RULES

PUBLICATION 28/P

TESTS OF I.C. ENGINES

January
2025

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków complete or extend the Rules and are mandatory where applicable.

GDAŃSK

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1 TYPE TESTING OF I.C. ENGINES

1.1 General

1.1.1 Type approval of I.C. engine consists of drawing approval (in the scope required in para.1.3.2, *Part VII*), specification approval, conformity of production, approval of type testing programme, type testing of engines, review of the obtained results, and the issuance of the Type Approval Certificate by PRS.

1.1.2 Type testing is required for every new engine type intended for installation onboard ships subject to classification. A type test carried out for a particular type of engine at any place of manufacture will be accepted for all the engines of the same type built by licensees or the licensor, subject to each place of manufacture being found to be acceptable to PRS.

1.1.3 A type of engine is defined by:

.1 bore and stroke;
.2 injection method (direct or indirect);
.3 valve and injection operation (by cams or electronically controlled);
.4 kind of fuel (liquid, dual fuel, gaseous);
.5 working cycle (4- stroke, 2-stroke);
.6 turbo charging system (pulsating or constant pressure);
.7 the charging air cooling system (e.g. with or without intercooler);
.8 cylinder arrangement (in-line or V)[1)];
.9 cylinder power, speed and cylinder pressures [2)].

Notes:

1) One type test will be considered adequate to cover a range of different numbers of cylinders. However, a type test of an in-line engine may not always cover the V-version. Subject to the individual Societies discretion, separate type tests may be required for the V- version. On the other hand, a type test of the V-engine covers the in-line engines, unless the mep is higher.

2) The engine is type approved up to the tested ratings and pressures (100% corresponding to MCR). Provided documentary evidence of successful service experience with the classified rating of 100 % is submitted, an increase (if design approved *) may be permitted without a new type test if the increase from the type tested engine is within:

.1 5% of the maximum combustion pressure, or
.2 5% of the mean effective pressure, or
.3 5% of the rpm.

* Only crankshaft calculations and crankshaft drawings, if modified.

Providing maximum power is not increased by more than 10%, an increase of maximum approved power may be permitted without a new type test provided engineering analysis and evidence of successful service experience in similar field applications (even if the application is not classified) or documentation of internal testing are submitted if the increase from the type tested engine is within:

.1 10% of the maximum combustion pressure, or
.2 10% of the mean effective pressure, or
.3 10% of the rpm.

1.1.4 De-rated Engine

If an engine has been design approved, and internal testing per stage A is documented to rating higher than the one type tested, the Type Approval may be extended to the increased power/mep/rpm upon submission of an Extended Delivery Test Report at:

.1 test at over speed (only if nominal speed has increased),
.2 rated power, i.e. 100% output at 100 % torque and 100%speed corresponding to the load point1, 2 measurements with one running hour in between;

.3 maximum permissible torque (normally 110%) at 100 % speed corresponding to the, load point 3 or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a, ½ hour;
.4 100% power at maximum permissible speed corresponding to load point 2, ½ hour.

1.1.5 Integration Test

An integration test demonstrating that the response of the complete mechanical, hydraulic and electronic system is as predicted maybe carried out for acceptance of sub-systems (turbo charger, engine control system, dual fuel, exhaust gas treatment etc) separately approved. The scope of these tests shall be proposed by the designer/licensor taking into account of impact on engine.

1.1.6 Safety Precautions

1.1.6.1 Before test run is carried out, all relevant equipment for safety of attending personnel is to be made available by the manufacturer/shipyard and it is to be operational, and its correct functioning is to be verified.

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

1.1.6.3 The inspection for jacketing of high-pressure fuel oil lines and proper screening of pipe connections (as required by 1.4.8.1) is also to be carried out before the test runs.

1.1.6.4 Interlock test of turning gear is to be performed when installed.

1.1.7 Scope of type test

Type test is subdivided into three stages:
.1 Stage A – internal tests.
.2 Stage B – type approval tests, carried out at the manufacturer's test-bed, in the presence of PRS' Surveyor.
.3 Stage C – component inspection, to the extent as required by PRS Surveyor.

1.1.8 The complete type testing program is subject to approval by PRS. The extent the Surveyor's attendance is to be agreed in each case, but at least at stage B and C.

1.1.9 Testing prior to the type approval testing (stage B and C), is also considered as a part of the complete type testing program.

1.1.10 Upon completion of complete type testing (stage A through C), a type test report is to be submitted to PRS for review. The type test report is to contain:
.1 overall description of tests performed during stage A. Records are to be kept by the builders QA management for presentation to PRS;
.2 detailed description of the load and functional tests conducted during stage B;
.3 inspection results from stage C.

1.1.11 Special testing such as LCF[1)] and endurance testing will normally be conducted during stage A.

Note:

1) LCF- means parts subjected to low cycle fatigue such as "hot" parts when load profiles such as idle-full load –idle (with steep ramps) are frequently used.

1.1.12 High speed engines for marine use are normally to be subjected to an endurance test of 100 hours at full load. Omission or simplification of the type test may be considered for the type approval of engines with long service experience from non-marine fields or for the extension of type approval of engines of a well-known type, in excess of the limits given in 1.1.3

1.1.13 Propulsion engines for high speed vessels that may be used for frequent load changes from idle to full are normally to be tested with at least 500 cycles (idle-full load-idle) using the steepest load ramp that the control system (or operation manual if not automatically controlled) permits. The duration at each end is to be sufficient for stable temperatures of the hot parts.

1.2 Measurements and Recordings

1.2.1 During all testing the ambient conditions (air temperature, air pressure and humidity) are to be recorded.

1.2.2 As minimum, the following engine data are to be measured and recorded:

.1 engine rpm;
.2 torque;
.3 maximum combustion pressure for each cylinder [1];
.4 mean indicated pressure for each cylinder [1];
.5 charging air pressure and temperature;
.6 exhaust gas temperature;
.7 fuel rack position or similar parameter related to engine load;
.8 turbocharger speed;
.9 all engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

Notes:

1) For engines where the standard production cylinder heads are not designed for such measurements, a special cylinder head made for this purpose may be used. In such a case, the measurements may be carried out as per stage A and are to be properly documented. Where deemed necessary e.g. for dual fuel engines, the measurement of maximum combustion pressure and mean indicated pressure may be carried out by indirect means, provided the reliability of the method is documented.

Calibration records of the instrumentation used to collect data as listed above are to be presented to and reviewed by attending PRS Surveyor.

Additional measurements may be required in connection with design assessment.

1.3 Stage A – Internal Tests

1.3.1 During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are be recorded. The load conditions to be tested are also to include the testing specified in the applicable type approval programme.

1.3.2 Normal Operation

At normal operation at least the following conditions are to be tested:

- the load points 25%, 50%, 75%, 100% and 110% of the maximum engine rated power for continuous operation along the nominal (theoretical) propeller curve and at constant speed for propulsion engines (if applicable mode of operation i.e. driving controllable pitch propellers); and at constant speed for engines intended for generator sets including a test at no load and rated speed;
- the limit points of the permissible operating range. These limit points are to be defined by the engine manufacturer;

– for high speed engines, the 100 hr full load test and the low cycle fatigue test apply as required in connection with the design assessment;
– specific tests of parts of the engine, required by PRS or stipulated by the designer.

1.4 Stage B – Type Approval Test

The tests listed below are to be carried out in the presence of PRS' Surveyor. The results of the tests are to be recorded in the type test report and signed by the attending PRS Surveyor after the type test is completed.

Prior to engine bed tests, the Manufacturer is to furnish PRS' Surveyor with the test-bed measuring error, the brake and other equipment verification Certificates. If the brake Certificate is not available, the brake is to be checked in the presence of PRS' Surveyor according to the brake Manufacturer's instructions.

The engine parameters and setting are to be in accordance with maintenance manual.

The type test report is to include the properties of fuel and lubricating oils used during the test.

1.4.1 The over-speed test is to be carried out and is to demonstrate that the engine is not damaged by actual engine over-speed within the over-speed shutdown system set-point. This test may be carried out at the manufacturer's choice either with or without load during the speed overshoot.

1.4.2 Load Points

The load points at which the engine is to be operated on the test-bed are marked on the power/speed diagram (see Fig. 1.4.5).

The data measured and recorded when testing the engine at various load points, are to include all necessary parameters listed in 1.2.

The operating time per load points depends on the engine size (achievement of steady – state condition) and on the time necessary for collection of the operating values. Normally, an operating time of 0.5 hour can be assumed per load point, however sufficient time should be allowed for visual inspection by PRS Surveyor.

1.4.3 The engine operation parameters are to be measured at the following load points, marked in Fig. 1.4.5:

.1 rated power (MCR), i.e. 100% output at 100% torque and 100% speed – load point 1, normally for 2 hrs with data collection with an interval of 1 hr. If operation of the engine at limits as defined by its specific alarm system (e.g. at alarm levels of lub oil pressure and inlet temperature) is required, the test should be here;

.2 100% power at maximum permissible speed – load point 2;

.3 maximum permissible torque (at least and normally 110%) at 100% speed – load point 3 or maximum permissible power (at least and normally 110%) and 103,2% speed according to theoretical propeller curve – load point 3a. Load point 3a applies to engines only driving fixed pitch propellers or water jets. Load point 3 applies to all other purposes. Load point 3 (or 3a as applicable) is to be replaced with a load that corresponds to the specified overload and duration approved for intermittent use. This applies where such overload rating exceeds 110% of MCR. Where the approved intermittent overload rating is less than 110% of MCR, subject overload rating has to replace the load point at 100% MCR. In such case the load point at 110% of MCR remains.

.4 minimum permissible speed at 100% torque – load point 4;

.5 minimum permissible speed at 90% torque – load point 5 (applicable to propulsion engines only);

.6 part loads, e.g. 75%, 50%, 25% of rated power and speed according to theoretical propeller curve (i.e.90.8%,79,3% and 62,9%) corresponding to points 6, 7 and 8 or at constant rated speed setting corresponding to points 9, 10 and 11, depending on the intended application of the engine;

.7 crosshead engines not restricted for use with C.P. propellers are to be tested with no load at the associated maximum permissible engine speed.

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

1.4.5 Operation with Damaged Turbocharger

1.4.5.1 For 2-stroke propulsion engines, the achievable continuous output is to be determined in the case of turbocharger damage.

1.4.5.2 Engines intended for single propulsion with a fixed pitch propeller are to be able to run at a speed (r.p.m) of 40% of full speed along the theoretical propeller curve when one turbocharger is out of operation. (The test can be performed by either by-passing the turbocharger, fixing the turbocharger rotor shaft or removing the rotor).

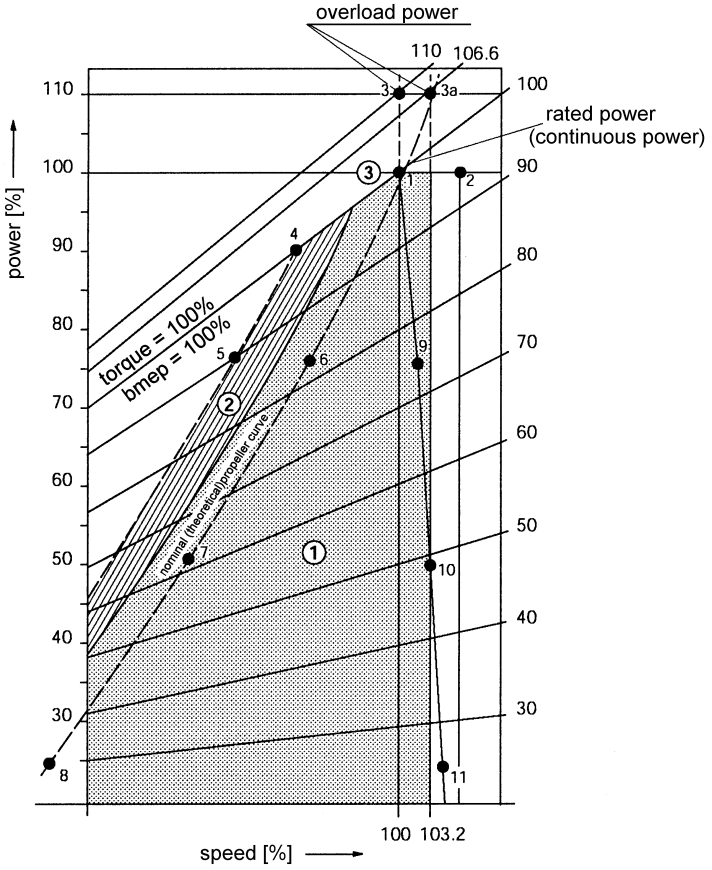

Fig. 1.4.5 Power/speed diagram

1.4.6 Functional Tests

.1 verification of the lowest specified propulsion engine speed according to theoretical propeller curve as specified by the engine designer (even though it works on a water-brake). During this operation, no alarm shall occur;
.2 starting tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for start;
.3 governor tests: tests for compliance with UR M3.1 and UR M3.2 are to be carried out.

1.4.7 Integration Test

1.4.7.1 For electronically controlled diesel engines, integration tests are to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with PRS for selected cases based on failure mode and effects analysis (FMEA) required in UR M44.

1.4.8 Fire Protection Measures

1.4.8.1 Engines are to be inspected for:

.1 jacketing of high-pressure fuel oil lines, including the system for the detection of leakage, and proper screening of pipe connections in piping containing flammable liquids;
.2 proper insulation of hot surfaces is to be verified while running the engine at 100% load, alternatively at the overload approved for intermittent use. Readings of surface temperatures are to be done by use Infrared Thermoscanning Eguipment. Readings obtained are to be randomly verified by use of contact thermometers.

1.5 Stage C – Engine Components Inspection

1.5.1 The crankshaft deflection are to be measured in the specified (by designer) condition (except for engines where no specification exists).

1.5.2 High speed engines for marine use are normally to be stripped down for a complete inspection after the type test.

1.5.3 For all the other engines, after the test run the components of one cylinder for in-line engines and two cylinders for V-engines are to be presented for inspection (engines with long service experience from non-marine fields can have a reduced extent of opening) as follows:

.1 piston removed and dismantled;
.2 crosshead bearing, dismantled;
.3 guide planes
.4 connecting rod bearings (big and small end) dismantled (special attention to serrations and fretting on contact surfaces with the bearing backsides);
.5 main bearing, dismantled;
.6 cylinder liner, in the installed condition;
.7 cylinder head, valves disassembled;
.8 cam drive gear or chain, camshaft and crankcase with opened covers. (The engine must be turnable by turning gear for the inspection).

1.5.4 For V-engines, the cylinder units are to selected from both cylinder banks and different crank throws.

1.5.5 If deemed necessary by PRS Surveyor, further dismantling of the engine may be required.

2 I.C. ENGINES TRIALS

2.1 General

2.1.1 Before any official testing, the engines shall be run- in as prescribed by the engine manufacturer.

2.1.2 Adequate test bed facilities for loads as required in 2.3 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.

2.1.3 The testing consists of workshop and shipboard (quay and sea trial) testing.

2.1.4 Engines are to be inspected for:

.1 jacketing of high-pressure fuel oil lines, including the system for the detection of leakage;

.2 screening of pipe connections in piping containing flammable liquids;

.3 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 PRS Surveyor. If the insulation is modified subsequently to the Type Approval Test, PRS may request temperature measurements as required in 1.4.8.1.2.

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

2.2 Works Trials (Factory Acceptance Test)

Works trials are the final stage of PRS' survey during engine manufacture. On satisfactory completion of the trials, PRS issues a Certificate for the surveyed engine.

Works trials are to be carried out within the scope specified in 2.3. The scope of the trials may be limited subject to PRS' consent.

2.2.1 The following environmental test conditions are to be recorded:

.1 ambient temperature;

.2 ambient air pressure;

.3 atmospheric humidity.

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

.1 power and speed;

.2 fuel index (or equivalent reading);

.3 maximum combustion pressures (only when the cylinder heads installed are designed for such measurement;

.4 exhaust gas temperature before turbine and from each cylinder (to the extent that monitoring is required in UR M73 and UR M35/36);

.5 charge air temperature;

.6 charge air pressure;

.7 turbocharger speed (to the extent that monitoring is required in UR M73).

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

2.3 Scope of Works Trials (Test Loads)

For the engine subjected to trials, the pertaining operating values are to be measured and recorded by the engine Manufacturer. All results are to be compiled in a report prepared by the engine Manufacturer. In each case all measurements conducted at the various load points are to be carried out at steady operating conditions. The readings for MCR i.e. 100% power (rated maximum continuous power at rated speed) are to be taken twice at an interval of normally 30 minutes.

The scope of the trials, given below, may be extended, depending on the engine application, service experience, or other relevant reasons.

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

2.3.1 Propulsion Engines Driving Propeller or Impeller only

.1 100% power (MCR) at rated engine speed n_o: at least 60 min;
.2 110% power at engine speed n = 1.032 n_o: 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.

.3 approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer;
.4 90% (or normal continuous cruise power), 75%, 50% and 25% power in accordance with theoretical propeller curve, the sequence to be selected by the engine manufacturer;
.5 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 PRS. In that case, the fuel delivery system is to be blocked to that power.

2.3.2 Engines Driving Generators for Electric Propulsion

.1 100% power (MCR) at corresponding speed n_0: at least 60 min;
.2 110% power at engine speed n_0: 15 min – after having reached steady conditions;
.3 governor tests for compliance with UR M3.1 and M3.2 are to be carried out;
.4 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 so adjusted that full power plus a 10% margin for transient regulation can be given in service after installation on board. 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 electronic distribution system can be activated before the engine stalls.

2.3.3 Engines Driving Generators for Auxiliary Machinery

Tests are to be performed in accordance with 2.3.2.

2.3.4 Propulsion Engines also Driving Power Take off (PTO) Generator

.1 100% power (MCR) at corresponding engine speed n_0: at least 60 min;
.2 110% power at engine speed n_0: 15min. – after having reached steady conditions;
.3 approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer;
.4 90% or normal continuous cruise power), 75%, 50%, and 25% power in accordance with the theoretical 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. The margin may be 10% of the engine power but at least 10% of PTO power.

2.3.5 Engines Driving Auxiliaries

.1 100% power (MCR) at rated engine speed n_0: at least 30 min;
.2 110% power at engine speed n_0: 15 min. – after having reached steady conditions;
.3 approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer;
.4 for variable speed engines, 75%, 50%, and 25% power in accordance with the theoretical 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 normally to be so adjusted that overload power cannot be delivered in service, unless intermittent overload power is approved. In this case, the fuel delivery system is to be blocked to that power.

2.3.6 Turbocharger Matching with Engine

2.3.6.1 Turbochargers shall have a compressor characteristics that allows the engine, for which it is intended, to operate without surging during all operating conditions and also after extended period of operation. For abnormal, but permissible, operation conditions, such as misfiring and sudden load reduction, no continuous surging shall occur.

Note: 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 only once.

2.3.6.2 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 some nozzle rings).

Note: The parameter for turbocharger category (A,B,C) is the engine power (at MCR) supplied by group of cylinders served by the actual turbocharger (e.g. for a V- engine with one turbocharger for each bank the size is half of the total engine power). For turbochargers category C the engine power (at MCR) supplied by group of cylinders is more than 2500 kW (see UR M73).

For 4 – stroke engines

The following shall be performed without indication of surging:

.1 with maximum continuous power and speed (= 100%), the speed shall be reduced with constant torque (fuel index) down to 90% power;
.2 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 fuel 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 stabilized at the new load within 20 seconds. For applications with more than one turbocharger the fuel shall be cut-off to 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 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 stabilized at new load within 20 seconds when the power is abruptly reduced from 100% to 50 % of the maximum continuous power.

2.4 Shipboard Trials

2.4.1 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.

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

2.4.3 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)

2.4.4 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.

Where special operating conditions are to be considered, such as towing, trawling, etc., the scope of the trials may be extended.

2.4.5 Propulsion Engines Driving Fixed Propeller or Impeller

.1 at rated engine speed n_o – at least 4 hours;
.2 at engine speed n = 1,032 n_o (if engine adjustment permits – see 2.3.1.2) – 30 minutes;
.3 at approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer;
.4 minimum engine speed to be determined;
.5 the ability of reversible engines to be operated in reverse direction is to be demonstrated.

Note: During stopping tests see 2.4.9 for additional requirements in case of barred speed range.

2.4.6 Propulsion Engines Driving Controllable Pitch Propellers

.1 at rated engine speed n_o with a propeller pitch leading to rated engine power (or to the maximum achievable power if 100% cannot be reached) – at least 4 hours;
.2 at approved intermittent overload (if applicable): testing for duration as agreed with the manufacturer;
.3 with reverse pitch suitable for manoeuvring, see 2.4.9 for additional requirements in case of barred speed range.

2.4.7 Engine(s) Driving Generator(s) for Electrical Propulsion and/or Main Power Supply

.1 at 100% power (rated electrical power of generator) – at least 60 min;
.2 at 110% power (rated electrical power of generator) – at least 10 minutes;

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 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.

.3 demonstration of the generator prime movers and governors ability to handle load steps as described in UR M3.2.

2.4.8 Propulsion Engines also Driving Power Take off (PTO) Generator

.1 100% engine power (MCR) corresponding speed n_0: at least 4 hours;
.2 100% propeller branch power at engine speed n_0: 2 hour (unless already covered in .1 ~~A~~);
.3 100 % PTO branch power at engine speed n_0: at least one hour.

2.4.9 Engines Driving Auxiliary Machinery

.1 100% power (MCR) at corresponding speed n_0: at least 30 min;
.2 approved intermittent overload: testing for duration as approved.

2.4.10 Torsional Vibrations

2.4.10.1 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 bsr in reverse rotational direction, especially during the stopping test.

Note: Applies both for manual and automatic passing-through systems.

2.4.10.2 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).

3 DF AND GF ENGINES

3.1 General

The following Definitions are applicable:

Dual fuel engine (DF engine) – means an engine that can burn natural gas as fuel simultaneously with liquid fuel, either as pilot oil or bigger amount of liquid fuel (gas mode), and also has the capability of running on liquid diesel fuel oil only (diesel mode)

Gas fuel only engine (GF engine) – means an engine capable of operating on gas fuel only and not able to switch over to oil fuel operation.

Lower Heating Value (LHF) – means the amount of heat produced from the complete combustion of a specific amount of fuel, excluding latent heat of vaporisation of water.

Methane number – is a measure of resistance of a gas fuel to knock, which is assigned to a test fuel based upon operation in knock testing unit at the same standard knock intensity.

3.2 Type testing

3.2.1 General

Type approval of DF and GF engines is to be carried out taking into account the additional requirements below.

3.2.2 Type of engine

In addition to the criteria given in 1.1.3 the type of engine is defined by the following:

.1 gas admission method (cylinder injection after compression stroke, cylinder individual injection before compression stroke or pre-mixed)
.2 gas admission valve operation (mechanical or electronically controlled);
.3 ignition system (pilot injection, spark ignition, glow plug or gas self-ignition);
.4 ignition system (mechanical or electronically controlled).

Note: Cylinder-individual injection before compression stroke may be port injection into the air inlet channel before the cylinder inlet valve, injection into the cylinder before or during compression stroke, or similar arrangements.

3.2.3 Safety precautions

In addition to the safety precautions mentioned in 1.1.6, measures to verify that gas fuel piping on engine is gas tight are to be carried out prior to start-up of the engine.

3.2.4 Test programme

The type testing of the engine is to be carried out in accordance with 1.1.7, taking into account the additional requirements of this chapter.

The influence of the methane number and LHV of the fuel gas is not required to be verified during the Stage B type tests. It shall however be justified by the engine designer through internal tests or calculations and documented in the type approval test report.

3.2.5 Measurements and records

In addition to the measurements and records required in 1.2, the following engine data are to be measured and recorded:

.1 each fuel index for gas and diesel if applicable (or equivalent reading);
.2 gas pressure and temperature at the inlet of the gas manifold;
.3 pilot fuel temperature and pressure (supply or common rail as appropriate)
.4 gas concentration in the crankcase

Note: The gas concentration in the crankcase should normally be measured inside the crankcase or at the crankcase outlet (crankcase vent pipe).
Gas concentration measurements may be carried out as part of Stage A if the method and the results are properly documented.

Additional measurements may be required in connection with the design assessment.

3.2.6 Stage A – internal tests

In addition to tests required in 1.3 the following conditions are to be tested

.1 DF engines are to run the load points defined in 1.3 in both gas and diesel modes (with and without pilot injection in service) as found applicable for the engine type
.2 for DF engines with variable liquid/gas ratio, the load tests are to be carried out at different ratios between the minimum and the maximum allowable values
.3 for DF engines, switch over between gas and diesel modes are to be tested at different loads.
.4 the influence of the methane number and LHV of the fuel gas on the engine's maximum continuous power available in gas mode is to be verified.

3.2.7 Stage B – witnessed tests

3.2.7.1 General

Gas engines are undergo the different tests required in 1.4

In case of DF engine, all load points must be run in both gas and diesel modes that apply for the engine type as defined by the engine designer. The independent overspeed protection device has to be tested both in gas and diesel mode (1.4.1).

For engines with variable liquid / gas ratio, selected load tests are to be carried out at different ratios between the minimum and the maximum allowable values. (most relevant and critical loads and ratios should be selected for the test).

The maximum continuous power available in gas mode (see Sea Going Ships Part VII p. 2.12.9.1.1) is to be demonstrated.

Overload testing is not required in gas mode for DF engines, provided that changeover to oil fuel mode is automatically performed in case of overload.

The load tests are to be carried out in diesel mode and in gas mode at the different percentages of the engine's MCR.

3.2.7.2 Functional tests

In addition to the functional tests required in 1.4.2, the following tests are to be carried out:

.1 for DF engines, the lowest specified speed is to be verified in diesel mode and gas mode;

.2 for DF engines, switch over between gas and diesel modes are to be tested at different loads;

.3 or DF engines, verification of automatic changeover to diesel mode when the load demand exceeds the maximum continuous power available in gas mode (see Sea Going Ships Part VII p. 2.12.9.1.1-2)

.4 the efficiency of the ventilation arrangement or other approved principal of the double walled gas piping system is to be verified;

Engines intended to produce electrical power are to be tested as follows:

.1 capability to take sudden load and loss of load in accordance with the provisions of UR M3.2;

.2 for GF and premixed engines, the influence of LHV, methane number and ambient conditions on the dynamic load response test results are to be theoretically determined and specified in the test report. Referring to limitations as specified in UR M78 2.1.1, the margin for satisfying dynamic load response is to be determined.

Note:

1. For DF engines, switchover to oil fuel during the test is acceptable

2. Application of electrical load in more than 2 load steps can be permitted in the conditions stated in UR M3.2.3.

3.2.7.3 Integration tests

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes. The scope of these tests is to be agreed with PRS for selected cases based on the risk analysis, and shall at least include the following incidents:

.1 failure of ignition (spark ignition or pilot injection system), both for one cylinder unit and common system failure;

.2 failure of gas admission valve;

.3 failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc);

.4 abnormal gas pressure;
.5 abnormal gas temperature [1].

Note: [1] This test may be carried out using a simulation signal of the temperature.

3.2.8 Stage C – Component inspection

Component inspection is to be carried out in accordance with the provisions of 1.5.

The components to be inspected after the test run are to include also:
.1 gas admission valve including pre-chamber as found applicable;
.2 spark igniter (for GF engines);
.3 pilot fuel injection valve (for DF engines).

3.2.9 Engine type approval certificate

For DF engines, the maximum continuous power available in gas mode should be specified on the type approval certificate in addition to the maximum continuous rating in diesel mode if differing.

3.3 Factory acceptance test

3.3.1 General

Factory acceptance tests for DF and GF engines are to be carried out, taking into account the additional requirements below.

For DF engines, the load tests referred to in 2.3 are to be carried out in diesel mode and gas mode at the different percentages of the engine's MCR.

Maximum continuous power available in gas mode is to be demonstrated (see Sea Going Ships Part VII p. 2.12.9.1.1).

3.3.2 Safety precautions

In addition to the safety precautions mentioned in 1.1.6.1, measures to verify that gas fuel pip-ing on engine is gas tight are to be carried out prior to start-up of the engine.

3.3.3 Records

In addition to the records required in 2.2, the following engine data are to be recorded:
.1 fuel index, both gas and diesel as applicable (or equivalent reading);
.2 gas pressure and temperature.
.3 pilot fuel temperature and pressure (supply or common rail as appropriate)

3.3.4 Test loads

Test loads for various engine applications are given in 2.3. DF engines are to be tested in both diesel and gas mode as found applicable. In addition the scope of the trials may be expanded on the engine application, service experience, or other relevant reasons.

3.3.5 Integration tests

GF and DF engines are to undergo integration tests to verify that the response of the complete mechanical, hydraulic and electronic engine system is as predicted for all intended operational modes.

The scope of these tests is to be agreed with PRS for selected cases based on the risk analysis, and shall at least include the following incidents:
.1 failure of ignition (spark ignition or pilot injection systems), for one cylinder unit,

.2 failure of gas admission valve,
.3 failure of the combustion (to be detected by e.g. misfiring, knocking, exhaust temperature deviation, etc),
.4 abnormal gas pressure,
.5 abnormal gas temperature.

The above tests may be carried out using simulation or other alternative methods, subject to special consideration by the PRS.

3.4 Shipboard trials

A leak test is to be carried out for the gas piping system (IGF Code 16.7.3.3) after assembly on board.

Shipboard trials are to be carried out in accordance with the provisions of 2.4 considering the additional requirements below..

For DF engines, the test loads required in 2.4.4 are to be carried out in all operating modes (gas mode, diesel mode, etc.) as applicable (see Sea Going Ships Part VII p. 2.12.9.1.1).

The maximum continuous power available in gas mode is to be demonstrated.

Note: If a test load is performed in all applicable operation modes without interruption (direct changeover at same power and speed), the duration as required in 2.4.4 may be considered as the total duration demonstrated in all fuel modes. However, demonstration at each mode shall not be less than one hour.

The starting manoeuvres required in 2.4.1 are to be carried out in diesel mode and gas mode, if applicable.

For DF engines, automatic switching over to oil fuel mode is to be tested. Further, manual change over from diesel to gas mode and vice versa is to be tested.

The efficiency of the ventilation arrangement, or other approved principle, of the double walled gas piping system is to be verified.

4 TYPE TESTING PROCEDURE OF EXPLOSION RELIEF DEVICES FOR COMBUSTION AIR INLET AND EXHAUST GAS MANIFOLDS OF I.C. ENGINES USING GAS AS FUEL

4.1 General

To specify testing procedure for explosion relief devices for combustion air inlet manifold and exhaust gas manifold of internal combustion engines using gas as fuel.

4.2 Definitions

Definitions addressing gas as fuel as given in Chapter 3, apply.

Explosion relief device (ERD) means a device to protect a component against a determined overpressure in the event of a gas explosion. The device is fitted with a flame arrester and may be a valve, a rupture disc or other, as applicable.

4.3 Documents

Prior to testing, the following documentation for the ERD shall be submitted for approval:
.1 drawings (sectional drawings, details, assembly etc.);
.2 specification data sheet including operating conditions and design limits such as:

- maximum permissible operating pressure, resulting from maximum charging air or exhaust gas back pressure:
- maximum permissible operating temperature, resulting from maximum charging air or exhaust gas temperature:
- static opening pressure, resulting from maximum charging air or exhaust gas back pressure:
- maximum explosion pressure, i.e. maximum pressure that the device can withstand;
- geometric relief area;

.3 product marking;
.4 installation and operation manual;
.5 test program;
.6 specification of test vessel.

4.4 Tests

4.4.1 Test specimens

The ERD used for the explosion test is to be selected from the manufacturer's production line by a representative of the PRS:
- as a finished certified component itself, or
- on samples taken from earlier stages in the production of the component, when applicable.

If necessary, an additional ERD may need to be selected for the demonstration of the opening pressure. The selected ERD has to be clearly marked.

If applicable, the selected ERD shall be representative for the type range and operating conditions, for example:
- kind of ERD (valve, rupture disc, etc.);
- mounting orientation (vertical, horizontal);
- design of ERD (e.g., spring design, sealing);
- design of flame arrester;
- ERD intended to be fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with characteristics as per the testing conditions in 4.4.3.2.

The selection of the representative ERD is subject to approval by the PRS.

4.4.2 Demonstration of opening pressure

The ERD which has been selected is to be subjected to a pressure test at the manufacturer's works to demonstrate that the static opening pressure is kept within the manufacturer's specification and that the ERD is air tight at the maximum permissible operating pressure for at least 30 seconds.

4.4.3 Explosion test

4.4.3.1 Test facility

The test facilities are to be accredited to a national or international standard, e.g. ISO/IEC 17025:2017, and are to be acceptable to the PRS.

The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.

The test facilities are to have equipment for controlling and measuring a methane gas concentration within a test vessel to an accuracy of ± 0.1%.

The test facilities are to be capable of effective point-located ignition of a methane/air mixture.

The test facility arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognizing the speed of the events during an explosion (10 kHz or above).

The explosion test (Para 4.4.3.5) is to be documented by high speed (250 frames/s or above) video recording. The video recording shall be provided with a time stamp.

4.4.3.2 Test vessel

The test vessel is a simplified model of the air inlet or exhaust gas manifold. The free area of the connected turbo charger (compressor or turbine wheel) is to be considered.

The test vessel shall comply with the following requirements:
- the shape of the test vessel is to correspond to a pipe with L/D ≥ 10;
- the test vessel is to be equipped with a rupture disc at one front end to simulate the turbo charger. The relief area of the rupture disc shall be in relationship to the test vessel diameter based on turbocharger manufacturer data for an equivalent free area of compressor or turbine wheel. The opening pressure shall be ± 10% of the static opening pressure of the ERD;
- the volume of the test vessel is to comply with the specific relief area of the ERD of 700 cm^2/m^3 ± 15%;
- the test vessel is to be provided with all necessary flanges and connection to mount the ERD in the intended position, to mount a rupture disc as turbo charger simulation, to connect the Methane-air mixture supply and the measurement equipment;
- the ignition is to be made at the middle of the test vessel;
- the test vessel is to be designed to verify a homogeneous air / methane mixture inside the vessel;
- the test vessel is to have connections for measuring the pressure in the test vessel in at least two positions, one at the ERD and the other at the test vessel center;
- the test vessel is to have a design pressure of not less than the maximum explosion pressure of a stoichiometric air / methane mixture at test conditions in Para 4.4.3.6;
- the test vessel configuration is subject to approval by the PRS.

Typical test vessel configurations:

All test vessel configurations to be equipped with a rupture disc (1) (turbo charger simulation) at one front end. The ignition is in the centre of the test vessel (↯). The pressure sensors are mounted at the valve flanges (p1) and at the test vessel centre (p2). The measuring of the methane concentration to verify a homogeneous air / methane mixture can be performed at both ends of the test vessel, e.g. (c1) and (c2).

Figure 2 Configuration without ERD (flanges for ERDs closed (2))

Figure 3 Configuration with ERD (3) mounted at the front end of the test vessel

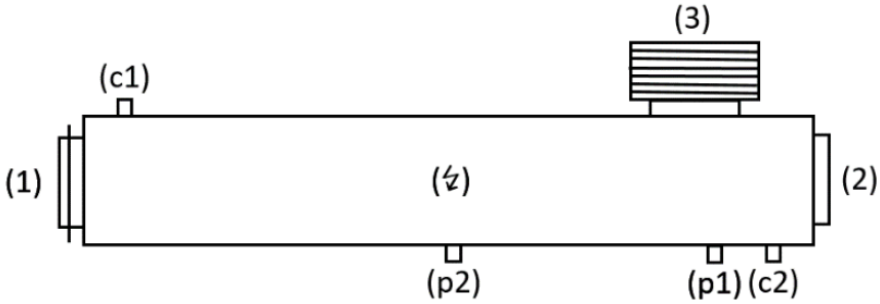

Figure 4 Configuration with ERD (3) mounted on top of the test vessel

4.4.3.3 Explosion test process

The explosion testing is to be performed in two stages according to 4.4.3.4 and 4.4.3.5 for each ERD that is required to be approved as type tested.

The explosion testing is to be witnessed by a PRS surveyor.

Calibration records for the instrumentation used to collect data are to be presented to, and reviewed by, the attending surveyor.

4.4.3.4 Reference test – Explosion test without ERD

Two explosion tests are to be carried out in the test vessel without ERD. The test vessel configuration is shown in Figure 2.

The aim of this test is to establish a reference pressure level in the test vessel which can be used for determination of the capability of a relief valve in terms of pressure relief.

4.4.3.5 ERD test – Explosion test with ERD

Two explosion tests are to be carried out in the test vessel with the same ERD at the required position. If the ERD is a rupture disc with flame arrester, the rupture disc shall be replaced.

If shielding arrangements to deflect the emission of explosion combustion products at the ERD are intended, the ERD are to be tested with the shielding arrangements fitted. The test vessel configuration is shown in Figure 3 or 4.

4.4.3.6 Explosion test method

The test conditions shall comply with the intended use of the ERD, such as:
- pipe diameter;
- operating pressure;
- operating temperature;
- installation orientation.

All explosion tests are to be carried out using an air and methane mixture with a volumetric methane concentration of 9.5% ± 0.5%. A homogeneous air / methane mixture inside the test vessel is to be verified. The concentration of methane shall not differ by more than 0.5%.

The initial pressure in the test vessel is to be the specified maximum operating pressure of the ERD.

The initial temperature in the test vessel is to be the specified maximum operating temperature of the ERD.

If the initial pressure and/or initial temperature deviate from the design limits, the ERD manufacturer shall prove the acceptability of this deviation either using standards or generally applicable calculation methods.

The ignition is to be made using an explosive charge of 50 - 100 Joule

Successive explosion testing to establish an ERD functionality is to be carried out as quickly as possible during stable weather conditions.

The pressure rise and decay during all explosion testing is to be recorded.

The effect of an ERD in terms of pressure relief following an explosion is ascertained from maximum pressure recorded at the centre of the test vessel during the two stages. The pressure relief within the test vessel due to the installation of an ERD is the difference between average pressure of the two explosions of the reference test (4.4.3.4) and the average of the two explosions of the ERD test (4.4.3.5).

For acceptance of correct functioning of the flame arrester, there is to be no indication of flame or combustion outside of the ERD during its testing (4.4.3.5). This is to be monitored by a high-speed video camera (4.4.3.1), for which ambient light conditions are to be considered to maximise the potential for flame/combustion detection. The use of a dark, ideally matt finish, background and an avoidance of direct light onto the video camera monitored area are recommended.

After each ERD test (4.4.3.5), the external condition of the flame arrester to be examined for signs of damage and/or deformation that may affect the operation of the ERD.

4.4.3.7 Check of ERD components

After completing the explosion tests, the ERDs are to be dismantled and the condition of all components are to be ascertained and documented.

4.5 Test report

A complete test report has to be submitted to the PRS for:
- the demonstration of opening pressure (4.4.2) and
- the explosion test (4.4.3).

The reports shall include respective information according to the requirements in 4.4, as applicable:
- test specimens;
- test facility, including measuring equipment and test vessel;
- measuring results (pressures, temperatures, flame velocities, volumetric methane concentration, ambient conditions etc.);
- video documentation of explosion tests;
- photo documentation of ERD components.

4.6 Assessment

To verify compliance with this requirement the assessment has to address the following:

Function and mechanical integrity of the ERD.

- After dismantling of the ERD, the flame arrester shall not show signs of damage or any deformation that may affect the operation of the ERD.
- If a valve is used any indication of valve sticking or uneven opening during the explosion that may affect subsequent operation of the valve has to be considered.
- The mechanical integrity of the ERD is proven up to a maximum explosion pressure (as average of the two explosions) of the ERD tests in 4.4.3.5.
- The functioning of the flame arresters is considered satisfactory if there is no indication of flame or combustion outside the ERD during the explosion tests.

4.7 Approval

The approval of an ERD is based on the appraisal of plans and particulars and the test report of type testing.

The type approval is valid only for an ERD fitted to the air inlet or exhaust gas manifold of an engine having a turbocharger with compressor or turbine wheel characteristics corresponding to those required in 4.4.3.2 for the test vessel rupture disc in terms of free area.

List of amendments effective as of 1 January 2025

Item	*Title/Subject*	*Source*
3.2.2-3.2.6 3.2.7.1-3.2.7.3 3.2.8, 3.3.1 , 3.3.3, 3.3.5, 3.4	Update of requirements	UR M78 Rev.2
