INTERNATIONAL MARITIME ORGANIZATION

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MARITIME SAFETY COMMITTEE
110th session
Agenda item 6

MSC 110/INF.30
11 April 2025
ENGLISH ONLY

Pre-session public release: ☒

DEVELOPMENT OF A SAFETY REGULATORY FRAMEWORK TO SUPPORT THE REDUCTION OF GHG EMISSIONS FROM SHIPS USING NEW TECHNOLOGIES AND ALTERNATIVE FUELS

Suggestion for the development of training measures for crews of hydrogen ships

Submitted by ZESTAs

SUMMARY

Executive summary:	This document provides a suggestion for the development of training measures for crews of hydrogen ships.
Strategic direction, if applicable:	3
Output:	3.8
Action to be taken:	Paragraph 10
Related documents:	Resolution A.1173(33); CCC 9/INF.17; MEPC 81/INF.5; CCC 10/16 and HTW 11/INF.16

Background

1 HTW 10 agreed that the existing output of the Committee on "Development of a safety regulatory framework to support the reduction of GHG emissions from ships using new technologies and alternative fuels" could be utilized to develop training provisions for seafarers on ships using alternative fuels, taking into account the ongoing work by the Committee, the CCC Sub- Committee and any other relevant bodies. HTW 10 therefore invited the Committee to include this output in the provisional agenda for HTW 11 (HTW 10/10, paragraph 6.32.2).

2 MSC 108 endorsed the agreement by HTW 10 to proceed with the development of training provisions for seafarers on ships using alternative fuels (MSC 108/20, paragraph 5.4).

3 CCC 10 noted a view expressing that a new section on training and personnel protection should be included in the interim guidelines (CCC 10/16, paragraph 3.10).

4 At HTW 11, the Working Group on Development of training provisions for seafarers on ships using alternative fuels and new technologies, in revisiting discussions on the relationship between the draft generic interim guidelines and fuel/technology-specific interim guidelines, agreed that fuel/technology-specific interim guidelines would be developed using the draft generic interim guidelines as a basis.

Context

5 Due to time constraints, the Working Group did not embark on developing other draft fuel/technology-specific interim guidelines besides for methyl/ethyl alcohol during HTW11 (HTW 11/WP.5, paragraph 22).

6 For consideration, this document presents a suggestion for hydrogen interim guidelines, under the same format as the one used for methyl/ethyl alcohol and is mapped against it for easier reference and comparison.

Suggested specifications for hydrogen

7 The training for hydrogen needs to be broad enough to flex around many permutations of hydrogen fuel, storage, and conversion, as well as unique properties of hydrogen, in liquid and gaseous forms.

8 In this context, tables 1 and 2, set out in the annex to this document, are presenting suggestions of specifications of minimum standards of competence in basic training for seafarers on board ships using hydrogen as fuel.

9 These specifications have been mapped against table A-V/3-1 of the STCW Code, for reference.

Action requested of the Committee

10 The Committee is invited to note the information provided and to take action, as appropriate.

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ANNEX
SPECIFICATION OF MINIMUM STANDARD OF COMPETENCE IN BASIC TRAINING FOR SEAFARERS ON BOARD SHIPS USING HYDROGEN AS FUEL

(mapped against table A-V/3-1 of the STCW Code for reference)
This specification covers gaseous, liquid, compressed and cryo-compressed hydrogen, on vessels
*(Note: Competences assessed to be different from the existing IGF Code training are shown in **bold/grey**)*

[Table 1]

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
1 Contribute to the safe operation of a ship subject to the IGF Code	1.1 Design and operational characteristics of ships subject to the IGF Code 1.2 Basic knowledge of ships subject to the IGF Code, their fuel systems and fuel storage systems: .1 fuels addressed by the IGF Code .2 types of fuel systems subject to the IGF Code .3 atmospheric, cryogenic or compressed storage of fuels on board ships subject to the IGF Code .4 general arrangement of fuel storage systems on board ships subject to the IGF Code .5 hazard zones and areas .6 typical fire safety plan .7 monitoring, control and safety systems aboard ships subject to the IGF Code Basic knowledge of fuels and fuel storage systems'	1.1 Design and operational characteristics of ships having Hydrogen as fuel under different storage conditions 1.2 Basic knowledge of fuel systems and fuel storage systems: .1 Hydrogen as fuel on board ships .2 types of hydrogen fuel systems (liquid, ambient compressed, cryogenic compressed) .3 atmospheric, compressed, cryo-compressed, cryogenic storage of hydrogen as fuel on board ships .4 general arrangement and design of fuel storage and piping systems on board ships having hydrogen as fuel (including cylinders, removable hydrogen storage, tanks, tank and pipe insulation, and Tank Connection Space) .5 hazard zones and areas, including spaces contiguous with hazardous zones .6 typical fire safety plan monitoring, control and safety systems aboard ships having hydrogen as fuel (including remote monitoring systems)

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
	operations on board ships subject to the IGF Code: .1 piping systems and valves .2 atmospheric, compressed or cryogenic storage .3 relief systems and protection screens .4 basic bunkering operations and bunkering systems .5 protection against cryogenic accidents .6 fuel leak monitoring and detection 1.4 Basic knowledge of the physical properties of fuels on board ships subject to the IGF Code, including: .1 properties and characteristics .2 pressure and temperature, including vapour pressure/ temperature relationship 1.5 Knowledge and understanding of safety requirements and safety management on board ships subject to the IGF Code.	1.3 Basic knowledge of fuels and fuel storage systems' operations on board ships having hydrogen as fuel: .1 piping systems (single and double walled) and valves including safe isolation .2 storage including level and pressure monitoring, .3 relief systems, venting, tank connection space .4 basic bunkering operations and bunkering systems including fuelling nozzles, and breakaway couplings .5 role of tank connection space and vaporisers .6 fuel leak monitoring and detection 1.4 Basic knowledge of the physical properties of hydrogen as fuel on board ships, including: .1 properties and characteristics of hydrogen .2 pressure and temperature, including vapour pressure/ temperature relationship, including during phase change 1.5 Knowledge and understanding of safety requirements and safety management on board ships having hydrogen as fuel

2 Take precautions to prevent hazards on a ship subject to the IGF Code	2.1 Basic knowledge of the hazards associated with operations on ships subject to the IGF Code, including: .1 health hazards .2 environmental hazards .3 reactivity hazards .4 corrosion hazards	2.1 Basic knowledge of the hazards associated with operations on ships having hydrogen as fuel: .1 health hazards .2 environmental hazards .3 reactivity hazards .4 corrosion hazards (including hydrogen embrittlement)

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
	.5 ignition, explosion and flammability hazards .6 sources of ignition .7 electrostatic hazards .8 toxicity hazards .9 vapour leaks and clouds .10 extremely low temperatures .11 pressure hazards .12 fuel batch differences 2.2 Basic knowledge of hazard controls: .1 emptying, inerting, drying and monitoring techniques .2 anti-static measures .3 ventilation .4 segregation .5 inhibition .6 measures to prevent ignition, fire and explosion .7 atmospheric control .8 gas testing .9 protection against cryogenic damages (LNG) 2.3 Understanding of fuel characteristics on ships subject to the IGF Code as found on a Safety Data Sheet (SDS)	.5 ignition, explosion and flammability hazards .6 sources of ignition .7 electrostatic hazards .8 toxicity hazards .9 vapour leaks and clouds .10 extremely low temperatures .11 high pressure hazards .12 fuel batch differences – impact of impurities (particulate and atomic) in hydrogen 2.2 Basic knowledge of hazard controls: .1 emptying, inerting, vapourising, and monitoring techniques .2 anti-static measures .3 ventilation protocols .4 segregation .5 n/a .6 measures to prevent ignition, fire and explosion .7 atmospheric control .8 gas testing .9 protection against cryogenic damages (liquid hydrogen) 2.3 Understanding of fuel characteristics on ships having hydrogen as fuel as found on a Safety Data Sheet (SDS)
3 Apply occupational health and safety	3.1 Awareness of function of gas-measuring instruments and similar equipment:	3.1 Awareness of function of gas-measuring instruments and similar equipment:

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
precautions and measures	.1 gas testing 3.2 Proper use of specialized safety equipment and protective devices, including: .1 breathing apparatus .2 protective clothing .3 resuscitators .4 rescue and escape equipment 3.3 Basic knowledge of safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety relevant to ships subject to the IGF Code, including: .1 precautions to be taken before entering hazardous spaces and zones .2 precautions to be taken before and during repair and maintenance work .3 safety measures for hot and cold work 3.4 Basic knowledge of first aid with reference to a Safety Data Sheet (SDS)	.1 gas detection (flammability and asphyxiant limits of hydrogen) 3.2 Proper use of specialized safety equipment and protective devices, including: .1 breathing apparatus .2 protective clothing .3 resuscitators .4 rescue and escape equipment 3.3 Basic knowledge of safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety relevant to ships having hydrogen as fuel, including: .1 precautions to be taken before entering enclosed spaces, hazardous zones and areas, including spaces contiguous with hazardous zones .2 precautions to be taken before and during repair and maintenance work .3 safety measures for hot and cold work 3.4 Basic knowledge of first aid with reference to a Safety Data Sheet (SDS)
4 Carry out fire-fighting	4.1 Fire organization and action to be taken on ships subject to the IGF Code 4.2 Special hazards associated with fuel systems and fuel	4.1 Fire organization and action to be taken on ships having hydrogen as fuel 4.2 Special hazards associated with fuel systems and fuel

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
operations on a ship subject to the IGF Code	handling on ships subject to the IGF Code 4.3 Fire-fighting agents and methods used to control and extinguish fires in conjunction with the diWerent fuels found on board ships subject to the IGF Code 4.4 Fire-fighting system operations	handling on ships having hydrogen as fuel 4.3 Fire-fighting agents and methods used to control and extinguish hydrogen-based fires 4.4 Fire-fighting system operations
5 Respond to emergencies	5.1 Basic knowledge of emergency procedures, including emergency shutdown	5.1 Basic knowledge of emergency procedures, including emergency shutdown protocols
6 Take precautions to prevent pollution of the environment from the release of fuels found on ships subject to the IGF Code	6.1 Basic knowledge of measures to be taken in the event of leakage/spillage/ venting of fuels from ships subject to the IGF Code, including the need to: .1 report relevant information to the responsible persons .2 awareness of shipboard spill/leakage/venting response procedures .3 awareness of appropriate personal protection when responding to a spill/ leakage of fuels addressed by the IGF Code	6.1 Basic knowledge of measures to be taken in the event of leakage/spillage of fuels from ships having hydrogen as fuel, including the need to: .1 report relevant information to the responsible persons .2 awareness of shipboard spill/leakage/venting response procedures .3 awareness of appropriate personal protection when responding to a spill/leakage of hydrogen

[Table 2]

Specification of minimum standard of competence in advanced training for seafarers on board ships using methyl/ethyl alcohol as fuel (mapped against table A-V/3-2 of the STCW Code for reference)

This specification covers gaseous, liquid, compressed and cryo-compressed hydrogen, on vessels

*(Note: Competences assessed to be di2erent from the existing IGF Code training are shown in **bold/grey**)*

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
1 Familiarity with physical and chemical properties of fuels aboard ships subject to the IGF Code	1.1 Basic knowledge and understanding of simple chemistry and physics and the relevant definitions related to safe bunkering and use of fuels used on board ships subject to the IGF Code, including: .1 the chemical structure of different fuels used on board ships subject to the IGF Code .2 the properties and characteristics of fuels used onboard ships subject to the IGF Code, including: .1 simple physical laws .2 states of matter .3 liquid and vapour densities .4 boil-off and weathering of cryogenic fuels .5 compression and expansion of gases	1.1 Basic knowledge and understanding of simple chemistry and physics and the relevant definitions related to safe bunkering and use of hydrogen used as fuel: .1 the chemical structure of hydrogen .2 the properties and characteristics of hydrogen including: .1 simple physical laws .2 states of matter .3 liquid and vapour densities .4 boil-off of cryogenic hydrogen and possibility to freeze air

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
	.6 critical pressure and temperature of gases .7 flashpoint, upper and lower flammable limits, auto-ignition temperature .8 saturated vapour pressure/ reference temperature .9 dewpoint and bubble point .10 hydrate formation .11 combustion properties: heating values .12 methane number/ knocking .13 pollutant characteristics of fuels addressed by the IGF Code .3 the properties of single liquids .4 the nature and properties of solutions .5 thermodynamic units .6 basic thermodynamic laws and diagrams .7 properties of materials .8 effect of low temperature, including brittle fracture, for liquid cryogenic fuels 1.2 Understanding the information contained in a Safety Data Sheet (SDS) about fuels addressed by the IGF Code	.5 compression and expansion of gases (including Joule-Thomson effect for hydrogen) .6 critical pressure and temperature of gases .7 flashpoint, upper and lower flammable limits, auto-ignition temperature .8 n/a .9 dewpoint of hydrogen .10 n/a .11 combustion properties: heating values .12 knocking .13 pollutant characteristics of hydrogen .3 properties of liquid hydrogen .4 n/a .5 thermodynamic units .6 basic thermodynamic laws and diagrams .7 properties of materials and compatibility with hydrogen .8 effect of low temperature, including brittle fracture, for liquid cryogenic hydrogen 1.2 Understanding the information contained in a Safety Data Sheet (SDS) about hydrogen

2 Operate controls of fuel related to propulsion plant and engineering systems and	2.1 Operating principles of marine power plants 2.2 Ships' auxiliary machinery	2.1 Operating principles of marine power plants (combustion and fuel cells) 2.2 Ships' auxiliary machinery

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
services and safety devices on ships subject to the IGF Code	2.3 Knowledge of marine engineering terms	2.3 Knowledge of marine engineering terms
3 Ability to safely perform and monitor all operations related to the fuels used on board ships subject to the IGF Code	3.1 Design and characteristics of ships subject to the IGF Code 3.2 Knowledge of ship design, systems, and equipment found on ships subject to the IGF Code, including: .1 fuel systems for different propulsion engines .2 general arrangement and construction .3 fuel storage systems on board ships subject to the IGF Code, including materials of construction and insulation .4 fuel-handling equipment and instrumentations on board ships: .1 fuel pumps and pumping arrangements .2 fuel pipelines .3 expansion devices .4 flame screens .5 temperature monitoring systems .6 fuel tank level-gauging systems .7 tank pressure monitoring and control systems .5 cryogenic fuel tanks temperature and pressure maintenance	3.1 Design and characteristics of ships having hydrogen as fuel 3.2 Knowledge of ship design, systems, and equipment found on ships having hydrogen as fuel, including: .1 fuel systems for different propulsion systems .2 general arrangement and construction .3 fuel storage systems on board ships having hydrogen as fuel, including materials of construction and insulation .4 fuel-handling equipment and instrumentations on board ships: .1 fuel pumps and pumping arrangements .2 fuel pipelines (double-walled piping) and valves .3 expansion devices .4 flame screens and arrestors .5 temperature monitoring systems .6 fuel tank level-gauging systems .7 tank pressure monitoring and control systems .5 fuel tanks temperature and pressure maintenance

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
	.6 fuel system atmosphere control systems (inert gas, nitrogen), including storage, generation and distribution .7 toxic and flammable gas-detecting systems .8 fuel Emergency Shut Down system (ESD) 3.3 Knowledge of fuel system theory and characteristics, including types of fuel system pumps and their safe operation on board ships subject to the IGF Code .1 low pressure pumps .2 high pressure pumps .3 vaporizers .4 heaters .5 pressure build-up units 3.4 Knowledge of safe procedures and checklists for taking fuel tanks in and out of service, including: .1 inerting .2 cooling down .3 initial loading .4 pressure control .5 heating of fuel .6 emptying systems	.6 fuel system atmosphere control systems (inert gas, nitrogen), including storage, generation and distribution .7 toxic and flammable gas-detecting systems .8 fuel Emergency Shut Down system (ESD) 3.3 Knowledge of fuel system theory and characteristics, including types of fuel system pumps and their safe operation on board ships having hydrogen as fuel .1 low pressure pumps .2 high pressure pumps .3 vaporizers .4 hydrogen engines and hydrogen fuel cells .5 pressure relief systems / venting 3.4 Knowledge of safe procedures and checklists for taking fuel tanks in and out of service, including: .1 inerting .2 cooling .3 initial loading .4 tank atmosphere pressure control .5 n/a .6 emptying systems / degassing of steel cylinders
4 Plan and monitor safe bunkering, stowage and securing of the fuel	4.1 General knowledge of ships subject to the IGF Code 4.2 Ability to use all data available on board related to bunkering, storage and securing of fuels addressed by the IGF Code	4.1 General knowledge of ships having hydrogen as fuel 4.2 Ability to use all data available on board related to bunkering, storage and securing of hydrogen as fuel

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
on board ships subject to the IGF Code	4.3 Ability to establish clear and concise communications and between the ship and the terminal, truck or the bunker-supply ship 4.4 Knowledge of safety and emergency procedures for operation of machinery, fuel- and control systems for ships subject to the IGF Code 4.5 Proficiency in the operation of bunkering systems on board ships subject to the IGF Code including: .1 bunkering procedures .2 emergency procedures .3 ship-shore/ship-ship interface .4 prevention of rollover 4.6 Proficiency to perform fuel-system measurements and calculations, including: .1 maximum fill quantity .2 On Board Quantity (OBQ) .3 Minimum Remain On Board (ROB) .4 fuel consumption calculations 4.7 Ability to ensure the safe management of bunkering and other IGF Code fuel related operations concurrent with other onboard operations, both in port and at sea	4.3 Ability to establish clear and concise communications between the ship and the terminal, truck or the bunker-supply ship 4.4 Knowledge of safety and emergency procedures for operation of machinery, fuel and control systems for ships having hydrogen as fuel 4.5 Proficiency in the operation of bunkering systems on board ships having hydrogen as fuel including: .1 procedures related to pre-bunkering including tank conditioning and post-bunkering .2 emergency procedures .3 ship-shore/ship-ship interface and use of ship- shore checklist including fuelling nozzles, and breakaway couplings .4 prevention of rollover for systems where hydrogen storage is on/oWloaded in a container 4.6 Proficiency to perform fuel-system measurements and calculations, including: .1 maximum fill quantity .2 On Board Quantity (OBQ) .3 Minimum Remain On Board (ROB) .4 fuel consumption calculations 4.7 Ability to ensure the safe management of bunkering and other hydrogen related operations concurrent with other onboard operations, both in port and at sea

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
5 Take precautions to prevent pollution of the environment from the release of fuels from ships subject to the IGF Code	5.1 Knowledge of the eWects of pollution on human and Environment 5.2 Knowledge of measures to be taken in the event of spillage/leakage/ venting	5.1 Knowledge of the eWects of pollution on human and Environment 5.2 Knowledge of measures to be taken in the event of spillage/leakage
6 Monitor and control compliance with legislative requirements	6.1 Knowledge and understanding of relevant provisions of the International Convention for the Prevention of Pollution from Ships (MARPOL), as amended and other relevant IMO instruments, industry guidelines and port regulations as commonly applied 6.2 Proficiency in the use of the IGF Code and related documents	6.1 Knowledge and understanding of relevant provisions of the International Convention for the Prevention of Pollution from Ships (MARPOL), as amended and other relevant IMO instruments, industry guidelines and port regulations as commonly applied 6.2 Proficiency in the use of the IGF Code and related documents
7 Take precautions to prevent hazards	7.1 Knowledge and understanding of the hazards and control measures associated with fuel system operations on board ships subject to the IGF Code, including: .1 flammability .2 explosion .3 toxicity .4 reactivity .5 corrosivity .6 health hazards .7 inert gas composition .8 electrostatic hazards	7.1 Knowledge and understanding of the hazards and control measures associated with fuel system operations on board ships having hydrogen as fuel, including: .1 flammability (including hydrogen-air mixtures) .2 explosion .3 toxicity .4 reactivity .5 corrosivity .6 health hazards .7 inert gas composition .8 electrostatic hazards

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
	.9 pressurized gases .10 low temperature 7.2 Proficiency to calibrate and use monitoring and fuel detection systems, instruments and equipment on board ships subject to the IGF Code 7.3 Knowledge and understanding of dangers of non- compliance with relevant rules/regulations 7.4 Knowledge and understanding of risks assessment method analysis on board ships subject to the IGF Code 7.5 Ability to elaborate and develop risks analysis related to risks on board ships subject to the IGF Code 7.6 Ability to elaborate and develop safety plans and safety instructions for ships subject to the IGF Code 7.7 Knowledge of hot work, enclosed spaces and tank entry including permitting procedures	.9 pressurized gases .10 low temperature 7.2 Proficiency to calibrate and use monitoring and fuel detection systems, instruments and equipment on board ships having hydrogen as fuel 7.3 Knowledge and understanding of dangers of non- compliance with relevant rules/regulations 7.4 Knowledge and understanding of risks assessment method analysis on board ships having hydrogen as fuel 7.5 Ability to elaborate and develop risks analysis related to risks on board ships having hydrogen as fuel 7.6 Ability to elaborate and develop safety plans and safety instructions for ships having hydrogen as fuel 7.7 Knowledge of hot work, enclosed spaces, hazardous zones, spaces contiguous with hazardous zones and tank entry including permitting procedures

8 Apply occupational health and safety precautions and measures on board a ship subject to the IGF Code	8.1 Proper use of safety equipment and protective devices, including: .1 breathing apparatus and evacuating equipment .2 protective clothing and equipment .3 resuscitators	8.1 Proper use of specialized safety equipment and protective devices compatible with hydrogen exposure, including: .1 breathing apparatus and evacuating equipment .2 protective clothing and equipment .3 resuscitators

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
	.4 rescue and escape equipment 8.2 Knowledge of safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety including: .1 precautions to be taken before, during and after repair and maintenance work on fuel systems addressed in the IGF Code .2 electrical safety (reference to IEC 600079-17) .3 ship/shore safety checklist 8.3 Basic knowledge of first aid with reference to a Safety Data Sheets (SDS) for fuels addressed by the IGF Code	.4 rescue and personal escape equipment 8.2 Knowledge of safe working practices and procedures in accordance with legislation and industry guidelines and personal shipboard safety relevant to ships having hydrogen as fuel, including: .1 precautions to be taken before and during repair and maintenance work .2 electrical safety [reference to IEC 600079-17:2024] .3 ship/shore safety checklist, including precautions to be taken before entering hazardous zones and areas, including spaces contiguous with hazardous zones 8.3 Basic knowledge of first aid with reference to a Safety Data Sheet (SDS) 8.X Knowledge of function, calibration and limitation of gas- measuring instruments and similar equipment: .1 atmosphere testing and gas detection of asphyxiant levels of hydrogen
9 Knowledge of the prevention, control and fire-fighting and extinguishing systems on board ships subject	9.1 Knowledge of the methods and fire-fighting appliances to detect, control and extinguish fires of fuels addressed by the IGF Code	9.1 Knowledge of the methods and fire-fighting appliances to detect, control and extinguish fires of hydrogen fuels 9.2 Fire organization and action to be taken on ships having hydrogen as fuel

Competence	Knowledge, understanding and proficiency	
	Existing IGF Code training	**Hydrogen**
to the IGF Code		9.3 Special hazards associated with fuel systems and fuel handling on ships having hydrogen as fuel 9.4 Fire-fighting system operations

Explanatory notes

The training for hydrogen needs to be broad enough to flex around many permutations of hydrogen fuel, storage, and conversion, as well as hydrogens unique properties in liquid and gaseous forms.

The changes in this version align broadly with those previously proposed. The following notes are intended as clarifications.

Basic training

Item	Note
1.2.2	Reflects diversity of current fuel systems options for hydrogen
1.2.3	Reflects diversity of current fuel storage options for hydrogen
1.2.4	Reflects diversity of current fuel storage arrangement options for hydrogen
1.2.5	Reflects expanded hazard zoning for hydrogen systems – and lower explosion limit risks
1.2.7	Remote monitoring is a critical system for hydrogen builds to deal with hydrogen's properties
1.3.1	Expanded to include double walled tubes for LH2
1.3.4	Added detail to cover generic bunkering systems – this will evolve over time so more prescriptive details are not helpful at this stage.
1.3.5	Adjusted wording to handle LH2. Original text could be reinserted.
1.4.2	Additional LH2 specific content added
2.1.4	Hydrogen embrittlement included as specific detail as it is so important
2.1.12	Impact on engines and FCs will be different. How to confirm hydrogen is within spec. for deliveries? This is covered in Orkney College training
2.2.1	Added vapourizing for LH2 systems
2.2.5	Hydrogen systems do not need inhibiting
3.2.1	Additional detail added to reinforce importance of gas detection`
3.3.1	See 1.2.5 above

Advanced training

Item	Note
1.1.4	Expanded detail for LH2
1.1.5	Added Joule-Thomson effect (absent from previous drafts). Important for decompression of pressurized systems as potential heat source.
1.1.8	Saturated vapour pressure / reference temperature not relevant to hydrogen
1.1.9	Bubble point excluded (see (a) below)
1.1.10	Hydrate formation not relevant for hydrogen
1.1.12	Limited information on hydrogen knocking in engines – not currently included in training, however, 100% hydrogen marine engines still in development, so may become a topic to cover (see (b) below)
1.4	Not relevant as hydrogen is a pure gas or liquid

1.7	Material compatibility with hydrogen is an important sub-topic due to the molecular size, and embrittlement
2.1	Expanded description to include both types of power plant for hydrogen
3.2.5	Broadened scope to cover all storage options
3.4.5	Fuel tanks will be empty as hydrogen will be a gas at service temperature and therefore vented – this heading not required
3.4.6	Expanded scope to cover storage vessels made of steel where hydrogen can diffuse into the vessel walls and rediffuse in air forming microflames potentially
4.5.3	Broadened scope to include generic terminology – sector has not standardized on common interfaces / connectors etc.
4.5.4	Rollover possible if hydrogen is being managed via removable hydrogen stores.
8.2.3	Scope broadened to cover hazard zones as 1.2.5 table 1
8.x	Required additional section – potentially covered elsewhere
9.2 / 9.3 / 9.4	Expanded scope for fire-fighting to manage specific challenges associated with hydrogen fires

(a) Bubble point

In thermodynamics, the bubble point is the temperature (at a given pressure) where the first bubble of vapour is formed when heating a liquid consisting of two or more components. Given that vapour will probably have a different composition than the liquid, the bubble point (along with the dew point) at different compositions are useful data when designing distillation systems. For a single component the bubble point and the dew point are the same and are referred to as the boiling point.

(b) Knocking

Knock in hydrogen engines occurs when fuel ignites before it's supposed to. It can be caused by a number of factors, including compression ratio, ignition timing, and initial temperature