COMMITTEE D02 ON PETROLEUM PRODUCTS AND LUBRICANTS

RESEARCH REPORT RR:DO2______________

STANDARD TEST METHOD FOR EVALUATION OF DIESEL ENGINE OILS IN THE CUMMINS M11 ENGINE WITH EXHAUST GAS RECIRCULATION

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INTRODUCTION

In 1998, Cummins Inc began development of new engine oil testing procedures designed to evaluate medium and heavy duty diesel engine lubricants for their ability to protect engines equipped with exhaust gas recirculation (EGR). Cummins testing showed that new engines designed to meet the 2002 (2004) EPA emissions requirements would result in higher soot loading and increased acidic contaminants in the used oil, as well as, higher overall bulk oil temperatures due to the use of EGR. The concern over valve train wear, oil filter plugging and engine sludge was demonstrated previously in the M-11 High Soot Test (HST), used as testing criteria for API category CH-4 and 1999 emissions requirements. In addition to the parameters in the M11 HST, the testing also showed increased ring wear. An ASTM Task Force was charged with the task of developing a test method based upon the Cummins M-11 engine with EGR and the guidelines set by the ASTM Heavy Duty Engine Oil Classification Panel (HDEOCP) and the American Chemistry Council (ACC). A list of the current members of this Task Force is in Appendix A. All of these factors resulted in the development of the Cummins M-11 Exhaust Gas Recirculation test, commonly referred to as the M-11 EGR Test. The Cummins M-11 EGR test is one of the test methods selected for inclusion in the PC-9 Heavy-Duty Diesel Engine Oil category.

TEST DEVELOPMENT

<u>Hardware</u>

This test method uses a Cummins M11 400 diesel engine, with a specially modified engine block. Test operation includes a 25-minute, warm-up, a 2-hour break-in, and 300 hours in six 50-hour stages. During three alternating stages, the engine is operated with retarded fuel injection timing and is overfueled to generate excessive soot. During the other three alternating stages, the engine is operated with advanced fuel injector timing, and is operated at peak torque conditions to induce valve train wear. "Prior to each test, a new parts kit is installed, which consists of pistons, rings, liners, and valve train components. The piston is a two piece articulated design, consisting of an aluminum skirt and steel crown which allows for higher top ring positioning. All of the critical parts are serialized for tracking purposes. A detailed list of all parts required for rebuild as well as ordering information is included in the test procedure attached as"[1] Appendix B.

As with many other tests, a Central Parts Distributor (CPD) has been designated for the M-11 EGR for serializing and distributing critical and non-critical parts. The CPD insures that all parts meet the required test specification prior to being tested.

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[1] ASTM Research Report D02:1440

Test Method

Initial Development

The initial Cummins M-11 EGR test was a 250-hour test with 15-minute alternating cycles. The first cycle was an idle stage and the second cycle was at peak torque conditions. The industry test labs began to install test stands and run the test procedure. After the analysis of several labs preliminary testing operations, it was determined that the labs did not have adequate controls in place to maintain some of the critical parameters. The ASTM Task Force met and the decision was made to use a cycle similar to the M11 HST test. The test length was originally proposed at 400 hours, the ASTM Task Force, in order to reduce the burden on the industry made the decision to incorporate six fifty hour stages for a total length of 300 hours. Due to delays in getting the new stands in place at the industry labs, several tests were run at the Cummins Technical Center to provide preliminary data on test repeatability and the ability of the test to discriminate between oils. This "proof of concept" data was presented to the ASTM Task Force and the HDEOCP (Refer to the June 27, 2000 minutes of HDEOCP). This initiated the widespread usage of the test in industry test labs.

Finalizing the Test Method

Through the last quarter of 1999 and throughout 2000 the ASTM Task Force made several significant improvements in the test method. The test stand and the hardware to set up were modified to improve test performance and improve the similarity between labs. Four labs participated in the development of the test (Appendix C). The four labs became part of the operations and hardware subgroup (O&H Subgroup) of the ASTM Task Force. The O&H Subgroup conducted several lab visitations to insure each lab had the correct test stand set-up and was following the procedures set forth in most current test method at the time. One of the most important changes to the test was made to the Stage A intake manifold temperature and air inlet system aftercooler. The original Stage A intake manifold temperature would cause the hot, humid air in the San Antonio labs to condense into a fog. This fog would cause rust to form in the aftercooler allowing small rust particles to enter the intake air stream and into the power cylinder. The fog also became acidic as it mixed with the recirculated exhaust gas corroding the aluminum intake manifold allowing aluminum oxide particles to enter the power cylinder as well.. This caused a significant increase in ring wear that was not acceptable to the Task Force. The Stage A temperature was increased out of the condensation range and an aftercooler with aluminum internal components replaced the original aftercooler. Other changes to the test method procedure included clarification statements on certain test stand set-up procedures and others, which are all, included in the latest draft of the test method (Appendix B).

PRECISION MATRIX

After the many improvements to the test procedure the ASTM Task Force and the ASTM HDEOCP considered the test ready for precision matrix testing. The matrix design incorporated the four industry tests labs with a total of 26 engine tests on 6 test stands. The oils used in the test were blended from three different base stocks with three different additive chemistries. The matrix design can be seen in Appendix D.

The results of the matrix testing are posted on the Test Monitoring Center website[2] and have been attached to this research report (Appendix E). The data were analyzed statistically and the observations of this analysis were presented to the Task Force (Appendix D). Upon review of the statistical analysis, discussion of results and resolution of test stand calibration issues, the Task Force finally recommended the inclusion of the test in the new Proposed Category 9 (PC-9) engine oil category. The ASTM HDEOCP and ACC concurred and registered testing began on August 20, 2001.

SUMMARY AND CONCLUSIONS

The latest draft of the standard test method defines a heavy duty diesel engine test that has been developed to evaluate valve train and power cylinder wear, oil filter plugging and engine sludge formation in diesel engine oils. These oils will be formulated for the aggressive environment the engine will endure with the addition of exhaust gas recirculation. The data obtained from the matrix indicates that the M-11 EGR Test has acceptable reproducibility and has the ability to discriminate between various non-reference oils. All of the data analysis and hard work put into developing this test has led to the recommendation by the Task Force and the HDEOCP to accept the M-11 EGR Test for inclusion into the new PC-9 engine oil category.

[2] TMC website address: http://www.tmc.astm.cmri.cmu.edu