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RETROFIT SOLUTIONS TO ACHIEVE 55% GHG REDUCTION BY 2030

Class Approval in Principle

WP 4 – Wind Assisted Ship Propulsion
Task 4.3 – Approval in Principle - AIP (M3-M12)
D4.5 – Class Approval in Principle
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Greg Johnston (AWS)	General revision
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Table of Contents

List of Figures

Executive Summary

The present document constitutes the Deliverable D4.5 “Class Approval in Principle”, developed within Work Package (WP) 4, which aims to identify a modular system design and layout to fit into the ISO container format of a Wind Assisted Ship Propulsion system (WASP) within the RETROFIT55 project as well as providing preliminary insight into the certifications possibly required for their approval by Class Societies.

All novel technologies are to be approved according to existing Rules and Regulations before considering their installation onboard vessels, thus a detailed analysis of applicable regulatory framework and certification schemes available from Class Societies is of paramount importance to ensure a broad impact of the project.

This Deliverable will present the process and the result of the Class Approval in Principle (AIP) of the wind-assisted propulsion system (WASP), based upon the definition, application, and compliance with rules and regulations aimed at verifying that this novel technology is feasible, fit for purpose and safe throughout the ship lifecycle.

The AIP requires a systematic approach, and a risk assessment conducted according to the methods described in the RINA GUI015 “Guide for Risk Analysis” [7] to identify, rank, and control hazard and/or failure modes potentially affecting the novel technology. The objective of the risk assessment is to help “eliminate or mitigate any adverse effect to the persons on board, the environment or the ship”. The risk assessment helps identify and recommend safeguards that could reduce risk and helps determine if the risks have been mitigated as necessary. Engineering analyses will be used to demonstrate that the design fulfills the general requirements for its intended service.

1 Introduction

The overall objective of RETROFIT55 is to create an advanced web-based Decision Support System (DSS), featuring a catalogue of retrofitting solutions that are up-to-date, developed, demonstrated, ready to be deployed and scaled-up at the end of the project.

The DSS will allow combining retrofitting solutions in order to achieve a GHG emission reduction of 35% compared to the original design.

The consortium will focus on solutions to improve the ship efficiency, such as Air Lubrication Systems, Smart Energy Management, holistic Hydrodynamic and Operational optimization, as well as solutions to exploit renewables or zero- and low-emission energy sources, such as Wind Assisted Ship Propulsion, Fuel Cells and hybridization of the propulsion system.

The task to which this deliverable is related, will involve a Class Approval in Principle on the existing preliminary designs of a WASP system, to identify areas where actual rules can be implemented. A scale model of the system will be constructed to allow testing of operational functionalities and to provide some early validation ahead of detailed design. The Task 4.1 design will be elaborated to produce detailed designs to be used for the system's construction.

This Deliverable presents an overview of the international regulatory regime in the maritime field, emphasizing the methodology to be adopted for the assessment of novel technologies, and thereafter the regulations related to safety and environment compliance for the approval in principle of a WASP system.

The following chapters are included in this document:

- Chapter 1: introduction, with the overall objectives of the RETROFIT55 project and a summary of the current task.
- Chapter 2: regulatory framework, where an overview of the marine regulatory framework is presented.
- Chapter 3: certification scheme, where the certification of a generic product is shown.
- Chapter 4: risk assessment, where the risks analysis provided in the deliverable D4.2 [2] is shown.
- Chapter 5: class approval in principle, where the Approval in Principle (AIP) of novel technologies is presented in detail.
- Chapter 6: conclusions, with closing remarks on the study performed.

2 Regulatory framework

Regulations concerning shipping are developed at the global level. Since shipping is inherently international, it is vital that it is subject to uniform regulations on matters such as safety, security, stability, environmental protection, construction standards, navigational rules and standards of training, certification and watchkeeping for Seafarers.

Global regulations on the safety and security of shipping, the prevention of pollution, and liability and compensation for damage, such as GHG emissions caused by ships, provide an indispensable technical requirement for vital trade activities related to the carriage of goods and passengers on board commercial vessels.

It was asserted that maritime governance encompasses international requirements whose jurisdiction is then extended to national, regional and local (port) levels. Its global reach calls for an international perspective but, at the same time, policies need to be effectively applied and tuned locally. This chapter summarizes the applicable regulatory framework, addressing ship safety and protection of the marine environment, its structure, content and application. An overview regarding the various types of conventions and ship certificates is provided. Special emphasis is placed on the implementation of amendments to regulations.

2.1 International conventions and codes

Shipping is the safest and most environmentally friendly form of commercial transport. Perhaps uniquely amongst industries involving physical risk, the commitment to safety has pervaded virtually all shipping operations for long time. Shipping was amongst the very first industries to adopt widely implemented international safety standards.

Because of its inherently international nature, the safety of shipping is regulated by various United Nations agencies, and primarily by the International Maritime Organization (IMO, see their logo in Figure 1), which has developed a comprehensive framework of international maritime safety and environmental regulations.

Figure 1: International Maritime Organization

IMO establishes conventions mainly related to:

- grant safety of life at sea (SOLAS)
- protect the marine environment, preventing pollution (MARPOL)

2.1.1 Safety of life at sea

SOLAS (International Convention for the Safety of Life at Sea, 1974) lays down a comprehensive range of minimum standards for the safe construction of ships and the basic safety equipment (e.g.

fire protection, navigation, lifesaving and radio) to be carried on board. SOLAS also requires regular ship surveys and the issue by flag states of certificates of compliance.

SOLAS specifies minimum SAFETY standards for:

- *ship construction*
- *ship equipment*
- *ship operation*

as applicable in relation with ship type, navigation and size.

2.1.2 Prevention of marine pollution

MARPOL (International Convention for the Prevention of Pollution from Ships, 1973/1978) contains requirements to prevent pollution, which may be caused both accidentally or during routine operations. MARPOL, in its six Annexes, addresses the prevention of pollution from oil, bulk chemicals, dangerous goods, sewage, garbage and atmospheric emissions, which have an essential impact on the design and operation of all kinds of vessels. A chapter of Annex VI, adopted in 2011 also covers mandatory technical and operational energy-efficiency measures aimed at reducing greenhouse gas emissions from ships.

2.2 European Institutions and Regulations

In the European Union (EU) a number of different policies and directives supplement the international regulations, applicable to ships flying the flag of EU Member States as well as to non-EU flag ships that are operated in EU waters and ports. These directives often define targets to be achieved rather than solutions or technologies to be adopted to meet the targets. The implementation, the monitoring and the general compliance with the directives is under the responsibility of each EU Member State. Member States must adapt their laws and policies to meet the mandatory goals set by the EU directives.

The countries that make up the EU (its ‘member states’) remain independent sovereign nations, but they pool their sovereignty in order to gain a strength and world influence that none of them could have on their own. Pooling sovereignty means, in practice, that the member states delegate some of their decision-making powers to some shared institutions they have created, so that decisions on specific matters of joint interest can be made democratically at European level.

EU consists of three main institutions:

- European Parliament (EP), which represents the EU citizens and is directly elected by them
- Council of the European Union, which represents the individual member states
- European Commission (EC), which seeks to uphold the interests of the Union as a whole

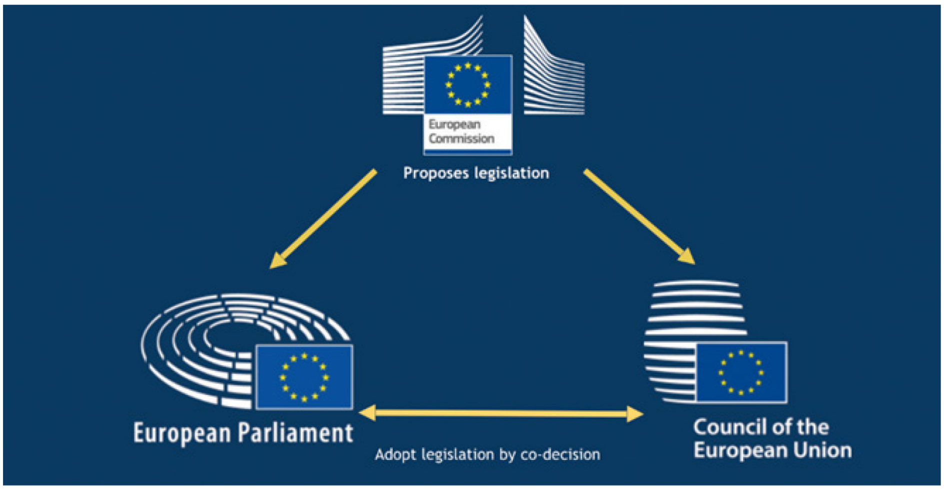

Figure 2: EU "institutional triangle"

This 'institutional triangle', shown in Figure 2, summarizes the policies and laws that apply throughout the EU. In principle, it is the Commission that proposes new laws, but it is the Parliament and Council that adopt them.

2.2.1 The European commission

The term 'Commission' is used in two senses. First, it refers to the team of men and women – one from each EU country – appointed to run the institution and take its decisions. Secondly, the term 'Commission' refers to the institution itself and to its staff. The appointed Members of the Commission are known as 'commissioners'. They have all held political positions in their countries of origin and many have been government ministers before.

The European Commission has four main roles:

- propose legislation to the Parliament and the Council
- manage and implement EU policies
- enforce the European law
- represent the European Union on the international stage, for example by negotiating agreements between the EU and other countries.

To carry out the above duties, the EC is organised into departments, known as 'Directorates-General' (DGs): each DG is responsible for a particular policy area and is headed by a Director-General who is answerable to one of the commissioners. DGs actually devise and draft legislative proposals, which are 'adopted' by the Commission and then submitted to the Council and the European Parliament for their consideration. Matters relevant to the marine sector are dealt with by the Directorate-General for Energy and Transport.

2.2.2 The European Maritime Safety Agency

The European Maritime Safety Agency (EMSA), which refers to the EC (DG MOVE) is the EU agency charged with reducing the risk of maritime accidents, marine pollution from ships and the loss of human lives at sea, by helping to enforce the pertinent EU legislation.

The EU is specifically committed to lower its total greenhouse gas (GHG) emissions by at least 55% by 2030 compared to 1990 levels. This is a core step to reach carbon neutrality by 2050 and on a wider scale, to achieve the UN Sustainable Development goals.

Maritime transport plays a pivotal role in the effective Fit for 55 package as part of the European Green Deal.

2.3 Classification societies

Classification Society ("Class") provide ship classification services (plan approval, inspection and survey to construction, testing, certification, assignment of class and lifecycle compliance) as well as statutory certification and services as a Recognised Organisation acting on behalf of a flag Administration. Moreover, Classification Societies assist the maritime industry and regulatory bodies to develop, implement and continuously improve the provisions (rules, regulations and industrial standards) addressing safety and pollution prevention, based on the accumulation of specific experience, knowledge and available technology.

Classification Societies inspect and test vessels from the early design stage and throughout ship construction and commissioning, to verify their regulatory compliance in accordance with Class rules, which cover ship structures, power generation systems, propulsion, steering, auxiliaries, marine equipment and other onboard mechanical and electrical equipment. Classification societies also inspect and class a large variety of waterborne assets, such as submarines and submersible vehicles, oil platforms, offshore structures and wind farms, dredgers, workboats, tugs, barges, vessels for inland navigation, pleasure crafts, yachts and much more. After the construction, commissioning and delivery of a ship or other waterborne vehicles, the Classification Society will perform periodic inspections and surveys to confirm the continuous conformity with Class requirements as well as with the statutory requirements on behalf of the flag Administration.

It is recalled that a Classification Society is an organization that:

1. publishes its own classification Rules (including technical requirements) in relation to the design, construction and survey of ships, and has the capacity to (a) apply, (b) maintain and (c) update those Rules and Regulations with its own resources on a regular basis
2. verifies compliance with these Rules during construction and periodically during a classed ship service life
3. publishes a register of classed ships
4. is not controlled by, and does not have interests in, ship-owners, shipbuilders or others engaged commercially in the manufacture, equipping, repair or operation of ships
5. is authorized by a Flag Administration as defined in SOLAS Chapter XI-1, Regulation 1 and listed accordingly in the IMO database, Global Integrated Shipping Information System (GISIS)

When safety and reliability of materials, equipment and components present on board a vessel play a relevant role, classification is involved. Depending on how critical the system is to safety, classification is involved differently, as shown by the safety hierarchy shown in Figure 3.

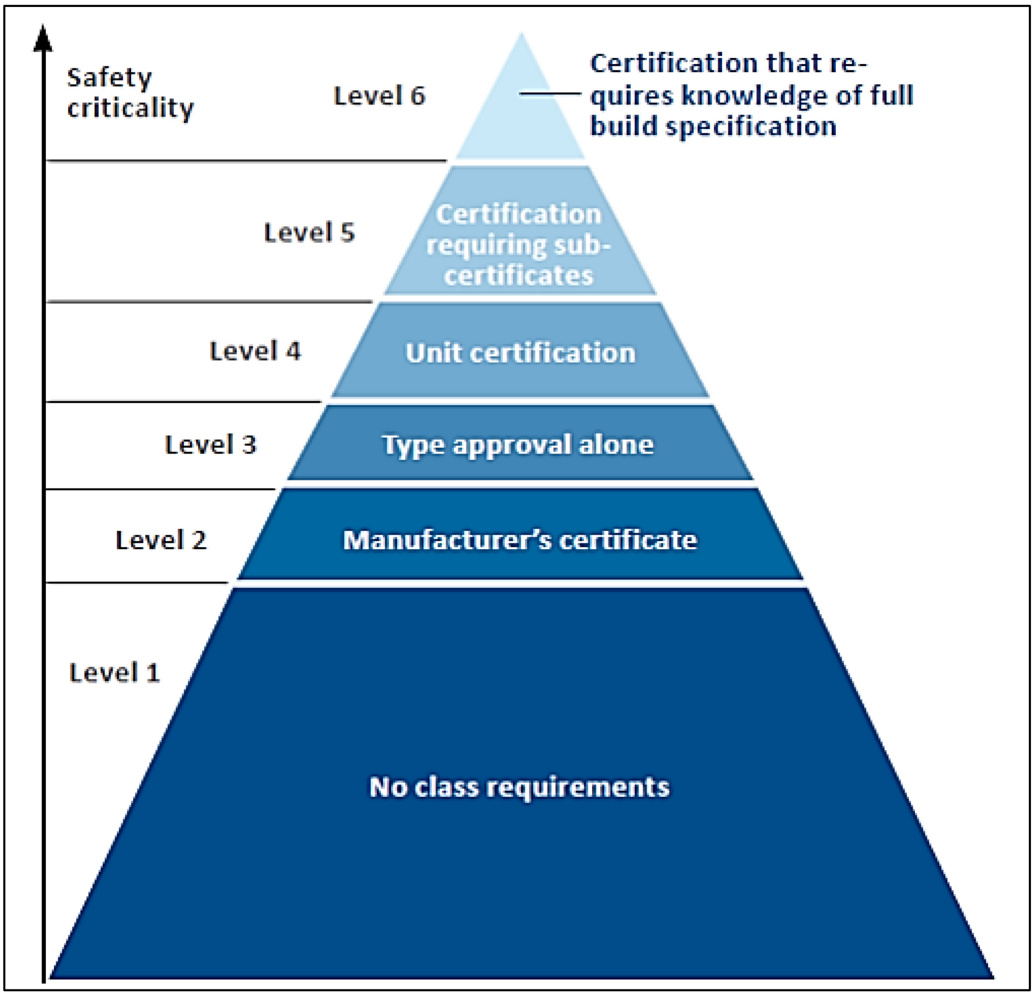

Figure 3: Safety hierarchy usually considered for equipment classification purposes

Specifically, six different levels of safety relevance are identified:

- Level 1: no Class involvement and certification are required: this level applies to non-safety critical systems as well as to equipment out of safety critical systems. Examples of equipment belonging to Level 1 are furniture and entertainment systems
- Level 2: quality certificate from the Manufacturer is sufficient: this level applies to equipment dealing with weak safety relevance, hence certification is not mandatory, despite certain individual Class Societies may have requirements on it. Examples of equipment belonging to Level 2 are converters, condensers, sounding rods etc.
- Level 3: Type Approval certification is required and Class involvement is necessary: this level applies to equipment dealing with low grade of safety criticality, hence Type Approval is sufficient to guarantee that the design and manufacturing processes comply with specifications and standards. Examples of equipment belonging to Level 3 are electrical heating cables and sensors.
- Level 4: each manufactured unit requires certification: this level applies to equipment which is safety critical, hence each unit shall be approved and its manufacturing process and/or testing is to be witnessed. Examples of equipment belonging to Level 4 are large electrical

machines, pumps, propeller shafts and sub-components of main and auxiliary prime movers installed onboard.

- Level 5: both main unit and its components require certification: this level applies to complex equipment (i.e., system) specifically designed and manufactured for a particular vessel, whose sub-assemblies may be relevant for the ship's safety. In this case, both the system and the components require certification. Examples of equipment belonging to level 5 are main engines, thrusters and podded thrusters.
- Level 6: certification requires deep knowledge of the complete system: this level applies to complete systems which are highly relevant for safety purposes. In this case deep knowledge concerning both construction and operation of the ship is required, together with specifications related to many other onboard systems. Examples of equipment belonging to Level 6 are main propulsion systems and dynamic positioning systems.

2.3.1 IACS

IACS is an association of Classification Societies which:

1. establishes, reviews, promotes and develops minimum technical requirements in relation to the design, construction, maintenance and survey of ships and other marine related facilities.
2. acts as a catalyst to assist international regulatory bodies and standard organizations to develop, amend and interpret regulations and industry standards in ship design, construction and management, with a view to improving safety at sea and the prevention of marine pollution.
3. provides a Quality System Certification Scheme (QSCS) that its Members shall comply with, as an assurance of professional integrity and maintenance of high professional standards.

IACS (see logo in Figure 4) has a wide perspective on relevant matters through monitoring the developments in EU legislation related to shipping safety and environmental performance in addition to its technical advisory role to the IMO and its interaction with the industry and flag states. IACS technical representatives can therefore bring cross-cutting knowledge and experience from one forum to another.

IACS International Association of Classification Societies

Figure 4: Logo of the International Association of Classification Societies

An up-to-date list of the IACS members is reported below:

1. American Bureau of Shipping (ABS) - www.eagle.org
2. Bureau Veritas - www.veristar.com
3. China Classification Society - www.ccs.org.cn/ccswzen/
4. Croatian Register of Shipping – www.crs.hr

5. DNV – www.dnv.com
6. Indian Register of Shipping – www.irclass.org
7. Korean Register - www.krs.co.kr
8. Lloyd's Register Group Ltd. (LR) - www.lr.org
9. Nippon Kaiji Kyokai General Incorporated Foundation - www.classnk.or.jp
10. Polish Register of Shipping - www.prs.pl
11. RINA Services S.p.A. - www.rina.org

To keep pace with changes in technology, market trends and new legislation, RINA and other IACS members are dedicated to an on-going programme of research and development to enhance existing technical standards and publish new Rules as shown in Figure 5.

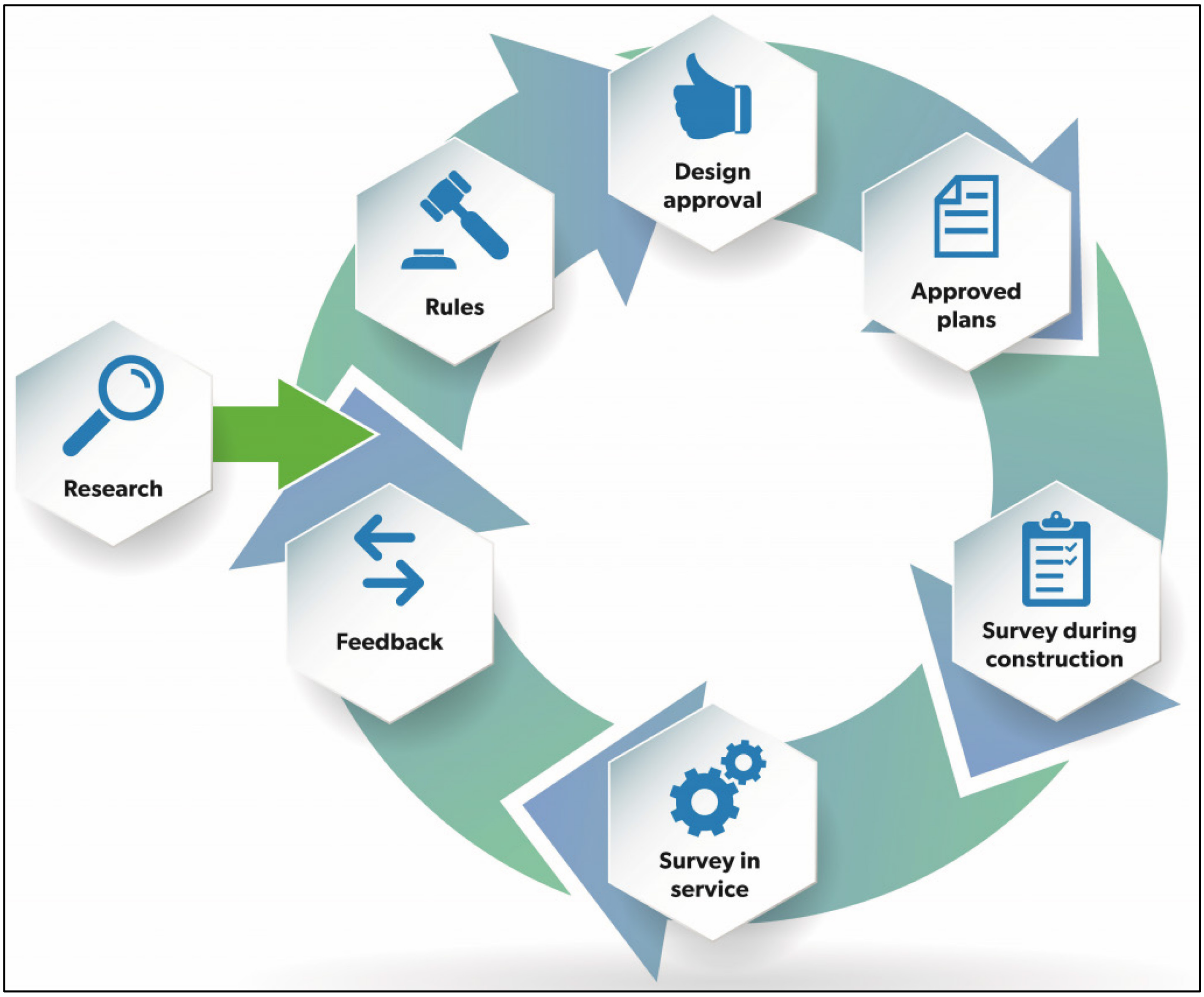

Figure 5: Class societies research cycle

2.3.2 Scope of classification

Implementing the published Rules, the classification process consists of:

- a technical review of the design plans and related documents for a new vessel to verify compliance with the applicable Rules;
- attendance at the construction of the vessel in the shipyard by a Classification Society surveyor(s) to verify that the vessel is constructed in accordance with the approved design plans and classification Rules;
- attendance by a Classification Society surveyor(s) at the relevant production facilities that provide key components such as the steel, engine, generators and castings to verify that the component conforms to the applicable Rule requirements
- attendance by a Classification Society surveyor(s) at the sea trials and other trials relating to the vessel and its equipment prior to delivery to verify conformance with the applicable Rule requirements
- upon satisfactory completion of the above, the builder's/shipowner's request for the issuance of a class certificate will be considered by the relevant Classification Society and, if deemed satisfactory, the assignment of class may be approved and a certificate of classification issued;
- once in service, the owner must submit the vessel to a clearly specified program of periodical class surveys, carried out onboard the vessel, to verify that the ship continues to meet the relevant Rule requirements for continuation of class.

Class Rules do not cover every piece of structure or item of equipment on board a vessel, nor do they cover operational elements. Activities that generally fall outside the scope of classification include such items as: design and manufacturing processes; choice of type and power of machinery and certain equipment (e.g. winches); number and qualification of crew or operating personnel; form and cargo carrying capacity of the ship and maneuvering performance; hull vibrations; spare parts; life-saving appliances and maintenance equipment. These matters may however be given consideration for classification according to the type of ship or class notation(s) assigned.

It should be emphasized that it is the shipowner who has the overall responsibility for the safety and integrity of a vessel, including the manner in which it is operated and maintained. The effectiveness of classification depends upon the shipbuilder, during construction, and the shipowner, once the vessel enters service, cooperating with the Class Society in an open and transparent manner on all issues that may affect its class status. For the shipowner, this particularly requires acting in good faith by disclosing to the Class Society any damage or deterioration that may affect the vessel classification status. If there is the least question, the owner should notify class and schedule a survey to determine if the vessel is in compliance with the relevant class standard.

A Class surveyor may only go on board a vessel once in a twelve-month period. At that time, it is neither possible nor expected that the surveyor scrutinizes the entire structure of the vessel or its machinery. The survey involves a sampling, for which guidelines exist based upon empirical experience and the age of the vessel which may indicate those parts of the vessel or its machinery that may be subject to corrosion, or are exposed to the highest incidence of stress, or may be likely to exhibit signs of fatigue or damage.

2.4 Statutory

Once a ship is registered, the Flag State must effectively exercise its jurisdiction and control in administrative, technical and social matters over ships flying its flag and take such measures for ships flying its flag as are necessary to ensure safety at sea.

International Conventions have been agreed, setting out standards to facilitate acceptance of a ship registered in one country in the waters and ports of another and in general for the safety of life at sea and the protection of the environment.

The Recognized Organization ("RO") is empowered to require repairs or other corrective actions to a ship in most cases, to withdraw/invalidate the relevant certificate, if the necessary actions are not taken.

SOLAS and the other International Conventions permit the flag Administration to delegate the inspection and survey of ships to a RO. This is in recognition of the fact that many flag Administrations do not have adequate technical experience, manpower or global coverage to undertake all the necessary statutory inspections and surveys using their own staff. The degree to which a flag State may choose to delegate authority to a RO (Class Society) is for each flag State to decide, with the authority granted being clearly identified in the relevant memoranda of understanding agreed between the Class Society and the Administration. In most cases the RO is empowered to require repairs or other corrective action to a ship and to withdraw or invalidate the relevant certificate if the necessary action is not taken (e.g. SOLAS Chapter I, Reg 6).

IMO Resolution A.739(18) [18] lays down mandatory minimum requirements for ROs. Fundamentally it requires the organization to demonstrate its technical competence and to be governed by the principles of ethical behavior.

The RO is to be subject to the certification of its quality system by an independent body of auditors accepted by the Administration.

A.739(18) [18], together with Resolution A.789(19) [19], which presents specifications on the survey and certification functions of ROs, provides the criteria and framework which a flag must be satisfied is met by their ROs.

IACS Members have been found to meet Resolutions A.739(18) [18] and A.789(19) [19] by all the Administrations (approximately 100) that are Parties to SOLAS.

The RO is responsible and accountable to the flag Administration for the work that it carries out on its behalf. The principles of the inspection and survey work are to a very large extent the same as in respect of classification surveys, that is, the verification by the RO that a ship is in compliance with applicable requirements at the time of the survey or inspection. The scopes of these inspections and surveys are laid down by the relevant national laws based on International Conventions to which the Government is a signatory, together with additional instructions that may be issued by the flag Administration. IACS Members generally do not undertake 'statutory' work on ships that they do not themselves class. The significant exceptions to this policy are International Safety Management (ISM) Code and International Ship and Port Facility Security (ISPS) Code certification where it may be efficient for a Company to implement a common Safety Management System (SMS) or Ship Security Plan (SSP) on a fleet basis as that fleet may be classed by more than one Society. However, systems are in place for the classing Society to inform the owner, the ISM certifying Society and/or the flag Administration in cases where there is reason to doubt the continuing effectiveness of the SMS or SSP.

2.4.1 Statutory certificates

Statutory certificates are issued by the Recognized Organization “RO” in accordance with the terms of its recognition by the flag Administration. Variation of the delegation of statutory authority or certificates that can be issued by the RO exists between Administrations. The Administration should be contacted for specific details of the authorization.

Flag state regulations, local laws and international conventions require initial and periodic inspections for ships. The vessel must make its survey and inspection records available to charterers and insurance companies, and they may be necessary for port entry and when transiting certain canals and waterways.

3 Certification scheme

Where certification of a generic product is concerned, Chapter 2 of the RINA Rules for Testing and Certification of Marine Materials and Equipment, NC/C.57 [13] specifies the procedures to be applied in each possible phase (e.g. document reviews, inspections, onboard tests, etc.), even though a specific product may not deal with all the phases reported in general. Specifications for reviews and inspections include the following aspects:

- Approval of technical documentation: the Manufacturer needs to prepare the technical documentation according to applicable Class Rules and to submit it to RINA. Understanding of design, manufacturing and operation processes is required to be guaranteed by the submitted documentation, in order to assess compliance with Rules and applicable standards. Among all the technical documents possibly required, the most common consist of:
    1. general description of the product
    2. the conceptual design, the component schemes, the manufacturing drawings as well as standards
    3. explanatory notes and descriptions referring to the drawings, schemes and operation of the product
    4. computations and assumptions underlying the design procedure
    5. manuals addressing installation, usage and maintenance
    6. control and test procedures applied to the product

Eventually, attestations and certificates related to components and manufacturing/inspecting/monitoring methods shall be included in the design documentation.

- Type tests: they consist of more extensive tests compared with standard production tests and aim at validating prototype design. They can be applied to purpose-built prototypes or products randomly sampled within the production line. Tests can be carried out at either the Manufacturer's facility, RINA laboratory or independent laboratory. In case tests are performed at independent laboratory, witness from a RINA Surveyor is required, unless stated otherwise, with complete reporting to be submitted to RINA for approval or information.
- Design approval: the Manufacturer shall prepare technical documentation in accordance with applicable Rules and Standards. Generally, the design documentation is to include:
    1. general description of the product
    2. conceptual design, schemes of components as well as sub-assemblies and the Standards adopted for manufacturing. Additional descriptions and explanations of drawings and schemes may be required to improve understanding.
    3. description of the operation and limitations of the product
    4. analyses, computations and examinations related to the design process
    5. control and test procedures
    6. manuals addressing installation, use and maintenance

- Manufacturer and manufacturing process approval: details on the requirements related to the approval of Manufacturers and manufacturing processes are available in the RINA "Rules for the approval of Manufacturers of materials".
- Material testing: material testing shall be carried out according to applicable Rules and Standards. Surveyors need to attend material testing if required by the Rules, and shall be allowed to access certificate of material testing. The raw material supplier must provide the chemical composition of the materials and the corresponding analyses shall be carried out in adequately equipped laboratories by qualified personnel. All the testing and measuring equipment shall be kept in good condition as well as properly calibrated.
- Attendance and final inspection and testing at workshop: free access of Surveyors to all the production phases, collection of test samples and internal control shall be guaranteed. Final inspection of products encompasses document review, visual examination, dimensional check, non-destructive examination, as far as applicable. Instead, equipment and materials to be installed onboard are to be tested through a procedure similar to tests at workshops, integrated together with all the products or materials they are part of. In particular, testing may include, depending on the complexity of the product as well as on application standards:

    1. final tests of completed product (e.g., hydrostatic tests for pressure vessels)
    2. performance tests (e.g., running tests for reduction gears)
    3. collection of data (e.g., performance data for energy systems)

    Three main certification schemes are identified by the Rules:

    1. individual or traditional inspection scheme: it is applicable if inspection and testing are carried out as prescribed in the Rules and are witnessed by a RINA Surveyor.
    2. alternative inspection scheme: it involves a properly qualified Manufacturer in the inspection, testing and certification processes. The type of product, its mass production and the quality control plans of the Manufacturer are considered in setting up the alternative inspection scheme. Qualification of Manufacturers must be periodically checked.
    3. type approval scheme: it is applicable either when product certification is required by the Rules and in case no specific requirements exist, i.e. certification is requested by the Manufacturer on a voluntary basis. In the latter case, particular standards and/or specifications agreed with the Manufacturer are adopted by the Class Society for product approval. Type Approval certificate can be optionally combined with Production Control Certificate, which in turn is divided into two schemes:
        - Product verification
        - Production quality assurance, for Manufacturers having a certified Quality Assurance System

    Generally, the type approval certificate remains valid for five years, despite variations can arise depending on specific requirements of the reference Standards the certification is based on.

- MED Type Approval scheme: it concerns products listed in the implementing Regulation of the European Directive 2014/90/EU [5] and, simultaneously, intended to be installed on vessels flying European Community flags. These products need to be certified in accordance with the requirements of the RINA "Rules for the certification of marine equipment in accordance with European Directive 2014/90/EU [5] and subsequent amendments". Alternatively, they can be certified using equivalent Rules developed by other Class Societies.

The EU has acted through the Marine Equipment Directive 2014/90/EU [5] to harmonize testing standards and certification for marine equipment in the EU. This is carried out by specialized entities, known as Notified Bodies. EMSA supports the EC and EU Member States by coordinating an annual update of the list of relevant safety equipment and associated standards, and also manages the MED Portal which lists the approved products that can be carried on board EU Member State-flagged ships. The MED Portal currently holds details of more than 200 000 marine equipment items and has more than 7 000 users worldwide, offering to the industry a quick and reliable way to check the validity of certificates of marine equipment placed on the EU market.

In the following sections, deep insight into the two main certificates possibly issued by RINA for either equipment and software products is provided, focusing on the steps and requirements the certification process relies on. Thus, attention is paid to:

- Type Approval Certificate (TA)
- Prototype Design Assessment Certificate (PDA)

Both the certification schemes can be applied either when product certification is required by the Class Rules and in case no specific requirements exist, i.e. certification is requested by the Manufacturer on a voluntary basis. In the latter case, industrial standards and/or particular specifications agreed with the Manufacturer are adopted for approval.

3.1 Type approval certificate

Type Approval certificate is compulsory for products covering essential services to be fitted on board ships and consists in the approval of the product design, including drawing appraisal, and prototype test performance. Nevertheless, Type Approval can also be requested on a voluntary basis by the Manufacturer. The Type Approval for a specific product is assessed once, since the certificate successively remains valid for all the subsequent products dealing with identical design and manufacturing process. For this reason, Type Approval is a commercially valuable option for Manufacturers who intend to broaden their selling activities. In detail, since it gives evidence of compliance with performance as well as safety requirements, Type Approval can be useful to facilitate product acceptance by potential buyers.

The type approval certification procedure consists of the following operational steps:

- the Manufacturer forwards an application to RINA for requesting Type Approval
- technical documentation requested by applicable Rules is thoroughly examined
- technical drawings are preliminarily approved, if required by the Rules
- test campaign for prototypes or sample products is defined according to the Rules or industrial standards
- the laboratory where to conduct tests is identified (Manufacturer's facility, RINA laboratory or independent laboratory). In particular, initial audit and evaluation of the Manufacturer's production facility is first carried out as starting point

- the type tests are conducted in laboratory and reports containing the required information are generated
- the technical reports related to the testing activity are reviewed in detail
- the Type Approval certificate is issued, in case results obtained from the tests met industrial standards/specifications as well as rules

Successively, the Production Quality Assurance Certificate is issued. It remains valid for 5 years, subject to the positive outcome of periodical audits according to the following surveillance cycles:

1. An intermediate audit at the Manufacturer's facility is required in case of products for which testing shall be carried out by the Surveyor for each unit or batch
2. At least an annual audit to the Manufacturer's production site is required in case of products for which testing of each unit or batch is not required to be attended by the Surveyor (e.g., sensors).

In case of certification of software, the TA certificate is issued upon satisfactory outcome of design approval and prototype tests only. The initial audit to the software house and the issuance of a Production Quality Assurance Certificate is not required.

When the certification process of onboard systems (e.g., Approval in Principle of new technologies) and the classification of the vessel are performed by two distinct Class Societies, relationships and procedures are regulated by the “Mutual Agreement on the implementation of Mutual Recognition Provisions of Art 10 of Regulation (EC) No 391/2009 of the European Parliament and of the Council of 23 April 2009 on Common Rules and Standards for Ship Inspection and Survey Organizations” [6], which entered into force on 7 October 2010.

Mutual Recognition (MR) typically works for equipment classified in Level 3 (Type Approval required) or, eventually, in Level 4 (certification of each single unit required). Indeed, equipment belonging to Level 3 are characterized by low safety criticality and are typically manufactured in series in standardized form, hence technology providers have a strong interest in reducing multiple certifications. Furthermore, no specific Class requirements exist for the manufacturing and testing processes of equipment belonging to Level 3, since Type Approval is issued according to standards and specifications agreed with the technology provider. Thus, MR can be useful for establishing a common and widely recognized procedure.

However, almost all components may generate serious safety risk under particular operating conditions. E.g., failure of a pressure or temperature sensor installed into a boiler may have strong effect on its safe operation. For this reason, a common and widely recognized framework for Type Approval issuance is necessary to minimize risks. Towards this end, mutual recognition has been introduced. Nevertheless, within the MR framework, further testing aimed at demonstrating safety compliance may be possibly requested by Class Society for equipment which previously obtained Type Approval.

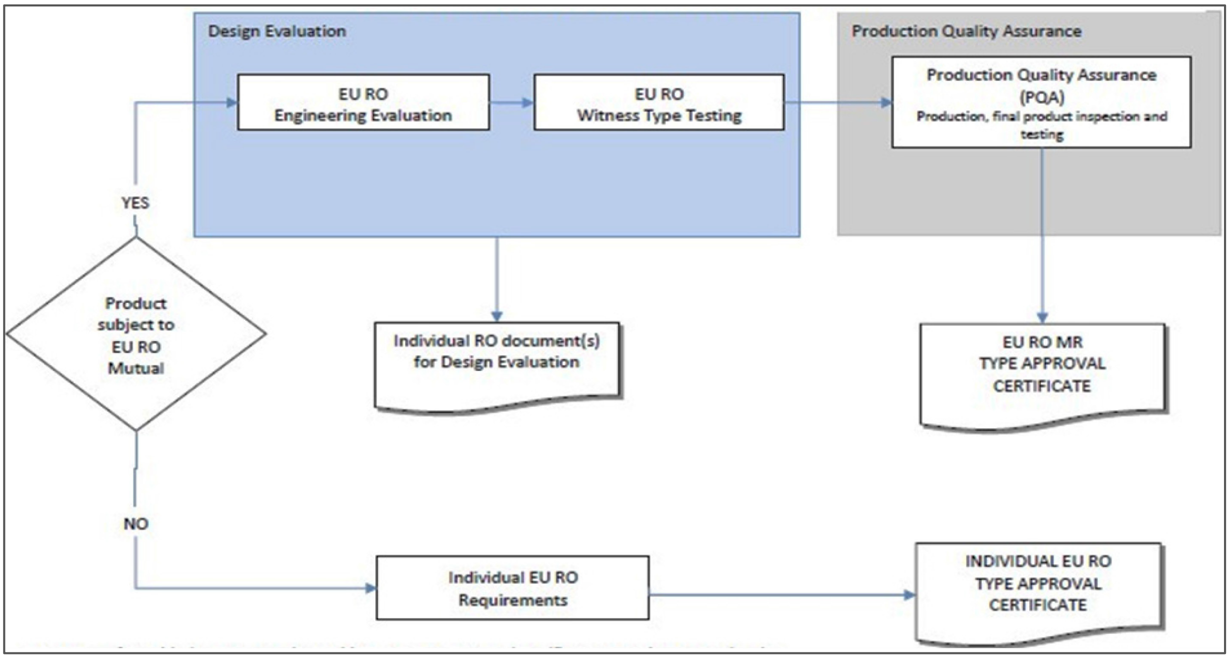

Figure 6: Flow chart illustrating the technical and procedural conditions for EU RO Mutual Recognition of Type Approval Certificates for equipment and components based on equivalent standards

Overall, technical requirements for mutual recognition as well as for relevant certificates are agreed among EU Recognized Organizations (RO) and are included in Tiers.

Figure 6 shows the flow chart underlying the mutual recognition of Type Approval Certificates by the EU RO entities. Overall, the following rules are valuable for the EU RO MR Type Approval Certification process:

- EU RO MR Type Approval Certification may be requested on a voluntary basis
- EU RO MR Type Approval Certification can be requested by Manufacturers independently from their company location the Manufacturer is free to choose the organization issuing the EU RO MR Type Approval of its product and no need to repeat the same procedure with other RO is present.
- In case a product is not already covered by the existing Technical Requirements (TRs), the Manufacturer can ask the EU RO MR Group to consider the development of suitable MR TR for such a product. As an examples, product belonging to the Tier 9 release (2022) are:
    - Cable glands
    - Corrosion-resistant paints
    - Electric space heating equipment
    - Electric motor starters other than soft starters
    - Inverters
    - Resilient mountings of machinery
    - Strainers
    - Vertical surface reference system for DP system
    - Wind velocity and direction gauge for DP system
    - Power supply units (<5 kVA)

- In case change requests for the Technical Requirements arise with respect to procedural updates, test requirement updates, rule changes or industry feedback, the procedure reported in Figure 7 is followed.

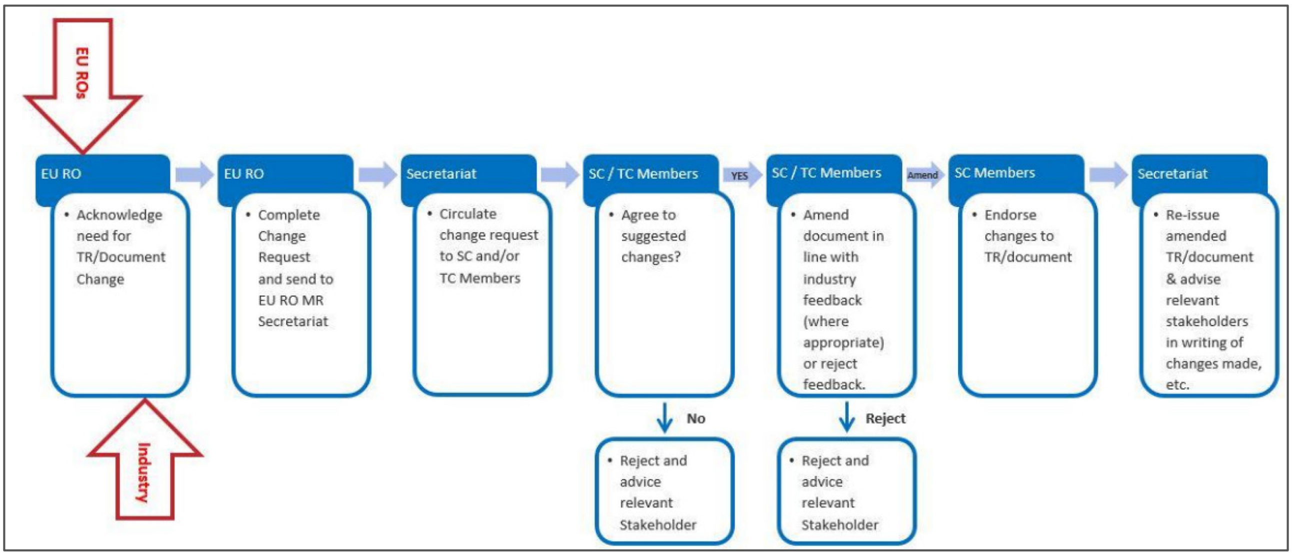

Figure 7: EU RO MR Maintenance Process

Further details concerning the procedural requirements as well as terms and conditions of EU RO MR Type Approval Certification are available in the EU RO Framework Document. Instead, Technical Requirements for products being eligible for EU RO MR Type Approval Certification are included into the TR table embedded in the Regulation (EC) No 391/2009 on Common Rules and Standards for Ship Inspection and Survey Organizations [6].

3.2 Prototype Design Assessment Certification

This certification is applicable to products for which there are no specific requirements in the Class Rules. For this reason, Prototype Design Assessment Certification cannot be applied to products that are required to be Type Approved and can be requested on voluntary basis by Manufacturers.

The approval process is established against standards/specifications agreed with the Manufacturer and shipowner installing prototypes onboard, according to a case-by-case approach.

The Prototype Design Assessment Certification consists of the two following steps:

- Design approval and prototype tests, intended to verify compliance of the product with the Manufacturer's specification and/or the applicable standards.
- Issuance of the Prototype Design Assessment Certificate.

The procedure aims at verifying that performance of the product guarantees the service for which the shipowner intends to install and operate it onboard (fit for service). Furthermore, it must be ensured that the installation of the product on board does not have negative consequences due to the marine environment rather than land based (marinization).

In general, the validity of Prototype Design Assessment Certificates lasts for 5 years, subject to possible changes in the reference Standards in terms of product requirements/specifications.

4 Risk Assessment

The risk assessment was performed on the Wind Assisted Ship Propulsion (WASP) system which is becoming widely accepted as part of the solution for reducing greenhouse gas emissions from shipping. There are many vessels in operation that could benefit from a retrofit solution for wind assistance. One of the challenges in retrofitting wind propulsion is to devise a system that does not impact on the normal operation of the vessel. Wind propulsion systems are inherently large pieces of equipment. The size of these devices is not a major consideration when the vessel is at sea.

In general, the intent of a risk assessment study is to stimulate, by means of a facilitator, a systematic discussion among the stakeholders, if possible, with the aid of the concept design drawings, layout plans and operating philosophies.

The goal is the identification of the main hazards at a high level, and the relevant solutions if they are readily available. Unanswered questions have to be noted and handled after the meeting.

A risk assessment is not intended to be a design review meeting: it just paves the way for more in-depth subsequent analyses.

As part of deliverable 4.2 the risk assessment has been conducted to ensure that risks arising from the use of the system affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Considerations were given to the hazards associated with physical layout, operation and maintenance, following any reasonably predictable failure.

Moreover, the risks have been analyzed using acceptable and recognized risk analysis techniques. The analysis ensured that risks are eliminated wherever possible. Risks that cannot be eliminated were mitigated, as necessary.

4.1 Overview of the risk assessment report

The activities performed in the course of Task 4.2 were performed with the aim of defining a risk assessment report of the Advanced Wing System (AWS) WASP system, to be manufactured and validated in the next phases of the project.

The main results can be summarized as follows:

- HAZID of the proposed design identified no significant issues or unacceptable risks associated with the design of the system.
- Recommendations for further consideration have been identified. The responses to these items, along with details of potential failure scenarios and safeguards identified in the study, will further improve the design from a safety and operability perspective.
- The HAZID Study Team confirms that the Advanced Wing System installation, subjected to the Risk Assessment, meets the safety objectives and functional requirements and therefore ensures a level of safety and reliability.
- Possible revision of this analysis can be performed in case of any significant modification that may affect the current analysis.

5 Class Approval in Principle

In this section the Approval in Principle (AIP) of novel technologies is presented in detail.

The expression “novel technology” refers to a technology that is not proven, i.e. a documented track record for its defined application does not exist. According to this definition, the concept of novel technology encompasses the application of both proven technology in a new environment and unproven technology in a known environment.

The AIP procedure is applicable to components, equipment and systems that can be defined as a novel technology. Since novel technologies are generally not adequately covered by established codes and procedures, a two-fold verification is requested:

- the concept underlying the novel technology needs to be feasible and realistic
- the intent of the applicable rules and regulations is to be met

Since the AIP is a systematic process of verification, which includes examination of the design procedure and engineering analyses, it depends on the engineering phase of the novel technology, potentially ranging from the conceptual design to the complete design. The complete design possibly includes tests on prototypes, as detailed testing programs on full scale products are typically not encompassed in an AIP procedure; they are carried out in successive engineering phases.

The AIP verification program needs to be focused on novel elements or novel applications of known elements, therefore identifying where the novelty is located constitutes the preliminary step of the AIP.

The systematic application of the AIP procedure traditionally consists of the following steps:

1. Description of the technology to be qualified
2. Detailed assessment of the operational conditions and corresponding constraints related to the novel technology
3. Definition of the functional requirements the novel technology deals with
4. Risk and safety assessment aimed at identifying, ranking and controlling hazards or failures which affect the novel technology
5. Engineering analyses and, possibly, tests on prototypes as supporting evidences to demonstrate that the design of the novel technology fulfils the requirements for its intended service. In details, the novel technology must be shown fit-for-service, i.e. it must fulfil functionality, safety, reliability, availability and maintainability requirements , which were defined in the qualification process.

Official statement of fitness-for-service can be obtained by Technology Qualification Process (TQP), in the form of a certificate, a class notation or other equivalent documents (see section below for more details on TQP). In the event that engineering analyses and prototype tests are not available, the feasibility of novel technology may be demonstrated by means of alternative methods, providing proper justifications.

The typical documentation to be produced during an AIP process consists of, as far as applicable:

- Design criteria of the novel technology

- Applicable rules and regulatory framework
- Detail drawings and schemes
- Technical specifications ensuring fitness-for-service
- Engineering analyses performed during design procedure
- Reports on risk and safety assessment

Finally, following the evaluation of all the documents reported above, the AIP certificate can be issued, thus confirming that the novel technology meets the general requirements for its intended service.

Details on the systematic approach underlying the Approval in Principle of new technologies that are not adequately covered by established codes and procedures can be found in the RINA Guidelines GUI19 “Guide for Approval in Principle of Novel Technologies” [9] or equivalent. On the other hand, risk assessment involved in the AIP procedure is to be conducted according to the methods described in the RINA GUI015 “Guide for Risk Analysis” [7] and GUI23 “Guide for Failure Mode and Effect Analysis (FMEA)” [10] or equivalent.

Systems to be installed on board for demonstration purposes (e.g., demo prototypes) require at least an Approval in Principle. Therefore, the required documents outlined above need to be submitted for consideration and approval to a Class Society, which in turn may witness compliance with the applicable rules and regulations as well as applicable Standards.

Successively to the AIP procedure, the assessment of the integration of the novel technology onboard ship takes place.

As said above, novel technologies are not adequately covered by established codes and procedures. Therefore, they need to be qualified through a specific procedure called Technology Qualification Process (TQP), in order to prove that novel technologies meet all the requirements for their intended use (fitness-for-service concept).

It must be reminded here that novel technology has no documented track record for a defined application. Thus, both new technologies applied in known environment and known technologies applied in new environment are included within the novel technology concept.

Novel technologies are considered fit for service when supporting evidence demonstrates that they fulfil all the requirements of functionality, safety, reliability, availability and maintainability defined in the Technology Qualification (TQ) basis, i.e. specified criteria, boundary conditions and interface requirements.

The systematic and documented process of qualification encompasses examination of the design, engineering analyses and testing programs.

Preliminary steps for the evaluation of the novel technology are reported below:

- the novel technology is subdivided into subsystems and components by means of system schematics and P&ID. Particularly, attention is focused on manufacturing, installation, and operation processes concerning subsystems and components.
- the possible novelty of each subsystem and component is investigated
- the main challenges and uncertainties faced by the novel technology are identified

The main steps the TQP is based on are listed in the following:

- risk and safety assessment aimed at identifying, ranking and controlling failure modes that possibly compromise the fitness for service of the novel technology
- engineering analyses to demonstrate that all specific requirements for intended service are met by the design of the novel technology
- measurements and tests to support evidence that the novel technology fulfils the specified requirements for its intended service
- functionality assessment aimed at ensuring that the functional requirements as well as the safety, reliability, availability and maintainability criteria are fulfilled.

As far as the first step is concerned, risk and safety aspects of the novel technology are to be assessed applying well established techniques to investigate compliance with regulations. Attention is here focused on the events possibly affecting the fitness for service of the novel technology as well as its interfaces with the ship systems based on already proven technologies.

The risk assessment is typically carried out as follows:

- hazards are identified
- risks are assessed against the defined acceptance criteria and interfaces with other ship systems
- risk control options (RCO) are defined. In detail, strategies of prevention, mitigation or a possible combination of them are built up; the risk is to be reduced according to the ALARP principle, to settle it to acceptable levels
- the overall study is documented

Examples of potential hazards to be accounted for within the risk assessment are:

- extreme weather, influencing maximum ship motions, accelerations, inclinations, temperatures
- mechanical damage, possibly leading to liquid/gas release or progressive ship flooding
- fire and/or explosion
- release of flammable or toxic gases
- release of cryogenic liquids or gases
- loss of electrical power supply with negative impact on ship essential services
- failures related to single or possibly multiple systems onboard

Technical outcomes provided by the systematic application of TQP include:

- Description of the technology to be qualified together with its boundaries
- Detailed information on the operational conditions and corresponding constraints related to the novel technology
- Definition of the functional requirements the novel technology deals with

- Formulation of the safety, reliability, availability and maintainability criteria to be adopted for the novel technology

The information reported above is successively used as input to define the specifications concerning the design, manufacturing and installation of the novel technology. Analogously, the maintenance schedule is defined in a lifecycle perspective.

Official statement declaring that the novel technology is fit for service on the TQ basis is finally issued as positive outcome of the TQP, in the form of a certificate, class notation or equivalent document. The appropriate documentation reported below must be included with the aim of supporting evidence of fitness-for-service concept:

- system specifications, drawings, technical reports, design calculations
- applicable rules, regulations and standards
- survey requirements for construction/installation/commissioning
- operational instructions in normal and in emergency situations
- maintenance requirements

Additionally, requirements in terms of crew training and/or personnel certification are to be possibly inserted in the TQP documentation.

Detailed insight into the application of Technology Qualification Process can be found in the RINA guidelines (GUI16) “Guide for Technology Qualification Processes” [8] and both the IMO MSC/Circ. 1002 “Guidelines for alternative design and arrangements for fire safety” and the IMO MSC.1/Circ.1212 “Guidelines on Alternative Design and Arrangements for SOLAS Ch II-1 and III”

[20] shall be taken into account.

5.1 Current rules

In recent times, the WASP technology has started to be covered by class rules. The intention of this Approval in Principle is to define the regulations to be applied. Some of the WASP component can be anyhow reviewed under the actual rules, such as Rules for Testing and Certification of Marine Materials and Equipment NC/C.57 [13], where the procedures to be applied on equipment nonspecific covered by RINA Rules for classification of ships [11] are specified.

Besides, RINA Part C Machinery, Systems and Fire Protection [11] can cover some equipment/components, for example the electrical part of the WASP and can define tests and trials for the system approval.

As a general rule, all materials, machinery, boilers, auxiliary installations, equipment, items, etc., which are covered by the class and used or fitted on board ships surveyed by the Society during construction, are to be new and, where intended for essential services, tested by the Society.

5.2 Approval In Principle (AiP) of the WASP system

5.2.1 Additional class notation

An additional class notation expresses the classification of additional equipment or specific arrangement, which has been requested by the Interested Party.

The additional class notation for Wind Assisted Propulsion System can be assigned, in accordance with the RINA Rules for the Classification of Ships Pt A, Ch 1, Sec 2 [11], to ships with a wind propulsion system complying with the requirements of this Section.

In this chapter, the following wording WASP (Wind Assisted Ship Propulsion), will be replaced by WAPS (Wind Assisted Propulsion system) without any change in terms of meaning for the system. This substitution is made in order to match the class notation already being used in RINA rules for Ships - Part F 1.1.2024 [12].

A system (WAPS) is a mechanical device able to convert the kinetic energy of the wind into thrust or electrical power for the propulsion of the ship, thus reducing the fuel consumption and the GHG emissions from the internal combustion engines.

The WAPS system is considered as an additional propulsion system, not essential for the safety and the navigation of the ship.

Depending on the available effective power of the WAPS - calculated according to the IMO MEPC.1/Circ.896 [21], as amended - the WAPS notation is assigned as follows:

- WAPS-A (Auxiliary) when the available effective power of the WAPS is equal or less than 15% of the propulsion power
- WAPS-H (Hybrid) when the available effective power of the WAPS is more than 15% and equal or less than 60% of the propulsion power
- WAPS-M (Main) when the available effective power of the WAPS is more than 60% of the propulsion power.

The WAPS may be based on different technologies (e.g. sails, wing-sails, kite-sails, Flettner rotors, wind turbines) and the WAPS notation may be completed with the commercial denomination of the technology identifying the type of installation.

The propulsion power is to be calculated according to the IMO MEPC.308(73) "2018 guidelines on the method of calculation of the attained energy efficiency design index (EEDI) for new ships" [22] or according to the IMO MEPC.333(76) "2021 Guidelines on the method of calculation of the attained energy efficiency existing ship index (EEXI)" [23]. For those ships not subject to EEDI and EEXI MARPOL Annex VI regulations, an alternative method for the calculation of the available effective power and of the propulsion power may be accepted on a case-by-case basis.

Alternative arrangements, designs and technologies not expressly mentioned or not in compliance with the following perspective requirements may be accepted on a case-by-case basis, provided that they are subject to a risk assessment.

5.2.2 Documentation to be submitted

These documents are intended to be relevant to the WAPS, unless otherwise specified. The list of documents requested is to be intended as guidance for the complete set of information to be submitted, rather than an actual list of titles. The Society reserves the right to request the submission of additional documents in the case of non-conventional design or, if it is deemed necessary, for the evaluation of the system, equipment or components.

The documents to be submitted are, only for information purposes:

- General arrangement of the wind assisted propulsion system including the location and the layout of electrical and hydraulic components
- Description of the actuation system and of the safety system preventing overloads on the WAPS system
- Forces distribution at the design conditions, as applicable for the WAPS components transmitting thrust or torque
- Report on the aerodynamic testing of the profiles (if any)
- Risk Assessment Report (HAZID, FMECA or HAZOP)
- Information about the shrouds and stays pre-tensioning values, specifying the pre-tensioning control process at construction and in operation (if any) for WAPS with sails as applicable
- Power supply wiring diagram of the electrical installations intended to power the WAPS system and the operating running rigging system (if any)
- Strength Calculation of all WAPS main components transmitting forces
- EEDI or EEXI preliminary technical file including the WAPS available effective power and its comparison with the propulsion power
- Master Instruction for the use of WAPS (e.g. sailing table)

The documents to be submitted for the approval are:

- Operating manual including procedures for emergency operation and allowable weather conditions for the use of WAPS
- Block Diagram for the control, monitoring and safety system
- Construction drawings of the standing rigging structure, specifying the materials and connections between the different elements of the standing rigging for WAPS with sails as applicable
- Construction drawings of the running rigging structure specifying the materials and the mechanical characteristics of the different elements of the running rigging for WAPS with sails as applicable
- Information about halyard, sheet ropes characteristics and sail furling devices (if any) for WAPS with sails as applicable
- Information of chain plates, pad eyes and similar elements supporting the forces reactions induced by the standing rigging WAPS with sails as applicable
- Characteristics of winch, clutch, sheet track rails and osupports transmitting the forces reactions induced by the running rigging for WAPS with sails as applicable
- Local hull structure reinforcements in way of WAPS foundation, specifying the forces reactions induced by the running rigging (winch, clutch, sheet track rails, sheave sup- ports, if any) as applicable
- Piping diagram of hydraulic installations intended to power the WAPS system and the operating running rigging system (if any)
- Mast rotating system and its equipment, system of measurement of the strain gauge and all systems provided as automatic release systems to avoid wind overload on the WAPS system when taken into account for the scantling of the standing rigging
- Operating and Maintenance Manual (OMM) including a corrosion protection plan for WAPS elements

5.2.3 Design requirements

The connections between the WAPS system and the outer hull plating, ordinary stiffeners and/or primary supporting members are to comply with the requirements of Pt B, Ch.7, [11] taking also into account the local and hull girder loads described in Pt B, Ch 5 [11]. The scantlings of main WAPS components and of the connection elements for the different design cases are to be checked for yielding, buckling and fatigue strength, using:

- WAPS loads defined by the designer (in operational and extreme cases), taking into account lift and drag induced by apparent wind with gusts effect (specifying the associated combination of the WAPS configurations and the wind angle of attack), applicable wind speed profile, reactions forces on mast and boom induced by halyards or hooks, main sheet and pre- tensioning forces when provided in rigging elements (e.g. shrouds, stays).
- Acceleration loads defined by the designer (in operational and extreme cases), considering the ship motions in the longitudinal, vertical and transversal directions with reference to Pt B, Ch 5, Sec 3 [11] and applicable navigation notation according to Pt A, Ch 1 [11]. The acceleration in case of a collision event is also to be taken into consideration.
- Accidental loads set(s) from the scenario(s) as defined by the designer and identified in the risk assessment.
- Resulting additional hull girder loads applied by the WAPS system to the hull, if not negligible (depending on the WAPS technology selected). If the additional hull girder loads are not negligible, the checks of Pt B, Ch 6 [11] are to combine them in the most unfavourable conditions with the other hull girder loads for both yielding and buckling strength requirements.

Structure and outfitting

All the structures of the WAPS exposed to atmosphere are to be protected against corrosion and a corrosion protection plan is to be available on board. Coatings or other protective measures (e.g. corrosion addition) and identification of structural members more sensitive to corrosion are to be evaluated in the risk assessment. Hull structures supporting WAPS are to be designed with a corrosion addition as defined in Pt B, Ch 10, Sec 4 [11].

The characteristics of the steel or aluminium materials to be used in the construction of WAPS components (e.g. masts, booms, wings, rotors) are to be in line with the requirements specified in Pt B, Ch 4, Sec 1 [11]. The use of composite materials for blades, wings and sails and other components may be accepted case-by-case if these are type approved according to the RINA "Rules for the Type Approval of Components of Composite Materials Intended for Hull Construction" [14].

Other materials may be considered on a case-by-case basis by the Society.

For ships intended to operate in areas with low air temperatures (below -10°C), e.g. regular service during winter seasons in Arctic or Antarctic waters, the steel materials in exposed WAPS structures are to be selected according to Pt B, Ch 4, Sec 1 [11].

Rigging elements are to be designed, tested and inspected according to RINA "Rules for the masting and rigging of sailings ships" [15] and RINA "Rules for the certification of sailing rigs" [16], as far as applicable and practicable. Alternative methods for the design and testing of rigging may be evaluated on a case-by-case basis by the Society.

Steel wire ropes and fibre ropes for rigging are to be manufactured and tested according to Pt D, Ch 4, Sec 1 [11].

For the calculation of the Equipment Number (EN) as established in Pt B, Ch 10, Sec 4 [11] the additional projected area of WAPS system as foreseen in anchoring condition (i.e. not in sailing condition) is to be duly taken into consideration if the WAPS elements are not tiltable or retractable.

The supporting hull structures of winches and windlasses used for the control of the WAPS system are to be designed to withstand the foreseen loads according to Pt B, Ch 10, Sec 4 [11] taking into account the accidental loads set(s), as identified in the required risk assessment.

Welded connections of the WAPS elements are to be verified according to RINA "Rules for Loading and Unloading Arrangements and for other Lifting Appliances on Board Ships" Ch 14 [17]. These welded connections are to be executed according to the approved plans, which includes a qualification of welding procedures as given in Pt D, Ch 5 [11].

Stability

Ships fitted with a WAPS system are to comply with the intact stability requirements in Pt B, Ch 3 [11] and possible additional requirements from the Administration. In general, two types of WAPS ships are identified:

A. WAPS type I ship:

- Small aerodynamic driving force compared to the propeller thrust
- Small "sail area" compared to hull windage area
- Small heel angle due to aerodynamic heeling moment
- Stability verified according to the Intact stability criteria based on IMO Resolution A.562(14) "Recommendation on a severe wind and rolling criterion (Weather Criterion) for the intact stability of passenger and cargo ships of 24 metres in length and over" [24]
- Low inertia response to gusts
- Aerodynamic heeling moment can be counteracted using transverse ballast adjustments.

B. WAPS type II ship:

- Large aerodynamic driving force compared to the propeller thrust
- Large "sail area" compared to the hull windage area
- Large heel angle due to the aerodynamic heeling moment
- Stability verified according to Intact stability criteria based on IMO Resolution A.562(14) "Recommendation on a severe wind and rolling criterion (Weather Criterion) for the intact stability of passenger and cargo ships of 24 metres in length and over" [24]
- High inertia response to gust. The calculation of heeling moment may be carried out for a specific wind profile, whereas the sailing surface may vary upon Master adjustment.
- Aerodynamic heeling moment can be counteracted using transverse ballast adjustments.

The additional projected lateral area (wind profile), the icing accretion (if any), the added weight and centre of gravity due to the WAPS system installation are to be considered in the intact stability calculation.

The adverse impact of the additional heeling moment generated by any aerodynamic effect is to be considered in the intact stability calculations.

The trim and stability booklet is to include additional guidance for the operation of the wind assistance equipment. The need to include considerations for operational envelopes or 'weather windows' for their deployment and retrieval will be dependent on the system installed. Intermediate settings of the wind propulsion system, between fully deployed and fully retrieved conditions is also to be duly taken into account in the guidance.

A wind force, to cover an extreme wind condition and the expected operational envelope, is to be agreed with the Society and is to be used to assess an additional wind heeling moment. Wind forces can be obtained from the following documents, however the value(s) used is(are) to be confirmed also with the Administration:

- MEPC.1/Circ.896 "2021 Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI and EEXI" [21].
- MSC.1/Circ.1200 "Interim Guidelines for Alternative Assessment of the Weather Criterion" [25].

The wind heeling moment is to be used to assess the intact stability in line with section 2.3 of Part A of the 2008 IS Code [26].

In case of multiple WAPS multiple, a supporting evidence that combinations of forces and moments generated by the sails on the vessel do not negatively influence the intact stability and the manoeuvrability is to be provided, depending on the specific arrangement adopted for the sails. Additionally, if the sails are arranged in such a way that they shelter one another, variations of wind loads on them are to be accounted for by means of properly defined sheltering coefficients (i.e. wake effect).

Machinery

The general requirements of Pt C, Ch 1, Sec 1 [11] are applicable as far as practicable where the WAPS machinery items are considered not essential for the propulsion and the safety of the ship.

Machinery items like drive and safety systems needed for the safe control or emergency operation of the WAPS system are considered as essential, so that any single failure does not to lead to an unsafe status for the WAPS. The critical machinery items are to be identified during the risk assessment required.

Hydraulic systems used for the movement of the WAPS elements (e.g. tilting or driving systems including hydraulic components as motors, cylinders, pistons) are to comply with Pt C, Ch 1, Sec 10 and Pt C, Ch.1, Sec.3 [11]. In case the tilting system is considered essential for the vessel, in order to survive the worst scenario identified in the risk assessment, at least two hydraulic power units and two actuating units (e.g. motors, cylinders) are to be provided with independent piping system or equivalent arrangement, subject to a single failure analysis of passive components (e.g. pipes) and active components (e.g. valves, pumps).

In general, all auxiliary piping systems (e.g. lubricating oil, cooling water, compressed air) relevant to the WAPS are to be designed, built, installed and tested according to Pt C, Ch 1, Sec 10 [11].

The hydraulic cylinders used for the tilting or driving system of WAPS are to be designed and tested according to Pt C, Ch 1, Sec 3 [11].

Retracted or tilted WAPS elements are to be provided with securing and locking arrangements, which are to be simple to operate and easily accessible. The securing and locking devices are to be interlocked in such a way that they can be only operated in the proper sequence. Where hydraulic securing devices are present, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when the WAPS is in tilted or retracted position.

Electrical installations

The electrical installations and the relevant electrical components for the WAPS system are to be designed and constructed according to the requirements in Pt C, Ch 2 [11].

In case the tilting system is considered as essential for the vessel, in order to survive the worst scenario identified in the risk assessment, at least two electrical power supplies and two actuating units (e.g. e-motors) are to be provided.

As far as practicable, the electrical installations intended for the WAPS system are not to be located in hazardous areas. In case it is not possible to avoid installation in hazardous areas, they are to be in compliance with the relevant risks and hazards valuated in the risk assessment.

Control, Monitoring, Alarm and Safety Systems

Automatic control, alarm, and safety functions are to be provided for the wind propulsion system so that the operations remain within the preset parameters for different operation conditions. The system is to be designed to avoid a single failure event leading to a potentially dangerous situation. In the event of failure in the WAPS system control, an alarm is to be activated. The design of the WAPS automation is to avoid that failures or malfunctions can cause danger to other essential services.

All alarms of the WAPS system are to be triggered from a manned control station. The control positions are to be inaccessible to unauthorised persons and must be located in a way to provide an appropriate visibility of the WAPS system to be operated.

Computer based systems of the WAPS technology, which provide control, alarm, monitoring, or internal communication functions, are to be in compliance with the requirements specified in Pt C, Ch 3, Sec 3 [11] for category II computer systems. The computer systems that provide safety functions are to be assessed in the risk assessment, to define their proper category.

The WAPS system control is to be performed by a single control device at the active control station indicating all the alarms and provided with an emergency stopping device, able to put the WAPS in a safe status (less wind resistance or sail furling) in case of the control system failure. Additionally, the WAPS is to be protected by a safety system, which is automatically activated in the event of identified conditions leading to a damage of the associated machinery, WAPS elements or structural part. The safety system is to be capable of:

- restoring the normal functioning of WAPS (e.g. starting of stand-by components like pumps, motors)
- adjusting the configuration of WAPS elements to avoid overload (e.g. reducing the tension of lines for sails and kites, changing position of wings or rotor spin speed)

- bringing the WAPS in a safe configuration where wind forces are reduced as much as possible on the structures (e.g. furling/trimming of sails, stopping flattener rotor, neutral position of wings).

The WAPS integrated safety system is to have the following characteristics:

- self-monitoring type in respect of internal failures
- "fail safe" design, so that any failure cannot result in an unsafe status for the WAPS
- independent from control and alarm system
- compliant with Pt C, Ch 3. Sec 2 [11].

Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel. to show that the WAPS is tilted or retracted and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function or equivalent means. It is not to be possible to turn off the indicator light. The indicator system is to be designed on the fail-safe principle where the panel is provided with power failure alarm, earth failure alarm and indication of tilted/retracted WAPS elements and properly locked. The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

5.2.4 Operation and maintenance

An Operating and Maintenance Manual (OMM) for the WAPS system is to be provided on board and must contain necessary information on:

a) main particulars and technical drawings of the WAPS system, including:

- description of the technology and its functioning theory
- block diagram of automation and HMI description
- power supply single line diagram
- safety precautions for the normal and emergency operation
- details of sailing configurations
- list of components (e.g. winches, ropes, wires, cylinders, motors) relevant to the rigging and tilting system
- critical machinery items considered as essential
- manufacturer's technical data sheets of the components transmitting forces

b) operating conditions envelop

- WAPS emergency operating instructions
- sailing operating conditions depending on weather
- operational restrictions for the WAPS
- safety system activation
- ship heel and trim restrictions for the safe operation of WAPS

c) maintenance

- annual, intermediate, renewal inspections for the WAPS elements
- corrosion protection scheme for the WAPS elements
- maintenance intervals for the WAPS components
- manufacturer's maintenance instructions

d) record of inspections

- annual, intermediate, renewal inspections for the WAPS elements
- indications for the visual inspection of locking/securing devices, tilting system, rigging and supporting structure
- verification criteria for the visual inspections
- record of damages and repair.

5.2.5 System tests

A detailed testing program is to be approved by the society and it is to include:

- visual inspection of the mechanical and electrical installations, according to the approved drawings
- pre-sea trials tests with the scope to verify the correct functioning of all WAPS elements at quay
- sea trials with the aim to verify the safe operation of the WAPS system at different configurations
- recording of the performances with WAPS on (active) and off (tilted or retracted) during navigation at established service speed of the ship
- all operational modes and configurations of WAPS foreseen during the navigation
- manoeuvrability tests with WAPS on (active) and off (tilted or retracted)
- emergency stop/shutdown of the WAPS elements from control station

The piping system, electrical components, hydraulic cylinders and pressure vessels are to be tested according to the requirements present in the relevant rules sectors.

After sea trials all the relevant testing protocols are to be kept on board together with the operating and maintenance manual.

6 Conclusions

In the previous sections of this deliverable the Standards, Rules and Regulations applicable to marine systems have been reviewed. In addition, an overview of the certifications that may be issued by Classification Societies has been provided to leverage the commercial impact of the project results and to drive further innovation, creating value for both industry and regulators.

Examples of codes regulating statutory aspects are the International Convention for the Safety of Life at Sea (SOLAS), the International Convention for the Prevention of Pollution from Ships (MARPOL), Seafarers' Training, Certification and Watchkeeping (STCW), High-Speed Craft (HSC) code, etc. whose validity and restrictions depend on the type and size of vessel are considered. It should be recalled here that the statutory requirements for safety are more stringent and detailed for passenger ships, thus making the assessment even more complicated.

This deliverable provides guidance on the as-is regulatory framework and its application, useful from the concept design, encompassing the engineering phases, testing, validation and integration onboard of marine equipment for the benefit of manufacturers, shipyards and shipowners.

Furthermore, the lessons learnt throughout the development of the RETROFIT55 activities, and the data from the test case ships will be collected and noted at a later stage, supplementing the current situation, to possibly suggest new future standards and solutions to policymaker, to fill possible regulatory gaps and promote a widespread diffusion of WASP systems.

Overall, although WASP appear to possibly contribute to the reduction of environmental impact of the waterborne transport, attention is to be paid on challenges arising from their integration onboard, which requires a careful case-by-case approach.

A tailored assessment of the impact of new technologies installed onboard should be carried out independently for each specific vessel, not only to verify compliance with the statutory aspects (IMO) by the Flag Administration or by Recognized Organizations, but also to help ship owners/operators to correctly estimate the CAPEX, OPEX and ROI in new ships or when retrofitting the existing fleet.

In general, by adopting a compartment or space-by-space based approach, statutory aspects concerning safety include the following points, but not limited to:

- identify candidate positions to set up the novel systems, taking into account the general layout of the ship, its services (including those required by the new technology) and possible interferences
- classify spaces according to their criticality for safety, i.e. based on which systems and services are contained and/or pass through them. Specifically, this point should consider the arrangement of compartments limited by watertight or "A" class boundaries, as well as location of active/passive fire protection systems
- evaluate the existence of possible constraints and requirements for the arrangement and operation of systems used for fire/flooding detection and of monitoring and safety systems
- define ventilation requirements for spaces where novel technologies are installed onboard and evaluate the impact of ventilation duct routing, as well as inlet/outlet locations on the general layout of the ship
- assess the level of automation and remote-control functionality required for governing novel technologies and ensuring their safe operation

- guarantee safe access to components or equipment requiring manual actions for restoration or maintenance
- verify power supply for the novel technologies and the routing of related cables
- assess protections, piping systems of sea chest, valves, provision for shut down/start, air vents and air intakes, necessary to ensure a safe and correct operation of the systems
- suggest training programs for seafarers aimed at increasing competence on novel systems

In conclusion, since the verification of compliance with all the statutory aspects requires a detailed analysis and is different for each vessel considered, it cannot be reported exhaustively in this deliverable. However, it must be assessed very carefully on a case-by-case basis by the Flag Administration or RO appointed by it.

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