CEC New Test Development – Proposal for a New Fuels Engine Test Method

Objectives of this ToR:

- Set out clearly what need is being addressed – to give industry stakeholders a chance to ensure the method delivers what they need.
- Gives lead labs a chance to start to consider their submission proposals.
- Give the TDG a chance to consider how a method will be developed without a hardware sponsor.
- Provide a document that the working group can refer to periodically and aid decision making.

TDG-F-nnn

"Diesel Injector Coking Test"

1. Demonstrated need:

Across Europe, direct-injection compression-ignition engines remain the dominant power source in light and heavy-duty commercial vehicles, off-road & non-road mobile machinery. At the time of writing, they also power a significant proportion of passenger cars.

1.1 Definitions

- 'Diesel' fuels are defined as any middle-distillate fuel including fossil, biodiesel or paraffinic e.g., HVO intended for use in compression-ignition internal combustion engines.
- 'Diesel' engines are defined as internal combustion engines capable of running on those same fuels.

Injector coking is the formation of deposits in the precisely made nozzle holes that deliver fuel into the combustion chamber of diesel engines. The coking process is complex, being influenced by fuel composition, injector tip temperature, fuel-system design, combustion by-products and residual engine-oil. [1-5]

Injector coking affects the fuel spray pattern, fuel/air mixing and injected fuel mass - altering combustion from that intended by the OEM. Unintended changes in combustion may lead to a deterioration of one or more of the following: vehicle performance, fuel efficiency, CO_2 and engine-out criteria emissions. [1-5]

In general, this new test development sets out to create an accurate method to measure injector coking or any proportional measure of coking e.g., power loss from modern diesel fuels in modern diesel engines.
The existing CEC diesel direct injection fouling method (CEC F-098 DW10b) has been a widely used tool of diesel fuel development since its inception. There has been no reported serious instance of injector coking field issues during its lifetime. So, there is a continuing need for this type of test and specifically a replacement to F-098 DW10b.

2. Endorsement

The members of the European automobile industry association (ACEA), European Fuel association (CONCAWE) and Additive industry association (ATC) give their full support to this new candidate test procedure.

3. Availability of Support

- Unlike previous Fuels test developments there is no Hardware sponsor or prototype test method. No engine manufacturer has offered to provide an engine platform and associated technical support.
- ***This requires a significant additional step of identifying a 'sensitive' set of hardware and associated test cycle and fuel(s).***
- This extra step should take place after a TDG is formed. (CEC Guideline 10, section 4, paragraph 1c)

As early as possible, the TDG must decide to either:

1. Take the task to identify this new hardware themselves,
2. or decide to include this as a requirement of the lead lab in the lead lab tender.

Identifying a sensitive test method is essential in the success of meeting the test method.

Examples of potential test hardware could be:

1. An engine OEM, for example a HD or Off-Road OEM who can sell engines to customers with the necessary ECU and wiring harness.
2. An existing industry test, for example a lubricants test.
3. Any other source capable of meeting the test objectives and guidelines and deemed acceptable by the TDG.

Due to the absence of a Hardware Sponsor, extra support may be required from 'Expert' members with relevant experience of engine calibration, fuel system design and manufacture. 'Expert' members can include individual consultants or commercial consultancies – depending on the group's technical requirements and cost.

Any consultant costs would be taken from the TDG's sponsorship fund and TDG must consider this aspect as part of the lead lab selection process.

Engine supply should be available for at least five years from the date that the Test Development Group (TDG) is formed. For reasons of urgency and it's suggested to investigate using the same hardware as an existing & recent industry test, for example, a lubricant test.

Any hardware that enables running in a laboratory such as a dedicated engine, wiring harness and Electronic Control Unit (ECU) must be made available to all off the sponsoring group members at the same time.

4. Confidentiality

- Any confidential information must be handled in line with CEC Guideline 15 paragraph 5d. Such information should be protected in documented proceedings (e.g., minutes) of the Group by the relevant CEC declaration.

In the case of using pre-existing industry test hardware:

The information provided to the CEC Project Group by the hardware supplier (normally an OEM) will be confidential where it pertains to the electronic engine control unit. The information provided by the supplying hardware supplier will also be confidential where it pertains to the design of the engine. It's not intended that other OEM's or fuel injection suppliers should be excluded from the test development and test-use by these constraints. Where the TDG hardware supplier has confidentiality concerns – please refer to CEC Guideline 15 paragraph 5d.

Objectives of the Test Method

- The test must be able to discriminate between fuels that generate little to no coking from those that generate significant amounts of coking.
- As a direct replacement for F-098, the priority for test development is KC method.
    a. However, so that a CU version could be developed later (if required) with minimal technical and commercial barriers - provision for a deposit removal / CU version of the test must be kept under consideration.
- Use an engine, fuel injectors and fuel system representative of a current technology widely deployed in the market.
- The test method should be applicable to base fuels meeting the following:
    - Priority 1: EN 590 (up to B7), EN 16734 (B10), EN 15940 (paraffinic fuels) and fuel *blends* with FAME based fuel, paraffinic fuel and fossil diesel fuel.
    - Priority 2: EN14214 (FAME based fuel) quality and fuels meeting less stringent quality standards.

Method Development Priority

- The mechanism of diesel injector coking can be categorised based on two broad groups of fuels:
    - Those containing significant concentrations of metal and
    - Those that do not.
- The current direct-injection coking method CEC F-098-08 has historically been focussed on metal (zinc) containing fuels.
- Recent CEC fuels test method development has been made more difficult by the complexity of modern engines, so TDG time and resource should be focussed on one method at a time.
- As F-098 currently faces an urgent hardware supply issue – ***the priority is replacing the zinc-containing fuel method (zinc method) as soon as possible.***

- Once a zinc method has been proven to meet its final precision targets, a non-zinc method can be considered.

- The TDG should be aware of the risk that the selected hardware for zinc method may not be suitable for the development of the non-zinc method.

- The initial round of sponsorship will be based on the zinc method only. A second non-zinc method will require additional sponsorship.

Guidelines for the Test Development

1. The initial TDG will be formed by parties expressing an interest to participate in the process.

2. The cost of remaining a member of the TDG during phase 1 and phase 2 will not be known until the tenders have been completed (lead laboratory, reference fuels, reference lubricant, expert assistance etc.) Members should be aware that any work prior to this point cannot be funded by CEC itself.

3. High and low-fouling reference fuels are required for precision to be demonstrated during phases 1 and 2.

4. For the lead-laboratory, fuel-supplier and lubricant supplier tenders, the working group must develop robust technical specifications that include all relevant technical and quality requirements and project management processes.

    a. There should be no unwritten expectations.
    b. No reference to production nor supply costs should be included in the technical specifications.

5. The TDG should assess the probability of success once:
    a. Suitable test hardware has been identified, unless the TDG makes this part of the lead lab tender.
    b. The technical specifications have been written for all tenders.

6. The role of the lead laboratory will be a key success factor due to the lack of an OEM partner and hence the lead laboratory tender should focus on technical capability at least as much as cost and efficiency.

7. The role of the TDG chair will be a key success factor due to the relatively complex nature of this project and the selection of the chair by TDG members should consider project management skills, collaboration, consensus building, problem solving, conflict resolution, communication, and adaptability etc.

8. Identify key performance characteristic to monitor fouling. Ideally, this will be measured during testing with a minimum number of additional operations or ‘bench’ measurements. The loss of maximum engine power at rated power, like CEC F-098, is favoured.

9. Develop a procedure which is optimised for both time and cost efficiency. The aim would be to complete one test in a five-day working period, including any start and end of test procedures.

10. Fuel consumed during a test should not be excessive. As a guide, a maximum in the range of 600-800 litres per test like CEC F-098 would be acceptable.

11. Both an engine and injector set should perform consistently for a minimum of 1000hrs.

12. The group should make appropriate use of the experience gained in the development of the CEC F-098, F-110 and F-113 test.

13. It's acceptable to increase the severity of the test to meet practical constraints, provided the fundamental mechanism of fouling doesn't deviate from that intended.

Supply of Resources and Materials

1. Engine

The test engine and supplier are currently unknown and identifying sensitive hardware is a priority for the TDG. An after-market ECU may need to be calibrated as part of the test development and this should be stated in the lead lab requirements.

2. Injectors and nozzles

The injector or nozzle/needle should be designed in such a way that there is a injector coking similar to that observed in CEC F-098-08. The injector design is not fixed & can be determined with the help of a Fuel Injection Equipment (FiE) OEM. The selected injector manufacturer should make the test injectors available for at least 10 years from the start of the test development.

3. Reference Fuel

The final reference fuel technical specifications will be defined by the TDG. Two fuels will be required, a low-fouling reference and a high-fouling reference with added soluble Zn. Expectations from the TDG around supply, storage and shipping must be explicitly defined by the TDG and written into the technical requirements for the tender.

4. Reference Lubricant

The test lubricant requirements will be defined by the TDG, and this information will be included in the final tender document. Expectations from the TDG around supply, storage and shipping must be explicitly defined by the TDG and written into the technical requirements for the tender.

5. Meetings

After the ToR is released, meetings should take place at least every 3 months to maintain momentum. The lead laboratory will be expected to send representatives to all CEC TDG meetings.

References:
1. SAE.org: Injection Nozzle Coking Mechanism in Common-rail Diesel Engine. Toyota. SAE 2011-01-1818
2. SAE.org: Experimental Analysis of Injector Nozzle Coking on Multi-Cylinder Diesel Engine Considering Worst-Case Operating Conditions Including Engine Exhaust Brake, Cummins India. SAE 2020-28-0332
3. SAE.org: Impact of the Nozzle Coking on Spray Formation for Diesel Injectors. CNR Italy. SAE 2013-01-2546.
4. SAE.org: Analysis of Nozzle Coking Impact on Emissions and Performance of a Euro5 Automotive Diesel Engine. CNR Italy. SAE 2013-24-0127
5. DieselNet: Combustion in Diesel Engines. https://dieselnet.com/tech/diesel_combustion.php#components