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# Ships and marine technology — Energy efficiency —

## Part 2:
## Energy efficiency of maritime functional systems

*Navires et technologie maritime — Efficacité énergétique —*

*Partie 2: Efficacité énergétique des systèmes fonctionnels maritimes*



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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*.

A list of all parts in the ISO 8933 series can be found on the ISO website.

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# Introduction

Environmental concerns, emission regulations, fuel prices and emission taxes are increasing the demand for greater energy efficiency in the shipping industry. In 2013, the International Maritime Organization (IMO) adopted the Ship Energy Efficiency Management Plan (SEEMP)[10] to significantly decrease the amount of carbon dioxide ($CO_2$) emissions by 10 % to 50 % per transport work in international shipping. This strategy refers to a pathway of $CO_2$ emission reduction which is consistent with the goals of the Paris Agreement[13], alongside the United Nations 2030 Agenda for Sustainable Development[14].

Standardizing methods to evaluate energy efficiency in the maritime sector interface is valuable for a range of different stakeholders, including:

— shipowners who are looking to buy maritime systems to comply with IMO SEEMP initiatives;

— maritime equipment and engine manufacturers who are responsible for the design and production of ship systems;

— governments that are committed to environmental regulations and environmental targets such as the “levels of ambition” adopted by the IMO.

The purpose of this document is to improve energy efficiency in ships by providing more energy-efficient options that can be considered when replacing malfunctioning components throughout the ship’s lifetime.

This document allows shipowners and shipyard workers to objectively identify the most energy-efficient components, systems and solutions for retrofits, as well as new-builds.

This document provides a method for comparing energy performance on an objective basis to prevent energy loss and to improve cost-efficiency and environmental conditions during maritime transport. This document makes it possible for users to compare the energy efficiency of different individual maritime components or functional units based on a standardized method to measure and calculate the values.



It is widely established that the usual combination of the most efficient single systems on board do not lead in sum to the most efficient ship. It is common practice that owners instruct shipyards to meet the criteria for an optimized operating point of the respective ship system during the design phase (new-build or reconstruction).

Accordingly, a shipyard checks before installation that each single system or component meets good energy efficiency values. It is not possible to calculate the ship’s overall efficiency if the operating conditions are not standardized.

An example of a system or component where the efficiency depends on the operational conditions is an engine room ventilation without a given fan speed control system. If the fan is designed and optimized for the tropical zone and the ship is operated under North Atlantic conditions, less power is necessary during winter times. Owing to the absence of a controller, the fan rotation speed cannot be adjusted. In sum, every single fan can operate efficiently on a test bed (value given by manufacturer). An efficient performance is questionable if the ship sails under different operational conditions than what it is designed for.

To raise the overall operational energy efficiency of a ship in different operational conditions, the overall ship-individual combined system efficiency check should be performed. In addition, manufacturers and operators should take into account the possible variations between test bed conditions and onboard test conditions when developing individual components and systems.

# Ships and marine technology — Energy efficiency —

# Part 2:
# Energy efficiency of maritime functional systems

## 1 Scope

This document specifies generic measuring and calculation methods to evaluate the energy efficiency of multiple components connected in a functional system installed on board ships, vessels for inland navigation and offshore structures.

A maritime functional system consists of multiple components integrating multiple functions, working together to achieve an overall goal.

The purpose of this document is to show how the energy efficiency of various functional systems correspond to the other installations on board of same functionality, thus ensuring that efficient design is rewarded.

Maritime systems are grouped according to their functionality, to compare the energy efficiency of functional systems which can fulfil the same task on board a ship.



This document is applicable to only the functional systems for which a unit output can be clearly defined, and which require energy to function.



This document is applicable to energy consuming functional systems. It does not provide a life cycle assessment (LCA).



NOTE An LCA can prove useful when considering systems which consume substances, and which would not meet the functional requirements without the use of these substances. An example is a ballast water management system (BWMS) using active substances (these types are not considered in this document).



This document is applicable to the following five types of functional systems:

a) pressure and flow;

b) lighting;

c) heating and cooling;

d) mechanical;

e) propulsion.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

**3.1**
**energy efficiency**
ratio or other quantitative relationship between an *output* (3.6) of performance, service, goods or energy, and an *input* (3.5) of energy

EXAMPLE Efficiency conversion energy; energy required/energy used; output/input; theoretical energy used to operate/energy used to operate.

Note 1 to entry: Both input and output shall be clearly specified in quantity and be measurable.

[SOURCE: ISO/IEC 13273-1:2015, 3.4.1, modified — "and quality" deleted in Note 1 to entry.]

**3.2**
**component**
element performing only one *function* (3.4) and whose efficiency is defined by the ratio between *input* (3.5) and *output* (3.6)

EXAMPLE Electric motor, water pump.

**3.3**
**functional system**
collection of *components* (3.2) creating a system which performs a well-defined *function* (3.4)

Note 1 to entry: The components included in the functional system can be energy consuming or passive components. A functional system can also contain a system, controlling the operation of the components.

Note 2 to entry: The energy consumption of a functional system is not only defined by the efficiency of the individual components but is also influenced by the design of the integration between these components.

Note 3 to entry: A functional system is supplied by a single supplier who is responsible for the integration of the components, and the function and performance of the unit based on a set of boundary conditions defining the quality/amount of *input* (3.5) and *output* (3.6).



**3.4**
**function**
operation that is performed by the system

Note 1 to entry: The function will have an *output* (3.6) characterized by the type and amount of output, i.e. treated volume/force/energy, and an *input* (3.5) in the form of consumed energy.

**3.5**
**input**
product, material or energy flow that enters a unit process

Note 1 to entry: Products and materials include raw materials, intermediate products and co-products.

**3.6**
**output**
product, material or energy flow that leaves a unit process

Note 1 to entry: Products and materials include raw materials, intermediate products, co-products and releases.

**3.7**
**system boundary**
boundary based on a set of criteria specifying which unit processes are part of the system under study

## 4 Symbols and abbreviated terms

The following symbols and abbreviated terms are used throughout the document.

| | | |
|---|---|---|
| $\eta$ | efficiency ratio | dimensionless |
| $EER$ | efficiency ratio used in the heating/cooling industry | non-dimensionless |
| $COP$ | performance coefficient used in the air-conditioning industry | dimensionless |
| $TPI$ | thermal power index used in the air-conditioning industry | dimensionless |
| $ECI$ | energy consumption index used in the ship cargo industry | non-dimensionless |
| $E$ | energy consumption | J |
| $P$ | power consumption | W |
| $Q$ | thermal energy | J |
| $q_V$ | volume flow rate | $m^3/s$ |
| $q_m$ | mass flow rate | kg/s |
| $\rho$ | density of water | $kg/m^3$ |
| $c_v$ | heat capacity of water | kJ/kg K |
| $h$ | enthalpy | J/kg |
| $T$ | temperature | K or °C |
| $V$ | volume | $m^3$ |



## 5 Methods to evaluate the energy efficiency of maritime functional systems

Maritime functional systems are grouped according to their functionality. This makes it easier to compare the energy efficiency of functional systems which can solve the same task on board a vessel.



This document examines functional systems divided into following topical areas:

a) pressure and flow functional systems (see Clause 6);

b) lighting functional systems (see Clause 7);

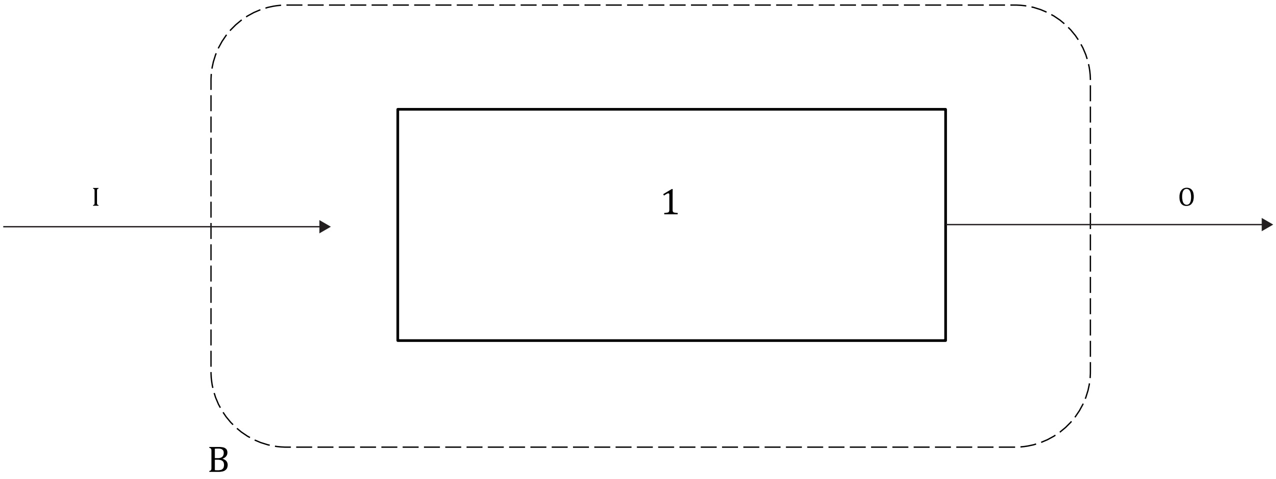
c) heating and cooling functional systems (see Clause 8);

d) mechanical functional systems (see Clause 9);

e) propulsion functional systems (see Clause 10).

The energy efficiency of the system is evaluated based on its expected operational purpose on board the ship and during its expected process operating window. This means that the boundary conditions on which the system is evaluated are defined to represent the normal operational pattern. This can include the variations in ambient conditions or variations in the ship's operational pattern. This is defined for each functional system.

The basic terminology of a maritime functional system is illustrated in Figure 5.1.




**Key**

B boundary

1 functional system

I input (energy, temperature, pressure, flow, concentration, force, velocity, torque, electricity, etc.)

O output (energy, temperature, pressure, flow, concentration, force, velocity, torque, electricity, etc.)

**Figure 5.1 — Basic terminology of a maritime functional system**



## 6 Pressure and flow functional systems

### 6.1 General

A pressure-driven functional system consists of several components and connections between those components. The combined key functionality of these components (and the connections between them) changes the pressure or flow in a fluid.

The systems under this category include:

- ballast water management system (BWMS) (see 6.2), including:
  - ultraviolet (UV) light technology;
  - electro-chlorination (EC) technology;
- freshwater generator (see 6.3);
- sea water cooling system (see 6.4);
- freshwater cooling system (see 6.5);
- engine lube oil system (see 6.6);
- steam boiler system, thermal fluid system and hot water system (see 6.7);
- cargo pump system (see 6.8);
- cargo heating system (see 6.9);
- volatile organic compound (VOC) recovery system (see 6.10);
- separator system (see 6.11).

## 6.2 Ballast water management system

### 6.2.1 General

A BWMS[6] processes ballast water so that the water discharged (the treated water) meets the specified performance requirements for eliminating, inactivating or reducing an aquatic organism to prevent the problem of invasive species.

The energy efficiency calculation should be made based on an “output” treated water quality, meeting at least the D-2 standard of the IMO’s Ballast Water Management (BWM) Convention.[6] If it is based on a stricter quality standard, this should be stated.

The BWM Convention requires BWMS to undergo type approval testing as described in the BWMS Code.[6][11] The data from the type approval test are needed for the establishment of the energy efficiency ratio (EER). A BWMS must be type approved for operation in:

— fresh water (< 1 PSU);

— brackish water (10 PSU to 20 PSU);

— marine water (28 PSU to 36 PSU).

NOTE 1 PSU = practical salinity unit.

The energy consumption of a BWMS can vary with the water type and therefore this must be considered when calculating the energy efficiency.

NOTE 2 If a system has not been part of a type approval, it must undergo testing under the same requirements as described in the BWMS Code to obtain the needed data to be able to compare systems on EER on a level basis.

The energy required to pump the water to the BWMS is not considered for several reasons, including:

— the pump(s) is normally out of the scope of the delivered BWMS;

— the pump(s) can have shared services on board the ship and is thus not necessarily dimensioned to fit the installed BWMS;

— the sizing of the pump(s) is dependent upon the location of the tanks and BWMS.



Hence, the pressure drop in the piping system from the pump(s) to the BWMS is also not considered.

Both UV and EC systems may deploy mechanical separation (filter, hydro-cyclone, etc.) to eliminate larger algae and organisms. For systems which are dependent on separation to comply with the BWM Convention, the separation units form part of the testing for type approval. The power needed for operation of separation under the approval conditions should be included in the EER consideration.

The energy efficiency of the BWMS is expressed through an EER as energy/volume. Since there are numerous parameter dependencies on the energy efficiency of BWMS, this document shows two EERs calculated for each water type, as applicable:

— one for nominal operation conditions: $EER_{\text{nom}}$;

— one for the combination of high or low range values of any given parameter which will provide the highest index: $EER_{\text{max}}$.

NOTE 3 The higher the EER, the lower the energy efficiency.

Along with results of the EERs, it is necessary to present information on the treatment rated capacity, the water type (as applicable) and the system design limitation, including the holding time. However, if these data are available from the type approval certificate (according to the BWMS Code), this certificate can be appended.

#### 6.2.2 Ultraviolet treatment systems

##### 6.2.2.1 General

The ballast water is treated prior to entering the ballast water tank(s). After a typical mechanical separation, the ballast water passes the UV reactor. Most systems can apply additional UV treatment when discharging the ballast water tank(s), which should also be reflected in the energy efficiency calculation.

##### 6.2.2.2 Definition of input and output

The input and output of UV treatment systems consists of the following:

— Input: Electricity (UV treatment, mechanical separation (if applicable) and other auxiliary systems tested during the type approval) and untreated ballast water.

— Output: Treated ballast water compliant with at least the IMO D-2 discharge standard[6] (if another stricter standard is the output, this should be stated) and separated material.

##### 6.2.2.3 Definitions of boundaries and media

The physical boundaries are defined to start from the inlet of the BWMS to the end at the outlet of the BWMS. Thus, any sampling ports, the ballast pump(s), and the piping to and from the BWMS are not included. Other electricity consumers, such as either a booster or backflushing pumps, should be included in the calculation if they are operated as part of the system-type approval. The cleaning in place (CIP) process is conducted independently of the treatment of ballast water and cannot be related to the functional unit. Therefore, the energy consumption of the CIP process is not included in the calculations.

The possible elements in a UV BWMS and the boundaries for the energy efficiency calculation are shown in Figure 6.1.