M51 Factory Acceptance Test of Reciprocating Internal Combustion Engines

(1987) (Rev.1 1990) (Corr.1 1997) (Rev.2 July 2003) (Rev.3 Jan 2008) (Rev.4 Feb 2015 Complete revision) (Corr.1 Oct 2018) (Rev.5 Apr 2025 Complete revision)

1. General

Factory Acceptance test is a part of the 'Certification scheme for reciprocating internal combustion engines' (hereafter is referred to as "engine").

2. Scope

2.1 This UR is associated with IACS UR M87 and contains the requirements for Factory Acceptance Test of engines and sub-systems.

2.2 This UR outlines the general requirements for Factory Acceptance Tests for engines. Additional testing requirements specified in the following URs apply as relevant,

- M78, Reciprocating Internal Combustion Engines Fuelled by Gases or Low-flashpoint Fuels.

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 are to be uniformly implemented by IACS Societies to engines with an application for certification dated on or after 1 July 2016.

4. The requirements of UR M51 Rev.5 are to be uniformly implemented by IACS Societies to engines:
   i) with an application for certification dated on or after 1 January 2027; or
   ii) installed on ships contracted for construction on or after 1 January 2027.

5. 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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3. Objectives

The purpose of the Factory Acceptance Test is to verify engine design parameters and functions such as power, safety against fire, adherence to approved limits (e.g. maximum pressure), are consistent with the type approved engine, and to establish reference values or base lines for later reference in the operational phase of the specific engine. The Factory Acceptance Test is to be attended by the Society's surveyor unless an alternative certification scheme is agreed with the society (ref. UR Z26).

Objectives include but not limited to,

- Conformity of production;
- Determine that the essential operating parameters are within approved specification;
- Integrated test of sub-system and components, including failure test;
- Confirmation of safety arrangements.

4. Definitions

4.1 The terms and definitions in M87 are also applicable to this UR.

4.2 For the purpose of this UR, the following definitions apply:

- 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.

5. General requirements of Factory Acceptance Test

5.1 Safety Precautions

5.1.1 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, and its correct functioning is to be verified. (e.g. safety barrier, safety railings, information and marking of escape routes, sirens, etc.)

5.1.2 This applies especially to crankcase explosive conditions protection, but also to over-speed protection and any other shut down function.

5.1.3 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.

5.1.4 The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required in M51 7.5 verification of fire protection measures) is also to be carried out before the test runs.

5.1.5 Adequate test bed facilities for loads as required in UR M51.7 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.

5.2 Documentation to be submitted

The extent of the documentation may be reduced by agreement, depending on the engine type and production.

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Before test:

- Valid Type Approval Certificate or Design Evaluation Certificate covering the tested engine.
- Design appraisal/review, when applicable and plans for test.

During test:

- Calibration records for the test bed instrumentation used to collect data;
- Certificate or reports of components required by the Society;
- Necessary internal test results to be made available, when requested by the Society's surveyor.

After test:

- The manufacturer shall submit a formal report to the Society, which includes,
  (1) Valid Type Approval Certificates or Design Evaluation Certificate covering the tested engine.
  (2) Calibration records for the instrumentation used to collect data;
  (3) Documentation and test results with the signature of attending surveyor;
  (4) Surveyor's comments during FAT, and the manufacturer's replies/explanations.
  (5) Certificate or reports of components to be made available, when requested by the Society.

6 Measurement and Records

6.1 The following environmental test conditions are to be recorded:

- Ambient air temperature
- Ambient air pressure
- Atmospheric humidity

6.2 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)
- All engine parameters required for control and monitoring for the intended use (propulsion, auxiliary, or emergency), if applicable to the scope of delivery

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6.3 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.

6.4 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.

6.5 During all load points, engine parameters are to be within the specified and approved values.

6.6 Calibration records for the instrumentation shall be made available to the attending Surveyor upon request.

7. Test program of witnessed tests

The following tests shall be conducted in the presence of a Surveyor.

7.1 Test of Safety Devices

Test of safety precautions according to manufacturer's specification to the extent applicable for the scope of delivery of the engine, especially for,

- over-speed protective device,
- Safeguards of the low pressure of lubricating oil system,
- Oil mist detection system, if applicable,
- Other safeguards specified in M35, M36, M63, if applicable,

The shutdown tests of above safety devices are to be carried out at running condition, testing by simulating the concerned parameter or adjusting the set-point may be accepted upon agreement with the Society.

7.2 Test loads

Test loads for various engine applications are given below. the scope of the trials may be adjusted depending on the engine application, service experience, or other relevant reasons. Records to be taken after steady conditions have been reached. The operating time per load point depends on the engine size (achievement of steady state condition) and on the time for collection of the operating values, however sufficient time should be allowed for visual inspection by the Surveyor.

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.

7.2.1 Propulsion engines driving propeller or impeller.

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

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B) 110% power at corresponding engine speed, normally $1.032n_0$ for driving fix pitch propeller or impeller.
n_0 for driving controllable pitch propeller: at least 15min.

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 depending on following application:
- in accordance with the nominal propeller curve, for an engine driving a fixed pitch propeller, water jet or controllable pitch propeller with variable speed and pitch. Or
- in accordance with modified propeller curve for an engine driving controllable pitch propeller with variable speed and pitch. Or
- at constant speed for an engine driving a controllable pitch propeller with constant speed.

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.

7.2.2 Engines driving generators for electric propulsion.

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

B) 110% power at engine speed n_0: at least 15 min.

C) Governor tests for compliance with UR M3.1 and M3.2 are to be carried out for engines driving constant speed (synchronous) generators.

D) 75%, 50% and 25% power and idle, the sequence to be selected by the engine manufacturer.

Note 1:
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.

Note 2:
10% overload power may not require for e.g. variable speed engines driving electrical machines for electric propulsion, when they are connected to a DC grid where the inverter is limiting the requested power.

7.2.3 Engines driving generators for auxiliary purposes.

Tests to be performed as in UR M51.7.2.2.

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7.2.4 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: at least15 min.

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.

7.2.5 Engines driving auxiliaries other than electric generators.

A) 100% power (MCR) at corresponding speed n_0: at least 30 min.

B) 110% power at engine speed n_0: at least 15 min.

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.

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 limited to that power.

7.3 Turbocharger matching with engine

7.3. 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.

7.3. 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

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successfully tested earlier on an identical configuration of engine and turbocharger (including same nozzle rings).

A) 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 speed (= according to propeller curve depending on application (see 7.2.1(D)), the speed shall be reduced with constant torque (fuel index) down to 45% power.

B) For 2-stroke engines:

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

The engine working characteristic established at workshop testing of the engine shall be plotted into the compressor chart of the turbocharger (which was established) by the turbocharger manufacturer's testing. 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).

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.
- The maximum engine load without auxiliary blowers running, corresponding to a charge air pressure of approximately 0.6 bar.

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.

7.4 Integration tests of sub-system

7.4.1 Integration tests for sub-system acceptance shall be conducted to verify that the response of the complete mechanical, hydraulic, and electronic system aligns with predictions across all intended operational modes.

7.4.2 The scope of these tests shall be proposed by the designer taking into account of multiple engine operational mode, FMEA reports, and the impact of the test on engine, and is to be agreed by the Society.

Typical examples of extended tests include, but are not limited to, the follows:

- Safety test of sub-system;
- Functional test of sub-system;
- Operational mode switch/Changeover test: Switch between multiple operational

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modes or turn on/off sub-systems.

- Extended performance and load test for engines with multiple operational modes, if applicable.

If the above tests are technically unfeasible on the test bed, they may be conducted during the sea trial.

7.5 Verification of fire protection measures

7.5.1 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.
- Proper insulation of hot surfaces is to be verified.

Readings of surface temperatures are to be done randomly by using of Infrared thermos scanning equipment while the engine is running at rated power. The use of equivalent measurement equipment is to be approved by the Society. If the insulation is modified subsequently to the Type Approval Test, the Society may request temperature measurements as required by UR M71.

7.5.2 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.

While verification of fire protection measures is not conducted integrally during FAT, the engine is to be inspected according to 7.5.1.

7.6 Component inspections

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

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