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Automotive fuels - Diesel fuel - Cold operability testing and fuel performance correlation

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European foreword

This document (CEN/TR 16884:2016) has been prepared by Technical Committee CEN/TC 19 "Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin", the secretariat of which is held by NEN.

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In 2010, CEN/TC 19 adopted Resolution 2010/11 setting the title and scope of WG 34 which were defined as follows:

Title: *"Diesel fuel cold operability correlation"*

Scope: *"Develop a study on the field correlation of the different cold operability (cold flow and cloud point) test results in relation to actual automotive diesel fuel performance in engines in real world cold conditions. For this work historical data on both manual and automatic tests and on 1988, current and, if possible, future engine concepts shall be used. Real market distillate fuels and FAME, plus common blends thereof, shall be used. The working group shall advice towards WG 14, WG 31 and WG 24 on possible improvements towards their test methods and specifications. The result of the group will be, as a minimum, the development of a Technical Report on "Cold operability testing and fuel performance correlation".*

In view of the parallel ongoing work within DGMK Project 764 "Cold flow properties of diesel and operability of vehicles in winter", this study is focusing on an investigation into the field correlation of cold operability descriptors (e.g. CFPP, Cloud Point) with actual vehicle performance. In addition the study is evaluating the impacts of fuel properties, cold flow additives and blending, and vehicle technology on cold operability. Given the close relationship between the work of WG 34 and the DGMK Project 764, a liaison between these groups has been established throughout the drafting of this report.

WG 34 would like to acknowledge the significant contributions by members of the working group who have contributed to the publication of this report.

Introduction

Low temperature operability of diesel vehicles is a common concern for all the stakeholders including the vehicle manufacturers and the fuel suppliers. The stakeholders' shared desire is to ensure that the end user is able to operate their vehicle regardless of the ambient temperature conditions.

The Cold Filter Plugging Point (CFPP) method is included in EN 590 as a means to ensure vehicle operability. As all European countries experience different climatic conditions, the limits for cold flow properties of diesel fuel are decided by the National Standardisation Body of each member state within the framework allowed by EN 590. For member states with temperate climates, a different grade of diesel fuel with its corresponding CFPP limit is selected from Table 2 of EN 590:2013 for each season depending upon the climatic conditions.

For member states with arctic or severe winter climates, a different class of diesel fuel is selected from Table 3 of EN 590:2013 for each season depending upon the climatic conditions. In addition to a CFPP limit, Table 3 also includes a maximum Cloud Point limit for each class of diesel, as well as different limits for several other fuel properties (e.g. density, viscosity, distillation, cetane). Some member states also select different climatic grades / classes for specific geographic regions within the country (for example mountainous or colder regions). A lower density can result in diesel fuel with lower volumetric energy content which can negatively impact vehicle volumetric fuel consumption. Thus a balance between ensuring vehicle cold operability and fuel cost is needed.

The application of the CFPP test in middle distillate fuel specifications has facilitated a trade-off between the needs of the market and the costs of the whole system for the customer (i.e. the investment costs in the vehicle diesel fuel filter system and the recurrent costs of the fuel supply). To meet the CFPP specifications without significantly decreasing the yield of middle distillate fuels, the use of cold flow improver additives has been widely adopted by refineries.

Since the CFPP method was developed in the 1960s, several studies have been performed to develop other laboratory methods in an attempt to improve upon the correlation with vehicle cold operability. However this has proved difficult due to constantly changing diesel engine technologies which have necessitated changes in vehicle fuel system design driven by ever more stringent emissions legislation (e.g. the move to direct injection and common rail systems with high pressure pumps requiring changes to fuel filter materials and efficiency). At the same time, middle distillate fuel production has changed significantly over the years as refineries have had to meet increasingly tight fuel quality requirements (e.g. reductions in sulfur content, density and polyaromatic hydrocarbons as well as the introduction of biofuels and higher cetane requirements). Despite all these changes to the vehicles and the fuels, and the development of alternative lab tests, the CFPP remains the foremost test used to protect the end user from cold operability vehicle failures.

At the 37th meeting of CEN/TC 19/WG 24 (November 2009, Brussels) questions were again asked regarding the correlation between cold flow tests and actual vehicle operability at low temperature. Some participants thought that the situation had worsened due to the introduction of finer fuel filters and FAME blending.

At the 38th meeting of CEN/TC 19/WG 24 (March 2010, Teddington) the WG 24 convenor and secretary suggested a scope for a new working group to be formed. This was accepted by WG 24 and the proposal was then forwarded to CEN/TC 19 members (CEN document N1451). The proposal was accepted by CEN/TC 19 on 10 May 2010 (resolution 2010/11).

Following a number of vehicle operability issues experienced, for example during a cold period in the first half of February 2012, in Germany and Austria in particular, a DIN-FAM "mirror" working group was set-up in Germany as a taskforce to investigate the issue. A key outcome was the creation of a new DGMK project 764 "Determination of Cold Operability of Diesel vehicles" to develop and execute a joint industry project. Phase 1 was intended to evaluate several current vehicles from different OEMs to select a new reference vehicle for operability testing. It was also proposed that Phase 2 would investigate the development of a rig test and evaluate a wider range of different fuels in the selected reference vehicle. CEN/TC 19/WG 34 is maintaining close contact with the DGMK project group.

This Technical Report covers operability and tests to assess diesel fuel performance below the fuel cloud point. Although a high filter blocking tendency above the cloud point can have an impact on vehicle operability at low temperature, the development of a lab test to identify this specific issue is being pursued by CEN/TC 19/WG 31 rather than by WG 34.

Finally, it should be borne in mind that the refiners and vehicle manufacturers are not the only stakeholders when it comes to ensuring low temperature vehicle operability. There are a number of other stakeholders involved, including fuel blenders, fuel retailers, biofuel suppliers, cold flow additive suppliers, vehicle fuel system manufacturers, motorists and standardisation bodies like CEN. With this in mind, it is important that each stakeholder shares the responsibility for ensuring low temperature vehicle operability.

1 Scope

This Technical Report lays down the results of a study on the field correlation of the different cold operability (cold flow and cloud point) test results in relation to actual fuel performance in engines in real world cold conditions (below the fuel's cloud point). For this work historical data on both manual and automatic tests and on old (1988), current and future engine concepts have been used. Real market distillate fuels and Fatty Acid Methyl Esters (FAME), plus common blends thereof, have been investigated.

2 Cold flow additives

2.1 Application

2.1.1 Diesel fuel characteristics

Middle distillate fuels are primarily complex mixtures of hydrocarbon molecules. Depending on the source of the petroleum crude and on the level of refinery processing, some 15 % to 30 % of these are *n*-alkanes (also referred to as *n*-paraffins). The carbon number chain length of these alkanes is typically in the region of C8 to C28/C32. As middle distillates are cooled, the heavier n-alkanes start to precipitate from the fuel. These are in the form of wax crystals which can be as large as 1mm^2 and are typically in the form of flat, thin rhomboid plates. As the cooling continues, the wax crystals grow very quickly with n-alkanes as low as C18 involved in the precipitation (Figure 1).

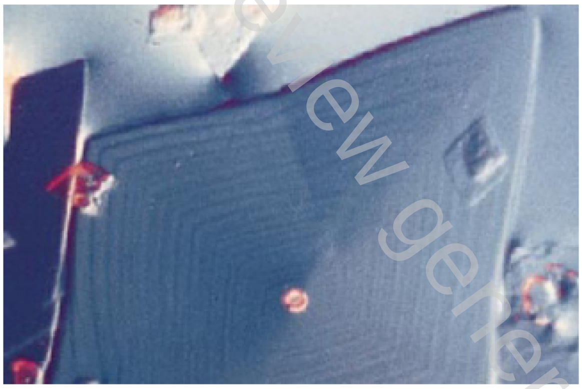

Figure 1 — Wax crystals in untreated diesel fuel (source: Infineum)

The plate-like crystals also exhibit strong edge-edge attractive forces between individual crystals which results in the formation of a gel structure where the majority of the fuel remaining in the liquid phase is trapped in the interlocking crystal lattice. As a consequence of this, a very small amount of precipitated wax may be sufficient to cause solidification of the fuel. Without the use of external heaters or cold flow additives, this phenomenon rapidly causes the fuel filters found within car and heating fuel systems to block resulting in fuel starvation to the engine, loss of power and eventually engine stalling.

In recent years diesel fuels have become more complex as fatty acid methyl ester (FAME), hydrotreated vegetable oils (HVO), Gas-To-Liquid (GTL), etc. have been increasingly introduced into diesel blends. HVO and GTL are paraffinic fuels that are composed of molecules already present in petroleum fuels. FAMEs on the other hand are chemical species that are not present in fossil fuels. However – like n-alkanes – saturated FAMEs can crystallise upon cooling and form part of the precipitated wax together with n-alkanes.