



**National Marine Manufacturers Association**

# NMMA Certification Test Manual

For

**TC-W3**<sup>®</sup>

Two-Stroke-Cycle  
Gasoline Engine Lubricant

# Recertified

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NMMA Certification for TC-W3®  
Two-Stroke-Cycle Gasoline Engine Lubricants

The design of two-stroke-cycle gasoline outboard motors has advanced to the point where higher output engines place severe demands on engine lubricants. Likewise, concern over pollution has increased fuel/oil ratios, which, in turn, increase lubricant requirements. To help boaters recognize lubricants that will give the engine life designed-in by outboard engine manufacturers, the National Marine Manufacturers Association (NMMA) has developed this procedure for the certification of these premium quality lubricants.

## 1. GENERAL

1.1 Procedures and Tests. In order to qualify for TC-W3® certification the oil marketer must follow both the procedures and the tests as specified below.

*Note: All referenced SAE, ASTM and CRC documents will be those in effect as of the date of this document.*

1.1.1 Procedures. In order to assure quality control, the marketer must enter into and comply with a licensing agreement with NMMA, including payment of an annual fee, as established by the NMMA Oil Certification Committee.

1.1.2 Tests. The tests defined here are intended to evaluate the following qualities of a lubricant:

- Lubricity
- General Performance
- Preignition Tendencies
- Rust Prevention
- Miscibility/Fluidity
- Filterability
- Compatibility
- Detergency and Ring Sticking

This test procedure provides a basis on which a candidate lubricant can qualify for Service TC-W3® by comparison of test results after a series of identical tests run with the candidate and a reference lubricant. The qualities of the candidate lubricant must be equal to or better than those of the reference lubricant, or within the tolerance specified.

## 2. TERMINOLOGY

2.1. As outlined in ASTM D-4857-88

2.11 Combustion chamber: in reciprocating internal combustion engines, the volume bounded by the piston crown and any portion of the cylinder walls extending above the piston crown when in the top dead center position, and the inner surface of the cylinder head including any spark plugs and other inserted components.

2.1.2 Preignition in a spark-ignition engine: ignition of the mixture of fuel and air in the combustion chamber before the passage of the spark.

2.1.3 Scuffing, scoring, and wiping: in lubrication, damage caused by instantaneous localized welding of surfaces in relative motion that may or may not result in immobilization of the parts. (Refer to CRC Rating Manual #18)

2.1.4 Spark plug fouling: deposition of essentially nonconducting material onto the electrodes of a spark plug that may, but will not necessarily, prevent the plug from operating. (From ASTM Test Method D-4857-88)

2.1.5 Spark plug whiskering, also spark plug bridging: a deposit of conductive material on the spark plug electrodes, which tends to form a bridge between them, thus shorting out the plug. (From ASTM Test Method D-4857-88)

2.1.6 Major preignition: Preignition that causes a temperature increase of more than 18° F (10° C) or more measured at the spark plug gasket surface of the cylinder head.

2.1.7 Minor preignition: Preignition that causes a temperature increase of more than 7° C (13° F) and less than 10° C (18° F) measured at the inner surface of the cylinder head.

### 3. CANDIDATE CERTIFICATION

3.1 Certifying Laboratory. One or more test laboratories shall be designated by the NMMA Oil Certification Committee to conduct these tests and certify the results.

3.2 Certification Marks. Upon certification by a designated laboratory and execution of licensing agreement with NMMA, the NMMA Oil Certification Mark (TC-W3®) must be applied to all registered oil containers (bottles, cans, drums, etc.), and the NMMA TC-W3® oil registration number must be used on all oil container packaging.

### 3.3 IMPROPER USE OF REGISTERED MARK

3.3.1 Licensed Oils. For oils displaying an improper label or unauthorized labeling data, NMMA will inform the Marketer to cease and desist the violation and will request verification that the violation has been corrected. The Marketer will be required to provide a copy of all labels reflecting the correction of the registered mark violation. If the violation has not been corrected in a reasonable time, NMMA may terminate the license agreement.

3.3.2 Non-Licensed Oils. For oils not licensed by NMMA and displaying the NMMA trademark or claiming to meet the NMMA TC-W3® specifications, NMMA will inform the Marketer to cease and desist the unauthorized labeling immediately. Within 30 days, the Marketer will be required to attest with an affidavit from a third party (law firm) that the unauthorized labeling has been remedied. If the Marketer does not comply, then NMMA will take legal action.

### 3.4 ENFORCEMENT AND CONFORMANCE TO LICENSE REQUIREMENTS

3.4.1 If supporting evidence demonstrates that a TC-W3® oil does not meet the technical requirements (specifications) of TC-W3® or has documented field performance problems, NMMA will attempt to work directly with the marketer to remedy the nonconformity and to make such additional corrective actions as appropriate on a voluntary basis. In the event the matter cannot be satisfactorily resolved, NMMA will take or initiate the actions listed below, singly or in combination, to maintain the credibility of the mark and protect the consumer. These actions must have approval of 3/4 of the NMMA Oil Certification Committee voting minus any abstentions.

1. Temporarily suspend the authority of a licensee to use the mark on the product until corrective action is taken.
2. Terminate the authority of a licensee to use the mark on the individual product.
3. Require removal of that particular product from the market place.

3.4.2 All enforcement actions must be resolved and approved by 3/4 of the NMMA Oil Certification Committee voting minus any abstentions before a license will be renewed or a new license issued.

### 4. REQUIRED TESTS

- 4.1 NMMA TC-W3® Lubricity Test: Modified (ASTM D4863)
- 4.2 NMMA TC-W3® OMC 40hp
- 4.3 NMMA TC-W3® OMC 70hp
- 4.4 NMMA TC-W3® Mercury 15hp
- 4.5 NMMA TC-W3® Preignition Test: Modified (ASTM D4858)
- 4.6 NMMA TC-W3® Rust Test
- 4.7 SAE Miscibility/Fluidity Test
- 4.8 NMMA TC-W3® Filterability Test
- 4.9 NMMA TC-W3® Compatibility Test

### 5. PASS-FAIL CRITERIA

- 5.1 NMMA TC-W3® Lubricity Test (ASTM D4863)

The average torque drop recorded for the candidate oil must be equal to (within the 90% statistical confidence limits or less than that for the XPA-3259 NMMA reference oil.

## 5.2 NMMA TC-W3® OMC 40hp General Performance Test

5.2.1 Piston Ring Rating: The average piston ring sticking rating of top rings of the candidate oil test shall not be lower than 0.6 points below the average rating of the 93738 NMMA reference oil test top ring ratings.

5.2.2 Piston Deposit: The average piston deposit rating for both pistons of the candidate oil test shall not be lower than 0.6 points below the average of both pistons of the 93738 NMMA reference oil test. Piston deposit average is calculated from taking an equally weighted average of the deposit ratings of both pistons in the following 4 areas:

1. Average of thrust and anti-thrust piston skirt varnish
2. Undercrown deposits
3. Crownland deposits
4. 2nd land deposits

5.2.3 Spark Plug Fouling: The candidate oil shall not have more than one more occurrence than the reference oil.

5.2.4 Exhaust Port Blocking: The exhaust port area blocked by deposits shall not be more than ten percent greater for the candidate oil than for the reference oil.

5.2.6 General Engine Condition: The condition of piston skirts, bearings and bearing journals of the candidate oil test shall be similar to or better than the reference oil test.

5.2.7 Concurrent Reference: A reference on NMMA 93738 Reference Oil is run concurrently with each candidate program and is used to compare and evaluate the candidate oil performance. However, concurrent candidates may be based on the weighted (50, 30, 20) average of the previous three references run in that same lab, where the most recent reference receives the highest weighting.

## 5.3 NMMA TC-W3® OMC 70hp Detergency Test

5.3.1 Piston Ring Rating: The average piston ring sticking rating of the second rings of the candidate oil test shall be compared to the results obtained on the concurrent NMMA 93738 reference oil result and a chart that was developed by the NMMA Oil Certification Committee. The candidate must perform a specified amount better than NMMA 93738 Reference Oil in order to obtain a passing result. The minimum amount of separation that the candidate oil must obtain compared to NMMA 93738 Reference Oil varies depending upon the performance of the concurrent run on the reference oil. This varying delta is obtained from the previously mentioned chart that was developed by the NMMA OCC.

5.3.2 Piston Deposit: The average piston deposit rating for the candidate oil test shall fall within the tolerance specified by the NMMA Oil Certification Committee when compared to the average candidate lubricant. Average piston deposits calculated from taking an equally weighted average of the deposit ratings in the following 4 areas:

1. Skirt: average of thrust and anti-thrust
2. Undercrown
3. Top ring lands
4. 2nd ring lands

5.3.3 Concurrent Reference: A reference on NMMA 93738 Reference Oil is run concurrently with each candidate program and is used to compare and evaluate the candidate oil performance. However, if the NMMA 93738 reference is declared mechanically or operationally invalid, the pass criteria for concurrent candidates may be based on the weighted (50, 30, 20) average of the previous references run in that same lab, where the most recent reference receives the highest weighting.

#### 5.4 NMMA TC-W3® Mercury 15hp Detergency Test

Pass Fail Criteria: To be considered acceptable for certification in TC-W3®, a candidate oil must pass the following criteria: 1) Compression Loss: No cylinder compression loss of equal to or greater than 20 psi is allowed within the 100 hours of test operation, including the 100 hour compression check. 2) Reported piston scuffing, scoring or wiping may not exceed 15% circumferentially on each side of the pistons. 3) Reported piston scuffing, scoring or wiping may not exceed 20% "total area coverage" per piston side. 4) Reported ring wiping may not exceed 5% of the circumference of the ring face of any ring. 5) The stickiness of the needle bearings is evaluated using the method described in the NMMA TC-W3® Outboard Engine Two-Cycle Rating Procedure. The needle bearings should fall from the wrist pin within 1 minute of the start of the evaluation described in the Rating Procedure. 6) Average Adjusted Second Ring Sticking should be greater than or equal to 6 merits. 7) Two consecutive or concurrent test passes on all of the above 7 criteria are required in order for a candidate to be considered as having passed the Mercury 15 hp test.

#### 5.5 NMMA TC-W3® Preignition Tests (ASTM D4858)

The candidate oil shall have no more major preignitions in a test period of 100 hours than the last reference test on 93738 NMMA reference oil in the same test stand.

#### 5.6 NMMA TC-W3® Rust Test

The candidate lubricant shall be equal to or better than the reference lubricant.

#### 5.7 SAE Fluidity/Miscibility Requirements

The candidate oil shall meet Category 3 or Category 4 of SAE J1536 Fluidity/Miscibility Classification. EXCEPTION: 6.6.5 of ASTM D4682. The passing limit for Category 3 Fluidity is less than or equal to 7500 Cp.

5.8 NMMA TC-W3® Filterability Test

The decrease in the flow rate of the candidate oil shall not be greater than 20 percent.

5.9 NMMA TC-W3® Compatibility Test

The sample must be homogeneous after being mixed 50/50 with reference oil 93738 NMMA reference oil and XPA-3259 NMMA reference oil and stored for 48 hours.

6. TEST REPORT AND RECORDS

6.1 A summary test report shall be forwarded to NMMA. The summary test report shall include the following:

6.1.1 Name of testing laboratory

6.1.2 Identification of candidate lubricant

6.1.3 Dates of Tests, both start and end

6.1.4 Inspection results and rating for both the candidate and reference oils with photographs where appropriate.

6.1.5 Statement that the candidate lubricant passed or failed within the tolerance specified.

6.1.6 Results from the required fuel:oil verification measurements. The Mercury 15 hp, OMC 40 hp, and OMC 70 hp methods require that fuel:oil verifications be performed.

6.2 The test records including log sheets, test data, recordings, photographs, where appropriate, and rated engine parts are to be retained by the testing laboratory for a minimum of six months. The original test report shall be kept on file for 5 years. A quart sample of the candidate lubricant is to be retained for three years.

6.3 Inspection and Rating of Parts: all parts described in the pass/fail criteria for the individual test are rated using the NMMA TC-W3® Outboard Engine Two-cycle Rating Procedure. The results of the ratings are included in the test report for the lubricant. Additional parts may be rated at the laboratory's or sponsor's discretion. Ratings should commence within 24 hours of the end of test.

6.6 Other Components: Any unusual wear or damage to any other engine components must be reported.

6.7 Parts Storage: Retain all rated parts (except for the cylinder head, which may be reused,) for six (6) months.

7. TESTS

7.1 NMMA TC-W3® Lubricity Test

7.1.1 Test in accordance with method for determination of the lubricity of two-stroke-cycle gasoline engine lubricants, to meet the requirements in 5.1 Use NMMA Reference Oil XPA-3259.

7.2 NMMA TC-W3® OMC 40 hp (See procedure with Document)

This method evaluates the overall performance of lubricants intended for use in two-stroke-cycle spark ignition water-cooled outboard engines. Piston ring sticking, piston deposits, bearing conditions, and general component wear are evaluated.

7.3 NMMA TC-W3® OMC 70 hp (See Procedure with Document)

This method evaluates the detergency performance of lubricants intended for use in two-stroke-cycle spark ignition water-cooled outboard engines. Piston ring sticking and piston deposits are evaluated.

7.4 NMMA TC-W3® Mercury 15 hp (See Procedure with Document)

This method evaluates the detergency and lubricity performance of lubricants intended for use in two-stroke-cycle spark ignition water-cooled outboard engine. Piston Ring sticking piston deposits ring face wiping, piston scuffing, and wrist pin needle bearing tackiness are evaluated.

7.5 NMMA TC-W3® Preignition Test

7.5.1 Test in accordance with ASTM D4858 test method for determination of the tendency of lubricants to promote preignition in two-stroke-cycle gasoline engines to meet the requirements in 5.5. The exceptions to the procedure are that the test duration is extended to 100 hours and 93738 NMMA Reference oil is used as the standard high reference oil.

7.6 NMMA TC-W3® Rust Test

7.6.1 Test must be run simultaneously on the candidate lubricant and the 93738 NMMA reference lubricant.

7.6.2 Measuring Rust Prevention: For the following test use Mercury Marine part No. 34-31942A1 reeds (4 per package).

7.6.3 Thoroughly clean reed, first removing any preservative with boiling naphtha and then in boiling anhydrous methanol. During cleaning and test, never touch reeds. Fingerprints often accelerate rusting. Suspend reeds on inert hangers. Reeds and oil samples must be stabilized at 70° to 80°F. before test.

7.6.4 Dip reeds in test lubricants for one minute. Hang reeds submerged in a salt solution made of 1/2 pounds reagent sodium chloride in one gallon of distilled water. Observe reeds every 1/2 hour until first spot of rust in excess of 1 mm diameter occurs. Maintain temperature of 70° to 80°F. for test in a dark location.

7.6.5 Inspection: Compare the candidate lubricant reed to the reference lubricant reed. The hours of exposure may be extended to obtain better comparison.

7.6.6 Preserve test reeds by sealing them with "Seal Peel" or equivalent sealer.

7.7 Two-stroke-cycle engine oil fluidity/miscibility classification

7.7.1 Test in accordance with SAE J1536

7.8 NMMA TC-W3® Filterability Test

7.8.1 Scope

This test is designed to determine the tendency of an oil to form a gel, or precipitate, which can plug oil filter screens in Two-Stroke-Cycle engine Oil Injection Systems. It simulates a problem which can be encountered in oil injection systems where ashless NMMA Certified Two-Stroke-Cycle Engine Oils are contaminated with calcium containing low ash Two-Stroke-Cycle Engine Oils in presence of small amounts of water (i.e., water of condensation). If the candidate oil is not dyed, .05% of the Automate Blue 8 shall be added before testing. This is to aid the tester in detecting contaminants in the neat oil.

7.8.2 Apparatus

7.8.2.1 4 oz. or 8 oz. Small glass or clear plastic bottles

7.8.2.2 25 ml burette (See Note 1)

7.8.2.3 Filter holder (Millipore xx300 01200 effective filter area  $\approx 0.6 \text{ cm}^2$ )

(See Note 2)

7.8.2.4 Outboard Marine Corporation Filter Screen 150 Micron Mesh Size

7.8.2.5 Stopwatch capable of timing sequential events (a Heathkit Model GE-1201E or equivalent can be used)

NOTE 1: To insure that there are no restrictions to the oil flow in the burette, a Teflon stopcock with a minimum opening of 1.8 mm must be used. Likewise the tip of the burette must have an opening of 1.8 mm or greater.

NOTE 2: Since Standard Reference Oils with accurate flow rates are not used in this test procedure, calculate the effective filter screen area using the inner diameter of the filter "O" ring.

7.8.3 Reagents and Materials

7.8.3.1 Calcium containing low ash Two-Stroke-Cycle Engine Oil (CITGO 935111).

7.8.3.2 93738 NMMA Reference

7.8.3.3 Water: For the purposes of this test use distilled water

7.8.3.4 Candidate NMMA Two-Stroke-Cycle Engine Oil

7.8.4 Sample Preparation

7.8.4.1 Volumetrically and at room temperature thoroughly mix 100 ml of Candidate Oil with 100 ml of CITGO 935111 Two-Stroke-Cycle Engine Oil.

7.8.4.2 Separate the mixed oil into an 80 ml portion and a 120 ml portion.

7.8.4.3 Place the 80 ml portion of mixed oil in sealable bottle and set sample aside undisturbed for use as a control sample. Each Candidate Oil will have its own control sample.

7.8.4.4 Place the 120 ml portion of mixed oil in a sealable container. Add 0.25 Volume Percent distilled water and vigorously shake by hand.

7.8.4.5 Separate the 120 ml water containing mixed oil into 2-60 ml portions, place in sealable bottles, and set aside undisturbed for 48 hours at room temperature.

NOTE: A 60 ml sample amount was selected in order to put all of the sample through the filter mechanism, 50 ml for actual test timing and 10 ml for filling and leveling of burette. This should help in introducing into the burette any heavy matter, which may have migrated to the bottom of the sample bottle.

#### 7.8.5 Filterability at room temperature

7.8.5.1 Set up the 25 ml burette equipped with a filter holder with discs of OMC Filter Screen material cut to fit the holder.

7.8.5.2 The control oil flow rate is determined by placing a sample of the control oil in the burette and passing enough of the control oil through the filter holder to remove air bubbles. The burette is then filled with control oil to a level 1-2 cm above the "O" mark; the stopcock is opened all the way; and the flow time of each successive 5 ml of oil is measured between the "O" and 25 ml graduations.

The flow rate of each 5 ml portion of oil is calculated using Equation (1).

Equation (1) Flow rate = (A)/(B)/(C)

Where A = Volume of oil (ml)  
B = Flow Time (sec)  
C = Area of Filter (cm<sup>2</sup>)

7.8.5.3 To determine the test oil flow rate, the flow times of the control oil are first determined as outlined in step 7.8.5.2 using the same filter screen and filter holder the control oil level in the burette is reduced to the lower level which allows no air bubbles below the stopcock. The burette is filled with the test oil to level 1-2 cm above "O" mark. Open the stopcock all the way and the flow time for each successive ml of oil is measured between the "O" and 25 ml graduation.

The flow rate for each 5 ml portion of test oil is calculated using Equation (1).

7.8.5.4 The percent decrease in flow rate of the test oil relative to the new oil is calculated from the final oil flow rates (between 10 and 25 ml measured with the same filter disc.) using Equation 2.

$$\text{Equation (2) Percent decrease in flow rate} = [(b - a) \times 100]/a$$

Where a = Final new oil flow rate  
 b = Final test oil flow rate

#### 7.8.6 Test results

7.8.6.1 Tests on candidate engine oils must be run in duplicate and the candidate oil test report is to contain the following information:

- (1) Candidate oil identification
- (2) New oil flow rate at 5, 10, 15, 20, 25 ml
- (3) Test oil flow rate at 5, 10, 15, 20, 25 ml
- (4) Percent change in flow rate for each test

#### 7.8.7 Requirements

7.8.7.1 Results from candidate oils must have a decrease in test oil flow rate of less than 20 percent in comparison to the new oil flow rate.

#### 7.8.8 Sample Calculations

7.8.8.1 MEASUREMENTS OF FLOW TIMES. The flow shown in the example in Table 2, is for the 5 ml portion of oil ending at the indicated volume. Flow times were measured with a digital stopwatch capable of timing sequential events (i.e., the time for the new oil to flow from the 5 ml mark to the 10 ml mark was 6.75 s).

7.8.8.2 CALCULATIONS OF FLOW RATE. The flow rate is calculated from Equation (1). Thus for the first 5 ml of new oil, the flow rate is:

$$\begin{aligned} \text{Flow rate} &= (A)/(B)/(C) \\ &= (5\text{ml})/(5.61 \text{ s})/(0.636 \text{ cm}^2) \\ &= 140 \text{ ml per sec per cm}^2 \end{aligned}$$

Where A = Volume of oil (ml)  
 B = Flow time (sec)  
 C = Area of filter (cm<sup>2</sup>)

Volume sec	Reference Oil sec	Test Sample Oil ml
5	5.61	7.61
10	6.75	11.24
15	6.77	16.00
20	6.81	22.01
25	7.61	30.99

The calculated flow rates obtained using Equation (1) for the rest of the sample are shown in Table 3.

### 7.8.8.3 Calculation of percent decrease in flow rate

The percent decrease in flow rate is:

$$\begin{aligned} \text{Percent Decrease} &= (b - a)/a \\ &= (0.25 - 1.1)/1.10 \\ &= -77.3 \text{ percent} \end{aligned}$$

Where a = Final new oil flow rate

Where b = Final test oil flow rate

Volume	Reference Oil	Test Sample Oil
ml	ml/s-cm <sup>2</sup>	ml/s-cm <sup>2</sup>
5	1.40	1.03
10	1.16	0.70
15	1.16	0.49
20	1.15	0.36
25	1.10	0.25

## 7.9 NMMA TC-W3® Compatibility Test

7.9.1 50 ml of candidate will be mixed at room temperature with 50 ml of 93738 NMMA Reference oil.

7.9.2 The resulting 100 ml sample will be stored in a cylindrical glass bottle, which will be sealed airtight.

7.9.3 The bottle will be stored at normal laboratory room temperature (15.6 - 26.7 C, 60 - 80 F) for a period of 48 hours.

7.9.4 At the beginning and end of the 48 hour storage period, the visual appearance of the sample will be noted and described. (This inspection may be assisted by the use of a back light.)

7.9.5 Evidence of inhomogeneity at the beginning or end of the 48 hour period and/or a change in the physical appearance of the sample from beginning to end of the 48 hour period will be cause for failing the compatibility test.

7.9.6 Steps 1-5 will be repeated using XPA-3259 NMMA Reference oil as the reference oil in Step 1.

## 8. FIELD SURVEILLANCE

8.1 All lubricants submitted for NMMA TC-W3® certification are analyzed using the test procedures listed below. The Oil Certification Committee wishes to ensure that the product which is available to the consumer and which bears the NMMA TC-W3® trademark is identical to the originally certified product. Normal blending variability, base oil and additive batch variations, and analytical test variability necessitate the adoption of an "acceptability envelope" for comparison of field samples to the originally certified blend.

Identification Tests	
Total Base Number	ASTM D2896
Viscosity, Kinematic	ASTM D445
Sulfated Ash	ASTM D874
Nitrogen Content	Kjeldahl/Carlo Erba ASTM D5291
Simulated Distillation	ASTM D6352
Infrared Spectrum	ASTM E168
Cloud Point	ASTM D2500

8.2 Properties critical to the satisfactory performance of a lubricant which were designed into an NMMA TC-W3® certified lubricant when it was submitted for certification can be adequately predicted to exist in a field sample of that lubricant by performing the following tests:

- 8.2.1 Weight percent nitrogen Kjeldahl Analysis/Carlo Erba ASTM D5291
- 8.2.2 Kinematic Viscosity @40° C ASTM D445
- 8.2.3 Infrared Spectrum ASTM E168

8.3 In two cases, the following limits may be applied to the analyses of the originally certified blend to establish the "acceptability envelope", recognizing that the variability in components, blending and testing may result in manufacturing limits that are wider than the "acceptability envelope":

- 8.3.1 Kjeldahl Nitrogen/Carlo Erba ASTM D5291 -5% to +10%
- 8.3.2 Kinematic Viscosity @40° C -2 cSt to +2 cSt

8.4 The infrared spectrum of the field sample must "essentially match" the infrared spectrum of the originally certified blend. The test for "essentially matching" is recommended to be:

8.4.1 That all major peaks present in the original IR is present at approximately the same absolute and relative intensities as the major peaks in the field sample.

8.4.2 That no additional peaks are present in the field sample, which are above the intensity of the third smallest peak in the original sample.

8.4.3 In the above cases, the hydrocarbon only peaks at 2800-300  $\text{cm}^{-1}$ , 1350-1400  $\text{cm}^{-1}$ , 1425-1475  $\text{cm}^{-1}$ , and 700-750  $\text{cm}^{-1}$  should be ignored. These peaks are strong intensity and can be then significantly affected by small variations in the instrument or sample cell. The gain of the instrument and the cell path length may be chosen such that these peaks are off-scale.

8.5 RESOLUTION OF DISCREPANCIES: The following course of action, should there be discrepancy between the field sample and original blend, will be followed.

8.5.1 The field sample and original sample shall be retested. If a significantly different result is obtained, a third test is advised. Appropriate outlier statistics may be applied to the three results. The means (excluding any outlier) of all the data shall be used.

8.5.2 If a discrepancy still exists, the Chairman of the Oil Certification Committee shall be notified of the test results on both the original and field samples. The Chairman shall consult with the NMMA Oil Surveillance Sub-Committee to determine the seriousness of the discrepancy and whether the issue bears further investigation.

8.5.3 If a serious discrepancy is deemed to still exist, the company holding the trademark license for the field sample product shall be contacted by NMMA for an explanation.

8.5.4 The explanation, if one is offered, shall be referred by the Oil Certification Committee Chairman to the NMMA Oil Surveillance Sub-Committee which will determine if the explanation could explain the discrepancy.

8.5.5 The NMMA Oil Surveillance Sub-Committee's opinion shall be forwarded to the Chairman of the Oil Certification Committee who will confer with NMMA to decide whether any further action is necessary.

8.5.6 At all times, the identity of the company shall remain confidential with NMMA Staff. The NMMA Oil Surveillance Sub-Committee shall not know the identity of the company during the investigation.

## 9. SOLVENT SUBSTITUTION

NOTE: NMMA Oil Certification Committee has determined that should a solvent substitution be utilized on a previously approved blend, the following conditions shall be met. No other substitutions are permitted.

9.1 The end and 90% points of the proposed substitute solvent's distillation curve may be no more than 5% greater than the end and 90% points of the certified solvent's distillation curve. The method measuring the distillation curve shall be by ASTM D2887.

9.2 Must pass the miscibility and fluidity tests.

9.3 A new set of identification tests must be conducted and submitted to NMMA.

## 10. REFERENCE FUEL USAGE REQUIREMENTS

10.1 Reference tests and candidate tests shall be run on the same batch of reference fuel.

10.2 Test Gasoline: The test gasoline for the OMC 70 hp and the Mercury 15 hp is Howell RSF (ring sticking fuel) reference fuel. It is commercially available from Howell Hydrocarbons and Chemicals (A.1.7). The fuel is identified by batch number. Different batches of RSF fuel should not be mixed unless there is less than 5% concentration of one of the batches. The test gasoline for OMC 40hp test and the TC-W3® Lubricity Test is Phillips J. It is commercially available from Phillips 66 Co. (A.1.7).

## ANNEX

### A1. PROCUREMENT OF TEST MATERIALS

The following is ordering information necessary to compete the references found in the text.

#### A.1.1 ASTM Standards

American Society for Testing and Materials  
100 Bar Harbor Drive  
West Conshohocken, PA 19428-2951  
610-832-9500

#### A.1.2 CRC

Coordinating Research Council, Inc.  
219 Perimeter Center Parkway  
Atlanta, GA 30346  
404-396-3400

#### A.1.3 NMMA Procedures

National Marine Manufacturers Association  
200 East Randolph Drive, Suite 5100  
Chicago, IL 60601-6528  
312-946-6200

#### A.1.4 OMC Procedures

Bombardier Recreational Products  
Boats & Outboard Engines Division  
300 Seahorse Drive  
Waukegan, IL 60085  
708-689-7700

#### A.1.5 NMMA Reference Oils

Citgo Petroleum Corp.  
555 E. Butterfield Road  
Lombard, IL 60148  
708-963-5760

Chevron Research Co.  
P. O. Box 1627  
Richmond, CA 94802-0627  
510-242-4625

#### A.1.6 SAE

400 Commonwealth Drive  
Warrendale, PA 15096-0001

724-776-4841

A.1.7 Fuel

Howell Hydrocarbons and Chemicals  
P. O. Box 429  
Channelview, TX 77530  
Attn: Mr. Mike Clark  
800-969-2542

Phillips 66 Company  
Specialty & Reference Fuels  
3 C3 HS&L Building  
Bartlesville, OK 74004  
Attn: Mr. Don E. Burnett

A.1.8 OMC 70 HP Drawings & OMC 40 HP

Bombardier Recreational Products  
Boats & Outboard Engines Division  
300 Seahorse Drive  
Waukegan, IL 60085  
708-689-7700

A.1.9 Mercury Marine  
W6250 Pioneer Rd.  
P. O. Box 1939  
Fond Du Lac, WI 54936-1939  
414-929-5000

A2. LIST OF OMC 70 HP BLUEPRINTS

A.2.1 B-1910-1255 OMC 70 Exhaust Coolant Modifications

A.2.2 C-1910-1254 OMC 70 HP Exhaust Coolant Modifications

A.2.3 D-1910-1253 OMC 70 HP Engine Coolant Modifications

A.3 List of OMC 40 HP Blueprints

A.3.1 B-1910-1262 OMC 40 HP Engine Coolant Modifications

A.3.2 C-1910-1261 OMC 40 HP Exhaust Coolant Modification

A.3.3 D-1010-1263 OMC 40 HP Engine Coolant Modifications

A.4 Mercury 15 HP Blueprints are included in the Mercury 15 HP test method.



**National Marine Manufacturers Association**

**MERCURY 15 HP PROCEDURE**

**RECERTIFIED**

**TC-W3<sup>®</sup>**

## 1. SCOPE

1.1 This procedure demonstrates a lubricant's ability to prevent piston ring sticking, cylinder scuffing and seizure resulting from lubricant and/or poor quality fuel related ring zone and skirt deposit formation in naturally aspirated, gasoline fueled, two-stroke-cycle outboard marine engines. It may also be used to show tendencies for lubricant related crank pin and wrist pin roller bearing wear and failure caused by marginal lubrication or localized varnish, gum and/or carbon deposits.

1.2 The scope of this procedure does not address every safety aspect regarding the use of materials and reagents recommended. Users must inform themselves, and others involved, of the potential hazards in testing gasoline fueled engines.

## 2. REFERENCED DOCUMENTS

2.1 Mercury Model 15, Service manual, Pt# 90-13449-1, 1987

2.2 Mercury Model 15, Parts Catalog, Pt# 90-19466 or 90-811286, 1989

2.3 SAE 841209: Evaluation of High Performance Two-Stroke-Cycle Engine Lubricants.

2.4 ASTM Standards, ASTM Annual Standards Publications:

2.4.1 D-235, Specification for Mineral Spirits (Petroleum spirits) (Hydrocarbon Dry Cleaning Solvent).

2.4.2 D-4857-88, Determination of the Ability of Lubricants to Minimize Ring Sticking and Piston Deposits in Two-Stroke-Cycle Engines Other than Outboards.

2.4.3 D-4858-88, Determination of the Tendency of Lubricants to Promote Preignition in Two-stroke-cycle Gasoline Engines.

2.4.4 D-4863-88, Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants.

2.5 CRC Rating Manuals:

2.5.1 CRC Manual No. 12

2.5.3 CRC Manual No. 14

2.5.4 CRC Manual No. 16

2.5.5 CRC Manual No. 17

2.5.6 CRC Manual No. 18

### 3. SUMMARY OF THE TEST METHODS

3.1 The test is run using a Mercury Outboard Engine, Model 15 ML, (Pt.# 61-816903A67 or 1015211MR) fitted with a "test powerhead" part number 61-816903A67 manufactured by Mercury Marine, Brunswick Corp.

3.2 A suitable loading device (trimmed propeller or test load wheel) is attached to the propeller shaft. The engine is set up in a water tank with appropriate exhaust evacuation, throttle control and instrumentation. Following a short break-in, the cylinder compressions are checked and recorded. After the compression check, the endurance portion of the test is run by continuously cycling the engine between idle and WOT conditions for 5 minutes and 55 minutes respectively. At the end of each 10 hours of test time, the engine is stopped and allowed to soak for 1 hour. During the soak, cylinder compressions are again checked and recorded.

3.3 Pass/Fail criteria. See CT 5.4.

### 4. SIGNIFICANCE AND USE

4.1 This procedure is primarily intended to evaluate the performance of two-stroke-cycle lubricants used in high specific output marine outboard engines.

### 5. APPARATUS

#### 5.1 Test Engine and Stand:

5.1.1 Engine: Mercury Model 15 EL or ML, 16 cubic inch, two cylinder, two-stroke-cycle outboard engine, modified for a remote coolant system, exhaust evacuation, and fitted with a new Test Powerhead, Part No. 61-816903A67.

5.1.2 Lubrication, Fuel System: The test fuel and oil is premixed at a 100:1 ratio. 200 gallons of test fuel is sufficient for 100 hours of testing at fuel consumption rates less than 12.0 lb/hr.

5.1.3 Loading Devices, WOT Speed Control: Loading devices include trimmed propellers or test wheels providing 5500 rpm at WOT.

5.1.4 Test Tank: To prevent speed surging at WOT, trimmed propellers and load wheels require tanks of sufficient size and/or design to provide a constant supply of non-aerated water to the input side of those devices. An exhaust gas tail pipe, refer to Figure 1 in the Annex, is required to provide proper exhaust pressure and helps de-aerate tank water. Modifications to the mounting brackets of the tail pipe are allowed.

5.1.4.1 Ventilation: Adequate ventilation should be provided to prevent exhaust dilution of the carburetor intake air supply.

5.1.5 Ambient Conditions: No control of engine intake air is specified. Barometer, humidity and temperature records must be maintained.

### 5.1.6 Controls and Alarms:

5.1.6.1 Control: The following parameters require either control or monitoring as specified by this procedure.

Critical Test parameters requiring control:  
Engine Speed Cycle Time (throttle control)  
Engine Speed at WOT  
Engine Speed at Idle  
Engine Coolant Outlet Temperature at WOT  
Engine Coolant Temperature Delta at WOT  
Fuel Consumption at WOT  
Ignition Timing at WOT  
Exhaust Back Pressure at WOT  
Engine Coolant Flow Rate

5.1.6.2 Alarms: Failure alarms, for critical test parameters, should be an integral part of the test stand design. Automatic shutdown on alarm occurrence is preferred. Audio or visual alarms suffice if laboratory personnel are alerted to take immediate corrective action.

5.1.7 Data Recording: Continuous alarm scanning with required end of cycle phase snapshot data recording is preferred. A record of the immediate history of all parameters preceding an alarm is desirable. A strip chart record of critical parameters is an acceptable alternate.

5.1.8 Inlet Air Temperature Measurement: The thermocouple for measuring inlet air temperature should be locate 1 inch away from the carburetor and at the height of the center of the carburetor throat. Please see appendix for print.

5.1.9 The speed sensor signal is usually taken off of the flywheel ring gear. If this method is used, care should be taken concerning the mounting point of the sending unit bracket to minimize engine distortion.

## 6. MATERIALS AND REAGENTS

6.1 Test Fuel: Howell RSF Test Fuel for TC-W3®. Available from Howell Hydrocarbons.

6.2 Reference Oils: 93738 NMMA Reference Oil is the low reference oil, 71591 NMMA Reference Oil is the high reference oil.

6.3 Stoddard Solvent: Hydrocarbon cleaning solvent, manufactured under ASTM D-235, Type I.

6.4 Gear Lubricant: Mercury Premium Blend Gear Lube Part # 92-19007 or equivalent outboard gear lube is recommended.

6.5 Engine Cooling Water: Clear water. Water treated to remove minerals or for anti-corrosion is permissible. Figure 12 and Attachment 1 offer schematic diagrams of two different engine cooling water control concepts. It should be noted that excessive cooling system deposits could result in poor heat transfer which could result in severe test results.

6.6 Engine Assembly Lubricant, 71591 NMMA Reference Oil: Used for all assembly lubrication of the powerhead and, if the laboratory chooses to perform compression ratio verifications, when blended with Stoddard solvent at 50% by volume, for volumetric verifications during build-up.

6.7 Sealant: Loctite Master Gasket Mercury Part # 92-12564-1 should be used to seal the crankcase to cylinder mating surfaces.

6.8 Grease: Petroleum Jelly, Needle Bearing Grease or equivalent: A non-lubricating grease used during volumetric checks.

6.9 Thread Locking Agents: Loctite Brand, Loctite Corp. Cleveland Ohio, or equivalents appropriate for specific application, utilization and life expectancy.

6.10 Wiping, Polishing and Mild Abrasive Cloths/Pads/Stones: Used for cleaning and de-burring engine component parts during assembly.

## 7. TEST ENGINE ASSEMBLY PROCEDURE

The procedures outlined in the Mercury Model 15 Service Manual, including the use of the Mercury recommended assembly compounds, are used for engine assembly and tear down. Any additional procedures for build-to-build consistency, hardware modifications and installation of special control hardware are detailed in the Annex. Except for the specially fabricated or modified parts, all parts are available by part number as listed in the Mercury Model 15 Parts Catalog. Contact Mercury Marine regarding procurement and Authorized Dealerships.

## 8. OPERATING PROCEDURE

8.1 Break-in: approximately four gallons of the specified fuel and oil are blended at a ratio of 50:1 by volume. The engine is run according to the outline in Table-1.

(Note: The fuel flow rate and coolant temperatures at WOT during Break-in should be targeted at the middle of the test specifications.)

TABLE-1

Speed (rpm)			Duration / Action
700-900	-	-	45 minutes @ Idle, set idle speed, mixture and idle timing, 1 <sup>st</sup> 5 minutes
5300-5700	-	-	2-3 seconds @ WOT
2500-3000	-	-	5 minutes @ part throttle
700-900	-	-	Time needed to verify idle speed and ignition timing (2-3 minutes)
5300-5700	-	-	Time to set WOT timing (2-3 minutes)
3500-3800	-	-	15 minutes @ part throttle
5300-5700	-	-	100 minutes @ WOT

At the end of the Break-in, the engine is stopped for one hour with the engine coolant pump off.

8.1.1 Compression Check: During the one hour shutdown, when the engine temperature, as observed by spark plug gasket thermocouples, reaches 100 F (38°C), set the carburetor to WOT and ignition off. Feel for compression on both cylinders by slowly pulling the manual starter rope. The electric starter should not be used to obtain compression readings. Remove both spark plugs. Leave the carburetor at WOT and ignition off. Without the use of any fluid to increase ring sealing, install a compression test gauge in the upper cylinder spark plug hole and spin the engine using the starter rope as if attempting a start. The cumulative compression of 5 pulls is observed and recorded. (120-145 psig is typical) Repeat compression check for the lower cylinder. Reinstall the spark plugs and allow the engine and coolant pump to remain stopped for the remainder of the hour.

8.2 Endurance Run: The endurance portion of the test is started after the end-of-break-in compression check and one hour shutdown. The engine is fueled with the test fuel and oil premixed at a ratio of 100:1 by volume. The test engine is run of ten individual, ten hour intervals (100 hours total) with one hour shutdowns and compression checks occurring at the end of each 10 hours. One test hour is comprised of 5 minutes at idle and 55 minutes at WOT with 2-5 second throttle position transition. Refer to Table-2.

TABLE-2

	<u>Idle</u>	<u>WOT</u>
Time (min)	5	55
Speed	800±100	5500±200
Coolant OUT	Record	130±4°F (54.4±2.2°C)
Coolant DELTA	Record	30±4°F (16.7±2.2°C)
Coolant Flow		Record
Fuel Flow	Best idle	* 10.0 to 13.0±0.3
Ign timing	Record	36°±1 BTDC (Check every 10 hours)
Exhaust BP		record

\* Candidates must be run to the same target mean fuel flow as the previous reference pair which demonstrated NMMA specified separation. The specified target fuel flow must be obtained within the first 5 test hours. After the fifth test hour, fuel flow should not be adjusted unless it deviates at least 0.3 lbs./hour from the target value. If the fuel flow exceeds the target flow by greater than 0.3 lbs./hour then the fuel flow should be adjusted back to the target value. If the fuel flow is greater than 0.3 lbs./hour less than the target flow, then an assignable cause should be investigated. If an acceptable assignable cause cannot be determined, then the test should continue at the lean condition. Acceptable assignable causes include items that may reduce air or fuel flow to the combustion chamber, such as: restricted fuel supply to carburetor, restricted main jet, restricted air flow to engine, crankcase seal leak, crankshaft seal leak, or intake manifold air leak.

Either a fixed jet Mercury carburetor or a Mercury carburetor modified with an adjustable main jet must be used.

\* *The laboratories will be allowed to run with an initial set point within these ranges, with a  $\pm 0.3$  lbs./hr control tolerance, in order to obtain ring sticking separation between 93738 and 71591. Separation will be defined as a compression loss  $\geq 20$  psi before 100 hours on 93738 and no compression loss  $\geq 20$  psi on 71591 through 100 hours. All candidates run within a laboratory shall be run with the same fifth hour set point and control tolerance as the previous reference and in no case shall the fifth hour control tolerance exceed  $\pm 0.3$  lbs./hr of the reference test runs. The fuel flow at the end of the 5<sup>th</sup> test hour shall normally be within 10-13 lbs./hr for all tests.*

A typical log sheet showing recorded parameters and other specification target values is shown in the Appendix as Form 1.

8.2.1 Preignition and Plug Fouling: Document all occurrences of Preignition and plug fouling, including test hours, spark plug condition and location. Removed spark plugs are vapor protected, identified and retained for EOT rating.

8.2.2 Compression Checks: At the end of each 10 hour interval, during the one hour shutdown the compression is checked (as in 8.1.1) and compared to the recorded end-of-break-in values. It is recommended that the same compression gauge be used throughout the test.

8.2.2.1 EOT Criteria: Test termination occurs when any 10 hour interval compression check indicates a compression loss greater than or equal to 20 psig relative to the end-of-break-in value for that cylinder. A test termination may also occur while the test is running between scheduled compression checks. This is indicated when the engine loses power and stalls. If the engine restarts and operates normally, continue testing, documenting the occurrence. If the compression feels abnormal on one or both cylinders, or if the engine fails to restart or to achieve stable operating conditions and full power, ring sticking and/or seizure are probable. Shutdown and perform a gauge compression check as in paragraph 8.1.1. If compression has decreased by 20 psig or more from the end-of-break-in value, terminate the test. If compression losses equal to or greater than 20 psig do not occur, the test is ended at 100 hours and one final compression check performed and recorded.

8.2.3 Sound Boxes: The use of sound boxes is allowed. If sound boxes are used over the engine, they must not interfere with air flow to the engine.

## 9. INSPECTION AND RATING OF EOT PARTS:

9.1 Preparation: Engine ratings should commence within 24 hours of end of test compression check. If inspection and rating cannot be performed immediately after tear down, the ratable parts must either be stored in a desiccated environment or individually wrapped in dry vapor barrier paper and placed in clean, dry, well sealed plastic bags. Piston rings are not removed nor disturbed by exerting any manual force. Bags are marked with corresponding run I.D., oil codes, physical location in engine, etc.

9.2 Rating Methods: Please refer to the document titled "NMMA TC-W3® Outboard Engine Two-Cycle Rating Procedure."

## 10. REPORTING, RECORD KEEPING AND PARTS RETENTION:

10.1 Report: The test report must include the most recent reference test dates, run number and results. The report also includes all pertinent test oil identification, sponsor, laboratory and NMMA certification coding if issued, stand-engine-run numbers, EOT ratings, EOT hours, EOT mode (i.e. observed compression loss, scheduled 100 hours, etc.), test start and finish dates. Critical operational parameters (specifications, minimum, maximum, % deviation and average values obtained during test operation), reports of occurrences of preignition, total downtime due to shutdowns, downtime for each shutdown, and WOT stalls are all reported. A typical report format is shown in the Appendix as Form 2. The testing laboratory must include reference data as an attachment.

10.2. Retention of Fluids, Test Parts & Records: See CT 6.2

## 11. PRECISION AND BIAS:

11.1 No bias has been determined through 4-92.

## 12. TEST STAND CALIBRATION:

The fuel flow rate measuring device, temperature measurement thermocouples, and temperature control thermocouples shall be calibrated by the laboratory.

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## ANNEX

### A-1 Engine Specifications:

Mercury Model 15 ML: A two cylinder, 16 cubic inch, 2.375 inch bore and 1.8 inch stroke, two-stroke-cycle engine, with cross scavenging, natural aspiration and water cooling. Compression ratios of 6.90 to 7.10 and cold cranking cylinder pressures of 115 to 135 psig are typical. The suffix EL designates electric start, long mid-section (20 inch), ML is manual start.

### A-2 Reference Oils:

93738 NMMA Reference Oil (TC-W3®) is a failing reference oil. 71591 NMMA Reference Oil is a passing reference oil.

### A-3 Modifications to the Mercury Model 15 for Test Application:

NOTE: Unless otherwise noted, the procedures and fastening torques provided in the Mercury 15 Horsepower Service Manual are used exclusively for assembly and disassembly.

### A-4 Lower Unit Gearbox Modification and Periodic Maintenance:

Modifications are limited to fittings for lubricating the gearbox, and mounting holes in the cavitation plate for the exhaust extractor. It is recommended the gear lube be replenished or replaced periodically during the course of each test. The gear lube must be replaced every 100 hours or at the beginning of each test as a minimum.

### A-5 Lower Unit Water Pump:

Remove and disassemble the water pump, discarding the shift shaft (Part No. 42146), the "E" ring (Part No. 53-42389), water outlet tube guide (Part No. 44467), impeller (Part No. 47-42038-2), drive key (Part No. 28-42376A1), and nylon trust washers. Remove and discard the water inlet tube assembly, (Part No. 32-42185A1). Save the water tube retainer and screw. Plug the pump inlet passage where the water inlet tube was attached. A plug fabricated of a ¼ inch length of 5/8 inch diameter nylon or other higher temperature plastic rod may be inserted and sealed into the recess normally housing the water inlet tube and seal.

(Use thread-locking agents to secure both the inlet tube retainer screw and the 5/16 inch shift shaft through-hole screw in the next steps.) Reinstall the water inlet tube retainer and screw to secure the plastic plug. Remove the shift shaft O-ring (Part No. 25-85594) and tap the shift shaft through-hole to 5/16 - 18 in. machine screw thread. After reassembling the water pump, face plate and cover to the gearbox, install a 5/16 -18x1/2 inch machine screw with lock washer in the shift shaft hole (torque to 18 lb/in max).

### A-6 Lower Unit Lubrication (Recommendation only):

(Recommendation only) Prior to reaching "100 hours since last change", drain and refill the gearbox with Mercury Premium Blend Gear Lube Part No. 92-19007 or equivalent.

### A-7 Mid-Section Exhaust Pipe Adaptor Plate Modifications:

Remove the water tube (Part No. 32-42122) and related seal, spacer, housing, gasket and screws. Refer to Figure 2; tap the adaptor plate for a 1/8 inch NPT plug at the outlet-to-shaft location. Tap the idle exhaust hole for a #6-32 machine screw. Install a 1/8 inch NPT pipe plug in the outlet-to-shaft hole and grind flush with the top surface of the adapter plate. Install a #6-32x1/4 inch machine screw in the idle exhaust hole. Use thread locking agents to secure both plugs and the screw. Using a 5/16 inch tubing bender, create a 90° bend in the water tube to allow it to exit the mid-section through the hole created per instructions in the next paragraph.

A-8 Mid-Section Remote Coolant Inlet Access Hole:

Refer to Figure 3. At the location illustrated, drill or hole saw a 1 inch diameter hole in either side of the housing assembly (Part No. 1597-8829A3) for Remote Cooling System Water Inlet.

A-9 Modifications to the Powerhead:

No modifications to the internal components of the Powerhead assembly are allowed. The Powerhead is to be used for testing as it is received from Mercury or the designated Central Parts Distributor. Minor modifications to the external portions of the Powerhead for items such as speed sensor and throttle actuation brackets, etc., are allowed.

A-10 Exhaust Back Pressure Tap Location:

Refer to Figure 4. Drill and tap a 1/8 inch NPT hole for the exhaust back pressure tap.

A-11 Exhaust Cover Modifications:

Refer to Figures 5, 6 and 7. Drill and tap a 1/4 inch NPT holes in the exhaust cover for closed circuit outlet-to-shaft relocation. Placement of this hole is critical because it must communicate with the proper water passage inside the exhaust cover. Fabricate a 1/4 inch NPT x 3/8 inch flare fitting with a 0.221 inch ID. Install the fitting in the tapped exhaust cover hole. Grind the fitting flush with the coolant passage surface inside the exhaust cover. Note: If the upper steam relief hole is not present, modifications are made to the baffle plate (Part No. 42365). Contact Mercury Marine Engineering, Plant 12, W6250 Pioneer Road, Fond du Lac, WI 54935.

A-12 Cylinder Head Cover and Thermostat Modifications:

Refer to Figure 8. Drill and tap a 1/8 inch NPT hole in the cylinder head cover at the location indicated for the installation of the cylinder jacket temperature thermocouple. Remove the thermostat housing, gasket and thermostat. Refer to Figure 10 and modify the thermostat as shown. Reinstall the modified thermostat, flange seal, gasket and housing.

A-13 Carburetor Main Circuit:

Use of a stock Mercury 15 hp carburetor with a fixed main jet providing the specified fuel flow is the primary fuel flow control method. A secondary method utilizes an adjustable main jet available as part number C-71-29-33-20 from

Facet Fuel System, Inc.  
1048 Industrial Park Road

Bristol, Virginia 24201  
Attention: Bob Callahan 703-669-5555

The adjustable main jet body is modified and installed as outlined in the appendix. See attached drawing. A one inch hold should be added to the lower shroud below the center of the carburetor bowl to allow passage of the jet needle shank through the shroud. To eliminate the potential for jet adjustment changes due to vibration, the packing gland nut must be torqued to 60 inch pounds after adjustment.

A-14 Powerhead, Pre-test Preparation:

Use a Mercury, 15 horsepower test powerhead (Part No. 61-816903A67). The spark plug seat diameter shall be counter bored to a 1.125 inch diameter to allow clearance for the spark plug base thermocouple and the stock spark plug seat depth shall be maintained.

A-15 Powerhead Disassembly and Inspection:

Remove the covers, plates and gaskets from the transfer ports, the exhaust ports and the cooling jacket. Separate the crankcase halves and remove the crankshaft and pistons as an assembly. Inspect all components and replace any damaged or defective items with new serviceable parts. Because crankcases are machined as a set, and connecting rods and the crankshaft center main roller bearing outer race have matched parting lines, each must be replaced as a set.

A-16 Compression Ratio Verification:

It is optional at the laboratory's discretion to measure the compression ratio. There is not a mechanism for varying compression ratio without changing port timing, since the cylinder head is cast into the block.

If measurement is desired: Thoroughly clean the cylinder crankcase halves with Stoddard solvent and air dry. Plug the decompression ports with suitably sized o-ring or other material trimmed to maintain the contour of the cylinder wall inside diameter. Install the spark plugs and position the crankcase (cylinder head downward) in a machinists compound vise or on a leveling table. Level the crankcase parting line in all directions.

A-17 Compressible Volume:

Lay a straight wire (.093 inch dial) through the transfer ports nearest the center of the crankcase across the bore and through the exhaust ports (also nearest center) of each cylinder. Allow the wires to position themselves by rolling them longitudinally on the top edges of the ports. Optimally, let the wires come to rest at the lowest points on the ports which are the points of exhaust port closing.

Using a 150 ml titration burette filled with pre-blended 71591 NMMA Reference Oil and Stoddard solvent (1:1 volumetric ratio), measure the compressible volume of the first cylinder by filling it with fluid from the burette until the fluid surface tension causes the fluid to begin rising on the wire. Note the volume of fluid used. Refer to Form 3 in the Appendix. Reduce this volume by 21.0 cc to account for the piston crown volume. Record the result and repeat for the second cylinder. Return the used fluid to storage, remove the decompression port plugs, drain and wipe any excess fluid from inside the cylinder bores.

A-18 Compressed Volume:

Remove the spark plugs and apply a thin coating of grease to the top land and rings of each piston and install the piston and crank assembly in the crankcase. Install and torque the crankcase cover. Position the crankcase so the spark plug seats are level and, using a depth micrometer or piston position indicator, position one cylinder at TDC. Again using the burette, measure the compressed volume of the cylinder at TDC by filling with fluid. It is necessary to rotate the crankcase at several angles to eliminate air pockets in the combustion chamber. Note the volume required, and reduce this volume by 1.1 cc, (spark plug volume). Record the result. Repeat for the other cylinder. Calculated Compression Ratio: This parameter is measured and calculated at the laboratories option. Divide the values obtained in paragraph Compressible Volume by the values from paragraph Compressed Volume for the respective cylinders to calculate the compression ratios. Ratios of 6.9 to 7.1 are acceptable. Record.

A-19 Port Chamfering:

Remove the pistons & crankshaft as an assembly. Inspect the transfer and exhaust ports for sharp edges. Without enlarging the port windows remove the sharp edges from the ports using a 220 grit flapper sanding wheel. This is the only allowable method for de-burring the cylinder ports.

A-20 Puddle Pumping Modifications:

None required.

A-21 Component Cleaning:

Thoroughly scrub cylinder bores induction passages and all surfaces of both the crankcase and cylinder assembly using suitably sized brushes. Use a solution of ¼ cup of detergent dissolved in a gallon of clear tap water. Thoroughly rinse in hot water. Immediately submerge both the cylinder and crankcase in an ultrasonic cleaner (DIRL LUM 603 from Blue Wave Ultrasonics, P.O. Box 4347, Davenport, IA 52808) to remove any clinging type residual debris. Again thoroughly rinse in hot tap water. Blow dry and apply a film of 71591 NMMA Reference Oil to the cylinder bores. Remove the piston rings. Orient them so they may later be returned to their original grooves. Thoroughly clean the rings, piston and crankshaft assembly, crankcase halves, covers, and related components with Stoddard solvent. Air dry. Apply a thin film of 71591 NMMA Reference Oil to cylinder bores.

A-22 Mechanical Measurements:

Refer to Form 3 in the Appendix. Measure the upper and lower cylinder bores and pistons. Calculate and report the piston clearance for each by subtracting the major transverse skirt dimension from the smaller of the transverse "Below Port" or "Bottom" cylinder diameters. Report the measurements. Piston clearance between .0025 and .0045 in. is required. Square each piston ring in its respective bore. Using a feeler gauge, measure ring gaps. Required ring gap is .012 - .016 in. for the top ring and .014 - .018 in. for the 2<sup>nd</sup> ring. Report. Install piston rings to their original locations being certain that the ½ keystone rings are located in the top grooves. Using a feeler gauge, measure and report the 2<sup>nd</sup> ring-side clearances. Required side clearance is .0015 - .0025 in. Measure and report the cylinder liner finish in the ring travel area above the ports. Required finish is 10-25 micro inches "R<sub>s</sub>" (average). If the finish is not within the allowed tolerance, powerheads should be returned to Mercury Marine

for credit of exchange. In no case shall cylinder honing be allowed to restore cylinder liner surface finish.

A-23 Cylinder Honing:

Cylinder honing is not permitted.

A-24 Exhaust Back Pressure Installation:

Install a 1/8 inch NPT X 1/4 inch flare 90° elbow fitting into the tapped hole created in paragraph A-10, Exhaust Back Pressure Tap Location. Fabricate an 18 inch long stainless steel tube with a flare and swivel nut on one end. Attach the tube to the elbow and bend the tube at points to allow it to exit the lower engine shroud through a notch cut into the shroud parting line.

A-25 Powerhead Assembly:

Liberally oil bearings, seals, rings, pistons and cylinder walls with 71591 NMMA Reference Oil before assembly. Seal the crankcase half parting lines with Loctite Master Gasket Mercury Part No. 92-12564-1. Completely assemble the powerhead. Install all brackets and linkages, discarding shift cross shaft (Part no. 42153) and related attachments. Connect the puddle pumping hoses and "T". Allow at least 24 hours for the crankcase sealant to "set up".

*NOTE: Special attention to the placement of the exhaust baffle and cover gaskets is required, refer to figures 6 and 7. Reversing the position or using two of the same gasket will allow direct entry of cooling water into the cylinders and crankcase.*

A-26 Water Jacket Thermocouple Installation:

Install a 0.188 inch thermocouple fitting into the drilled and tapped hole created in paragraph A-12, Cylinder Head Cover and Thermostat Modifications. Install the Jacket thermocouple with a 0.75 inch immersion depth. Tighten the compression nut on the fitting.

A-27 Final Assembly:

Note: It is necessary to insure that no extraneous water enters through the carburetor. This can lead to premature piston scuffing especially on the intake side. To alleviate this potential remove the two screws fastening the rear handle shield to the top cowl and discard the shield and screws. This will allow for an alternate air entry. Seal off the area in the vicinity of the shift shaft under the carburetor with a piece of closed cell foam or equivalent. Finally, if engine cover modification is necessary, minimize the size and number of holes made in the cover in order to minimize locations where water can enter the engine compartment.

A-28 Carburetor Deflector:

Do not use the carburetor inlet deflector, which was a stock item on engines at the release of TC-W3® in April 1992.

A-29 Spark Plug Torque:

It is recommended that spark plugs be torqued to 150 in-lbs.





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OMC 40 HP Procedure

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**TC-W3<sup>®</sup>**

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## 1. SCOPE

1.1 This method evaluates the overall performance of lubricants intended for use in two-stroke-cycle spark ignition water-cooled outboard engines. Piston ring sticking, deposits, bearing conditions, and general component wear are evaluated.

## 2. SIGNIFICANCE AND USE

2.2 This test procedure is primarily intended for the evaluation of lubricants for use in water-cooled outboard engines which have various and varying lubrication requirements such that they can operate on their recommended fuel to oil ratios of up to 100:1 (one percent oil) using either premix or oil injection lubrication systems.

## 3. DESCRIPTION AND TERMS

3.1 LOAD WHEEL, TEST TASK PROPELLER: A power-absorbing device used instead of a propeller when the outboard engine is operated in a test tank.

3.2 LOWER ENGINE ASSEMBLY: The portions of the outboard engine other than the powerhead and its cowlings.

3.3 POWERHEAD: The two-stroke-cycle gasoline engine that provides power to the outboard engine, including carburetors, fuel pumps, flywheel alternator, starter, ignition system, and all other directly connected components required for its operation, but excluding components attached to the short block by tubes or wires only.

3.4 SHORT BLOCK: The cylinder block, crankshaft, connecting rod and piston assemblies of the powerhead assembled into a complete unit with gaskets, cylinder heads, covers, seals, and all internal parts, but excluding the carburetors, fuel pump, flywheel alternator, and other powerhead components external to and separable from the cylinder block.

## 4. SUMMARY OF METHOD

4.1 The test is run in an outboard engine test tank on a modified OMC 44.99 cubic inch (737 cc) two-cylinder outboard engine. Overall candidate lubricant performance and spark plug fouling are evaluated and compared to a reference lubricant run simultaneously in a control test engine. More than one candidate lubricant may be run at the same time and is compared to one reference run. After break-in, the engines are run on a five (5) minute idle and fifty-five (55) minute wide open throttle (WOT) cycle for seven (7) hours followed by a one (1) hour minimum shutdown or soak period. This is repeated fourteen (14) times for a total of ninety eight (98) hours running time.

4.2 Pass-Fail Criteria: See CT 5.2

## 5. TEST ENGINE

5.1 An Outboard Marine Johnson Model J40ECC or Evinrude Model E40ECC outboard engine with a special short block assembly (part No. 433334) shall be used for this test. A 45 hp Commercial Chassis can be modified for use with this powerhead if the J40ECC or E40ECC is not available.

General specifications are:

- Two-Stroke Cycle Loop Charged
- Two Cylinder in Line
- 3.187 inch (80.95 mm) Bore
- 2.820 inch (71.63 mm) Stroke
- 44.99 Cubic inch (737 cc) Displacement
- Cast Iron Sleeve Cylinders
- Moly Piston Rings
- Anti-friction Bearings
- Water Cooled
- Dual Carburetors

Modifications to the engine are required, along with use of a special short block, to meet the requirements of this procedure.

### 5.2 Lubricant System:

The engine as manufactured is provided with an oil injection system by which oil is metered into the gasoline in the fuel pump. Since the test is run with premixed fuel, this system is not used and an alternate fuel pump, OMC part number 395713 or equivalent, is used.

### 5.3 Fuel System:

Fuel is supplied to the test engine fuel pump through a fuel connector on the lower cowl. Fuel pressure at the connector should not exceed 5 psi (35 kPa) with the engine stopped.

### 5.4 Load Wheel:

A load wheel (test stand propeller), OMC part number 382861, is required to maintain specified rpm at WOT. The wheel as produced will give a lower WOT speed than specified. To increase speed, remove metal from the rear edges of the vanes, as required.

### 5.4 Cooling System:

The cooling water for the powerhead is supplied directly by an electrically-driven pump with a capacity of approximately 20 gpm (76 L/min) at approximately 10-12 psi (69-83 kPa) pressure. The water supply is regulated to give the specified water outlet temperature from the cylinder head. A heat exchanger with automatic temperature regulation is suggested.

## 6. TEST TANK

6.1 All engine tests are to be run in suitable outboard engine test tanks with adequate ventilation to prevent exhaust dilution of carburetor inlet air. If a sound absorbing box is placed over the engine, it must be designed so it does not interfere with air flow to the engine.

## 7. INSTRUMENTATION

7.1 Temperature Measurement: For critical parameters including spark plug gasket temperatures and cooling system temperatures, a data recording system capable of continuous alarm scanning and required end of cycle phase snapshot data recording is preferred. A record of the immediate history of all parameters preceding an alarm is desirable. A strip chart record of all critical parameters is acceptable. Room air temperature in the vicinity of the engine should be recorded at least once per seven hour cycle.

7.1.1 Apparatus and mounting requirements associated with individual thermocouples are listed below:

7.1.1.1 Spark plugs – At the spark plug gasket. The recess for the spark plugs in the cylinder head must be modified to allow clearance for the thermocouple wires. Spark plug seats shall be counter-bored to a 1.125 inch diameter and stock spark plug seat depth shall be maintained. It is recommended that the specifications for spark plug thermocouple dimensions and material that are specified in the ASTM TC two-cycle procedure be utilized.

7.1.1.2 Coolant in – At the coolant pressure fitting on the exhaust manifold cover. 1/8 inch (3.18 mm) diameter, 6 inch (152 mm) length, inserted 4.75 inch (121 mm) into the coolant pressure fitting [3 inch (76 mm) pipe nipple with a Tee for coolant pressure] on the exhaust manifold cover (part No. 325308 shown on SwRI Drawing No. C-1910-1263).

7.1.1.3 Coolant out – At the 1/8 inch pipe compression fitting next to the coolant out port of the cylinder head. 1/8 inch (3.18 mm) diameter, 4 inch (102 mm) length, inserted 1.25 inch (32 mm) into the coolant out fitting (shown on SwRI Drawing No. C-1910-1263).

7.1.1.4 Carburetor inlet air – At the carburetor air silencer (shown on ALI Drawing No. TWC40-01).

7.2 Barometric Pressure: Record at seven-hour intervals.

7.3 Ambient Temperature and Humidity: Record at seven-hour intervals.

7.3.1 Inlet Air: Inlet air temperature shall be measured in the intake air box prior to the carburetor. Please refer to the print in the Appendix referring to carburetor air thermocouple placement.

7.4 Tachometer: An electronic or vibration tachometer accurate to  $\pm 25$  rpm. An instrument incorporating an automatic shutdown on alarm is desirable but not required.

7.5 Timing Light: Any timing light suitable for use with a high energy ignition system is satisfactory.

7.6 Fuel Flowmeter: Any type accurate to  $\pm 0.2$  lb/hr (0.09 kg/hr) at approximately 25 lb/hr (11 kg/hr) can be used.

## 8. REAGENTS AND MATERIALS

8.1 Reference Oil: The 93738 NMMA Reference Oil is supplied by Citgo Petroleum Corporation. It is commercially available under the designation 93738 NMMA Reference Oil. The amount of oil required for a test is approximately five US gallons (19 liters).

8.2 Candidate Oil: The amount of candidate oil required is also approximately five US gallons (19 liters).

8.3 Test Gasoline: The test gasoline is Phillips "J" reference fuel.

8.3.1 The amount of gasoline needed to run one candidate oil and one reference oil is approximately 800 US gallons plus 400 US gallons for each additional candidate oil run at the same time.

## 9. INSPECTION, MODIFICATION AND ASSEMBLY OF THE ENGINE

9.1 Powerhead: A new special test short block, part number 433334, must be used for each test. For details on disassembly, inspection and assembly not covered here, see OMC 40ECC Service Manual, part number 507661 or 507616 for the alternate engine type.

9.1.1 Cylinder Bores: Measure and record cylinder bore diameter in line with, and 90 degrees to the axis of, the crankshaft at the following locations:

- (1) 0.75 in. (19 mm) below the top of the bore.
- (2) Above the exhaust ports.
- (3) Above the bottom cutout.

The maximum out of round and taper must not exceed 0.002 in (0.05 mm). Bore finish must be 20-40 micro inch  $R_a$ . Honing of the cylinders to correct the bore finish is permitted.

### 9.1.1.1 Honing Instructions:

1. Remove sharp edges from the ports with a small hand file.
2. Honing is done using a 3 ¼ in. (82.55 mm) 180 grit Silicon carbide BRM Flex-hone (available through Snap-On Tools under part No. BC683).

3. A hand held 3/8 in. drill motor with a free running speed of 1250 rpm is used to drive the Flex-hone.
4. Wet the Flex-hone with Stoddard solvent.
5. Hone the bore of each cylinder for 20 seconds at a rate of approximately 30-60 strokes per minute. The hone must be turning before entry into the bore and upon exit from the bore.
6. Clean the cylinder after honing with hot water and laundry detergent. Following a rinse with clear hot water, spray with Stoddard solvent and air dry. To prevent rust from forming, wipe the bores with 7591 NMMA Reference Oil.
7. If the reference engine is honed, than the candidate engines run concurrently MUST be honed also. All engines in the same test program must be treated the same with respect to honing.

9.1.2 Pistons: Measure and record the piston diameter in line with, and at 90 degrees to, the wrist pin bore at the top ring land and below the bottom ring groove.

9.1.3 Piston to Cylinder Bore Clearances: Must be in a range of 0.021 to 0.024 in. (0.53 to 0.61 mm) at the top land and 0.016 to 0.019 in. (0.41 to 0.48 mm) below the bottom ring groove.

9.1.4 Compression Ratio: As measured per OMC Engineering Specification #356, the compression ratio on each cylinder should be in a range of 7.01:1 to 7.2:1. Modify cylinder heads to adjust compression ratio if needed.

9.1.5 Piston Ring End Gap: Measure and record the end gap of each piston ring in its respective bore. The ring gap must be within 0.007 to 0.017 in. (0.81 to 0.43 mm).

9.2 Midsection Modifications: The following modifications must be made to the engine midsection, which can be reused as long as it is serviceable.

9.2.1 The power head adapter, part number 332181, must be modified as required (SwRI drawing No. C-1910-1263) to facilitate the external supply of cooling water in and out of the powerhead, as well as provide exhaust housing cooling with water supplied by the engine-driven pump. The powerhead is modified to remove the pressure relief valve part number 335493, spring part number 314626, and grommet part number 316132.

9.2.2 The inner exhaust housing, part number 324042, must be modified by blocking exhaust relief holes below top flange (SwRI drawing No. C-1910-1261 and B-1910-1262.)

9.3 The thermostat is removed from the cylinder head to permit external control of coolant temperature.

9.4 The engine shroud shall be modified only as required for throttle linkage of engine monitoring equipment. Number and size of holes made in the cover should be minimized. Only the tall version of the engine shroud shall be used.

9.5 Spark plug seats shall be counter-bored to 1.125 inch diameter in order to allow clearance for spark plug base thermocouple leads. The depth of the seat should remain stock.

9.6 OMC Gel Seal II made by the Loc-Title Corporation is the required sealant for joining the crankcases.

10. PROCEDURE: Mount test engine in test tank with specified test equipment.

10.1 Break-in: Using 50:1 fuel:oil ratio mixture of reference fuel and candidate lubricant, run the following part throttle speeds:

3000  $\pm$  200 rpm for one hour

4000  $\pm$  200 rpm for one hour

180° F (82.2°C) maximum coolant outlet temperature

After break-in, re-torque head bolts to 19-20 ft. lbs. (25.8-27.1 Nm). Break-in must be run with the oil to be tested.

10.2 Running Conditions:

	<u>WOT</u>	<u>Idle</u>
RPM	4500 $\pm$ 200	1000 $\pm$ 100
Fuel Flow	21.5 $\pm$ 0.5 lbs/hr	Record
Ignition Timing	21° $\pm$ 1 BTDC	Record
Coolant Out	170 $\pm$ 5°F (77 $\pm$ 3°C)	Record
Coolant In	Record	Record
Coolant Delta T	20 $\pm$ 5°F (11 $\pm$ 3°C)	Record
Fuel/Oil Ratio	100:1	100:1
Ex Coolant flow	Record	Record
Engine Coolant flow	Record	Record

Engine running conditions should be targeted at the mid-point of the specifications listed.

10.3 Test Cycle: Run five minutes idle and 55 minutes WOT test cycle for seven hours. Shut engine down for at least one hour and repeat sequence fourteen (14) times for a total running time of 98 hours. Reference test and candidate test(s) must be run simultaneously. When repair or maintenance work is required on any test engine, the other test engines must also be stopped.

10.4 Recorded Data: A typical log sheet showing the recorded parameters and specifications is shown in the Appendix as Form 1.

10.4.1 Record as indicated:

Cooling system Temperatures: Five minutes prior to each idle period and on a recording system capable of continuous alarm scanning.

Spark Plug Gasket Temperatures: Five minutes prior to each idle period and on a recording system capable of continuous alarm scanning.

WOT RPM: Prior to and five minutes after each idle period.

Fuel Flow: Five minutes prior to each idle period.

Ignition Timing, Barometer, and Wet-Dry Bulb Temperature: Once per seven hour sequence.

10.4.2 Spark Plug: When it is determined that a spark plug is misfiring, remove and record condition and test time to failure.

10.4.3 Preignition: A sudden rise of 18°F (10°C) or more in a spark plug gasket temperature is an indication of preignition. Record the occurrence in the test data and replace the spark plug at each occurrence.

## 11. INSPECTION AND RATING OF PARTS

Rate the engine parts used to determine pass/fail at end of the test using the NMMA TC-W3® Outboard Engine Two-Cycle Rating Procedure.

11.1 Other Components: Any unusual wear or damage to any other engine components must be reported.

## 12. REPORT

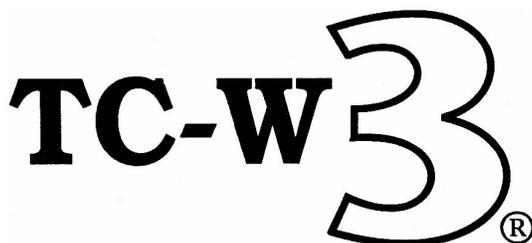
The test report must give evaluation of candidate oil performance as compared to the reference oil. A typical report format is shown in the Appendix as Form 2. The testing laboratory must include reference data as an attachment.



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## 1. SCOPE

1.1 This procedure evaluates the detergency and general performance of two-stroke-cycle water-cooled outboard engine lubricants at a 50:1 fuel:oil ratio. Piston deposits, and ring sticking are the evaluation areas.

1.2 The scope of this procedure does not address every safety aspect regarding the use of materials and reagents recommended. Users must inform themselves, and others involved, of the potential hazards encountered in testing gasoline fueled engines.

## 1. REFERENCE DOCUMENTS

1.1 Outboard Marine Corporation Model (OMC) 70 ELEIE Service Manual, part number 507948, available through the OMC Engineering Department.

2.2 CRC Rating Manual No. 14 (A.1.2)

1.2 ASTM Standards, ASTM Annual Standards Publications (A.1.1):

2.3.1 D-4857-88, Determination of the Ability of Lubricants to Minimize Ring Sticking and Piston Deposits in Two-Stroke-Cycle Engines Other Than Outboards.

2.3.2 D-4863-88, Determination of Lubricity of Two-Stroke-Oil Gasoline Engine Lubricants.

2.4 NMMA TC-W3® Outboard Engine Two-Cycle Rating Procedure

2.5 OMC Engineering Specification #356 (A.1.4)

## 3. SUMMARY OF TEST METHOD

3.1 The test is run in an outboard engine test tank on a modified Outboard Marine Corporation 56.1 cubic inch (913 cc) three-cylinder outboard engine. Candidate lubricant performance is evaluated and compared to a reference lubricant which is tested simultaneously. After a two (2) hour break-in, the engines are run on a five (5) minute idle and fifty-five (55) minute wide open throttle (WOT) cycle for a total of ninety-eight (98) hours running time. There are no scheduled shutdowns during the ninety-eight (98) hours running time.

3.2 Pass-Fail Criteria: See CT 5.3

## 4. SIGNIFICANCE AND USE

This procedure is primarily intended to evaluate the detergency and ring sticking resistance of two-stroke-cycle water-cooled outboard engine lubricants at 50:1 fuel:oil ratio. Piston deposits and ring sticking are the primary evaluation areas.

## 2. APPARATUS

### 5.1 Test Engine

An OMC Johnson Model J70ELEIE or Evinrude Model E70ELEIE or equivalent outboard engine with the following general specifications shall be used for this test.

General specifications are:

- Two-Stroke Cycle Loop Charged
- Three Cylinder in Line
- 3.188 Inch (80.97 mm) Bore
- 2.3437 Inch (59.53 mm) Stroke
- 56.1 Cubic Inch (913 cc) Displacement
- Cast Iron Sleeve Cylinders
- Anti-friction Bearings
- Water Cooled
- Three stock OMC single-throat carburetors (Modified to allow barometric fuel bowl control to adjust fuel flow, a typical pressure control system is shown in Attachment No. 1)
- Substitution of Moly Rings for Chrome

Modifications to the engine are required to meet the requirements of this procedure.

5.2 Lubricant System: The fuel and oil are premixed.

5.3 Fuel System: The fuel delivery system shall be designed to provide adequate fuel delivery to the carburetor for full throttle and idle conditions. Under no circumstances shall fuel pressure exceed the carburetor needle/seat/float system closing pressure (approx. 5 psig (35 kPa) while the engine is stopped). This could result in engine flooding. There are two types of carburetors used during the production of the OMC 70 hp test powerhead. OMC has specified that the newer type carburetors are deemed equivalent. However, the same types of carburetors should be used on all engines in the same program.

5.4 Load Wheel: A load wheel (test stand propeller), OMC part number 386665, is required to maintain specified rpm at WOT. The wheel as produced will normally give a lower WOT speed than specified. A suggested speed control method is the use of plugs. To increase speed, remove metal from the leading edges of the vanes, as required. The WOT speed can be fine tuned by adding or changing the length of the "plugs" installed in the test wheel. A "plug" is a 1/8 in NPT pipe nipple of various lengths that can be installed symmetrically around the outside diameter of the load wheel to reduce the WOT speed. It is recommended by OMC that a test wheel of known performance be used during break-in to verify power output of the engine.

5.5 Cooling System: The cooling water for the powerhead is supplied directly by an ancillary electrically-driven pump with a capacity of approximately 10 gpm (38 liters/min) at

approximately 10-30 psi (69-207 kPa) pressure, measured at the existing OMC water pressure tap on the exhaust manifold cover. The engine coolant water is regulated to give the specified water inlet and outlet temperatures. The engine cooling water can be any clear water. Treatment to remove minerals or for anticorrosion is permissible. A typical cooling system is shown in Attachment No. 2. Coolant flow should be measured and reported.

5.6 TEST TANK: All engine tests are to be run in outboard engine test tanks (1700 gallon (6435 L) capacity suggested) equipped with adequate ventilation to prevent exhaust dilution of carburetor inlet air. The test tank design and size shall be sufficient to minimize speed surging at test conditions. If a sound absorbing box is placed over the engine, it must be designed so it does not interfere with air flow to the engine.

## 5.7 INSTRUMENTATION

5.7.1 Temperature Measurement: For critical parameters including spark plug gasket temperatures and cooling system temperatures, a data recording system capable of continuous alarm scanning and required end of cycle phase snapshot data recording is preferred. A record of the immediate history of all parameters preceding an alarm is desirable. A strip chart record of all critical parameters is acceptable. Room air temperature in the vicinity of the engine should be recorded at least once every 8 hours.

5.7.2 Apparatus and mounting requirements associated with individual thermocouples are listed below:

5.7.2.1 Spark plugs – At the spark plug gasket. The recess for the spark plugs in the cylinder head must be modified to allow clearance for the thermocouple wires. The spark plug seat shall be counter-bored to a diameter of 1.125 inch diameter. The stock spark plug seat height shall be maintained. Please refer to ASTM TC two-cycle specification D-4857 for details concerning the recommended spark plug gasket dimensions and material.

5.7.2.2 Coolant In – At the coolant pressure fitting on the exhaust manifold cover. 1/8 in. (3.18 mm) diameter, 6 in. (152 mm) length, inserted 4.75 in. (121 mm) into the coolant pressure fitting [3 in. (76 mm) pipe nipple with a pipe Tee for coolant pressure] on the exhaust manifold cover (part number 329834 shown on SwRI Drawing No. D-1910-1253).

5.7.2.3 Coolant out – At the 3/8" pipe Tee at the coolant out port of the cylinder head. 1/8 in. (3.18 mm) diameter, 4 in. (102 mm) length, inserted 2 in. (51 mm) into the coolant out fitting (shown on SwRI Drawing No. D-1910-1253).

5.7.2.4 Ambient Air and Carburetor air – See drawing in Appendix.

5.7.3 Barometric Pressure: Record every four hours.

5.7.4 Humidity: Record every four hours.

5.7.5 Tachometer: An Electronic tachometer accurate to  $\pm 25$  rpm shall be used. An instrument incorporating an automatic engine over-speed shutdown is recommended.

5.7.6 Timing Light: Any timing light suitable for use with a high energy ignition system is satisfactory.

5.7.7 Fuel Flowmeter: Any type accurate to  $\pm 0.2$  lb/hr (0.09 kg/hr) at approximately 40 lb/hr (18 kg/hr) can be used. A mass flowmeter is recommended. The fuel flow system shall be calibrated by the laboratory.

5.7.8 Bore Surface Finish Analyzer: An instrument is required to measure the cylinder bore surface finish in the range 20 to 40 micro inches Ra (.51 to 1.02 micro meters), using a 0.030 in. (.76 mm) cutoff. An instrument having a mechanically driven profilometer stylus is suggested. Since repeatable measurements are difficult to achieve with a hand-held instrument. The Federal Surf-Indicator System model 21-1350-00 or equivalent, is suggested.

## 6. REAGENTS AND MATERIALS

6.1 Reference Oils: 32299 NMMA Reference Oil is the OMC 70 hp high reference oil that is used to compare candidate performance. The low reference oil is commercially available under the designation 93738 NMMA Reference Oil. The amount of oil required for a test is approximately 15 US gallons (57 liters).

6.2 Candidate Oil: The amount of candidate oil required is approximately 15 US gallons (57 liters).

6.3 Test Gasoline: The test gasoline is Howell RSF (ring sticking fuel) reference fuel. It is commercially available from Howell Hydrocarbons and Chemicals (A.1.6). The fuel is identified by batch number.

6.3.1 The amount of gasoline needed to run each engine is approximately 725 US gallons (2744 liters).

6.4 Engine Coolant: Clear water. Water treated to remove minerals or for anticorrosion is permissible. Excessive cooling system deposits could result in test severity problems.

6.5 Engine assembly Lubricant: 32299 NMMA Reference Oil. Used for all assembly lubrication.

## 7. PRECISION AND BIAS

7.1 No bias has been determined through date 4-92.

## 8. INSPECTION, MODIFICATION AND ASSEMBLY OF THE ENGINE

8.1 Powerhead: A new OMC short block, part number 436276, must be used for each test. For details on disassembly, inspection and assembly not covered here, see OMC 70ELEIE Service Manual, part number 507948 or 508144.

8.1.1 Cylinder Bores: Measure and record cylinder bore diameter in line with, and 90 degrees to the axis of, the crankshaft at 0.75 in. (19 mm) and 3 in. (76.2 mm) below the top of the bore. The maximum out of round must not exceed 0.003 in. (0.08mm). The maximum taper must not exceed .002 in. (0.05 mm). Bore finish should be 20-40 micro inch Ra (51 to 1.02 micro meters). Honing of cylinder bores is not allowed under any circumstance. If cylinder bore finish is unacceptable or if surface rust is observed that cannot be removed by wiping with reference oil then the powerhead should be returned to OMC for credit or exchange.

8.1.2 Pistons: Measure and record the piston diameter in line with, and at 90 degrees to, the wrist pin bore at the top ring land and .250 in. (6.35 mm) up from the bottom of the piston skirt.

8.1.3 Piston to Cylinder Bore Clearances: Must be in a range of 0.023 to 0.026 in. (0.58 to 0.66 mm) at the top land and 0.004 to 0.006 in. (0.10 to 0.15 mm) at the bottom of the piston skirt.

8.1.4 Compression Ratio: As measured per OMC Engineering Specification #356 (A.1.4.), the compression ratio on each cylinder should be in a range of 6.2:1 to 6.5:1.

8.15 Piston Rings and Piston Ring End Gap: Moly piston Rings, available from OMC Engineering (A.1.4.) must be used (engines manufactured after April 1, 1992 should have moly rings installed). Measure and record the end gap of each ring in its respective bore. The ring gap must be within the range of 0.007 to 0.017 in. (0.18 to 0.43 mm).

8.2 Engine and Midsection Modifications: The following modifications must be made to the engine and midsection. These components can be reused as long as they are serviceable.

8.2.1 The exhaust manifold cover, part number 329834, and cylinder head, must be modified and an exhaust housing adapter block off plate must be fabricated as shown on SwRI drawing No. D-1910-1253 (A.1.7.), to facilitate the external supply of cooling water in and out of the powerhead.

8.2.2 The exhaust housing adapter, part number 336274, must be modified as shown on SwRI drawing number C-1910-1254 (A.1.7.).

8.2.3 The water tube, part number 319281, must be modified as shown on SwRI drawing number B-1910-1255 (A.1.7.).

8.2.4 Install lower unit lube lines in place of the "fill" and "vent" screws in the lower unit. These lines should be run up to the transom mount so that the lower unit can be lubricated while the engine is running in the tank.

8.3 Reassemble engine as per Service Manual.

8.4 The thermostat is removed from the head to permit external temperature control.

8.5 Install spark plug gasket thermocouples in place of the spark plug gaskets.

8.6 Install new champion QL77JC4 spark plugs gapped to .030 inch (.76 mm) in each cylinder.

8.7 Reassemble the engine to the midsection as per Service Manual.

8.8 The engine cover shall be modified only as required for throttle linkage or engine monitoring equipment. Number and size of holes made in the cover shall be minimized.

## 9. OPERATING PROCEDURE

Mount the test engine in a test tank equipped with the specified test equipment.

9.1 Break-in and Ignition Timing: Start the engine and run at  $1000 \pm 100$  rpm for 10 minutes. After this warm-up period run the engine at WOT and  $5000 \pm 200$  rpm just long enough to adjust the ignition timing to 19 BTDC.

Break-in: Using 50:1 fuel:oil ratio fuel mixture with the candidate lubricant, run the following part throttle speeds:

3000  $\pm$  200 rpm for one hour  
4000  $\pm$  200 rpm for one hour  
140°F max Coolant Out Temperature

After break-in, re-torque head bolts to 18-20 ft-lbs (24-27 Nm). Break-in must be run with the oil to be tested.

9.2 98 Hour Test Operation:

9.2.1 Idle Operating Conditions:

RPM	1000 $\pm$ 100
Throttle Position	Idle
Fuel:Oil Ratio	50:1

9.2.2 WOT Running Conditions:

RPM	5000 $\pm$ 200
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Throttle Position  
Fuel Flow

WOT  
Set Point  $\pm 0.5$  lbs/hr

As necessary to provide the NMMA specified separation between the high and low reference oils. Candidates must be run at the same conditions as the reference. References and all candidates in the same program shall be targeted at the same set point. The acceptable tolerance from the set point on fuel flow is  $\pm 0.5$  lbs/hr.

Ignition Timing	19° +0 -1 BTDC
Coolant Out/Minus In Temp	130 $\pm$ 4°F (54.4 $\pm$ 2.2°C)
Coolant In	Temp record
Coolant Flow Rate	Record
Out-In Temp	30 $\pm$ 4°F (16.7 $\pm$ 2.2°C)
Fuel/Oil Ratio	50:1
Ex Back Pressure	25-45 inches of water is typical
Ex Coolant flow	Record (5-10 gpm suggested)

Engine running conditions should be targeted at the mid-point of the specifications listed. The exception to the midpoint rule is exhaust back pressure.

9.3 Test Cycle: Run a five minute idle and 55 minute WOT test cycle. Repeat this one hour cycle for 98 hours. The total test time including break-in, is 100 hours. Reference test and candidate test(s) must be run simultaneously. When repair or maintenance work is required on any test engine, the other test engines must also be stopped.

9.4 Recorded Data: A typical log sheet showing the recorded parameters and specifications is shown in the Appendix as Form 1.

9.4.1 Record as indicated:

Coolant In Temperature: On a strip chart recorder or data acquisition system and every hour on the Data Log, five minutes prior to each idle period.

Coolant Out Temperature: On a strip chart recorder or data acquisition system and every hour on the Data Log, five minutes prior to each idle period.

Spark Plug Gasket Temperatures: On a strip chart recorder or data acquisition system and every hour on the Data Log, five minutes prior to each idle period.

WOT RPM: Five minutes prior to and five minutes after each idle period

Idle RPM: Once per idle period

Fuel Flow: Every hour, five minutes prior to each idle period

Ambient temperature: Every hour, five minutes prior to each idle period

Coolant in pressure: Every hour, five minutes prior to each idle period

Ignition Timing WOT: At least once every seven hours

Ignition Timing Idle: At least once every seven hours

Barometer: Every four hours

Wet and Dry Bulb Temperature: Every four hours

9.4.2 Spark Plug: When it is determined that a spark plug is misfiring, remove and record condition and test hours to failure. A loss of engine speed at WOT of 200 rpm or a sudden change in spark plug temperature is sufficient cause to stop engine and determine cause.

9.5 Fuel Flow Rate: Fuel flow set point may be modified in order to obtain the NMMA required separation on ring sticking between the high and low reference oils. Subsequent candidate evaluations must be operated at the same set point on fuel flow as the reference pair that obtained the NMMA required separation. All candidates run concurrently with reference tests shall be run at the same set point as the reference and the control tolerance should not exceed plus or minus 0.5 lbs/hour.

## 10. REPORT

The test report must give evaluation of candidate oil performance as compared to the reference oil. A typical report format is shown in the Appendix as Form 2. The testing laboratory must include reference data as an attachment.



**National Marine Manufacturers Association**

NMMA AF-27-03 Engine Lubricity

Test Procedure

Recertified

**TC-W3<sup>®</sup>**

# NMMA AF-27-03 Engine Lubricity Test Procedure

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# NMMA AF-27-03 Engine Lubricity Test Procedure

## 1. SCOPE:

- 1.1) This procedure evaluates the lubricity performance of two-stroke-cycle water-cooled outboard engine lubricants at a 50:1 fuel:oil ratio.
- 1.2) The scope of this procedure does not address every safety aspect regarding the use of materials and reagents recommended. Users must be aware of the potential hazards encountered in testing gasoline fueled engines.

## 2. REFERENCE DOCUMENTS:

- 2.1) ASTM D 4863-00: Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants.
- 2.2) ASTM E 178-02: Standard Practice for Dealing With Outlying Observations.
- 2.3) JASO M 340-92: Lubricity Test Procedure for Evaluating Two-Stroke Gasoline Engine Oils.
- 2.4) NMMA TC-W3 Lubricity Test.
- 2.5) NMMA TC-W3 Product Approval System.
- 2.6) Each of these procedures can be obtained from the respective organizations.

## 3. SUMMARY OF TEST METHOD:

- 3.1) The test has been developed to compliment the NMMA TC-W3 Lubricity Test. It is run using a modified Honda AF-27 (type SK50MM), single-cylinder, air-cooled, spark ignition, two-stroke-cycle gasoline engine.

A test is composed of four sets of five to seven "tightenings". A "tightening" consists of measuring the torque decrease as the spark plug gasket temperature increases from 200C to 300C. The first and third sets are conducted using XPA-3259 reference lubricant. The second and fourth sets are conducted using a candidate lubricant. The sets are then compared using a prescribed statistical analysis.

4. SIGNIFICANCE AND USE:
  - 4.1) This procedure is intended to evaluate the propensity of a two-stroke-cycle lubricant to diminish the occurrence of piston and cylinder scuffing.
5. Apparatus, Modifications, and Engine Assembly:
  - 5.1) Use the JASO M 340-92 test method.
6. Reagents and Materials:
  - 6.1) Benchmark Reference Oil: NMMA reference oil XPA-3259.
  - 6.2) Calibration Reference Oil: JASO reference oil JATRE-3.
  - 6.3) Sponsored Candidate Oil: Minimum of 1 qt. is recommended.
  - 6.4) Test Fuel: Halterman EEE fuel is recommended. If unavailable, a fuel with comparable properties is suitable. Candidate tests must be performed on the same batch as the most recent reference test. Approximately 10 gallons will be required.
  - 6.5) Engine Assembly Oil: NMMA reference oil XPA-3259
7. PRECISION AND BIAS
  - 7.1) No precision statement can be made as of 6/03.
  - 7.) No bias can be established as of 6/03.
8. OPERATING PROCEDURE:
  - 8.1) The operational parameters of JASO M 340-92 shall be used.

9. DATA ANALYSIS:

- 9.1) The data analysis method of the NMMA TC-W3 Lubricity shall be used. The NMMA TC-W3 Lubricity uses the method of the ASTM D 4863-00.
- 9.2) The ASTM D 4863-00 utilizes the ASTM E 178-02 to determine if there are outliers among the data. The AF-27 will adhere to the following criteria:
- A) Testing for outliers is not required if the standard deviation of all the data for an individual oil is less than or equal to .0100 NM.
  - B) If the standard deviation is above .0100 NM, five specific tests from ASTM E 178-02 will be applied to all the data for an individual oil to determine if outliers exist. If the standard deviation drops to 0.0100 NM or below, during the outlier detection process, then removing additional outliers is not required.
  - C) The five specific tests are in:
    - a) Section 6.1: Test for a Single High, using Table 1 at upper 10%.
    - b) Section 6.1: Test for a Single Low, using Table 1 at upper 10%.
    - c) Section 6.8: Tietjen-Moore for Each End, using Table 4 with k of 2 And alpha of 0.10.
    - d) Section 6.9: Test for Two Largest, using Table 5 at lower 10%.
    - e) Section 6.9: Test for Two Smallest, using Table 5 at lower 10%.
  - D) If an outlier is detected, remove the data point and recalculate the five specific tests of the ASTM E 178-02.
  - E) If more than one outlier is detected, remove the outlier furthest from the mean and recalculate the five specific tests of the ASTM E 178-02.
  - F) Repeat Section C items a) through e) until no outliers are detected, or the standard deviation drops to .0100 NM.

- G) Two outliers per set, four per oil, can be removed. If a third outlier is detected in a set and the standard deviation of the individual oil is above .0100 NM, the test is invalid.
  - H) When no further outliers are detected or the standard deviation is at or below .0100 NM, the average torque decrease of the candidate is compared to the average torque decrease of the reference using the Student T test at the 90% confidence level.
  - I) If the candidate's average torque decrease is less than or equal to the reference based on the Student T at 90%, the candidate is deemed to be as good as or better than the reference and therefore a "Pass".
- 9.3) A "request for clarification" has been approved by the NMMA OCC and ASTM B02 D06 committees. The NMMA TC-W3® Lubricity and ASTM D 4863-00 procedures have been clarified to ensure all the "torque decrease values" are used in the final statistical analysis. Manual removal of data other than outlier/s identified by the methods discussed in section 9.2 should not be performed without an assignable cause, i.e. the engine stalls, a preignition occurs, etc.

#### 10. TEST SITE ACCEPTANCE:

- 10.1) A test lab shall run two consecutive TC-W3® AF 27 Lubricity reference tests using XPA-3259 as the benchmark reference oil, and JATRE-3 as the calibration oil. The intent is for the XPA-3259 to give lower torque drop values than JATRE-3.
- 10.2) Results are evaluated by the following criteria: The mean torque drop for the low reference oil JATRE-3 shall be in the range of .3000 to .5000 NM. The mean torque drop value of the JATRE-3 shall exceed the mean torque drop value of the XPA-3259. The delta shall fall within the range of .2 – 1.2 in-lbs (.0226 - .1356NM) inclusive. To calculate the mean torque drop values refer to section 9 "Data Analysis".
- 10.3) Results shall be reviewed and approved by the OCC prior to acceptance of the test site.
- 10.4) Acceptance results shall also be submitted to the Office of Test Data Administration (OTDA).

11. REFERENCE RESULTS/FREQUENCY

11.1) Reference Results: Once a test site is approved by OCC, subsequent reference results shall continue to meet the requirements of Section 10 "Test Site Acceptance".

11.2) Reference Frequency: A reference test shall be run at the following times:

- a) After a complete engine overhaul, or piston/cylinder replacement.
- b) Prior to starting a candidate, six or more months have elapsed since the last acceptable reference.
- c) A decrease of 10% in the initial torque has occurred that cannot be restored by cleaning.
- d) After a total of 40 candidate tests (20 NMMA AF-27's + 20 JASO Lubricity's, or any combination) per piston/cylinder set. It is recommended the head gasket be replaced every 5 tests, and the ring grooves, piston crown, and head be cleaned every 20 tests.

12. CANDIDATE PASS/FAIL CRITERIA:

12.1) The average torque decrease value of the candidate oil must be equal to or less than that of the XPA-3259 using a Student T Test confidence level of 90% outlined in Section 9 "Data Analysis".

13. READACROSS PROTOCOL:

13.1) Applicable read-across information is in Section XII of the NMMA TC-W3 Product Approval System.

14. GENERAL PRACTICES:

14.1) The general practices of the NMMA TC-W3 Product Approval System shall apply.

15. REPORT (TBD)

16. CONTACT INFORMATION

16.1 ASTM International  
100 Barr Harbor Drive  
P.O. Box C700  
West Conshohocken, PA 19428-2959  
Phone: (610) 832-9585  
Fax: (610) 832-9555  
[www.astm.org](http://www.astm.org)

16.2 Japan Lubricating Oil Society  
16-1, 2-Chome  
Hinode, Fanabashi-Shi, Chiba  
Japan  
Phone: +81-47-433-5181  
Fax: +81-47-431-9579  
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