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		Date:	2018-01-30 Gerd Petra Haugom
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[Copied to]			

APPLICABLE RULES FOR HYDROGEN FUEL CELL HIGH SPEED PASSENGER VESSELS IN NORWAY

1 SUMMARY

As part of their aim towards zero emission high speed passenger vessels, Trøndelag County Municipality has initiated a R&D competition. The target routes being considered are between Trondheim – Vanvikan, Trondheim – Brekstad, and Trondheim Kristiansund. It is expected that fuel cells operating on hydrogen might be part of the solution. Today maritime hydrogen specific rules are not available. Therefore, general rules have to be applied.

DNV GL has been commissioned by Trøndelag County Municipality to prepare a summary of applicable general rules for hydrogen and fuel cells for the participants in the ongoing R&D competition. This memo therefore provides an introduction to the general rules and regulations that Norwegian high speed passenger vessels and other ships with fuel cells operating on hydrogen need to consider.

The memo outlines the current understanding of the rules based on available experience, and it focuses on the early stages of the project development. This is the project phase where the preliminary design of the concept is developed. An approval of preliminary design can be granted at the completion of this phase. When this is completed, the project can move into the final design phase. Although this memo introduces the main steps in the whole approval process, the requirements to obtain a final approval is not part of the scope.

The Norwegian regulation FOR-2016-12-27-1883 (2016) is applicable for ships wanting to use fuels with flash point below 60 °C (Low-Flashpoint Fuels), and anybody wanting to use hydrogen on board a Norwegian flagged ship needs to familiarise with these rules. This Norwegian regulation makes the IGF Code compulsory for all hydrogen fuel cells ships under the Norwegian Flag. In line with the requirements in the IGF Code and the Alternative Design Process outlined in MSC.1/Circ. 1455, the Norwegian regulation requires that the overall safety level is as high as for conventional oil-powered machinery. And it gives requirements for risk analysis and explosion analysis.

The use of this general framework is expected to create a comprehensive and rather expensive design and approval process for each maritime hydrogen project.

2 INTRODUCTION

Trøndelag County Municipality has initiated a development project where the use of fuel cells and hydrogen as fuel in high speed passenger vessels are considered. The project is in an early phase, but it has become clear that it is important that the participants become aware of applicable rules and that they understand the implications of these.

Quite a few of the early hydrogen projects, e.g. for hydrogen filling stations, hydrogen cars and hydrogen in ship-based applications[1, 2, 3], have experienced challenges in gaining the required approvals to operate. It is known that there are significant gaps in the rules concerning the use of hydrogen and fuel cells in shipping (EMSA, 2017). The IGF Code enables the use of low flashpoint fuels, such as hydrogen, in shipping, by providing high-level requirements. These requirements are not prescriptive. So far, the IGF Code has mainly been applied for natural gas, and therefore the experience with using the IGF Code for hydrogen is very limited.

This memo describes the overall approval process, with main focus on the first phase (towards Preliminary Approval). The available rules for the use of hydrogen and fuel cell systems on vessels are described. It is assumed that the rest of the vessel is covered by existing rules. If other parts of a vessel is not covered by existing rules, these might also be subject to, either part of, or the overall approval process outlined in Chapter 2.1 and Figure 3. This will depend on the specific case. There might be different levels of approval depending on how challenging the proposed alternative and/or equivalent design is in light of prescriptive regulations. Chapter 2.1 gives a high-level introduction to the approval process. Chapter 4 describes the applicable rules and regulations and the studies these refer to as needed as part of the approval process. As the rules, the safety concerns and the approval process are different than for conventional vessels, some recommendations on competence requirements are included in Chapter 5. The documentation requirements are listed in Chapter 6.

This is a high-level document covering the regulatory situation in Norway for planned ferries/passenger vessels planned to operate with hydrogen, prepared by DNV GL in close cooperation with the Norwegian Maritime Authority (NMA)[4]. The basis is that such vessels will need to be approved by the Norwegian Maritime Authority (NMA) and that available DNV GL Class Rules will apply.

It should be noted that the situation might be different for projects selecting another Class Society that does not have rules for e.g. Battery Systems and Fuel Cells.

2.1 Hydrogen properties and safety

The properties associated with hydrogen need to be considered for a project involving hydrogen storage, bunkering of hydrogen, and/or on-board storage and utilisation of hydrogen.

Some safety related properties require special attention. This includes the low ignition energy, the wide flammability range, and that hydrogen is potentially explosive, as illustrated in Table 1.

A hydrogen explosion could be a secondary consequence from a hydrogen leak (and ignition) in an enclosed space, and this scenario might for certain conditions lead to high explosion overpressures.

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[1] Hybrid ferry enters service but awaits approval for hydrogen fuel cell. http://www.professionalmariner.com/April-2012/Hybrid-ferry-enters-service-but-awaits-approval-for-hydrogen-fuel-cell/

[2] Bergensferge først med brencelcelle. http://forskning.no/fangst-alternativ-energi-bil-og-trafikk-marin-teknologi-miljoteknologi/2010/10/bergensferge-forst

[3] Driftssesong MF Vågen. Transnova sluttrapport, 2010 https://docplayer.me/6415649-Transnova-p1-erstatte-fossilt-drivstoff-med-alternative-drivstoff-i-transportsektoren-prosjekttittel.html

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The table illustrates that the safety related properties regarding auto ignition and boiling point are comparable for hydrogen and methane. Hydrogen gas is a lot lighter than methane and the high buoyancy can be both an advantage and a challenge and it needs to be considered in design of hydrogen systems.

Compared to methane, the very low boiling point for hydrogen makes it more challenging (and energy consuming) to store hydrogen in liquid form. The properties of hydrogen need to be considered when selecting materials that will be in contact with hydrogen (e.g. to avoid hydrogen embrittlement and unwanted leaks).

Table 1: Comparison of safety related properties for hydrogen and methane (based on ISO/TR 15916).

Property	Hydrogen	Methane
Gas density (2 0°C and 100 kPa)	0.0827 kg/m^3	0.659 kg/m^3
Flammability range (25 °C, 101.3 kPa)	4 – 75 % vol fraction	4.4 – 17 % vol fraction
Auto ignition temperature	585 °C	537 °C
Minimum ignition energy	0.017 mJ	0.27 mJ
Boiling point	-253 °C	-161 °C

Reference is made to ISO/TR 15916 for further and more in-depth introduction to hydrogen and safety including specific aspects of hydrogen as a compressed gas and/or cryogenic liquid.

The above illustrate that well-structured risk assessments are important to identify, control and mitigate the potential risks related to hydrogen applications. Due to the potentially serious consequences in case of an explosion involving hydrogen, assessment of and implementation of risk controlling measures will be important. This is in line with the general requirements outlined in the IGF Code, Part A (para 4.2 and 4.3) and MSC.1/Circ 1455.

3 THE APPROVAL PROCESS

The approval process is separated in two main phases. The preliminary design phase, covered in this memo, is analysed in the first phase and the goal of this phase is to achieve an "Approval of preliminary design". Figure 1 shows the steps required towards an "Approval of preliminary design" and the illustration of the complete process provided in Chapter 7 shows how this fits into the total approval process for non-regulated fuels or systems. It is common that a statement of preliminary approval outlines requirements for further analysis or other conditions that need to be fulfilled in the next phase.

It should be noted that the issue of a "Statement of preliminary assessment" (also known as "Approval of Preliminary design" (ref. MSC.1/Circ. 1455) issued by the Administration does not imply that final approval will be granted.

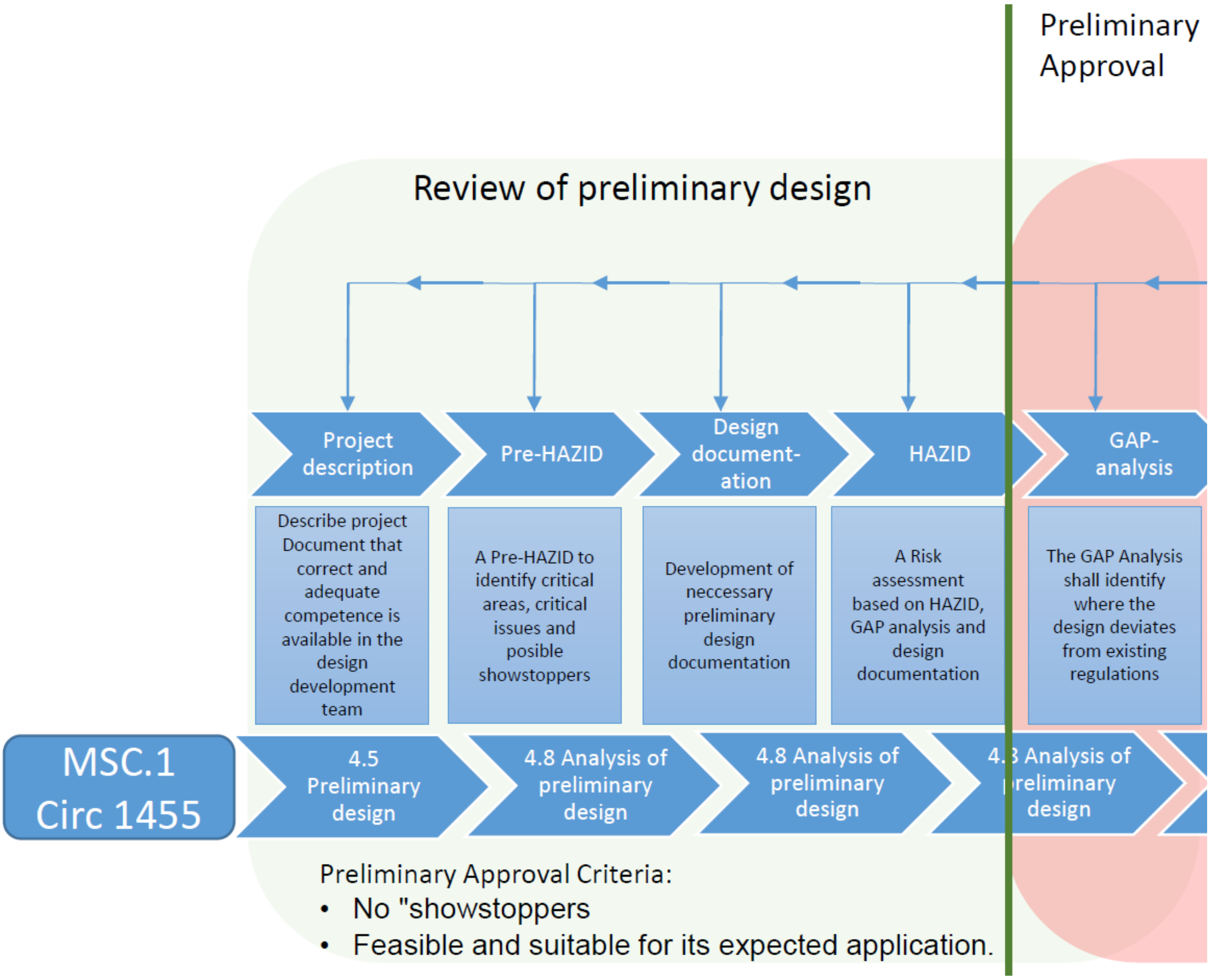


Figure 1: Overview of the process towards the issue of a "Statement of preliminary assessment", also known as "Approval of Preliminary design". The complete process for non-regulated fuels or systems are shown in Chapter 7 (source NMA).

The final design is analysed in the second phase. The overall Alternative Design process is described in detail in MSC.1/Circ.1455, and as illustrated in Figure 3 it includes the following milestones (1 and 2 is covered in this memo):

1. Development of a preliminary design
2. Approval of preliminary design
3. Development of final design
4. Final design testing and analyses
5. Approval

The final "Approval" is required to gain the approval from the Flag State (NMA). It should be noted that an "Approval" from a Class Society is not the same as the approval from the Flag State (NMA), unless the Class Society is Authorized by the Flag State (NMA) to act as a Recognized Organization as per

SOLAS X-1/1. The approval from the Flag State is the permission to sail that is needed before normal operation of the vessel can start.

According to MSC.1/Circ.1455, the overall approval process should consider among others, definition of the approval basis, HAZID (HAZard IDentification study), review of the approval basis after HAZID, and quantitative risk assessment.

The required approval process is challenging and as shown in Figure 3, the process requires a high degree of interaction between the Submitter (hydrogen project owner) and the Administration (Norwegian Flag State, i.e. the Norwegian Maritime Authorities). A range of specific documents have to be developed as part of this process.

The requirements described in Figure 3 and Figure 3 are the minimum requirements. The actual process will depend on the complexity and the features of the chosen concept and its design. Therefore, the process might identify need for further modifications of the requirements. Modifications and re-assessment of different steps should be expected during the approval process, and each phase could include a series of iterations. The degree of this will depend on the input and feedback from the Administration (Flag State) and the Submitter (project owner).

4 APPLICABLE RULES AND REGULATIONS

This chapter describes the applicable rules and regulations, and the studies needed as part of the approval process. The Norwegian regulation for ships using fuel with a flashpoint of less than 60 °C (FOR-2016-12-27-1883) is the document that formally makes the IGF code compulsory for all hydrogen fuel cells ships under the Norwegian Flag.

Existing class rules can ease the alternative design process, provided that the rules are acknowledged by the relevant Administration. DNV GLs Class Rules for Fuel Cell installations may be recognised as applicable input by NMA. The details of the alternative design process are given in MSC.1/Circ.1455.

It is to be noted that the DNV GL Rules for fuel cell installations cover the fuel cell installation only. The remaining installation arrangements for the use of hydrogen as fuel are not covered directly by the DNV GL rules.

4.1 Norwegian regulation for ships using fuel with a flashpoint of less than 60 °C

The Norwegian regulation FOR-2016-12-27-1883 (2016) is applicable for ships wanting to use fuels with flash point below 60 °C (Low-Flashpoint Fuels), and anybody wanting to use hydrogen on board a Norwegian flagged ship needs to familiarise with these rules.

FOR-2016-12-27-1883 (2016) makes the IGF code compulsory for all hydrogen fuel cells ships under the Norwegian Flag. The English version of the document is available on the NMA website (NMA, 2016).

In line with the requirements in the IGF Code and MSC.1/Circ. 1455, the Norwegian regulation requires that the overall safety level is as high as for conventional oil-powered machinery. And it gives requirements for risk analysis and explosion analysis.

4.1.1 Requirements to equipment

Section 3 in Regulation no. 1883, states that: …"*equipment constituting or forming a part of the tank or fuel system shall be accepted. Accepted equipment means equipment accepted by the Norwegian Maritime Authority based on approval or type-approval from:*

a) *a recognized classification society;*

b) *other public or private institution;*

c) *the administration of a State that has ratified the International Convention for the Safety of Life at Sea, 1974 (SOLAS 1974), as amended"*.

Product Certificate for main components are needed and these can be obtained from a classification authority: In particular, this is valid for the FC, valves, and hydrogen storage tanks.

4.2 IGF Code

The International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IGF Code), entered into force on the 1st of January 2017. As the IGF Code governs the use of low flashpoint liquids and gaseous fuels, it is applicable for hydrogen.

The IGF Code outlines an approach and provides requirements that makes it possible to gain approval for the use of hydrogen as a fuel in ships. The IGF Code contains two applicable main parts:

- Part A: General function-based requirements for low-flashpoint fuel installations
- A-1: Functional and prescriptive requirements for engine installations using natural gas as fuel

IGF Code Part A: 2.3 – Alternative Design

The IGF Code contains functional requirements for all appliances and arrangements related to the use of Low-Flashpoint fuels. Fuels, appliances and arrangements of low-flashpoint fuel systems may either:

1. deviate from those set out in the IGF Code, or
2. be designed for use of a fuel not specifically addressed in the IGF Code.

Low-Flashpoint fuels, appliances and arrangements can be used provided that these:

> **meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety, based on the requirements described in the relevant chapters of the Code.**

The text marked with "bold" describes the overall goal of the Alternative Design approval process. The equivalence of the alternative design shall be demonstrated as specified in SOLAS regulation II-1/55 and approved by the Administration. SOLAS regulation II-1/55 points to MSC.1/Circ 1455 (see chapter 4.4).

The Administration shall not allow operational methods or procedures to be applied as an alternative to a particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by the IGF Code.

IGF Code Part A: 3 – Goal and functional requirements

The overall goal of the IGF Code and the Alternative Design approach is that the safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery.

The IGF Code provides a list of functional requirements that must be fulfilled. This is not necessarily a complete list:

- The probability and consequences of fuel-related hazards shall be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions shall be initiated.
- The design philosophy shall ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.
- Hazardous areas shall be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.
- Equipment installed in hazardous areas shall be minimized to that required for operational purposes and shall be suitably and appropriately certified.
- Unintended accumulation of explosive, flammable or toxic gas concentrations shall be prevented.
- System components shall be protected against external damages.
- Sources of ignition in hazardous areas shall be minimized to reduce the probability of explosions.
- It shall be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system shall be designed to prevent venting under all normal operating conditions including idle periods.
- Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application shall be provided.
- Machinery, systems and components shall be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.
- Fuel containment system and machinery spaces containing source that might release gas into the space shall be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.
- Suitable control, alarm, monitoring and shutdown systems shall be provided to ensure safe and reliable operation.
- Fixed gas detection suitable for all spaces and areas concerned shall be arranged.
- Fire detection, protection and extinction measures appropriate to the hazards concerned shall be provided.
- Commissioning, trials and maintenance of fuel systems and gas utilization machinery shall satisfy the goal in terms of safety, availability and reliability.

- The technical documentation shall permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.
- A single failure in a technical system or component shall not lead to an unsafe or unreliable situation.

IGF Code Part A: 4.2 Risk assessment and 4.3 Limitations of explosion consequences

The goal of Chapter 4 of the IGF Code Part A is to ensure that the necessary assessments of the risks involved are carried out in order to eliminate or mitigate any adverse effect to the persons on board, the environment or the ship. It provides details regarding risk assessment and explosion consequences as quoted in the following:

4.2 Risk assessment

- *"4.2.1 A risk assessment shall be conducted to ensure that risks arising from the use of low-flashpoint fuels affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration shall be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure."*
- *"4.2.2 For ships to which part A-1 applies, the risk assessment required by 4.2.1 need only be conducted where explicitly required by paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10 as well as by paragraphs 4.4 and 6.8 of the annex."*
- *"4.2.3 The risks shall be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion and electric shock shall as a minimum be considered. The analysis shall ensure that risks are eliminated wherever possible. Risks which cannot be eliminated shall be mitigated as necessary. Details of risks, and the means by which they are mitigated, shall be documented to the satisfaction of the Administration."*

4.3 Limitation of explosion consequences

"An explosion in any space containing any potential sources of release[5] and potential ignition sources shall not:"

- *Cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs;*
- *damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;*
- *damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;*
- *disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;*
- *damage life-saving equipment or associated launching arrangements;*
- *disrupt the proper functioning of firefighting equipment located outside the explosion-damaged space;*

[5] *Double wall fuel pipes are not considered as potential sources of release.*

- *affect other areas of the ship in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise; or*
- *prevent persons access to life-saving appliances or impede escape routes."*

4.3 Rules and processes towards DNV GL Class approval

It is to be noted that only the fuel cell installation is covered by the DNV GL rules. The DNV GL fuel cell installations rules include requirements for the design and arrangement of fuel cell power installations and the spaces containing such installations. It covers all aspects of the installation from primary fuel supply up to, and including, the exhaust gas system. The remaining installation arrangements for the use of hydrogen as fuel i.e. the hydrogen fuel storage, and preparation and distribution of hydrogen are not covered directly by the DNV GL rules.

Figure 2 illustrates the qualification process from an Approval in Principle (AiP) to Approval.

Figure 2: Illustration of the qualification process from Approval in Principle (AiP) to Approval.

For the early phase of a project, it is possible to obtain an Approval in Principle (AiP) from DNV GL, see Section 4.3.2 for further details. An AiP can be an important step towards obtaining a Preliminary Approval.

Existing class rules can ease the alternative design process, provided that the rules are acknowledged by the relevant Administration. The Flag state will always evaluate the relevant systems as a whole. DNV GLs Class Rules for Fuel Cell installations may be recognised as applicable input by NMA.

The DNV GL Rules for fuel cell installations cover the fuel cell installation only. The remaining installation arrangements for the use of hydrogen as fuel are not covered directly by these rules. The following gives a brief introduction to DNV GL Class rules for fuel cell installations:

Part 6, Chapter 2 of DNV GLs Rules for Classification of ships is "Additional class notations" for "Propulsion, power generation and auxiliary systems". The following parts are relevant:

Section 3 – *Fuel cell installations* – FC

- Sets requirements for the FC power systems, design principles for FC spaces, fire safety, electrical systems, control, monitoring and safety systems, manufacture, workmanship and testing.
- It should be noted that Section 3 doesn't include any fuel specific requirements.

Two different class notations are possible, and which one that is applicable depends on the planned use of the fuel cell installation:

FC(Power)

- Given to ships that fulfil design requirements in the Rules, where FCs are used for essential-, important- or emergency services

FC(Safety)

- Given to ships that fulfil the environmental- and safety requirements in the Rules, where the FCs are not used for essential-, important- or emergency services.

4.3.1 Natural gas rules might provide guidance

The current DNV GL rules for gas fuelled ship installations "*Section 5 – Gas fuelled ship installations – Gas Fuelled"* are not applicable for hydrogen as fuel. Still, these rules have in some cases been used to provide guidance also for hydrogen. It is important to note that the rules are intended for natural gas that have different properties compared to hydrogen, and that the rules are written for internal combustion engines, boilers and gas turbines, not for fuel cell installations.

4.3.2 The process towards an Approval in Principle (AiP)

Approval in Principle (AiP) is recognized as an early phase verification level for new design concepts or for existing designs in new applications. An AiP is a stand-alone process, but it may be followed by a General Approval for Ship Application (GASA). The AiP will typically identify technical items or issues that will need to be addressed during detailed design to prepare the design for Classification Approval.

The review process for an AiP is usually initiated by a meeting between DNV GL and the designer. In this meeting the novel design is presented, and the intended application specified. DNV GL may request specific information to evaluate the novelty of the design and define the scope of the AiP review.

The initial meeting will normally be used by DNV GL to decide on the required scope of documentation.

Based on this, the designer needs to prepare a document list that is their interpretation of what documentation that will cover the requested information. It is often an advantage that the designer and DNV GL maintain a close communication and discuss issues and uncertainties and provide feedback. The list of required documentation can be modified during the process based on new knowledge. When the final package of documentation is submitted, DNV GL will evaluate the design based on this information and the AiP principles.

It needs to be acknowledged that significant economic and technical efforts are required from a designer to issue the requested documentation for an AiP review. The results from an AiP process is therefore an important milestone for a designer.

If an AiP is granted, three documents are issued:

- Approval in Principle Statement
    - Document that confirms compliance with the AiP requirements and specifies the rules that have been used for the review and state the assumptions made in the evaluation.
- Approval in Principle Letter
    - Describes the design that the AiP review covers, its limitations, assumptions and the basis for the review. The letter describes the assumptions in more detail than the AiP statement.
    - If an AiP is not granted, the reasoning will be included in the Approval in Principle Letter.

- Appendix
  - The Appendix normally summarize all the comments to the provided documentation.
  - These comments need to be addressed for the final approval of an installation onboard a ship, the General Approval for Ship Application (GASA) or at the new building approval.

4.4 Alternative Design Process (MSC.1/Circ.1455)

The document "Guidelines for the approval of alternatives and equivalents as provided for in various IMO instruments" (MSC.1/Circ.1455) is a key document to understand the approval process required for a hydrogen fuelled ship. The process described in MSC.1/Circ.1455 and visualised in Figure 3 is applicable for all alternative design processes, and it describes the details of the Alternative Design process that have to be followed. It is a challenging and complicated process requiring close interaction between the Submitter and the Administration.

MSC.1/Circ 1455 provides a definition of "*Novel/new technology or design*" that is relevant for hydrogen. A "*new technology is a technology that has no documented track record in a given field of application, i.e. there is no documentation that can provide confidence in the technology from practical operations, with respect to the ability of the technology to meet specified functional requirements. This implies that a new technology either is a:*

- *technology that has no track record in a known field;*
- *proven technology in a new environment; or*
- *technology that has no track record in a new environment."*

The specific documentation requirements are outlined in Chapter 6.

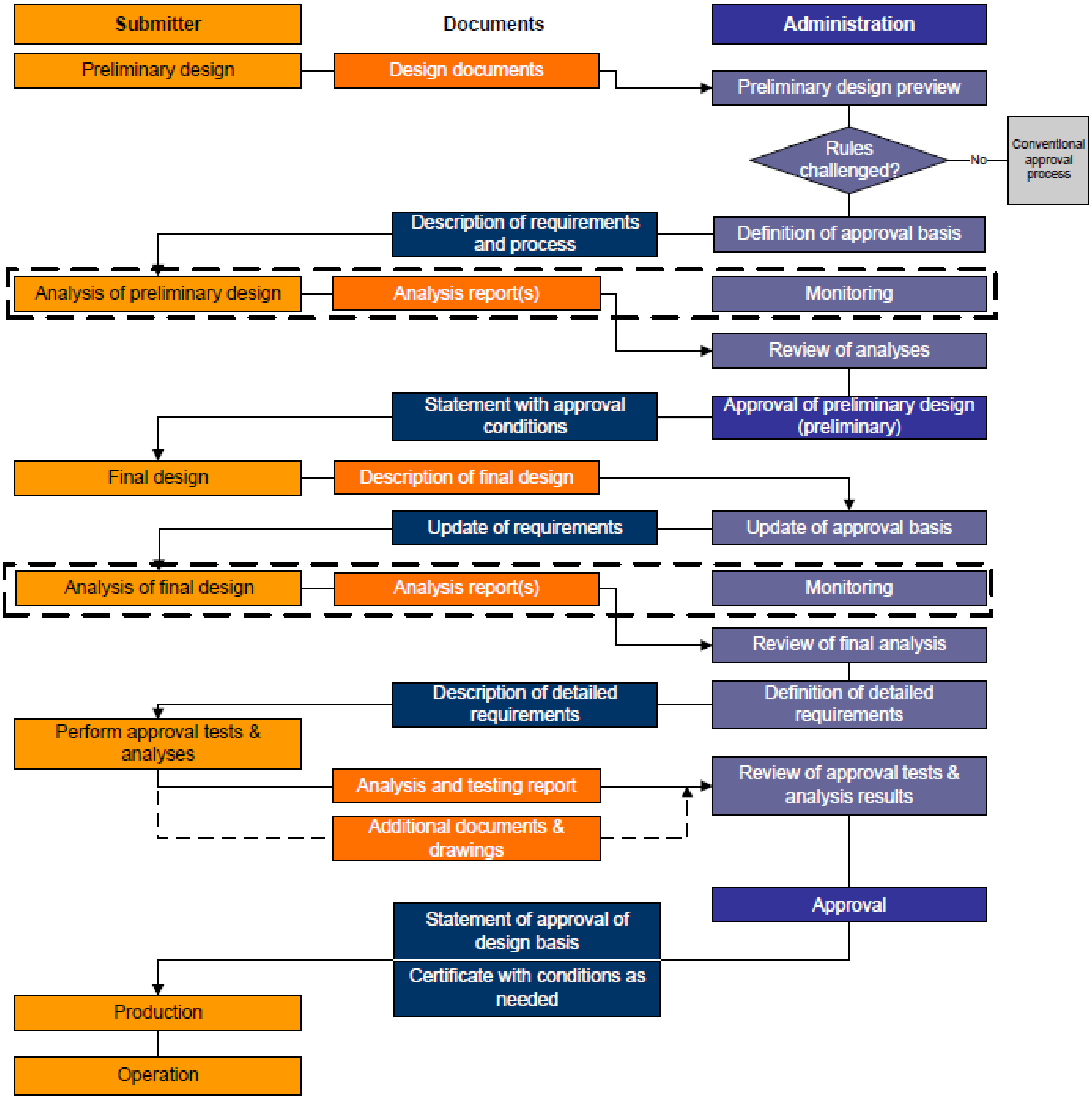


Figure 3: Overview of the approval procedure required according to the Alternative Design approach (ref. MSC.1/Circ.1455), describing the roles of the Administration (Flag State) and the Submitter (project owner).

Some of the key elements preliminary design and approval phase are described in the following. It is recommended to consult MSC.1/1455 during the process.

4.4.1 Preliminary approval

The purpose of the preliminary approval is to verify that the alternative is feasible and sound and suitable for its expected application. As shown in Figure 1, this can be expected to be an iterative process. A pre-HAZID and early phase assessments shall if possible identify possible showstoppers. If any showstoppers are identified in this phase, a re-evaluation of the preliminary design with possible improvements would be needed prior to granting the preliminary approval. The HAZID is a central part of this process and the basis for providing sufficient documentation for this. Part of this preliminary approval process is to document that there is sufficient and appropriate knowledge and competence within the project organisation and project team.

4.4.1.1 HAZID

The HAZID is an important part of the preliminary approval process, and it is essential that the HAZID team and competence is adequate. This includes competence from the relevant design and engineering disciplines, operation, hydrogen technologies, hydrogen properties, and hydrogen safety. Key requirements for the HAZID are outlined in Chapter 4.8 in MSC.1/Circ. 1455.

The following outlines the minimum competence requirements that have to be included in the HAZID team and in the HAZID workshop to ensure that the HAZID results are credible and that possible showstoppers are identified:

- HAZID facilitator
- Hydrogen safety expertise (hydrogen safety properties, leaks, fires and explosions; simulation tools for hydrogen leaks, fires and explosion)
- Simulation tools for hydrogen systems and safety
- Equipment suppliers, in particular fuel cell system, hydrogen storage system and bunkering system suppliers
- Ship and system designers
- Ship owner
- Hydrogen supplier (bunkering provider)
- The Administration (Flag state)
- Class Society

Further input on safety assessment and Hazard identification principles are outlined in Appendix B of DNVGL-OS-A101.

The HAZID results should be documented in a HAZID report and the report should be submitted to the Administration (Flag state).

Depending on the scope defined by the Submitter and the Administration, the preliminary design analyses might include a risk assessment. If so, a coarse risk model should be developed based on the HAZID.

5 COMPETENCE REQUIREMENTS

It is central success criteria to have adequate competence available in the project team. The project (submitter) may be asked to supply details regarding the knowledge and experience of their project team members and other participants, e.g. in the HAZID, to the Administration.

It is recommended that the project includes resources with competence regarding hydrogen safety and applicable hydrogen rules.

The project needs to have competence available to evaluate the relevant hydrogen technologies and their maturity, expected performance and durability, i.e. the strengths and weaknesses. It is important to understand how the properties of hydrogen (gas, liquid, compressed gas as applicable) can affect safety and performance, and if the team does not include specific safety modelling competence (leak, ignition, fire and explosion), it is recommended to establish a dialogue with such competence at an early stage.

It will be an advantage for the team to possess previous experience from marinization of equipment and systems that have not previously been used in the maritime industry.

For the HAZID, MSC.1/Circ.1455 points out that the Administration may consider whether the composition of the HAZID team ensures that all relevant areas of expertise are represented and heard in the process when reviewing the HAZID report. The Administration reserves the right to request further participants if certain areas have not been adequately covered.

6 DOCUMENTATION REQUIREMENTS FOR PRELIMINARY APPROVAL/APPROVAL IN PRINCIPLE AND FINAL APPPROVAL OF HYDROGEN FUELLED SHIP CONCEPTS

Table 2 below lists the required documents for the approval process towards the Class Society and NMA. The document has been prepared through a cooperation between NMA and DNVGL, and it is based on the current development status. The documentation list is the starting point for the approval process and it will be reviewed and updated during the start-up phase of the project.

The list has separate columns for Preliminary Approval/Approval in Principle and Final Approval.

Table 2: Required documents in the approval process towards the Class Society and NMA.

Item	Requirement	Documentation needed for Preliminary Approval/Approval in Principle	Documentation needed for Final Approval
Alternative design approach (IGF Code 2.3)	MSC.1/Circ.1455 4.8.2 At a minimum, a Hazid should be required in order to request for preliminary approval of the preliminary design. The Submitter will be required to arrange a Hazid workshop, which is a structured brainstorming with the purpose of identifying all relevant hazards and their consequences and mitigating measures already included in the design. The Hazid provides a unique meeting place for designers, engineers, operational and safety personnel as well as Administration representatives to discuss the alternative and/or equivalency and its associated hazards. 4.8.3 The benefits of including Administration representatives are: 1. The Administration representatives will be able to point to issues relevant for approval that may be discussed; 2. The Administration representatives may have expertise within certain areas of the design under consideration and therefore may be able to contribute by drawing attention to issues that may unintentionally have been left out of discussions; and 3. The amount of questions and misunderstandings will be reduced during the review of the Hazid and the overall approval process. 4.8.4 Typically, results of the Hazid will include the following: 1. Identified hazards associated with the alternative and/or equivalency design; and 2. Identified potential safeguards already included in the design	4.8.5 The results of the Hazid should be documented (Hazid Report) by the Submitter and submitted to the Administration. A list of the participants in the Hazid and their expertise and experience should be submitted to the Administration as well 4.6.7 During the Preliminary design preview phase, the Submitter may be required to submit the following documents: 1. General description of alternative and/or equivalency; 2. Functional description of alternative and/or equivalency; 3. Identification of interfaces between alternative and/or equivalency and other systems/operations; 4. Preliminary general arrangement drawings; 5. Preliminary detail drawings, if required; 6. List of codes and standards applied; 7. Risk assessment plans; and 8. Further design basis documents, if necessary.	-
Functional requirements (IGF Code 3.2)	See specification of these requirements in Table 3 below.	-	Documentation needs to show compliance with the 18 functional requirements; it is expected that this should be possible to do by the risk assessment as required in IGF Code 4.2

Item	Requirement	Documentation needed for Preliminary Approval/Approval in Principle	Documentation needed for Final Approval
Risk assessment (IGF Code 4.2)	4.2.1 A risk assessment shall be conducted to ensure that risks arising from the use of low-flashpoint fuels affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration shall be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure. 4.2.3 The risks shall be analysed using acceptable and recognized risk analysis techniques, and loss of function, component damage, fire, explosion and electric shock shall as a minimum be considered. The analysis shall ensure that risks are eliminated wherever possible. Risks which cannot be eliminated shall be mitigated as necessary. Details of risks, and the means by which they are mitigated, shall be documented to the satisfaction of the Administration.	Hazid required by Alternative Design MSC.1/Circ.1455 is sufficient for preliminary approval.	Full safety assessment needed for final approval.
Explosion analysis (IGF Code 4.3)	4.3 An explosion in any space containing any potential sources of release (4) and potential ignition sources shall not: 1. cause damage to or disrupt the proper functioning of equipment/systems located in any space other than that in which the incident occurs.; 2. damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur; 3. damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured; 4. disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution; 5. damage life-saving equipment or associated launching arrangements; 6. disrupt the proper functioning of firefighting equipment located outside the explosion-damaged space; 7. affect other areas of the ship in such a way that chain reactions involving inter alia, cargo, gas and bunker oil may arise; or 8. prevent persons access to life-saving appliances or impede escape routes. (4) double wall fuel pipes are not considered as potential sources of release.	Considerations about explosion risks and consequences for at least the following spaces must be done and documented: - Hydrogen tank spaces; - Hydrogen tank connection spaces - Double ducts/piping for hydrogen piping - Fuel cell spaces - Any other spaces containing hydrogen equipment or piping. Unless the space has no hydrogen release source (all equipment/piping etc. are fitted with double barriers) or ignition is efficiently made impossible (by use of inert gas or similar), explosion must be considered possible. The size of the explosion must be evaluated based on safety barriers in place (leakage detection, shut down, etc.)	Explosion calculations for relevant spaces to be conducted and documented.
Documentation requirements for fuel cell installations			

Item	Requirement	Documentation needed for Preliminary Approval/Approval in Principle	Documentation needed for Final Approval
Design philosophy for the machinery and propulsion arrangement	Including information on the machinery configuration, machinery space arrangements, fuel arrangements, shut down philosophy, redundancy considerations, boil off handling etc. shall be submitted before other documentation, to give support of approval of these.	Yes	Yes
General arrangement plan	Giving location of: - Machinery and boiler spaces, accommodation, service and control station spaces - FC fuel tanks and FC fuel containment systems - FC fuel pump and compressor rooms - FC fuel piping with shore connections - Tank hatches, ventilation pipes and any other openings to FC fuel pump rooms, compressor rooms and other hazardous areas - Entrances, air inlets and openings to accommodation, service and control station spaces - Purge lines and safety blow-off lines of gaseous fuels	Yes	Yes
Hazardous area classification drawing	The relevance of zone definitions for natural gas should be specially considered when applied for hydrogen, and potential for large size releases should be included in evaluation of zones around mast	Yes	Yes
Tank and capacity plan	Including FC fuel containment systems	No	Yes
Hydrogen piping diagram	- drawings and specifications of FC fuel piping including vent lines of safety relief valves or similar piping, and including shore connections - drawings and specifications of offsets, loops, bends and mechanical expansion joints, such as bellows or similar means in the FC fuel piping - drawings and specification of flanges, valves and other fittings in the FC fuel piping system - documentation of type tests for expansion components in FC fuel piping systems - specification of materials, welding, post-weld heat treatment and non-destructive testing of FC fuel piping - specification of pressure tests (structural tightness tests) of FC fuel piping	Detailed specifications can be omitted for preliminary design phase. Details on location of valves, mechanical expansion joints, pressure reduction elements etc. should however be included. Tank connection arrangements including safety relief should be documented.	Yes
Structural fire protection drawing	-	Principles to be documented	Yes

Item	Requirement	Documentation needed for Preliminary Approval/Approval in Principle	Documentation needed for Final Approval
Fuel cell safety description	The safety aspects in this connection are for instance explosion hazards, fire effects from the fuel cell itself or from the fuel cell support systems. If a fuel cell is connected to the grid any potential hazards affecting the ship's total power system should be included.	To be documented in connection with the Hazid	Yes
Plans and particulars for the fuel cell	This is typically to include: — fuel cell principles — functional description — arrangement drawings of the fuel cell including dimensions, materials, operating temperatures, pressures, weights — strength calculations of pressure containing components, or test reports — documentation of compliance with environmental conditions, including calculations or test reports — voltage and current levels in different parts of the cell — type of fuels — maintenance plan (replacement of stack etc.) — earthing principles — safety devices with set points — documentation of life time and availability, e.g. deterioration rate curve or similar. The power deterioration rate for the fuel cell shall be documented through analysis or test results, and shall consider different power levels and different modes of operation.	Detailed specifications can be omitted for preliminary design phase, but main principles should as a minimum be documented	Yes
Fuel cell Failure Mode and Effect Analysis (FMEA)	A failure mode and effect analysis (FMEA) examining all possible faults affecting the processes in the fuel cells shall be submitted for approval, together with a test program for verification of the main conclusions from the FMEA.	No	Yes
Fuel cell test procedure at manufacturer, and for quay and sea trial	The test program can be based on the IEC standard 62282-3-1 Stationary fuel cell power systems – Safety, but shall also have to take into account the environmental and operating conditions in a ship.	No	Yes
Fuel cell design criteria	— design pressure — design temperature — volume(s) — fluid(s) — additional loads, if applicable — proposed set pressure of safety valve — pressure vessel class.	Yes	Yes

Item	Requirement	Documentation needed for Preliminary Approval/Approval in Principle	Documentation needed for Final Approval
Program for functional tests of all piping systems including valves, fittings and associated equipment for handling FC fuel (liquid or vapor)	-	No	Yes
Drawings and specifications of insulation where such insulation is installed	-	No	Yes
Specification of electrical bonding of FC fuel piping	-	No	Yes
Cooling/heating water system in connection with FC fuel system if fitted	-	Yes	Yes
Specification of heat tracing arrangements if fitted	-	No	Yes
Safety relief valve sizing calculations	For safety relief valves and pressure/vacuum relief valves	No	Yes
Mechanical ventilation system diagrams	For spaces with hydrogen (FC fuel) installations, giving capacity and location of fans and their motors. For fans and ventilators; drawings and material specifications of rotating parts and casings	Yes	Yes
Ventilation capacity analysis	For fuel cell spaces with singly hydrogen pipes, or other spaces where ventilation is used to keep concentration below flammable level after a leakage.	Preliminary assessment	Yes
Arrangement and specifications of piping systems for gas freeing and purging of fuel cell and hydrogen piping	-	Philosophy of purging and gas freeing should be documented as a minimum	Yes

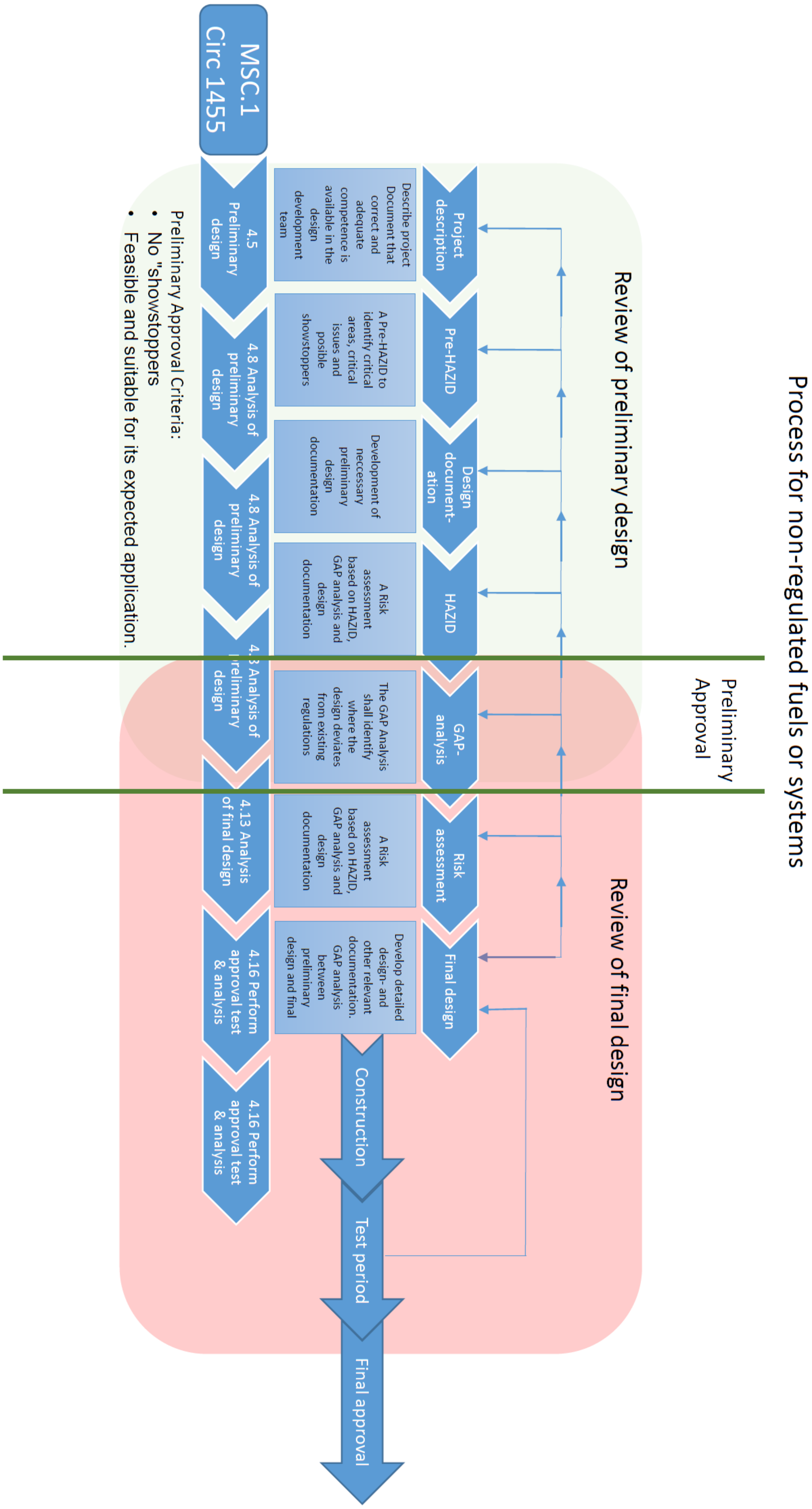
Item	Requirement	Documentation needed for Preliminary Approval/Approval in Principle	Documentation needed for Final Approval
Bilge piping system diagram, and drainage arrangement drawing in FC module, if applicable	-	No	Yes
Fuel cell air inlet arrangement including filters	-	Yes	Yes
Fuel cell exhaust arrangement	-	Yes	Yes
Fuel cell spaces fire detection and alarm system	-	Philosophy of fire detection and alarm should be documented as a minimum	Yes
Single line diagram for main power, auxiliary power and control power distribution	-	Yes	Yes
Electrical power conductors to the FC stacks documentation	Technical data sheets and design drawings	No	Yes
Semi-conductor converters	-	No	Yes
Short circuit contribution capability	-	No	Yes
For ships with notation FC-POWER documentation showing that the electrical power system's overall properties are in compliance with Pt.4 Ch.8 shall be submitted.	Such documentation may be in the form of system descriptions, system analysis and/or test programs/reports, covering: - voltage and frequency variations during steady state and transient modes - description of current DC components generated by the FC - black out and dead ship recovery required in Sec.2 A103 - active and reactive load capacities - configuration of the system in all operating modes and subsequent power distribution philosophy for different vessel systems or services (essential, important and emergency services) - system behavior in relevant failure modes.	Full documentation not necessary at this stage, but description of high level philosophy	Yes

Item	Requirement	Documentation needed for Preliminary Approval/Approval in Principle	Documentation needed for Final Approval
Reliability and availability analysis	For ships with notation FC(POWER) the reliability and availability shall be documented through analysis, complemented with results from development testing, as well as full scale testing	No	Yes
FMEA	For ships with notation FC(Power) a failure mode and effect analysis for the control, monitoring and safety systems for the whole installation including the support and supply systems shall be submitted for approval, together with a test program for verification of the main conclusions from the FMEA.	No	Yes
Control and monitoring systems	— system philosophy — functional description (incl. flow charts if applicable) — system block diagrams — power supply arrangements — list of control and monitoring points — circuit diagrams — test program for testing at the manufacturer — software quality plan — data sheets with environmental specification. In addition: — pipe and instrumentation drawings (P&IDs) — alarm list with cross reference to P&IDs.	System philosophy and functional description to be documented	Yes
Operation and maintenance manual	— bunkering procedure — gas freeing and inerting procedures — normal operation procedures of the FC system — emergency operation procedures of the FC system — FC deterioration rate curves.	Preliminary procedures should be available	Yes
Test program for onboard testing	-	No	Yes
Hydrogen containment system documentation	Documentation as given in DNVGL Rules Pt. 6 Ch. 5 Sec. 2 and Pt. 5 Ch. 7 for cryogenic tanks	Preliminary assessment of tank/containment system to be submitted, including arrangement of tank connection space/tank room	Yes
Material documentation	To show compatibility with medium and temperatures	No	Yes

Table 3: Specification of the Functional requirements as outlined in the IGF Code 3.2.

Requirement
3.2.1 The safety, reliability and dependability of the systems shall be equivalent to that achieved with new and comparable conventional oil-fueled main and auxiliary machinery
3.2.2 The probability and consequences of fuel-related hazards shall be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions. In the event of gas leakage or failure of the risk reducing measures, necessary safety actions shall be initiated.
3.2.3 The design philosophy shall ensure that risk reducing measures and safety actions for the gas fuel installation do not lead to an unacceptable loss of power.
3.2.4 Hazardous areas shall be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment.
3.2.5 Equipment installed in hazardous areas shall be minimized to that required for operational purposes and shall be suitably and appropriately certified.
3.2.6 Unintended accumulation of explosive, flammable or toxic gas concentrations shall be prevented.
3.2.7 System components shall be protected against external damages.
3.2.8 Sources of ignition in hazardous areas shall be minimized to reduce the probability of explosions.
3.2.9 It shall be arranged for safe and suitable fuel supply, storage and bunkering arrangements capable of receiving and containing the fuel in the required state without leakage. Other than when necessary for safety reasons, the system shall be designed to prevent venting under all normal operating conditions including idle periods.
3.2.10 Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application shall be provided.
3.2.11 Machinery, systems and components shall be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation.
3.2.12 Fuel containment system and machinery spaces containing source that might release gas into the space shall be arranged and located such that a fire or explosion in either will not lead to an unacceptable loss of power or render equipment in other compartments inoperable.
3.2.13 Suitable control, alarm, monitoring and shutdown systems shall be provided to ensure safe and reliable operation.
3.2.14 Fixed gas detection suitable for all spaces and areas concerned shall be arranged.
3.2.15 Fire detection, protection and extinction measures appropriate to the hazards concerned shall be provided.
3.2.16 Commissioning, trials and maintenance of fuel systems and gas utilization machinery shall satisfy the goal in terms of safety, availability and reliability.
3.2.17 The technical documentation shall permit an assessment of the compliance of the system and its components with the applicable rules, guidelines, design standards used and the principles related to safety, availability, maintainability and reliability.
3.2.18 A single failure in a technical system or component shall not lead to an unsafe or unreliable situation.

7 NMA PROCESS FOR NON-REGULATED FUELS



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