mercedes and Freightliner.

There are many technologies in development for reducing NO_x emissions (Fig. 1). Specialists in combustion processes are performing much of the key research, yet there is broad recognition that significant changes in cooling systems will be required to optimize the combustion cycle.

Fig. 1 – The basic EGR configurations proposed for 2007 include high-pressure loop (top) and low-pressure loop (bottom). There are many potential variations. The low pressure loop offers advantages in efficiency; meanwhile, the elimination of pre-coolers is a design goal. All candidate configurations present challenges in materials and design. (Illustrations courtesy of Carl Kiser, Honeywell.)





A Hard Look at Heat Exchangers

Carl Kiser of Honeywell Turbo Technologies, Thermal Systems also spoke at the environmental symposium in Tokyo. Kiser is renowned for pioneering work on charge air coolers. His work encompasses a deep understanding of combustion processes as well as turbochargers and cooling systems. The crux of Kiser's presentation in Tokyo was to sound an alarm that OEM truck makers will need to make significant changes in their choices of heat exchangers and that they are facing aggressive deadlines [9].

Apart from the important design decisions regarding parameters for the combustion chamber, it is necessary to develop suitable cooling systems that can provide charge air and exhaust gas at the necessary temperatures and pressures.

In Kiser's presentation, after reviewing the major technologies in development, including low-pressure and high-pressure EGR systems, Kiser examined issues with thermal systems in great detail, including EGR fouling and plugging, heat rejection, packaging, cost and durability. He highlighted performance degradation, engine compartment space, materials and processing, life cycles, thermal fatigue and corrosion as presenting challenges with high-flow EGR systems.

Kiser presented a typical EGR turbocharger compressor map, and he noted how recirculation rates go up significantly with pressure- and airflow-range requirements. The conclusion is that the increase in heat rejection will challenge cooling system performance.

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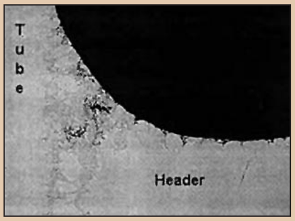

Fig. 3 – The low-pressure loop EGR system resulted in a new failure mode for an aluminum CAC. Evidence of corrosion attack of the braze joint is exhibited in this photomicrograph. Also, note the corrosion attack on the header. (Courtesy of Carl Kiser, Honeywell.)

Challenges in Materials & Design

Taking a hard look at current cooling systems and future requirements, Kiser then outlined the impact of EGR technology on CAC design. He pointed out the limitations of existing designs, especially 2004 CAC designs made from aluminum.

One driver of change is that, as the cooling requirements increase, customers are also demanding longer life cycles for cooling systems. But fatigue mechanisms of aluminum dictate that increasing metal temperature reduces the time before failure (Fig. 2). Kiser pointed out a new failure mechanism that drastically reduces aluminum CAC lifetimes in low-pressure EGR systems.

Needless to say, the conclusion of Kiser's presentation was that heat exchanger materials and designs must significantly change in 2007. *Cu*proBraze® was repeatedly mentioned by Kiser as a candidate material for replacing today's aluminum CACs.

Looking for Solutions

Besides Johansson and Kiser, the symposium in Tokyo featured lectures by Hideaki Suzuki of the Tokyo Metropolitan Government, who described recent measures taken against diesel emissions in Tokyo; and Professors Ingemar Denbratt and Erick Fridell, both of Chalmers University of Technology, Gothenburg, Sweden, who lectured on the diesel combustion processes and catalytic converters, respectively [7].

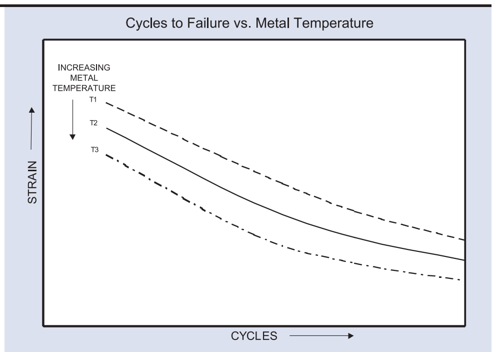

Fig. 2 – Cycles to Failure versus Metal Temperature, for typical aluminum CACs. Increasing metal temperature reduces life of aluminum. (Illustration courtesy of Carl Kiser, Honeywell.)

Meanwhile, a new materials technology that can be used in new charge air coolers is already in production. Soon after the environmental symposium in Tokyo, many of the attendees flew to Nanning, in southern China, where Nanning Baling Technology Inc. announced new *Cu*proBraze CAC designs and dedicated a new plant for production of the same. In addition, SHAAZ in Russia is already producing CACs made of copper/brass in volume [10] and these CACs have been installed in URAL and IVECO-URAL trucks [11].

Additional production is taking place in North America and Europe with major manufacturers gearing up with this new technology. These plants benefit from *Cu*proBraze technology, which consists of new alloys and a new process for brazing copper fins to brass tubes as well as brazing brass to brass. ■

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COPPER
International Copper Association, Ltd.

International Copper Association, Ltd.
260 Madison Avenue, 16th Floor, New York, NY 10016-2401
Tel: 212.251.7240, Fax: 212.251.7245