

Ford 6.7L VTW Test

Form 1

Version

Conducted For

| | |
|--|---|
| | V = Valid; The Reference Oil/Non-Reference Oil was evaluated in accordance with the test procedure. |
| | I = Invalid; The Reference Oil/Non-Reference Oil was not evaluated in accordance with the test procedure. |
| | N = Results Cannot be Interpreted As Representative of Oil Performance (Non-Reference Oil) and shall not be used in determining an average test result using multiple test criteria |

| | |
|--|-----------------------------|
| | NR = Non-Reference Oil Test |
| | RO = Reference Oil Test |

| Test Number | | | |
|---------------------------------------|--|-------------------|--|
| Stand: | | Stand Run Number: | |
| Engine: | | Engine Hours: | |
| End of Test Date: | | End of Test Time: | |
| CPD Kit Number: | | | |
| Oil Code ^A : | | | |
| Formulation Stand Code ^B : | | | |
| Alternate Codes: | | | |

In my opinion the test _____ been conducted in a valid manner in accordance with Test Method DXXX and the appropriate amendments through the information letter system. The remarks included in this report describe the anomalies associated with this test.

^A Reference Testkey or Non-Reference Oil Code ^B ACC-Registered Tests Only

Submitted By:

Testing Laboratory

Signature

Typed Name

Title

Form 2
Table of Contents

| | | |
|-----|--------------------------------------|---------|
| 1. | Title / Validation Declaration Page | Form 1 |
| 2. | Table of Contents | Form 2 |
| 3. | Summary of Test Method | Form 3 |
| 4. | Test Results Summary | Form 4 |
| 5. | Operational Summary Controlled | Form 5 |
| 6. | Operational Summary Uncontrolled | Form 6 |
| 7. | Rocker Arm Wear | Form 7 |
| 8. | Rocker Arm Wear Summary | Form 7A |
| 9. | Pushrod Wear | Form 8 |
| 10. | Pushrod Wear Summary | Form 8A |
| 11. | Rocker Arm Fulcrum Ball Wear | Form 9 |
| 12. | Rocker Arm Fulcrum Ball Wear Summary | Form 9A |
| 13. | Roller Follower Wear | Form 10 |
| 14. | Oil Analysis Summary | Form 11 |
| 15. | Oil Consumption Calculation | Form 12 |
| 16. | Downtime & Maintenance Summary | Form 13 |
| 17. | Test Comments | Form 14 |
| 18. | Test Fuel Analysis (Last Batch) | Form 15 |

Ford 6.7L VTW Test

Form 3 Summary of Test Method

This test method was developed to evaluate the performance of engine oils in controlling engine valvetrain wear in turbocharged and intercooled four-cycle diesel engines with roller-style cam followers, and a ball and socket style rocker arms and running on ultra-low sulfur diesel fuel. The test is 200 hours and is run at peak power to induce wear.

The engine is a MY 2019 Ford Power Stroke diesel engine with a displacement of 6.7L. It is an electronically controlled, turbocharged, charge air-cooled, eight-cylinder, direct-injection, compression ignition engine with an in-block camshaft, dual push tube per cam-follower, and a four valve per cylinder arrangement. The engine is re-used for multiple tests with new valvetrain parts installed prior to each test.

Schedule of Conditions for the Test Procedure

| | Set Point for Wear Phase |
|---|--------------------------|
| Time, h | 200 |
| Engine Speed, r/min | 2800 |
| Fuel Flow Rate, kg/hr | 70.5 |
| Air Temperature at CAC Outlet, °C | 50 |
| Air Temperature in Engine Intake, °C | 25 |
| Engine Coolant-Outlet Temperature, °C | 90.5 |
| Fuel Temperature at Engine Inlet, °C | 35 |
| Oil Temperature in Engine Gallery, °C | 109 |
| Air Pressure in CAC Coolant System, kPag | >25 |
| Air Pressure in Engine Coolant System, kPag | >120 |
| Air Pressure in Engine Intake, kPaA | 95 |
| Exhaust Pressure in Tailpipe, kPaA | 194 |
| Air Pressure at CAC Outlet, kPag | >160 |
| Engine Torque, Nm | Record |
| Air Dewpoint Temperature at Engine Inlet, °C | Record |
| Air Temperature at Turbo-Compressor Outlet, °C | Record |
| Air Temperature of Ambient Test Cell, °C | Record |
| CAC Coolant-Inlet Temperature, °C | Record |
| CAC Coolant-Outlet Temperature, °C | Record |
| Engine Coolant-Inlet Temperature, °C | Record |
| Exhaust Temperature in Left Exhaust Manifold, °C | Record |
| Exhaust Temperature in Right Exhaust Manifold, °C | Record |
| Exhaust Temperature in Tailpipe, °C | Record |
| Fuel Temperature at Engine Outlet, °C | Record |
| Oil Temperature in Oil Pan, °C | Record |
| | |
| Air Pressure at Dewpoint Measurement Location, kPaA | Record |
| Air Pressure at Turbo-Compressor Outlet, kPag | Record |
| Air Pressure in Engine Crankcase, kPag | Record |
| Barometric Pressure, kPaA | Record |
| Exhaust Pressure in Left Exhaust Manifold, kPag | Record |
| Exhaust Pressure in Right Exhaust Manifold, kPag | Record |
| Fuel Pressure at Engine Inlet, kPag | Record |
| Oil Pressure in Engine Gallery, kPag | Record |
| Oil Pressure Pre-Filter, kPag | Record |
| Oil Pressure Filter Delta, kPa | Record |
| Engine Coolant Flow Rate, L/min | Record |
| Air Moisture Content at Engine Inlet, g/kg | Record |
| Voltage from Engine Coolant Temperature Sensor, V | Record |
| Fuel Injection Timing, degBTDC | Record |

Ford 6.7L VTW Test

**Form 4
Test Results Summary**

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| | |
|-------------------|---|
| Lab Oil Code | TMC Oil Code ^A |
| SAE Viscosity | Number of Tests Since Last Calibration ^C |
| Soot @ 100 hours: | Soot @ 200 hours: |

| Start Dates and Time | |
|-----------------------|-----------------------|
| Engine Start Date | Engine Start Time |
| Test Clock Start Date | Test Clock Start Time |

| | Rocker Arm Wear (mg) | Push Rod Wear (mg) | Roller Follower Wear (µm) |
|----------------------------------|----------------------|--------------------|---------------------------|
| Original Result | | | |
| Transformed Result | | | |
| Correction Factor | | | |
| Corrected Transformed Result | | | |
| Severity Adjustment ^B | | | |
| Final Transformed Result | | | |
| Final Original Unit Result | | | |

| Last Stand Reference Results ^B | | | |
|---|----------------------|--------------------|---------------------------|
| Test Number: | | | |
| Oil Code: | | | |
| Test Length: | | TMC Oil Code: | |
| EOT Date: | | EOT Time: | |
| Stand Calibration Expiration Date: | | | |
| Soot @ 100 hours: | | Soot @ 200 hours: | |
| | Rocker Arm Wear (mg) | Push Rod Wear (mg) | Roller Follower Wear (µm) |
| Final Original Unit Results | | | |

A - Reference Tests Only

B - Non-Reference Tests Only

C - Operationally Valid Tests Only, including current test

Ford 6.7L VTW Test

**Form 5
Controlled Quantities**

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Controlled Quantities | Quantity | Units | QI Threshold | EOT QI ⁴ | Target | Avg | Std Dev | Max | Min | No of Samples | BQD |
|----------------------------|-----------------------------------|-------|--------------|---------------------|--------|-----|---------|-----|-----|---------------|-----|
| | Engine Speed | r/min | 0.000 | | 2800 | | | | | | |
| | Fuel Flow Rate | kg/h | 0.000 | | 70.5 | | | | | | |
| | Air Temperature at CAC Outlet | °C | 0.000 | | 50 | | | | | | |
| | Engine Coolant-Outlet Temperature | °C | 0.000 | | 90.5 | | | | | | |
| | Air Temperature in Engine Intake | °C | 0.000 | | 25 | | | | | | |
| | Fuel Temperature at Engine Inlet | °C | 0.000 | | 35 | | | | | | |
| | Oil Temperature in Engine Gallery | °C | 0.000 | | 109 | | | | | | |
| | Air Pressure in Engine Intake | kPaA | 0.000 | | 95 | | | | | | |
| | Exhaust Pressure in Tailpipe | kPaA | 0.000 | | 194 | | | | | | |
| | CAC Coolant System Pressure | kPag | | | >25 | | | | | | |
| | Engine Coolant System Pressure | kPag | | | >120 | | | | | | |
| Air Pressure at CAC Outlet | kPag | | | >160 | | | | | | | |

A - QI values above the threshold are acceptable by the surveillance panel. QI values below the threshold may be considered acceptable based on engineer review.

| Operational Power Check Summary | | | | | | |
|---------------------------------|-------|--------|-----|---------|-----|-----|
| Quantity | Units | Target | Avg | Std Dev | Max | Min |
| Engine Speed | r/min | 2800 | | | | |
| Torque | Nm | >1050 | | | | |

Ford 6.7L VTW Test

Form 6
Uncontrolled Quantities

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Uncontrolled Quantities | Quantities | Units | Target | Avg | Std Dev | Max | Min |
|--|--|-------|--------|-----|---------|-----|-----|
| | Torque | Nm | tbd | | | | |
| | Turbo-Compressor Outlet Temperature | °C | tbd | | | | |
| | Test Cell Ambient Temperature | °C | tbd | | | | |
| | CAC Coolant-Inlet Temperature | °C | tbd | | | | |
| | CAC Coolant-Outlet Temperature | °C | tbd | | | | |
| | Engine Coolant-Inlet Temperature | °C | tbd | | | | |
| | Left Exhaust Manifold Exhaust Temperature | °C | tbd | | | | |
| | Right Exhaust Manifold Exhaust Temperature | °C | tbd | | | | |
| | Exhaust Tailpipe Temperature | °C | tbd | | | | |
| | Engine Outlet Fuel Temperature | °C | tbd | | | | |
| | Oil Sump Temperature | °C | tbd | | | | |
| | Turbo-Compressor Outlet Pressure | kPag | tbd | | | | |
| | Engine Crankcase Pressure | kPag | tbd | | | | |
| | Barometric Pressure | kPaA | tbd | | | | |
| | Left Exhaust Manifold Exhaust Pressure | kPag | tbd | | | | |
| | Right Exhaust Manifold Exhaust Pressure | kPag | tbd | | | | |
| | Engine Inlet Fuel Pressure | kPag | tbd | | | | |
| | Oil Gallery Pressure | kPag | tbd | | | | |
| | Oil Filter Inlet Pressure | kPag | tbd | | | | |
| Oil Filter Delta Pressure | kPa | tbd | | | | | |
| Engine Coolant Flow Rate | l/min | tbd | | | | | |
| Engine Inlet Air Moisture Content | g/kg | tbd | | | | | |
| Voltage from Engine Coolant Temperature Sensor | V | tbd | | | | | |
| Fuel Injection Timing | degBTDC | tbd | | | | | |

Ford 6.7L VTW Test

Form 7
Rocker Arm Wear

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Rocker Arm Wear | | | | |
|-----------------|----------|------------------|-------------------|---------------|
| Bank | Location | Pre-Test Mass, g | Post-Test Mass, g | Mass Loss, mg |
| Right | 1I | | | |
| | 2I | | | |
| | 3E | | | |
| | 4E | | | |
| | 5I | | | |
| | 6I | | | |
| | 7E | | | |
| | 8E | | | |
| | 9I | | | |
| | 10I | | | |
| | 11E | | | |
| | 12E | | | |
| | 13I | | | |
| | 14I | | | |
| | 15E | | | |
| | 16E | | | |
| Left | 17I | | | |
| | 18I | | | |
| | 19E | | | |
| | 20E | | | |
| | 21I | | | |
| | 22I | | | |
| | 23E | | | |
| | 24E | | | |
| | 25I | | | |
| | 26I | | | |
| | 27E | | | |
| | 28E | | | |
| | 29I | | | |
| | 30I | | | |
| | 31E | | | |
| | 32E | | | |

Ford 6.7L VTW Test

Form 7A
Rocker Arm Wear Summary

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Intake Rocker Arm Mass Loss Summary, mg | Right | Left | Overall |
|--|--------------|-------------|----------------|
| Average | | | |
| Minimum | | | |
| Maximum | | | |
| Standard Deviation | | | |

| Exhaust Rocker Arm Mass Loss Summary, mg | Right | Left | Overall |
|---|--------------|-------------|----------------|
| Average | | | |
| Minimum | | | |
| Maximum | | | |
| Standard Deviation | | | |

| Overall Rocker Arm Mass Loss Summary, mg | |
|---|--|
| Average | |
| Minimum | |
| Maximum | |
| Standard Deviation | |

| | |
|-------------------------|--|
| Rocker Arm Batch | |
|-------------------------|--|

Ford 6.7L VTW Test

Form 8
Pushrod Wear

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Pushrod Wear | | | | |
|--------------|----------|------------------|-------------------|---------------|
| Head | Location | Pre-Test Mass, g | Post-Test Mass, g | Mass Loss, mg |
| Right | 1I | | | |
| | 2I | | | |
| | 3E | | | |
| | 4E | | | |
| | 5I | | | |
| | 6I | | | |
| | 7E | | | |
| | 8E | | | |
| | 9I | | | |
| | 10I | | | |
| | 11E | | | |
| | 12E | | | |
| | 13I | | | |
| | 14I | | | |
| | 15E | | | |
| | 16E | | | |
| Left | 17I | | | |
| | 18I | | | |
| | 19E | | | |
| | 20E | | | |
| | 21I | | | |
| | 22I | | | |
| | 23E | | | |
| | 24E | | | |
| | 25I | | | |
| | 26I | | | |
| | 27E | | | |
| | 28E | | | |
| | 29I | | | |
| | 30I | | | |
| | 31E | | | |
| | 32E | | | |

Ford 6.7L VTW Test
Form 8A
Pushrod Wear Summary

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Intake Pushrod Mass Loss Summary, mg | Right | Left | Overall |
|--|-------|------|---------|
| Average | | | |
| Minimum | | | |
| Maximum | | | |
| Standard Deviation | | | |

| Exhaust Pushrod Mass Loss Summary, mg | Right | Left | Overall |
|---|-------|------|---------|
| Average | | | |
| Minimum | | | |
| Maximum | | | |
| Standard Deviation | | | |

| Overall Pushrod Mass Loss Summary, mg | |
|--|--|
| Average | |
| Minimum | |
| Maximum | |
| Standard Deviation | |

| Pushrod Batch | |
|---------------|--|
|---------------|--|

Ford 6.7L VTW Test
Form 9
Rocker Arm Fulcrum Ball Wear

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Fulcrum Ball Wear | | | | |
|-------------------|------------|------------------|-------------------|---------------|
| Head | Location | Pre-Test Mass, g | Post-Test Mass, g | Mass Loss, mg |
| Right | 1I | | | |
| | 2I | | | |
| | 3E | | | |
| | 4E | | | |
| | 5I | | | |
| | 6I | | | |
| | 7E | | | |
| | 8E | | | |
| | 9I | | | |
| | 10I | | | |
| | 11E | | | |
| | 12E | | | |
| | 13I | | | |
| | 14I | | | |
| | 15E | | | |
| | 16E | | | |
| Left | 17I | | | |
| | 18I | | | |
| | 19E | | | |
| | 20E | | | |
| | 21I | | | |
| | 22I | | | |
| | 23E | | | |
| | 24E | | | |
| | 25I | | | |
| | 26I | | | |
| | 27E | | | |
| | 28E | | | |
| | 29I | | | |
| | 30I | | | |
| | 31E | | | |
| | 32E | | | |

Ford 6.7L VTW Test

Form 9A

Rocker Arm Fulcrum Ball Wear Summary

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Intake Fulcrum Ball Mass Loss Summary, mg | Right | Left | Overall |
|--|--------------|-------------|----------------|
| Average | | | |
| Minimum | | | |
| Maximum | | | |
| Standard Deviation | | | |

| Exhaust Fulcrum Ball Mass Loss Summary, mg | Right | Left | Overall |
|---|--------------|-------------|----------------|
| Average | | | |
| Minimum | | | |
| Maximum | | | |
| Standard Deviation | | | |

| Overall Fulcrum Ball Mass Loss Summary, mg | |
|---|--|
| Average | |
| Minimum | |
| Maximum | |
| Standard Deviation | |

Ford 6.7L VTW Test

Form 10
Roller Follower Wear

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Head | Location | Wear, μm |
|--------------|----------|---------------------|
| Right | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 7 | |
| | 8 | |
| Left | 1 | |
| | 2 | |
| | 3 | |
| | 4 | |
| | 5 | |
| | 6 | |
| | 7 | |
| | 8 | |

| Roller Follower Wear Summary, μm | Right | Left | Overall |
|---|--------------|-------------|----------------|
| Average | | | |
| Minimum | | | |
| Maximum | | | |
| Standard Deviation | | | |

Ford 6.7L VTW Test
Form 11
Oil Analysis Summary

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Hours | Viscosity at 100°C, cSt | TGA, % Soot | TBN, mg KOH/g | TAN, mg KOH/g | IR Oxidation | | Fuel Dilution, % | Metal Elements, mg/kg ^A | | | | | | | | |
|-------|-------------------------|-------------|---------------|---------------|---------------------|--------------------------------------|------------------|------------------------------------|----|----|----|----|---|----|----|--|
| | | | | | Peak Height, ABS/cm | Integrated Area, ABS/cm ² | | Al | Cr | Cu | Fe | Na | K | Si | Sn | |
| 0 | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | | | | | |
| 100 | | | | | | | | | | | | | | | | |
| 125 | | | | | | | | | | | | | | | | |
| 150 | | | | | | | | | | | | | | | | |
| 175 | | | | | | | | | | | | | | | | |
| 200 | | | | | | | | | | | | | | | | |

A - The accepted SI units for concentration is mg/kg and it is a 1:1 conversion to ppm.

| | | |
|-----------------------------|----------------|----------------|
| | 175 Hrs | 200 Hrs |
| MRV, cP | | |
| MRV Yield Stress, Pa | | |

Ford 6.7L VTW Test

Form 12

Oil Consumption Calculation

| | | |
|-------------------------|--------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |

| Hours | Average Oil Consumption, g/h |
|--------------|-------------------------------------|
| 0-25 | |
| 25-50 | |
| 50-75 | |
| 75-100 | |
| 100-125 | |
| 125-150 | |
| 150-175 | |
| 175-200 | |
| Average | |

Ford 6.7L VTW Test

Form 15
Test Fuel Analysis (Last Batch)

| | | |
|-------------------------|----------------|-----------|
| Laboratory: | EOT Date: | EOT Time: |
| Test Number: | Test Length: | |
| Oil Code: | | |
| Formulation Stand Code: | | |
| Fuel Supplier: | Fuel Batch ID: | |

| Measurement | Specs. | Analysis | | Test Method |
|---------------------------------|---------|----------|-----|---------------------|
| | | New | EOT | |
| Total Sulfur ^A , ppm | 7 - 15 | | | D5453 or equivalent |
| Gravity ^A , °API | 34 - 37 | | | D4052 |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

A - Measurements are stand samples.