



## GM Stochastic Pre-ignition Test Monitoring System

### **Introduction**

The GM stochastic pre-ignition test procedure (GMSPI)<sup>1</sup> measures an oil's tendency to pre-ignite during high load operation in a turbocharged engine. GMSPI is a part of GM's dexos<sup>TM</sup> 1 and dexos<sup>TM</sup> 2 engine oil specifications.

### **Definitions**

Configuration – an engine installed on a test stand.

Day – Monday through Friday, excluding federal holidays, company holidays, or scheduled facility shutdown periods.

LCL – lower control limit

Qualification – the process whereby an engine installed on a test stand demonstrates the capability to discriminate between reference oils of differing performance levels.

SPI – stochastic pre-ignition

TMC – ASTM Test Monitoring Center

UCL – upper control limit

### **Reference Oils**

- A. Two reference oils will be provided by GM and stored at TMC. The reference oil will be labeled GMPI01 (high SPI) and GMPI02 (low SPI). TMC will dispense reference oils to the laboratory as needed. In addition to the TMC quality monitoring system, GM will measure oil properties and will report the results to TMC.
  
- B. Test methods used by GM for oil analysis will be the following:
  - 1. Additive profile (GM proprietary method)
  - 2. Differential scanning calorimetry (DSC): ASTM D6186
  - 3. Elemental analysis by ICP: ASTM D5185
  - 4. Kinematic viscosity at 40°C (KV40): ASTM D7279
  - 5. Kinematic viscosity at 100°C (KV100): ASTM D7279
  - 6. High temperature high shear viscosity at 150°C (HTHS150): ASTM D5481

<sup>1</sup>GMW17244

7. Oxidation: DIN 51 453
8. Thermogravimetric analysis (TGA): ASTM E1131
9. Water content: ASTM E2412

C. GM will measure initial reference oil batches for the following:

1. Additive profile
2. DSC
3. HTHS150
4. ICP (B, Ba, Ca, Fe, K, Mg, Mo, Na, P, S, Si, Zn)
5. KV40
6. KV100
7. Oxidation
8. TGA
9. Water content

D. GM will measure reference oil batches every 6 months for the following:

1. DSC
2. Oxidation
3. Water content

E. Gm will measure reference oil batches every 12 months for the following:

1. Additive profile
2. ICP
3. KV40
4. KV100

### **Test Measurement Parameters**

The critical test measurement parameter is the number of peak pressure pre-ignition events.

### **Test Stand Qualification Criteria**

One test stand at a single laboratory has been approved to run GMSPI. Every time a new engine is installed on the test stand, the laboratory will need to prove that the configuration can distinguish between 2 oils of differing performance.

#### **A. Qualifying a New Configuration**

1. The laboratory must use daily engine health data to determine if the current engine has reached the end of its useful life. The laboratory must consult GM before

replacing the current engine. GM must approve the new configuration before testing can begin.

2. The laboratory must consult GM before replacing the current engine except as noted below. GM must approve new engine configurations.
  - (a) The laboratory is permitted to replace an engine at its discretion if the following conditions are met:
    - i. The engine has experienced a mechanical failure that cannot be repaired by replacing external parts or
    - ii. GM personnel cannot be reached within 2 days (excluding weekends or holidays no more than 2 days in length) or
    - iii. The engine has exceeded 450 hours of run time.
  - (b) In the event that the laboratory replaces an engine at its discretion, GM thereafter will approve the configuration as soon as possible.
3. Once a new engine has been installed and is ready for testing, the laboratory must provide written notification to TMC of the new engine. TMC will provide a reference oil testing sequence within 2 days of receipt of the notification.
4. Upon receipt of the reference oil test sequence from TMC, the laboratory must complete testing within 10 days in the sequence specified by TMC.
5. The laboratory will run 5 sequential, operationally valid tests each on reference oils GMPI01 and GMPI02 uninterrupted by non-reference oil tests. The laboratory must report each individual reference oil result along with operational parameters to the TMC, who will perform all calculations necessary for the qualification process.
6. A test is operationally valid if:
  - (a) The test is run in accordance with GMSPI and is not terminated before its designed conclusion.
  - (b) Every controlled engine operating parameter meets its respective Quality Index.

7. TMC will determine pass/fail for reference oil GMPI01 as follows:
  - (a) Calculate the square root of each result.
  - (b) Calculate the average of the 5 results from 7(a).
  - (c) Use the value from 7(b) to determine if GMPI01 is within control limits.
    - i. If the GMPI01 value is above the LCL and below the UCL, the engine passes qualification on GMPI01 reference oil.
    - ii. If the GMPI01 value is on or beyond the LCL or UCL, the engine fails qualification on GMPI01.
  
8. TMC will determine pass/fail for reference oil GMPI02 as follows:
  - (a) Calculate the square root of each result.
  - (b) Calculate the average of the 5 results from 8(a).
  - (c) Use the value from 8(b) to determine if GMPI02 is within control limits.
    - i. If the GMPI02 value is above the LCL and below the UCL, the engine passes qualification on GMPI01 reference oil.
    - ii. If the GMPI02 value is on or beyond the LCL or UCL, the engine fails qualification on GMPI021.
  
9. If a configuration fails to qualify after the first attempt, the laboratory, when it is ready to continue with qualification, will request another reference oil testing sequence from TMC. The laboratory must complete reference oil testing within 10 days of receipt of the testing sequence from TMC.
  
10. If a configuration fails to qualify after 2 attempts, the laboratory and TMC will together investigate the cause and develop an action plan. TMC may request the assistance of GM in the investigation and development of an action plan. Once the laboratory submits an attestation to TMC that the action plan has been implemented, TMC will provide a reference oil testing sequence within 2 days of receipt of the notification. The laboratory must resume qualification starting at A.4.

11. After receipt of all reference oil results, TMC will provide written confirmation of the outcome to the laboratory within 2 days. The laboratory is permitted to start candidate oil testing immediately upon receipt of an affirmative confirmation.
12. A laboratory must notify TMC of an invalid test due within 2 days of occurrence. An operationally invalid test requires the laboratory to submit an action plan to TMC within 5 days after notification, identifying the problem, indicating the action to be taken, and providing a time line for implementation.
  - (a) In the event of a known root cause with a straight forward solution, the laboratory may, at its own discretion, implement the action plan and continue the reference oil sequence pending the decision of TMC. In this case the laboratory will submit the action taken and all available reference oil results to TMC with the invalid test notification.
13. TMC will provide a written reply approving/disapproving the action plan to be taken within 5 days of receipt of the report.
  - (a) TMC may consult GM regarding approving/disapproving the action plan.
  - (b) In the event of a known root cause with a straightforward solution that in the opinion of TMC does not represent a systemic problem and is approved by TMC, the laboratory will be allowed to complete the original reference oil sequence.
  - (c) For all other invalid tests, if TMC approves the action plan, the laboratory must submit an attestation to TMC once the action plan has been implemented. Upon receipt of the attestation, TMC will provide a reference oil testing sequence within 2 days of receipt of the attestation. The laboratory must resume qualification starting at A.4.
  - (d) If TMC disapproves the action plan, the laboratory must submit a second plan to TMC specifying the new action to be taken. This iterative process will continue until the action plan is satisfactory. If TMC approves the action plan, the laboratory must submit an attestation to TMC once the action plan has been implemented. Upon receipt of the attestation, TMC will provide a reference oil testing sequence within 2 days of receipt of the notification. The laboratory must resume qualification starting at A.4.

14. If a configuration experiences 2 operationally invalid tests during the course of engine qualification that in the opinion of the laboratory or TMC represent a systemic problem or have no readily identifiable root cause, the laboratory, TMC, and GM will together develop an action plan. Once the laboratory submits an attestation to TMC that the action plan has been implemented, TMC will provide a reference oil testing sequence within 2 days of receipt of the notification. The laboratory must resume qualification starting at A.4.

B. Monitoring of an Existing Configuration

1. An existing configuration will be monitored by TMC through periodic reference oil testing.
2. A reference test consists of two consecutive runs, one each on GMPI01 and GMPI02, in a sequence assigned to the laboratory by TMC.
3. A newly qualified configuration must begin a reference test after no more than 25 candidate test starts or no later than 30 calendar days from receiving qualification confirmation from TMC, whichever occurs first. TMC will randomly assign a reference oil testing sequence to the configuration.
  - (a) The laboratory may delay a reference oil test so not to break up 5 consecutive tests on the same candidate oil provided the first test of the sequence is no more than 23 tests after receipt of an affirmative confirmation of qualification.
4. An existing configuration must run a reference test after no more than 25 candidate test starts or no later than 60 calendar days from the last reference test, whichever occurs first. TMC will randomly assign a reference oil testing sequence to the configuration.
  - (a) The laboratory may delay a reference oil test so not to break up 5 consecutive tests on the same candidate oil provided the first test of the sequence is no more than 23 tests after the previous reference oil test.
  - (b) A reference oil testing sequence will not be assigned to an engine that has exceeded 500 hours of run-time.
    - i. The laboratory is not permitted to start a candidate oil sequence once an engine has reached 500 hours of run-time. However, the laboratory

is permitted to complete a candidate oil sequence that was begun prior to 500 hour engine run time.

5. All reference test results along with operational parameters must be reported to TMC for review. TMC will calculate the square root of both results. Both values will be plotted on the control charts.
6. An individuals, moving range chart will be used to monitor configuration performance on reference oil GMPI01.
  - (a) R chart for the moving range
    - i. A value for the mean of the moving range,  $R_{\text{bar}}$ , will be provided for GMPI01. The mean will be recalculated every 20 tests, incorporating each new set of data.
    - ii. The upper control limit is defined as:  $3.267*(R_{\text{bar}})$
    - iii. The lower control limit is 0.
  - (b) X chart for the mean
    - i. A value for the mean of pre-ignition events,  $X_{\text{bar}}$ , will be provided for GMPI01. The mean will be recalculated every 20 tests, incorporating each new set of data.
    - ii. The upper control limit is defined as:  $(X_{\text{bar}}) + 2.66*(R_{\text{bar}})$ .
    - iii. The lower control limit is defined as:  $(X_{\text{bar}}) - 2.66*(R_{\text{bar}})$ .
  - (c) An assignable cause exists if any of the following occur:
    - i. A point on the R chart is on or beyond the UCL.
    - ii. A point on the X chart is on or beyond the UCL.
    - iii. A point on the X chart is on or beyond the LCL.
    - iv. Eight consecutive points on the X chart fall on one side of the mean.

7. An individuals, moving range chart will be used to monitor configuration performance on reference oil GMPI02.
  - (a) R chart for the moving range
    - i. A value for the mean of the moving range,  $R_{\bar{}}$ , will be provided for GMPI02. The mean will be recalculated every 20 tests, incorporating each new set of data.
    - ii. The upper control limit is defined as:  $3.267*(R_{\bar{}})$
    - iii. The lower control limit is 0.
  - (b) X chart for the mean
    - i. A value for the mean of pre-ignition events,  $X_{\bar{}}$ , will be provided for GMPI02. The mean will be recalculated every 20 tests, incorporating each new set of data.
    - ii. The upper control limit is defined as:  $(X_{\bar{}}) + 2.66*(R_{\bar{}})$ .
    - iii. The lower control limit is 0.
  - (c) An assignable cause exists if:
    - i. A point on the R chart is on or beyond the UCL.
    - ii. A point on the X chart is on or beyond the UCL.
    - iii. A point on the X chart is on or beyond the LCL.
    - iv. Eight consecutive points on the X chart fall on one side of the mean.
8. If a control chart indicates an assignable cause exists, the laboratory cannot continue with candidate oil testing. The laboratory and TMC will together investigate the assignable cause and develop an action plan. The laboratory or TMC may request the assistance of GM in the investigation and development of an action plan. Once the laboratory submits an attestation to TMC that the action plan has been implemented, TMC will assign a reference oil testing sequence. The laboratory must resume reference tests with 2 days of receipt of the assignment.

- (a) If the initial failing result was on GMPI01 the reference oil sequence will consist of one run each on GMPI01 and GMPI02.
  - (b) If the initial failing result was on GMPI02 the reference oil sequence will consist of one run on GMPI01 and two runs on GMPI02. Each run on GMPI02 must fall within the UCL and LCL.
9. A test is operationally valid if it meets the criteria listed in A.6. A laboratory must notify TMC of an invalid test within 2 days of occurrence. An operationally invalid test requires the laboratory to submit an action plan to TMC within 5 days after notification, identifying the problem, indicating the action to be taken, and providing a time line for implementation.
- (a) In the event of a known root cause with a straight forward solution the laboratory may, at its own discretion, implement the action plan and continue the reference oil sequence pending the decision of the TMC. In this case the laboratory will submit the action taken and all available reference oil results to the TMC with the invalid test notification.
10. TMC will provide a written reply approving/disapproving the action to be taken within 5 days of receipt of the report.
- (a) TMC may consult GM regarding approving/disapproving the action plan.
  - (b) In the event of a known root cause with a straight forward solution that in the opinion of the TMC does not represent a systemic problem and is approved by TMC, the laboratory will be allowed to complete the original reference oil sequence.
  - (c) For all other invalid tests, if TMC approves the action plan, the laboratory must submit an attestation to TMC once the action plan has been implemented. Upon receipt of the attestation, TMC will assign a reference oil testing sequence to the configuration. The laboratory must resume reference tests within 2 days of receipt of the assignment.
  - (d) If TMC disapproves the action plan, the laboratory must submit a second plan to TMC specifying the new action to be taken. This iterative process will continue until the action plan is satisfactory. If TMC approves the action plan, the laboratory must submit an attestation to TMC once the action plan has

been implemented. Upon receipt of the attestation, TMC will randomly assign one SPI reference oil to the configuration. The laboratory must resume reference tests within 2 days of receipt of the assignment.

11. The TMC, in consultation with General Motors, will review all invalid test declarations to determine if a reason for an invalid test represents a systemic pattern within a stand. Re-occurring evidence and the frequency of invalid tests by a laboratory will be a strong factor in determining the need to suspend the stand from candidate oil testing. A laboratory will be required to provide detailed explanations for the cause of an invalid test and the action taken to prevent the re-occurrence.

Release and revision history

<b>Issue</b>	<b>Date</b>	<b>Description</b>
0	June 2015	Initial release
1	January 2016	Revised A.2 and B.4 to reflect engine replacement once approximately 500 hours of run-time have been accumulated.