OSK-ShipTech A/S

På Brint over Fjorden

Gennemgang af Klasse Reglerne med henblik på at opnå notationen

Fuel Cell (Power)

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Sign JBI

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Summary

A description of what would be required from an overall perspective if the Feggesund ferry should be refitted to be able to use electrical power from Hydrogen powered Fuel Cells as propulsion.

Document History

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1. The proposed installation with regards to the requirements for the notations FC (Power)

DNVGL-RU-SHIP Part6/Ch.2/Se.3

1 General

- 1.2 The scope includes requirements for the design and arrangement of fuel cell power installations and the spaces containing such installations. Requirements for storage, preparation and distribution of fuel are covered by Sec.5 Gas fuelled ship installations (Gas Code)
- 1.4.1 Class notation **FC(Power)**
  - Fuel cell installation is intended for propulsion power and class notation FC Power is therefore required

3 Design principles for FC(Power)

- 3.1.1, single failure of Fuel Cells should not lead to an unacceptable loss of power
  - Generators are kept as back up power and will act as back up in case of Fuel Cell failure

4 Requirements for fuel cell power system

- 4.1.1, All fuel piping to be fitted with secondary enclosure capable of safely containing any leakages. An arrangement where secondary enclosure is nitrogen filled and monitored for pressure may be an acceptable solution
  - Fuel piping to be double walled.
    Current arrangement is drawn with ventilated double walled pipes. Acceptable solution would also be as mentioned to fill double walled pipes with nitrogen and monitor pressure, ventilation inlet and outlet for Hazardous Area Zone 1 will then be avoided.

- 4.2.1, Exhaust air and exhaust gases from the fuel cell power systems shall be led to the open air and shall not be combined with ventilation systems.
  - Exhaust gas from fuel cells is led separately up to vent mast

- 4.2.2, If the presence of explosive gases cannot be excluded, the exhaust air and/or exhaust gas shall be arranged as an outlet from a hazardous zone.
  - Exhaust air from fuel cell is considered to contain explosive gases, exhaust gases is routed separately to vent mast and positioned as an outlet from hazardous zone.

- 4.3.1, Purge piping from the fuel cell power systems shall be led separately to the open air and shall be arranged as an outlet from a hazardous zone.
  - Purge gas is led to vent mast and is positioned as an outlet from hazardous zone.

5 Design principles for fuel cell spaces

- 5.1.1 Fuel cell space boundaries to be gas tight
- 5.1.2 Fuel cell space to be designed to safely contain fuel leakages
- 5.1.3 Fuel cell space to be arranged to avoid any accumulation of gas

➢ Fuel cell room to be built gas tight and with supporting structure on outside to get and smooth inside surface.

- 5.2.1 Fuel cell space to be arranged outside accommodation, service and machinery space.

➢ A new fuel cell room to be built where fuel cell is to be installed. Fuel cell room is positioned inside machinery/service space but 5.2.1 is considered achieved when fuel cell space is positioned inside a fuel cell room.

- 5.2.2 Where an independent and direct access to the fuel cell space from open deck cannot be arranged an air lock is to be installed.
- 5.2.3, For small fuel cell spaces with possibility of gas freeing the fuel cell power system before entering, access may be considered case by case.

➢ An air lock is installed and shown on arrangement. An air lock might be omitted since we have a small ship with a small fuel cell installation, this is to be investigated further later in the design process. Until then an air lock is to be considered a requirement.

- 5.3.1.1 Fuel cell space to be equipped with ventilation system of extraction type.
- 5.3.1.1 Ventilation hoods to be evaluated
- 5.3.1.2 Ventilation rate to be sufficient to dilute gas flammable range for any leakage scenarios.
- 5.3.1.3 Any ducting for fuel cell space ventilation is not to be combined with other ventilation
- 5.3.1.4 Ventilation ducts to be vertical or steadily ascending without sharp bends to avoid gas to accumulation.
- 5.3.1.6 2 x 100% fans to be installed fans to be supplied from separate circuits
- 5.3.1.7 In case of loss of ventilation or negative pressure in fuel cell space, fuel supply to fuel cell space is to be shut down.

➢ Ventilation system designed according to above is to be installed. System is to be of extraction type with 2x100% fans and ducting is to be separate from any other ventilation system.

- 5.3.2 & 5.3.3 Air inlets for hazardous spaces must be taken from areas which are non-hazardous. Air outlets from hazardous spaces shall be in an open area which has the same classification or less than the ventilated space.
  - All inlets cannot be located too close together. All outlets, which has the same classification, can be clustered together.

6 Fire safety

- 6.1.1 Fuel cell space to be regarded as a machinery space of category A according to SOLAS for fire protection purposes
- 6.2.1 Fuel cell space shall have A60 insulation to all surrounding spaces
- 6.3.1 An approved fire detection system is to be installed in the fuel cell space.
- It is to be noted that hydrogen fire is difficult to detect and detection system with only smoke detectors is not sufficient
- 6.4.1 A fixed fire-extinguishing system is to be installed suitable for hydrogen
- 6.4.2 Air inlets and outlets openings is to be provided with fire dampers

7 Electrical system

Electrical systems and wiring shall not be installed in hazardous areas unless essential for operational purposes.

The hazardous areas which are introduced below deck shall only have essential Ex-proof electrical installations (lights etc.). The hazardous zones introduced above deck due to ventilation inlets/outlets shall be kept clear of existing electrical installations. If this is not possible, these installations shall be made Ex-proofed accordingly.

Fuel cell should be possible to disconnect from electrical load at any load condition

Inverter to be designed to avoid reverse power to pass into the fuel cell installation

7.2.2 Area classification

- (7.2.2.1 & 7.2.2.2 & 7.2.2.3) Hazardous zones 0, 1, and 2 definitions.
  - Zone 0 spaces includes:
    - Interior of Gas bottles
    - Interior of gas fuel pipes
    - Interior of piping for gas venting system.
  - Zone 1 spaces includes:
    - Fuel tank vent outlet in top of vent mast and an area around this.
    - Other gas or vapor outlet located in the vent mast top and an area around this.
    - Fuel Storage hold space/Tank connection space including inlet/outlet ventilation ducts and an area around the outlets from these.

- Fuel Cell Space including inlet/outlet ventilation ducts and an area around the outlets from these.
- Interior of exhaust air/process air piping from the Fuel Cells and an area around the outlets from these.
- Area between inner and outer pipe in double wall gas fuel pipes including inlet/outlet ventilation ducts/pipes and an area around the outlets from these.
- Bunker station and an area around this.

- Zone 2 spaces includes:
  - An area within 1,5m surrounding the zone 1 areas created on open deck by the ventilation inlets/outlets from hazardous zones.
  - The two Air locks.
  - The Hatch Room.

8 Control, monitoring and safety systems

A comprehensive gas monitoring system is required in all rooms containing the gas installation. The monitoring system must be connected to a fuel safety system in order to automatically close down and isolate gas leaks upon detection. Detection of loss of ventilation of the gas installation spaces shall also be included in this system.

The control, monitoring and safety system will be quite extensive and complex, but at the same time, it can be expected to be similar to any other vessel build in accordance with the Gas Code.

2. The proposed instal. regards the requirement for the notation Gas Fuelled LNG ("Gas Code")

The proposed installation has been done in accordance with the Gas Code (DNVGL-RU-SHIP Part6/Ch.2/Se.5). The Gas Code is actually intended for LNG fuelled ships, but has been applied anyway due to lack of specific rules for Hydrogen installations.

1 General

1.2 Scope

- The notation Gas fuelled LNG is given to ships using LNG as fuel.
- This notation is not to be obtained, but the Gas Code shall be used due to requirement as stated in Section 3 Fuel Cell Installations.

3 Ship arrangement

3.1 Ship arrangement principles

- (3.1.2.1) For spaces below deck, it is not permitted to pass from a non-hazardous area to a hazardous area without going through an air-lock.
- The hazardous areas below deck which can be accessed directly (Hatch Room and Fuel Cell Space) must be provided with air-locks.
- Mustering stations and lifesaving equipment cannot be located in hazardous areas.

- So hazardous zones on open deck must be clear of for instance the life rafts (which are located on Bridge Deck)

3.2 Arrangement of machinery spaces

- (3.2.2 & 3.2.3) The machinery spaces can be arranged as Emergency Shut Down (ESD) protected spaces, or as a Gas Safe Machinery Space. In a ESD protected machinery space it is accepted that a single failure can result in gas leaking to the machinery space, safety is provided by gas detection, auto shutdown of gas-system, high ventilation capability, lower design pressure in gas supply system, Ex-requirements to machinery equipment. In a Gas Safe machinery space a single failure cannot result in gas leaks in the machinery space. This is achieved by using secondary barriers – most notably Double-Wall (DW) pipes.
- Gas Safe machinery space seems as the only viable option for an existing vessel including this one.

3.3 Arrangement of other spaces containing fuel systems

- (3.3.4.1) Tank connection spaces cannot be located adjacent to Cat A machinery spaces.
- Cat A machinery spaces are in this case FWD & AFT Engine Room.
- A cofferdam of 900mm between the Fuel Storage hold space/Tank Connection Space and the bulkhead at Fr.49.
- (3.3.4.7) Access to the tank connection space shall be independent and direct from open deck, otherwise it shall be a bolted hatch.
- Since the access to the Fuel Storage hold space/Tank Connection Space is not possible from open deck, the access to this space shall be through a bolted hatch.
- (3.3.6.1) The bunkering station must be located in an area with sufficient ventilation, if not special considerations (forced ventilation, air-lock, etc.) shall be provided.
- In this case the bunkering station is located in the fwd. part of the vehicle deck PS. This area is considered to be with sufficient ventilation since it is on open deck.

3.4 Arrangement of air locks

- (3.4.1.2) Air locks must be mechanically ventilated with an overpressure relative to the adjacent hazardous zone. The ventilation inlets and outlets shall be placed in open air.

4 Fuel containment systems

4.2 Liquefied gas fuel tanks

We do not consider liquefied gas fuel as part of this project.

4.3 Compressed gas fuel tanks

- (4.3.1.1) Gas tanks shall be certified as Class I pressure vessels.
- (4.3.1.2) Gas tanks shall be with pressure relief valves leading to vent mast.
- (4.3.1.3) It shall be possible to depressurize the tanks through the vent mast in case of a fire.

4.7 Requirements depending on fuel tank location

- (4.7.1.1) Compressed gas shall only be stored below deck on a case-by-case basis.
  - With the present arrangement, it is not deemed feasible to store the gas on open deck. Given the layout of the vessel, it should be expected that in this case Class and DMA would accept to store the gas in the bottles below deck in the Fuel Storage hold space/Tank Connection Space.

5 Piping systems

5.1 General

- (5.1.1.4 & 5.1.1.5) In case of leaks in the fuel piping system the leak shall be detected and isolated automatically.
  - This can be done by monitoring the atmosphere in the space in the space between barriers in the Double Wall pipes.
- (5.1.2.1) Safety actions may not result in an unacceptable loss of power.
  - In this project the existing diesel propulsion machinery will also be available along with a battery bank. A sudden shutdown of the fuel cells shall therefore not be considered as leading to an unacceptable loss of power.

5.2 Pressure relief systems

- (5.2.2.5) The outlet from the pressure relief valves shall be located B/3 or 6m, whichever is greater, above weather deck, and 6m above the working area and gangway, and 10m from air intake/outtake or opening into accommodation or exhaust outlet from machinery spaces. Lesser heights may be accepted for small ships due to operational limitations.
  - The vessel must be equipped with a vent mast of a considerable height. In the present project the term small ship is fulfilled, but there are no obvious operational limitations which would make a high vent mast an impossibility.
- (5.2.2.7) All fuel gas vent outlets shall be arranged as described above.
  - All gas vent outlets shall be collected in the vent mast.

5.4 Nitrogen installations

- (5.4.1.1) It shall be possible to purge the bunker lines with nitrogen.
- (5.4.3.1) It shall be possible to gas free fuel tanks.
  - A nitrogen system must be installed. It is not deemed feasible to install a nitrogen generator, so this should be based on bottled nitrogen.

5.5 Exhaust system

- (5.5.1.5) Machinery using gas as fuel shall have separate exhaust gas system.
  - Fuel Cells will be consuming gas as fuel, therefore exhaust air from these must be separate.

6 Ventilation systems

6.1 Ventilation of spaces

- (6.1.1.1) Vent ducting for hazardous spaces shall be separate from that used for non-hazardous spaces.
- (6.1.1.3) If a duct from a hazardous zone passes through a non-hazardous zone, leakages to the non-hazardous zone shall be prevented. Vent ducts shall have the same mechanical integrity as general piping systems.
  - Vent ducts from Hazardous zones do not have to be double wall pipes (e.g. like gas fuel pipes), but leaks shall be prevented by ensuring that over-pressure around ducts are present. So in all spaces where vent ducts from hazardous zones are present, the pressure must be monitored. It must therefore be made possible to control the various ventilation systems to a higher degree than what was originally required for this vessel.
- (6.1.1.4) Air inlets for hazardous spaces must be taken from areas which are non-hazardous. Air outlets from hazardous spaces shall be in an open area which has the same classification or less than the ventilated space.
  - All inlets cannot be located too close together. All outlets, which has the same classification, can be clustered together. In this case this means that ventilation outlets from zone 1 hazardous areas can be located in the vent mast (which also has a zone 1 classification) without being restricted by the pressure relief outlets which are located in the top of the mast.
- (6.1.1.5) Air inlets for non-hazardous spaces shall be placed at least 1,5m away from any hazardous zone boundary. Air outlets from non-hazardous areas shall be placed outside the boundaries of any hazardous zones.
  - This means that the ventilation inlets/outlets which must be created due to the different hazardous zones that are introduced below deck, must be placed with due consideration to the already existing ventilation system.
- (6.1.1.7) Hazardous zones must be continuously ventilated.
- (6.1.2.2) The Hatch Room shall be with separate ventilation.
- (6.1.4.2) Ventilation system for secondary enclosures shall be independent of ventilation systems in tank connection spaces.
- (6.1.5.1) Ventilation system for machinery spaces containing gas fueled consumers shall be independent from all other ventilation systems.
  - The double wall pipes, the Fuel storage space/Tank connection space, Hatch Room, and Fuel Cell space must have separate ventilation systems.
- (6.1.6.1) Non-hazardous spaces with access to a hazardous enclosed space shall be separated by an air-lock.
  - The access to the Hatch Room and the Fuel Cell Room must each have an air-lock.

7 Fire safety

7.2 Fire protection

- (7.2.2.2.) The fuel containment system shall be separated from Cat A spaces and other spaces with high fire risk, by a cofferdam of 900mm with A60 insulation. The space around the fuel containment system shall itself be regarded as a Cat A space.
  - The Fuel storage hold space/tank connection space must be separated from Engine Room FWD by a 900mm cofferdam provided with A60 insulation.
- (7.2.2.5) When a single bulkhead separates ESD protected machinery spaces, this bulkhead shall be A60 insulated.

7.3 Fire extinction

- (7.3.3.1) The bunkering station shall be protected by a permanently installed dry powder extinguishing system.

7.4 Fire detection and alarm systems

- (7.4.1.1) All rooms for the fuel gas system where fire cannot be excluded (incl the ventilation trunk for the tank connection space) must be with fixed fire detection.
  - All rooms containing the installation (Fuel Cell Space, Fuel storage hold space/tank connection space, Hatch Room) shall be with fixed fire detection.

8 Electrical systems

8.1 General

- (8.1.1.4) Electrical systems and wiring shall not be installed in hazardous areas unless essential for operational purposes.
  - The hazardous areas which are introduced below deck shall only have essential Ex-proof electrical installations (lights etc.) The hazardous zones introduced above deck due to ventilation inlets/outlets shall be kept clear of existing electrical installations. If this is not possible, these installations shall be made Ex-proofed accordingly.

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3. Remarks regarding changes to the ferry

This chapter is a summary of the changes which will be necessary to make to the vessel, based on the findings in the above.

- The Room containing Fuel bottles (Fuel Storage space/Tank connection space), Hatch Room, and Air lock must be constructed in the Ventilation Room.
- The Room containing the Fuel cells (FC Space), the air lock, and the Battery Room must be constructed in the Technique Room.
- The electrical system shall be re-designed and installed. This includes the battery installation, circuit board sections for the hybrid system and associated cabling.
- The piping systems shall be designed and installed. This includes (but is not limited to) Gas Fuel pipes, Bunker system pipes, gas tank connection piping, gas vent pipes, and various pipes for the Fuel Cell installation such as cooling water pipes.
- The ventilation system for the hazardous zones shall be designed and installed. This shall include ducts/pipes/fans/electrical installations for the various spaces.
- The existing ventilation system for the spaces below deck must be reviewed and updated/redesigned in order to make sure that overpressure will be present in the correct spaces relative to the hazardous spaces.
- The vent mast shall be designed and installed. This includes vent outlets at the top and hazardous zone ventilation outlets below the top.
- The ventilation inlets and outlets above the main deck shall be designed and installed. This will create a number of hazardous zones of varying sizes on the open decks. These inlets/outlets have been placed with due regard to the existing ventilation inlets/outlets

and tank vent-heads as far as possible. A number of tank vent heads on the main deck will have to be moved outside the hazardous zones which will be introduced. Any electrical installations which are located inside a hazardous zone shall either be relocated or made Ex-proof accordingly.

- The bunker station shall be designed and installed.
- Control Monitoring and Safety system must be designed and installed.

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