
**Ships and marine technology —
Maintenance and testing to reduce losses
in critical systems for propulsion**

*Navires et technologie maritime — Maintenance et essais pour réduire
les pertes dans les systèmes critiques pour la propulsion*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13613 was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 3, *Piping and machinery*.

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0 Introduction

0.1 General

This International Standard informs shipboard personnel and other parties about the need to consider factors affecting operational maintenance and testing for certain systems that have been linked to ship propulsion losses. A recently completed survey of SOLAS ship casualties from 2003 to 2007 revealed that a number of the reported casualties were propulsion losses involving air start systems for engines, fuel oil quality problems, and fuel switching.

Industry groups have stated that current procedures for fuel switching underway, in compliance with air quality regulations, may increase the risk of propulsion losses.

0.2 Air start system failure

Air start system failure typically occurs when a ship with direct drive diesel propulsion is changing direction. Air valves needed to stop and restart the engine in the other direction seize or fail to respond. Maintenance and testing of the air systems minimize the risk of failure.

0.3 Fuel oil quality problems

Fuel oil problems can cause propulsion loss by clogging a filter and starving the engine. Use of incorrect fuel over prolonged periods can cause damage to fuel pumps and engine cylinders. A ship can also lose propulsion when a generator shuts down because of fuel problems, as electrical power is generally needed to drive cooling and lubrication pumps for the propulsion engine. Maintenance and testing of fuel oil purifying equipment, tanks and piping minimize quality problems.

0.4 Fuel switching

In order to comply with air quality regulations, ships may need to switch to low sulfur fuel while underway. They perform the switch before they enter an emission control area (ECA). This procedure can involve a changeover from heavy fuel oil to a distillate fuel. Proper fuel switching procedures and awareness of possible fuel compatibility problems can minimize the risk of propulsion loss.

0.5 Informative annexes

Annexes A to E are provided for information only as examples of recommendations for ship engineering systems and components. The survey of ship propulsion casualties identified only high pressure air and fuel system (fuel quality and fuel switching) problems as being linked to a number of casualties.

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Ships and marine technology — Maintenance and testing to reduce losses in critical systems for propulsion

1 Scope

This International Standard provides shipboard personnel and other parties information concerning operational maintenance and testing for certain critical systems. Proper maintenance of these systems can help reduce the risk of ship propulsion and manoeuvrability losses.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1

delta p
differential pressure

ΔP

difference in pressure between two points in a system often used as a measurement parameter in filtering devices to indicate condition (clean or clogged) of the filter

2.2

viscosity

measure of a liquid's resistance to flow

NOTE Specified minimum and maximum viscosities are required for all fuel oils. A fuel oil's viscosity indicates how well the oil will flow, the extent to which it can be atomized, and the temperature at which the oil should be maintained to atomize properly.

3 Technical information and recommendations

3.1 General maintenance of ship systems

The purpose of general maintenance of ship systems is to maximize efficiency and reliability of systems and minimize downtime. Suitable maintenance intervals help avoid equipment failures.

3.1.1 Types of maintenance

3.1.1.1 Preventative

a) Routine

- greasing, lubricating, level checking (tanks, sump, etc.)
- operator checks (buttons/switches, valves/flaps, lamps, alarms)
- measurements (gauges, clearances, voltage, pressure, temperature, vacuum)

b) Planned

- calendar time (weekly, monthly, quarterly, annually, etc.)
- operating (running) hours

3.1.1.2 Condition based

- vibration analysis, diesel engine trend analysis
- laboratory oil analysis (fuel, lube, hydraulic)
- performance based (deviation from reference points), database building
- ultrasonic thickness/leak detection, etc. ± non-destructive examination
- on-board wear down measurement and/or particle density measurement of oil

3.1.1.3 Breakdown maintenance

- unplanned maintenance
- fix only when broken
- do minimum maintenance to keep equipment running (e.g. filters), until something breaks

NOTE It is important to remember that, even with proper maintenance, breakdown is possible on virtually any system at any time.

3.1.2 Logistical support

Detailed information for replacement parts in critical systems is needed, such as

- manufacturer,
- make/model/serial number,
- warranty information,
- maintenance recommendations,
- maintenance and repair history,
- vendor locations, and
- required spare parts to be kept on board, and on-board inventories.

The following may be associated with nearly all systems and equipment:

- scheduled maintenance intervals;
- equipment operating records;
- lubrication procedures and schedules;
- repair and maintenance parts details, notes, diagrams, and even digital photographs;
- complete listing of instruments and tests required during maintenance procedures;
- experience and time requirements of maintenance personnel (level of competence and man hours expected).

3.2 Compressed air systems maintenance

Compressed air systems require periodic maintenance. Inadequate maintenance can lead to

- lower efficiency,
- air leakage,

- high operating temperatures,
- poor moisture control, leading to too much moisture in the system,
- contamination by dirt or rust,
- excessive contamination, and
- unsafe working environments.

Maintenance of compressed air systems should take into account the manufacturer's recommendations for inspection and service, as well as company-specific requirements. Annex A provides some basic compressed air system maintenance recommendations.

3.3 Fuel oil system maintenance

3.3.1 General

Fuel systems on ships are a potential source of fire and/or explosion, and should, therefore, be maintained in optimum condition. Poor fuel quality can potentially cause an engine breakdown at sea, which could endanger the ship and cause loss of business.

Components of fuel systems from the fuel tank through to the engine and back to the tank should be checked regularly for leaks, wear, deterioration, and general damage. Components can include valves, pumps, heat exchangers, gaskets, filters and strainers.

Ship and company personnel should ensure that correct fuel filters are available for the types of fuel to be used.

Owners and operators, in consultation with manufacturers, should determine the method of record-keeping of maintenance work performed on the fuel systems.

3.3.2 Testing of fuel received

MARPOL Annex VI requires that a sample of bunker fuel be provided during each bunkering operation. A testing programme for fuel received may be beneficial in verifying fuel quality. In some instances, reports provided by suppliers may be considered inadequate or inaccurate when compared to the importance of the product to proper engine operation.

Users should consider the engine manufacturer's recommendations and ISO 8217 for more specific details on marine fuel oil properties, especially viscosity, in determining the most appropriate fuel for their installation.

3.3.3 Purifier maintenance

In addition to planned maintenance, most purifiers require at least occasional cleaning. Non-self-cleaning types may need more frequent cleaning.

Sludge, wax and other solids are normally cleaned from discs manually.

Sludge disposal timer (self-cleaning), correct RPM, and correct temperature of fluid are all important. Cleaning intervals are often determined by experience with various fuel quality types.

3.3.4 Properties of fuel that can affect maintenance and operation

In order to avoid fuel pump and injector difficulties, fuels should be delivered to the engine in a condition as close to the manufacturer's recommended technical specifications as possible. Water in fuel can cause ragged operation and may corrode the fuel handling system. Important fuel properties include

- viscosity (see 2.2),
- flashpoint; fuels having a flashpoint of less than 60 °C are generally not permitted, see Reference [4],

- sulfur content,
- total sediment,
- water (percent by volume), and
- density.

Some engine manufacturers may prescribe guidelines that differ from those above when burning heavy fuel oil (HFO). Correct viscosity, however, is essential to engines burning HFO, and adjusting viscosity may require fuel heating systems. Conversely, when ships switch from HFO to distillate, a cooling process may be required to ensure the distillate fuel temperature is not excessive.

3.3.5 Fuel switching

Fuel switching may involve a change-over from high sulfur fuel (HSF) to low sulfur fuel (LSF), either for the main engine(s), ship service diesel generators, or both. Fuel switching may be required by local area law for vessels mandating the use of LSF in order to limit oxides of sulfur (SO_x). (See Figure C.1 for a general diagram of a fuel/fuel switching system).

There are a number of important considerations involved with fuel switching, including

- separate storage tanks required for HSF and LSF,
- potential for clogged filters when “blending” or mixing HSF and LSF fuels during the switching process, resulting in loss of fuel supply to engine,
- engine is normally designed for optimum performance based on specific fuel oil temperature and viscosity range,
- improper fuel for a particular engine can result in premature wear to critical engine components, including injection pumps, cylinder liners, and piston rings,
- in certain engines, fuel leaks may cause fuel dilution of lubricating oil, which can degrade the lubricating properties and result in significant damage to expensive engine bearings,
- improper control of LSF temperature may result in excessively low viscosity of fuel,
- considering the total base number (TBN) of the lubricating oil (cylinder and engine) when the sulfur content of the fuel is not consistent,
- consulting engine and boiler manufacturers for fuel switching guidance,
- consulting fuel suppliers and engine manufacturers for proper fuel selection,
- exercising tight control over the quality of the fuel oils received, when possible,
- consulting manufacturers to determine if system modifications or additional safeguards are necessary for the particular fuels to be used,
- developing detailed fuel switching procedures, including system diagrams and the correct temperatures/pressures,
- establishing a fuel system inspection and maintenance schedule,
- ensuring that system pressure and temperature alarms, flow indicators, filter differential pressure transmitters, etc., are all operational,
- ensuring that system purifiers, filters and strainers are maintained,
- ensuring that system seals, gaskets, flanges, fittings, brackets and supports are maintained,
- ensuring that a detailed system diagram is available,

- conducting initial and periodic crew training,
- completing fuel switching well offshore prior to entering restricted waters or traffic lanes, such that the system is stabilized, and
- that some distillates may not be compatible with residual fuels that are rich in asphaltenes; this incompatibility can result in precipitation of asphaltenes during the mixing process, and further clog filters or injection pumps.

It is imperative that owners and operators realize the importance of maintaining optimum fuel quality as recommended by the engine manufacturer.

Vessels should have a specific plan in place that outlines the steps and associated timelines in the fuel switching process. Switching involving fuels with substantially different viscosities will likely necessitate a controlled rate of change in the switching process. Lack of a controlled process when switching from HFO to distillate can lead to overheating of the distillate, which can result in improper fuel flow and potential engine shutdown. Some engine manufacturers have recommended a transition temperature change rate of no greater than 2 °C per minute.

See Annex F and ISO 8217 for characteristics of marine fuels. For optimum engine operations and safety, it is critical that the viscosity of the fuel supplied does not go below (less than) the minimum viscosity specified by the manufacturer. Fuel viscosity should be monitored closely, with tight control of fuel temperature exercised.

Vessel owners and operators should consult engine manufacturers to determine the potential long-term problems associated with fuel switching, and how best to avoid those problems. Such issues may include damage to cylinder liners, fuel pumps and valves. Cylinder liner damage can result from incompatibility of the cylinder lube oil with distillate fuel, and fuel pumps can be damaged because of the reduced viscosity and lubricity of distillate. It is important that the correct viscosity fuel be supplied to the engine fuel pumps. This may necessitate a cooling process for low viscosity distillate fuels. Engine and individual cylinder performance should be monitored to ensure that the correct amount of fuel is delivered, and that differences in fuel specifications are not degrading fuel pump performance.

Vessel owners and operators may wish to seek the opinion of a third party such as a classification society expert to review and certify their fuel switching procedures.

3.3.6 Fuel switching and boilers

For similar reasons as with diesel engines, fuel switching is also a concern for propulsion and auxiliary boilers.

The issues include maintaining the proper viscosity and temperature of boiler fuel as applied to the boiler burner equipment that is installed. Similar to the diesel engine, most boiler burner equipment was designed to operate with a specific fuel type. In many cases, depending on the type of burner installed, significant modifications may be necessary for main and auxiliary boilers.

The following are areas of concern:

- Flame monitoring equipment, especially equipment that senses the frequency of the flame, should be checked to see that it operates properly with the range of fuels.
- All types of burners, and in particular rotary cup burners and steam atomization burners, should be verified for proper operation based on the viscosity and temperature of the low sulfur fuels. In some cases, key components of the burners may need to be modified or replaced.
- Automated combustion control systems should be checked. Because of the potential for fuel leakage into a hot furnace, which can raise the risk of a boiler explosion, the proper purge cycle prior to ignition of fires should be ascertained.
- Significant modifications to boiler fuel, burner, and combustion control systems should not be undertaken without careful consultation with manufacturers and classification society experts.

3.4 Maintenance and testing of ship automation systems

Procedures for switching between the local manual, remote manual and automatic modes of operation of equipment should be defined for ship systems critical to propulsion and manoeuvring. These procedures should be thoroughly understood and practiced periodically by the ship's engineering personnel.

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Annex A (informative)

Example maintenance items for compressed air systems

Compressed air system component	Maintenance check (as per manufacturer recommendation or company policy)
Propulsion system starting air valves	Test, inspect and/or overhaul or replace
Inlet filter cartridges	Inspect and clean or replace; required frequency may vary with operating conditions
Drain traps	Clean out debris and check operation
Compressor lubricant level	Inspect and top off, or renew oil
Air lubricant separator (lubricant-injected rotary screw compressors)	Change at high delta p (pressure differential)
Lubricant used	Use the motor and compressor lubricants recommended by the manufacturer for air compressors
Belt condition	Check belts for wear and proper tension
Operating temperature	Verify proper operating temperature
Air line filters	Replace particulate and lubricant removal elements when pressure drop limit or delta p (pressure differential) limits are exceeded
Water cooling system	For water-cooled systems, check water quality, flow, and temperature; clean strainers and heat exchangers
System cleanliness and leaks	Check lines (especially joints), fittings, clamps, valves, hoses, disconnects, regulators, filters, lubricators, gauge connections, and end-use equipment for leaks; adjust/replace o-rings as necessary
Reverse test of engine	Perform a reverse direction test of the engine while underway, ensuring air distribution system and valves are working correctly

Annex B (informative)

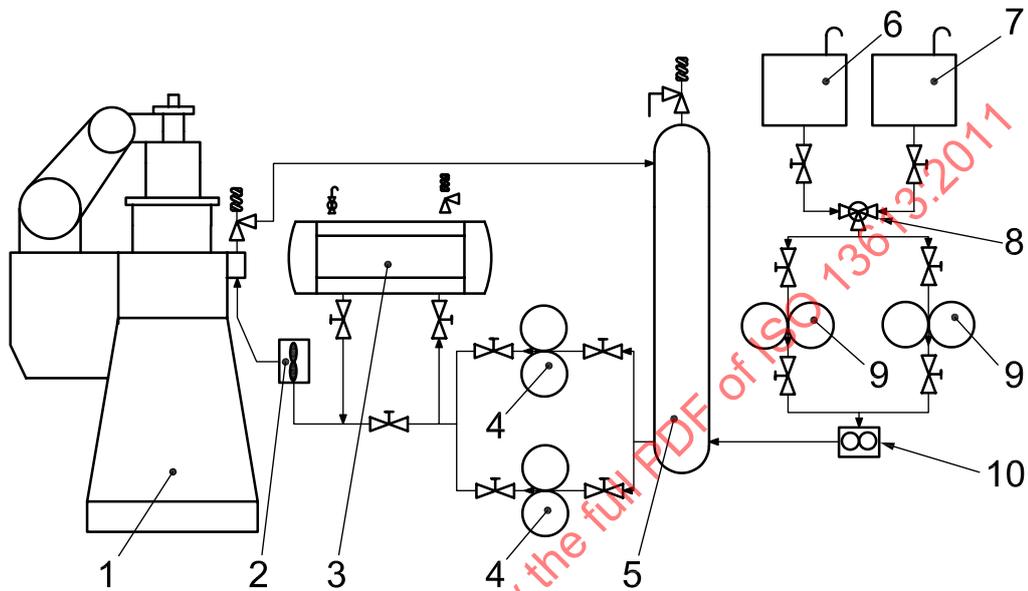
Sample record of periodic maintenance procedures

System	Equipment	Maintenance procedure	Frequency	Required personnel
Propulsion	Main engine	D1, Measure and record lube oil sump level	Daily	Qualified member of engineering department
Propulsion	Main engine	M1, Check and record all cylinder pressures	Monthly or every 500 running hours	Third Assistant Engineer
Propulsion	Main engine	Q1, Procure lube oil sample for analysis	Quarterly or every 1 000 running hours	Third Assistant Engineer (3rd A/E)
Propulsion	Main engine	S1, Torque cylinder head studs to proper setting	Semi-annual	3rd A/E
Propulsion	Main engine	Check main bearing clearances	Annual, or every 6 000 hours	1st A/E
Propulsion	Main engine	Wash out cylinder oil pumps	Annual, or every 6 000-8 000 hours	2nd A/E
Propulsion	Main engine	Check connecting rod bearing clearances	Annual, or every 6 000 hours	1st A/E
Fuel	Fuel system	R1, Obtain and retain main engine fuel sample	At each bunkering operation	2nd A/E
Heat exchangers	Salt water systems	S1, Check condition of zinc anodic protection devices	Semi-annually	3rd A/E

NOTE The list provided here is but a small fraction of the maintenance required for critical equipment, and is provided only as an example. A proper periodic maintenance programme for critical propulsion and manoeuvring systems, including the main engine(s), will require significant technical knowledge as applied to the particular installation, as well as expertise in proper record-keeping (documentation).

Annex C (informative)

Example diagram of engine fuel supply and switching system



Key

- | | | | |
|---|-------------------|----|--------------------------------------|
| 1 | main engine | 6 | HFO (heavy fuel oil) service tank |
| 2 | viscometer | 7 | MDO (marine diesel oil) service tank |
| 3 | fuel oil heater | 8 | three-way cock |
| 4 | circulating pumps | 9 | supply pumps |
| 5 | mixing tank | 10 | flow meter |

Figure C.1 — Typical main engine fuel supply system

Annex D (informative)

Recommendations for lubricating oil systems

D.1 General

Many of the same issues associated with fuel oils are potential concerns with lubricating oil. These issues include: cleanliness of the oil, minimization of water, maintenance of proper viscosity, and purifier operation and maintenance.

Care should be taken to avoid contaminating lubricating oils with water or fuel. Water will hasten the decomposition of many oils, washout additives, cause the oil to emulsify, and lead to engine failure. In used lubricating oils, sediment and water may have been caused by poor maintenance, failure of screens, or condensation of combustion products. The presence of sulfur in fuel oil can also cause contamination of lube oil through the creation of sulfuric acid. Additionally, sulfuric acid can cause excessive piston ring and liner wear.

Shipyards and ship operators may refer to the guidelines in ISO 28520 for flushing lubricating oil systems to maintain cleanliness.

D.2 Properties affecting lube oil performance

D.2.1 Bottom sediment and water

Petroleum products may gain sediment and water during storage and handling. This can adversely affect the performance of equipment in which the products are used.

D.2.1.1 Cloudy or hazy oil

Usually a cloud indicates water, but it may also indicate excessive amounts of fine sediment or finely dispersed stabilized emulsion. Oil containing a cloud from either cause is not acceptable in many installations. When clean and bright oil cools, a light cloud may form, indicating that dissolved water has precipitated out. This precipitation cloud represents a very slight amount of fresh water, which may or may not be acceptable. The filter/separator elements should be replaced and water and emulsion should be removed from the source tank. A properly operating filter/separator can be used to remove the precipitation cloud by recirculation or by draining the oil upstream.

D.2.1.2 Sediment in oil

Specks or granules of sediment indicate particles in the visible size range. An appreciable number of such particles in a sample indicates a failure of the filter/separator, contamination downstream of the filter/separator, or a dirty sample container. Even with the most efficient filter/separators and careful handling, an occasional visible particle will be noted. These stray particles are due to particle migration through the filter media and may represent no particular problem to the engine or oil control. The sediment ordinarily noted is an extremely fine powder, rouge, or silt. In a clean sample of oil, sediment should not be visible. If sediment continues to be noted, appropriate surveillance tests and corrective measures should be applied to the oil handling system.

Annex E (informative)

Recommendations for other common engineering system components

E.1 Valves

Basic maintenance:

- to prevent external leakage, renew the glands, packing, rings and seals as needed or as per manufacturer recommendation;
- trapped foreign matter can prevent valves from closing properly; a quick seating/unseating of the valve can dislodge trapped foreign matter;
- valves subject to throttling can be at risk of erosion to disc or seat. Gate valve discs and seats are difficult to repair, and these types of valves are not recommended for flow throttling;
- globe valve seats and discs can be repaired by replacement of parts or by valve lapping;
- valve fasteners subject to high temperatures should be reassembled with anti-seize compounds;
- gasket materials should be able to withstand the associated temperatures and pressures of the system, and should be chemically compatible with the fluid.

E.2 Heat exchangers

The critical fluid normally has a higher pressure than the cooling medium (e.g. in an oil cooler the oil will typically be at a higher pressure than the water).

Fouling of surfaces can cause pressure loss and efficiency reduction in heat transfer. Fouling is normally caused by microorganisms, small fish, mud, sand, and scale. Manual cleaning or chemical treatment may be required to periodically remove fouling.

Sacrificial anodes or sacrificial rods are used in cathodic protection of heat exchangers, where they wear away first in order to protect other metallic components. The more active metal corrodes first (hence the term "sacrificial"), and generally the anode must be completely consumed before the less active metal will corrode, thus acting as a barrier against corrosion for the protected metal.

Integrity of anodes should be checked periodically, and anodes must be replaced when near complete erosion.

E.3 Centrifugal pumps

Centrifugal pumps most often get eroded by the pumped liquid. Many pumps have wearing rings both at the impeller and in the casing. Replacement of rings restores close clearances to proper tolerances and improves performance.

Pump shaft sleeves and seals prevent leakage, but wear out over time. Seal/shaft sleeve renewal helps restore performance.

Monitoring and recording of suction and discharge pressures provide a general indication of pump performance. Vibration analysis can also detect the impending failure of pump or motor parts. Low flow rates may cause cavitation (boiling) of the water and serious pump damage.