National Marine Manufacturers Association

TC-W3®

RATING MANUAL

This rating procedure is intended for use with the proposed NMMA Recertified TC-W3® specification. All references to rating technique have been excluded from the proposed recertified TC-W3® methods.

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I. Purpose of Procedure

To document the TC-W3® outboard engine parts rating methods necessary to quantify outboard engine lubricant performance for TC-W3® lubricant certifications. There are no references to rating methods within the individual engine test procedures. All rating descriptions necessary for TC-W3® are included in or referred to in this document. The pass/fail criteria for each TC-W3® test are included in the most recent NMMA TC-W3® Test Manual.

II. Scope of Manual

This procedure describes TC-W3® outboard engine rating methods used on the OMC 70 hp, OMC 40 hp, and Mercury 15 hp TC-W3® engine tests. The TC-W3® lubricity and preignition evaluations, which are performed on a Yamaha CE-50S motorcycle engine, do not rely on engine parts ratings to quantify lubricant performance. Therefore, this procedure does not discuss rating methods for the Yamaha CE- 50S tests.

III. Relationship to the Proposed ASTM Rating Document

As much as possible, rating technique and definitions used in this rating method are consistent with the ASTM Committee D-2, Subcommittee B, Section VI “Two-Stroke Rating” procedure and terminology document drafted May 4, 1990 in San Antonio, Texas.

IV. Definitions

The following definitions are related to rating methods. Not all terminology is necessary for each individual method.

- **Blowby:** The portion of the intake air charge, unburned air-fuel mixture or combustion reactants that leak into the engine crankcase during operation of the engine.
- **Burnish:** An alteration of the original manufactured surface to a dull to brightly polished condition.
- **Carbon:** A firm, black, highly insoluble deposit composed primarily of organic residue and most readily defined by thickness or volume and texture. It is usually non-lustrous except when rubbed smooth between adjoining engine parts and found primarily on surfaces operating above engine bulk temperature. There is no distinction between rubbed and non-rubbed carbon. The same scale is used for both types of carbon.
- **Corrosion:** A general alteration of the finished surfaces by discoloration accompanied by roughening not attributable to mechanical action. Rust is a special case of corrosion.
- **Cylinder Head:** The entire area of the cylinder combustion area. If rated, use CRC manual No. 20.
- **Deposit:** Material other than fuel or lubricant as such as affixed to an engine surface as to have finite volume under operating conditions and classifiable as carbon, varnish, rust, etc.
- **Discoloration:** Any alteration in the color of rated surfaces compared to new parts.
- **Exhaust port:** The area where exhaust gas exits the cylinder. The exhaust port plugging percent number is made on a basis wherein a rating of ten designates a clean port and a zero is an exhaust port which is 100% plugged. The exhaust port plugging is determined by examining the port through the cylinder bore.
- **Indentation:** Displacement of metal by plastic deformation to form a crater of dent.
- **Merit Rating:** Definition of an engine condition in numerical terms on a descending scale from ten (10), which represents a part without deposits.
- **Piston Zones:**

1. Crown: Piston top surface combustion area.
2. Crownland (Top Land or Land no. 1): Vertical surface area above top ring.

3. Second Land: Vertical surface area between piston grooves no. 1 and 2.

4. Skirt: Piston skirt is the machined surface area located below the bottom of the last ring groove and extending to the bottom edge of the piston, excluding any relieved or port area.

    a. Anti-Thrust: Skirt located on the crankshaft rotation side of the engine.

    b. Thrust: Piston skirt located on the opposite side of the engine crankshaft rotation.

5. Undercrown: Specific undercrown area must be defined for each piston type. As a general rule, the area located inside the piston directly below the piston crown and up to the last ring grove.

- **Pinched or Pivotal Ring:** A ring stuck at a pinpoint only, allowing the remainder of the ring to pivot about that point.

- **Preignition:** Abnormal combustion initiated before and by some means other than the regularly timed spark at the spark plug. The usual cause is an overheated spot which may occur at the spark plug or at combustion chamber deposits. In its most severe form, preignition can result in melting of the piston crown and/or cylinder head. In a more minor form it may be indicated by absence of carbon in the combustion chamber with slight indentations on the engine surfaces in that area.

- **Rust:** The chemical combination of oxygen with ferrous engine parts including other iron complexes not removable by organic solvents.

- **Sludge:** A deposit composed of organic residue which may contain fuel, lubricant and/or water. Such deposits may be found on engine surfaces operating at bulk engine temperature, which are exposed to fuels and/or lubricants. These deposits do not drain from engine parts but can be removed by wiping with a soft cloth.

- **Spark Plug:** The entire area of the spark plug in the combustion area. Spark plug fouling is determined by examining the spark plug and noting the degree of conditions of electrodes, deposits and gap. Listed below are failure modes for rating a spark plug.
    A. General Deposits
    B. Core Bridging
    C. Gap Bridging
    D. Gap Erosion
    E. Preignition
    F. Other (Identify)

- **Varnish:** A thin, hard lustrous, oil-insoluble deposit, composed primarily of organic residue and most readily definable by color. It is not easily removed by wiping and is resistant to saturated solvents such as petroleum naphtha, but soluble in other solvents such as benzene, chloroform, ketones and similar compounds classed as "varnish solvents." It may be variously colored, usually in gray, brown or amber hues.

- **Wear:**

A. <u>Abrasive Wear:</u> Wear caused by lapping of mating surfaces by fine particles suspended in lubricant, fuel, air or imbedded in a surface.

1. <u>Abrasive Pitting:</u> Abrasive wear observed as crater-like pits formed by or around particles imbedded in a surface.
2. <u>Scratching:</u> Abrasive wear observed as sharp scratch marks in the direction of motion or in random directions.

B. <u>Adhesive Wear:</u> Wear caused by shearing of junctions formed between operating surfaces in direct metal-to-metal contact; sheared-off particles either remain affixed to the harder of the mating surfaces or act as wear particles between the surfaces.

1. <u>Scuffing*:</u> Localized adhesive wear distinguished by concentrated marks in the direction of motion, observed as a matte-finished area rather than individual score marks.

2. <u>Scoring*:</u> Adhesive wear distinguished by definite scratch-like marks in the direction of motion, the marks being more distinct and extensive than scuff marks. Scoring may often be distinguished from abrasive scratching by the burnishing of surface areas accompanying a scoring condition. This burnishing indicates definite contact between and consequent local heating of mating surfaces.

3. <u>Wiping*:</u> Adhesive wear characterized by mechanical deformation or flow of metal out of normal surface location, observed as extensive areas of polishing, discoloration and eventual smearing of surface metal.

4. <u>Seizing*:</u> The stopping of a moving part by a mating surface as a result of excessive friction caused by adhesive wear.

<u>*Note:</u> As defined above, "scuffing" describes a more concentrated, localized wear condition, whereas "scoring" and "wiping" describe wear over an extensive surface area. Therefore, the term "scuffing" lends itself to wear conditions associated with relative sliding motion of mating surfaces where duration of metal-to-metal contact is normally limited, such as in the case of cams and followers, piston skirts and liners. The terms "scoring" and "wiping" better describe wear conditions associated with bearing or rotating motion of mating

surfaces where duration of metal-to-metal contact may be longer, such as in the case of connecting rod journals and bearings.

For the Mercury 15 hp test, all adhesive wear on the piston skirts and piston lands is classified as scuffing in order to simplify the rating. No distinction is made between scuffing, scoring, wiping and seizing on the piston. However, a distinction is made on adhesive wear for the ring face rating.

C. Fatigue Wear: Wear due to surface fatigue resulting from high stress cyclic variation.

1. Pitting: Fatigue wear characterized by sporadic out-breaking of surface metal, observed as small crater-like pits.

2. Spalling: Extreme pitting observed as out-breaking of larger irregular shaped particles of surface material.

3. Flaking: Fatigue wear characterized by removal of thin-layer, irregular flakes of surface material. Observed as surface cracking in early stages.

4. Fretting: Wear occurring on mating surfaces due to slight relative motion resulting from dynamic stress.

V. CRC Rating Manuals Used for TC-W3® Rating

- CRC Manual 20

VI. TC-W3® Interpretations of Rating Methods

Manual 20 varnish scale is interpreted to include carbon. The heaviest deposit in a TC-W3® test is 1.0. Black Varnish and carbon deposits are all rated as 1.0 with no differentiation for depth.

The piston skirts are rated using the varnish scale found in Manual 20. The piston photographs in Manual 20 are not used to quantify varnish intensity for TC-W3®.

The ring sticking method described in CRC Manual 20 is not utilized. The outboard engine ring sticking rating methods used for TC-W3® are described in this document.

VII. Rating Environment

The parts rating area must be free of contaminants. All engine parts must be rated under cool white fluorescent lighting with approximately 4,500 degrees Kelvin color temperature and an illumination level of 350 to 600 foot candles (3766 to 6456 lx). Background and adjacent surfaces must be flat white.

It is recommended that the ratings be completed as soon as the pistons are removed from the test engine. If this is not possible, the pistons should be stored in a desiccator. For all TC-W3® outboard engine tests, the ring and piston ratings should commence within 24 hours of the end of test.

VIII. Parts Preparation

Lightly wipe pistons and rings with a terry towel or soft cloth before rating. All material removed by this process is not rated as a deposit. Do not soak any of the rated parts in solvent before rating.

Leave the rod on the piston until ready to rate the needle bearings for stickiness. To remove the pins and rate the stickiness of them, follow the process described in this document in section XIV.

IX. Ring Sticking Rating Methods

A. Visual Ring Sticking Rating Method

The visual ring sticking method should be performed before the NMMA ring sticking method except when obvious hot ring sticking is evident. In this case, go directly to the NMMA rating method describing hot ring sticking.

Visual ring sticking should be estimated from the point where the ring appears to be stuck in the groove 50% of its ring side width to the next point along the circumference of the ring where it again appears to be stuck in the groove 50% of its ring side width. The number of degrees that appear to be stuck is used to calculate the merit number for visual ring sticking.

Once the initial visual rating has been performed, a determination is made using the NMMA method. If the NMMA rating indicates a free ring, a sluggish ring or a ring that pivots in the groove, then the visual rating is not applicable.

B. NMMA Ring Sticking Rating Method

Each of the rings are individually rated and reported using a 0-10 merit scale having resolution of 0.1 merit numbers with a 10 indicating 100% free. The amount of sticking is determined by manually pressing on the ring face and measuring the number of degrees where no radial movement can be detected.

The rings are rated as to state of sticking and the degree of circumference stuck using the following merit system.

- A free ring rates a 10.0.
  A free ring will fall in its groove under its own weight when its plane is moved from horizontal to vertical. A slight touch to overcome friction is permissible.

- A sluggish ring rates 9.5.
  A sluggish ring will not fall under its own weight but offers resistance to movement in its own groove. It can be pressed into or out of the groove using the amount of pressure necessary to compress it by half of the ring side width without springing back.

- A pinched or pivotal ring rates a 9.0.

- A cold stuck ring 5.0 according to the Ring Rating Scale.
  A cold stuck ring will not yield to the pressure required to compress the ring but shows no evidence of blowby across its face. The cold stuck ring sticking merit number can be calculated between 30 to 330 degrees stuck by the following formula:

9.4 - (Degrees stuck X 0.01333)

Note: A ring cold stuck beyond 330 degrees is considered a 5.0.

Merit range 4.0 to 0.0 denotes hot sticking from 1 to 360 degrees with a 4.0 merit number assigned for up to 30 degrees of blowby across the ring face and a rating of 0.0 for 330 or more degrees of blowby across the ring face. Once any degree of hot ring sticking is observed on the ring face, the ring sticking rating can only be 4.0 merits or less. The amount the ring is cold stuck does not enter into the ring sticking calculation if hot ring sticking is observed. Degrees of hot ring sticking are defined as those degrees of the ring circumference, which displays signs of blowby as carbon or varnish deposits of 3.0 merits or less across the entire ring face.

Hot sticking is reported when a ring exhibits evidence of combustion blowby across its face in an area where the ring is firmly stuck in the groove. Carbon and varnish deposits of a 3.0 merit or less intensity are visible across the entire thickness of the ring face, causing the ring to appear packed in or covered by the deposit. In cases where the ring face is damaged, deposits on the piston surface below the ring may also constitute such evidence. The hot stuck ring merit number can be calculated between 30 to 330 degrees stuck by the following formula:

4.4 - (Degrees stuck X 0.01333)

C. Average Adjusted Ring Sticking

Average adjusted ring sticking is calculated as an average of the visual ring rating and the NMMA ring rating. An exception occurs when the visual rating is not applicable. In this case, the NMMA ring sticking rating is utilized as the average adjusted ring sticking rating.

*See attachments for 15 hp, 40 hp and 70 hp rating templates.

X. Piston Deposit Rating Method

A. Varnish Ratings:

Thrust and anti-thrust sides of the piston skirts, lands and undercrowns are all evaluated for deposits using the varnish/lacquer/rust scale provided in CRC Manual 20 with the interpretations described earlier in this method.

Example: % Area Covered X Deposit Factor = CRC Merit

B. Carbon Ratings:

Thrust and anti-thrust sides of the piston skirts, lands and undercrowns are evaluated for deposits using the carbon scale provided in CRC Manual 20 with the interpretations described earlier in this method. The piston crown and cylinder heads are rated using CRC Manual 20 with no modification. Exhaust port and exhaust passage ratings are determined by a percentage area of blockage; zero percent denoting no blockage.

XI. Miscellaneous Rated Parts

At the discretion of the laboratory and test customer, other engine parts not included for pass/fail determinations can be rated using applicable CRC Manuals.

XII. Piston Scuffing Rating Method

- Mercury 15 hp Piston Scuffing: Circumferential and total area adhesive wear including scuffing, scoring and wiping, is quantified on the piston skirts and lands using the supplied templates and definitions. In the Mercury 15 hp test, all adhesive wear is classified as scuffing. No distinction is made between scuffing, scoring, wiping and seizing. Templates to be used are ALI 1006-002 (circumferential) and ALI 1006-001 (total area). Note that each side of the piston is rated separately and is considered as 100%.

XIII. Ring Face Rating Method

- Mercury 15 hp Ring Face Adhesive Wear: Record all adhesive wear on the ring faces using the definitions of adhesive wear. Include scuffing and scoring as one category and wiping as another category. Laboratories may also report abrasive wear if they desire, although it is not required. Use the template supplied to rate adhesive wear and a scale of 1 to 100%.

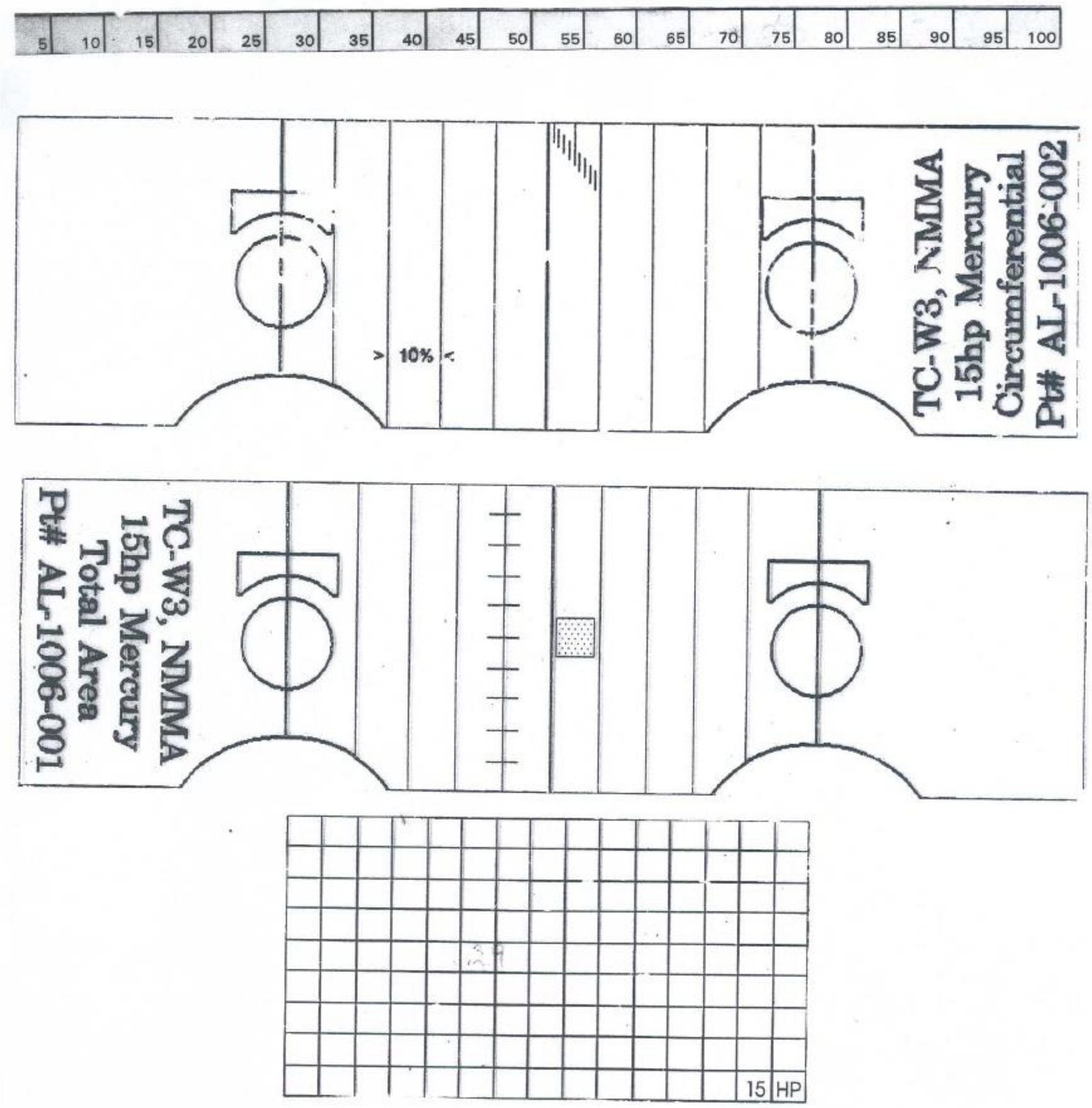
  100% corresponds to 360 degrees of the ring circumference.

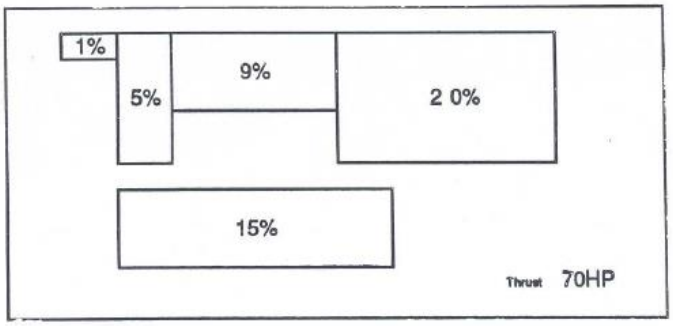
XIV. Rating Method For Mercury 15 hp Needle Bearing Deposits

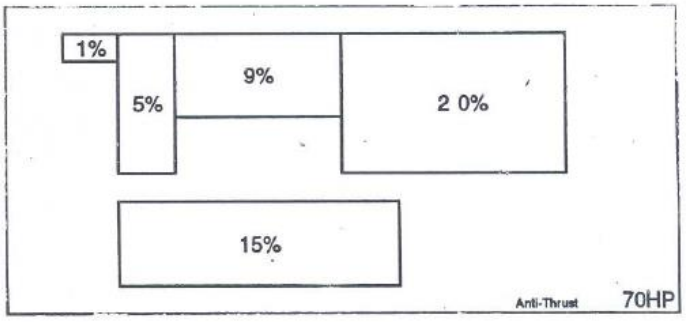
- Parts Preparation: Leave the rod connected to the piston until the rater is prepared to evaluate the wrist pin needle bearings for stickiness. When ready for evaluation, the piston pin is pushed out of the piston. The rod is then extracted from the piston and the wrist pin needle bearings are allowed to drop inside of the wrist pin, which is in a vertical position.
- Wrist Pin Roller Bearing Stickiness Evaluation Method: Once the needle bearings are all inside the wrist pin, allow the parts to sit for five minutes. After five minutes has elapsed, slowly raise the wrist pin above the table two to three inches, continuing to hold it in a vertical fashion with the length of the wrist pin perpendicular to the plane of the tabletop. If all the needles fall out within one minute, a pass is reported for this portion of the rating and the wrist pin roller bearing stickiness evaluation is complete.

  If all the needles do not fall out within one minute, a possible failure is impending. The needle bearings and wrist pins should immediately be stored in a plastic bag. The test laboratory should then contact the test client to determine if they wish to proceed to the next step in the process.

- Needle Bearing and Pin Wear: Report the amount of wear according to CRC Manual 20. Using CRC Manual 20, report the percent of each type of varnish and assign merit numbers for coverage.
- Needle Bearing and Pin Sludge: Report as comments when observed, according to CRC Manual 20.

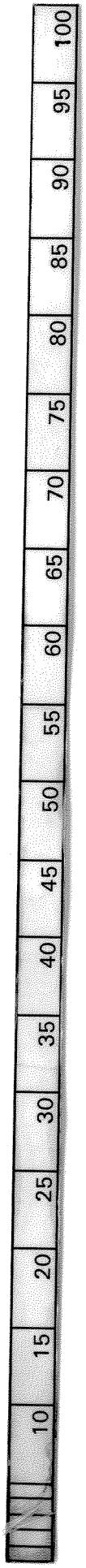

5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
10%
TC-W3, NMMA
15hp Mercury
Circumferential
Pt# AL-1006-002
TC-W3, NMMA
15hp Mercury
Total Area
Pt# AL-1006-001
15 HP


1%
5%
9%
2 0%
15%
Thrust 70HP


1%
5%
9%
2 0%
15%
Anti-Thrust 70HP


70 H.P.
40H.P.

40Hp Circumferencial Scale



40Hp Piston Undercrown and Skirt Varnish Templates