

# M51 Factory Acceptance Test and Shipboard Trials of I.C. Engines

(1987)  
(Rev.1  
1990)  
(Corr.  
1997)  
(Rev.2  
July  
2003)  
(Rev.3  
Jan  
2008)  
(Rev.4  
Feb  
2015  
Complete  
revision)

## 1. Safety precautions

- 1.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer / shipyard and is to be operational.
- 1.2 This applies especially to crankcase explosive conditions protection, but also to over-speed protection and any other shut down function.
- 1.3 The overspeed protective device is to be set to a value, which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point shall be verified by the surveyor.

## 2. General

- 2.1 Before any official testing, the engines shall be run-in as prescribed by the engine manufacturer.
- 2.2 Adequate test bed facilities for loads as required in UR M51.3.3 shall be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean, preheated if necessary and cause no harm to engine parts. This applies to all fluids used temporarily or repeatedly for testing purposes only.
- 2.3 The testing consists of workshop and shipboard (quay and sea trial) testing.

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### Notes:

1. The requirements in M51 Rev.3 are to be uniformly implemented by IACS Societies for engines; when an application for certification for an engine is dated on or after 1 January 2009.
2. The “date of application for certification of the engine” is the date of whatever document the Classification Society requires/accepts as an application or request for certification of an individual engine.
3. The requirements of UR M51 Rev. 4 – except for UR M51.4 – are to be uniformly implemented by IACS Societies to engines with an application for certification dated on or after 1 July 2016.

The requirement of UR M51.4 are to be uniformly implemented by IACS Societies to engines:

- i) with an application for certification dated on or after 1 July 2016; or
  - ii) installed on ships contracted for construction on or after 1 July 2016.
4. The “contracted for construction” date means the date on which the contract to build the vessel is signed between the prospective owner and the shipbuilder. For further details regarding the date of “contract for construction”, refer to IACS Procedural Requirement (PR) No.29.

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2.4 Engines are to be inspected for:

- Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
- Screening of pipe connections in piping containing flammable liquids.
- Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This shall be done while running at the rated power of engine. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, the Society may request temperature measurements as required by UR M71.8.9.

2.5 These inspections are normally to be made during the works trials by the manufacturer and the attending surveyor, but at the discretion of the Society parts of these inspections may be postponed to the shipboard testing.

### **3. Works trials (Factory Acceptance Test)**

#### **3.1 Objectives**

The purpose of the works trials is to verify design premises such as power, safety against fire, adherence to approved limits (e.g. maximum pressure), and functionality and to establish reference values or base lines for later reference in the operational phase.

#### **3.2 Records**

3.2.1 The following environmental test conditions are to be recorded:

- Ambient air temperature
- Ambient air pressure
- Atmospheric humidity

3.2.2 For each required load point, the following parameters are normally to be recorded:

- Power and speed
- Fuel index (or equivalent reading)
- Maximum combustion pressures (only when the cylinder heads installed are designed for such measurement).
- Exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in M73 and M35/36)
- Charge air temperature
- Charge air pressure
- Turbocharger speed (to the extent that monitoring is required in M73)

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3.2.3 Calibration records for the instrumentation are, upon request, to be presented to the attending Surveyor.

3.2.4 For all stages at which the engine is to be tested, the pertaining operational values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. This also includes crankshaft deflections if considered necessary by the engine designer.

3.2.5 In each case, all measurements conducted at the various load points are to be carried out at steady state operating conditions. However, for all load points provision should be made for time needed by the Surveyor to carry out visual inspections. The readings for MCR, i.e. 100% power (rated maximum continuous power at corresponding rpm) are to be taken at least twice at an interval of normally 30 minutes.

### 3.3 Test loads

3.3.1 Test loads for various engine applications are given below. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

Note:

Alternatives to the detailed tests may be agreed between the manufacturer and the Society when the overall scope of tests is found to be equivalent.

3.3.2 *Propulsion engines driving propeller or impeller only.*

- |    |   |  |
|----|---|--|
| A) | 100% power (MCR) at corresponding speed $n_0$ : | at least 60 min.   |
| B) | 110% power at engine speed $1.032n_0$ :         | Records to be taken after 15 minutes or after steady conditions have been reached, whichever is shorter. |

Note:

Only required once for each different engine/turbocharger configuration.

- |    |   |   |
|----|---|---|
| C) | Approved intermittent overload (if applicable):   | testing for duration as agreed with the manufacturer. |
| D) | 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve, the sequence to be selected by the engine manufacturer. |   |
| E) | Reversing manoeuvres (if applicable).   |   |

Note:

After running on the test bed, the fuel delivery system is to be so adjusted that overload power cannot be given in service, unless intermittent overload power is approved by the Society. In that case, the fuel delivery system is to be blocked to that power.

3.3.3 *Engines driving generators for electric propulsion.*

- |    |   |                  |
|----|---|------------------|
| A) | 100% power (MCR) at corresponding speed $n_0$ : | at least 60 min. |
|----|---|------------------|

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- B) 110% power at engine speed  $n_0$ : 15 min. - after having reached steady conditions.
- C) Governor tests for compliance with UR M3.1 and M3.2 are to be carried out.
- D) 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

### Note:

After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a 10% margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the required transient governing characteristics are achieved also at 100% loading of the engine, and also so that the protection system utilised in the electric distribution system can be activated before the engine stalls.

### 3.3.4 *Engines driving generators for auxiliary purposes.*

Tests to be performed as in UR M51.3.3.2.

### 3.3.5 *Propulsion engines also driving power take off (PTO) generator.*

- A) 100% power (MCR) at corresponding speed  $n_0$ : at least 60 min.
- B) 110% power at engine speed  $n_0$ : 15 min. - after having reached steady conditions.
- C) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
- D) 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with the nominal propeller curve or at constant speed  $n_0$ , the sequence to be selected by the engine manufacturer.

### Note:

After running on the test bed, the fuel delivery system is to be adjusted so that full power plus a margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the electrical protection of downstream system components is activated before the engine stalls. This margin may be 10% of the engine power but at least 10% of the PTO power.

### 3.3.6 *Engines driving auxiliaries.*

- A) 100% power (MCR) at corresponding speed  $n_0$ : at least 30 min.
- B) 110% power at engine speed  $n_0$ : 15 min. - after having reached steady conditions.
- C) Approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
- D) For variable speed engines, 75%, 50% and 25% power in accordance with the nominal power consumption curve, the sequence to be selected by the engine manufacturer.

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Note:

After running on the test bed, the fuel delivery system is normally to be so adjusted that overload power cannot be delivered in service, unless intermittent overload power is approved. In that case, the fuel delivery system is to be blocked to that power.

### 3.4 Turbocharger matching with engine

#### 3.4.1 Compressor chart

Turbochargers shall have a compressor characteristic that allows the engine, for which it is intended, to operate without surging during all operating conditions and also after extended periods in operation.

For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging shall occur.

In this section, *surging* and *continuous surging* are defined as follows:

*Surging* means the phenomenon, which results in a high pitch vibration of an audible level or explosion-like noise from the scavenger area of the engine.

*Continuous surging* means that surging happens repeatedly and not only once.

#### 3.4.2 Surge margin verification

Category C turbochargers used on propulsion engines are to be checked for surge margins during the engine workshop testing as specified below. These tests may be waived if successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

For 4-stroke engines:

The following shall be performed without indication of surging:

- With maximum continuous power and speed (=100%), the speed shall be reduced with constant torque (fuel index) down to 90% power.
- With 50% power at 80% speed (= propeller characteristic for fixed pitch), the speed shall be reduced to 72% while keeping constant torque (fuel index).

For 2-stroke engines:

The surge margin shall be demonstrated by at least one of the following methods:

1. The engine working characteristic established at workshop testing of the engine shall be plotted into the compressor chart of the turbocharger (established in a test rig). There shall be at least 10% surge margin in the full load range, i.e. working flow shall be 10% above the theoretical (mass) flow at surge limit (at no pressure fluctuations).
2. Sudden fuel cut-off to at least one cylinder shall not result in continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds. For applications with more than one turbocharger the fuel shall be cut-off to the cylinders closest upstream to each turbocharger.

This test shall be performed at two different engine loads:

- The maximum power permitted for one cylinder misfiring.

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- The engine load corresponding to a charge air pressure of about 0.6 bar (but without auxiliary blowers running).

3. No continuous surging and the turbocharger shall be stabilised at the new load within 20 seconds when the power is abruptly reduced from 100% to 50% of the maximum continuous power.

### 3.5 Integration tests

For electronically controlled engines, integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes and the tests considered as a system are to be carried out at the works. If such tests are technically unfeasible at the works, however, these tests may be conducted during sea trial. The scope of these tests is to be agreed with the Society for selected cases based on the FMEA required in UR M44.

### 3.6 Component inspections

Random checks of components to be presented for inspection after works trials are left to the discretion of each Society.

## 4. Shipboard trials

### 4.1 Objectives

The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, control systems and auxiliary systems necessary for the engine and integration of engine / shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing).

### 4.2 Starting capacity

Starting manoeuvres are to be carried out in order to verify that the capacity of the starting media satisfies the required number of start attempts.

### 4.3 Monitoring and alarm system

The monitoring and alarm systems are to be checked to the full extent for all engines, except items already verified during the works trials.

### 4.4 Test loads

4.4.1 Test loads for various engine applications are given below. In addition, the scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

4.4.2 The suitability of the engine to operate on fuels intended for use is to be demonstrated.

Note:

Tests other than those listed below may be required by statutory instruments (e.g. EEDI verification).

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## 4.4.3 Propulsion engines driving fixed pitch propeller or impeller.

- A) At rated engine speed  $n_0$ : at least 4 hours.
- B) At engine speed  $1.032n_0$   
(if engine adjustment permits, see 3.3.1): 30 min.
- C) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
- D) Minimum engine speed to be determined.
- E) The ability of reversible engines to be operated in reverse direction is to be demonstrated.

### Note:

During stopping tests according to Resolution MSC.137 (76), see 4.5.1 for additional requirements in the case of a barred speed range.

## 4.4.4 Propulsion engines driving controllable pitch propellers.

- A) At rated engine speed  $n_0$  with a propeller pitch leading to rated engine power (or to the maximum achievable power if 100% cannot be reached): at least 4 hours.
- B) At approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer.
- C) With reverse pitch suitable for manoeuvring, see UR M51.4.5.1 for additional requirements in the case of a barred speed range.

## 4.4.5 Engine(s) driving generator(s) for electrical propulsion and/or main power supply

- A) At 100% power (rated electrical power of generator): at least 60 min.
- B) At 110% power (rated electrical power of generator): at least 10 min.

### Note:

Each engine is to be tested 100% electrical power for at least 60 min and 110% of rated electrical power of the generator for at least 10 min. This may, if possible, be done during the electrical propulsion plant test, which is required to be tested with 100% propulsion power (i.e. total electric motor capacity for propulsion) by distributing the power on as few generators as possible. The duration of this test is to be sufficient to reach stable operating temperatures of all rotating machines or for at least 4 hours. When some of the gen. set(s) cannot be tested due to insufficient time during the propulsion system test mentioned above, those required tests are to be carried out separately.

- C) Demonstration of the generator prime movers' and governors' ability to handle load steps as described in UR M3.2.

## 4.4.6 Propulsion engines also driving power take off (PTO) generator.

- A) 100% engine power (MCR) at corresponding speed  $n_0$ : at least 4 hours.

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- B) 100% propeller branch power at engine speed  $n_0$   
(unless already covered in A): 2 hours.
- C) 100% PTO branch power at engine speed  $n_0$ : at least 1 hour.

**4.4.7 Engines driving auxiliaries.**

- A) 100% power (MCR) at corresponding speed  $n_0$ : at least 30 min.
- B) Approved intermittent overload: testing for duration as approved.

**4.5 Torsional vibrations****4.5.1 Barred speed range**

Where a barred speed range (bsr) is required, passages through this bsr, both accelerating and decelerating, are to be demonstrated. The times taken are to be recorded and are to be equal to or below those times stipulated in the approved documentation, if any. This also includes when passing through the bsr in reverse rotational direction, especially during the stopping test.

**Note:**

Applies both for manual and automatic passing-through systems.

The ship's draft and speed during all these demonstrations is to be recorded. In the case of a controllable pitch propeller, the pitch is also to be recorded.

The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the bsr. Steady fuel index means an oscillation range less than 5% of the effective stroke (idle to full index).

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