# Short study: Ammonia as fuel

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# Rule basis for $NH_3$ as fuel for sea-going vessels

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International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)

*16.9 Alternative fuels and technologies*
*16.9.2 The use of cargoes identified as toxic products shall not be permitted.*

International Code of Safety for Ships Using Gases or other Low-Flashpoint Fuels (IGF Code)

*2.3 Alternative design*
*2.3.2 Fuels, appliances and arrangements of low-flashpoint fuel systems may either:*
*.1 deviate from those set out in this Code, or*
*.2 be designed for use of a fuel not specifically addressed in this Code.*

*Such 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…*

➡ HAZID/ risk assessment has to be performed
Acceptance by Flag state/ Administration necessary

# Storage options for $NH_3$ on sea-going vessels

## IMO Type A Independent Tanks

*fully refrigerated (around -33°C, close to ambient pressure)*

- *superb space utilization*
- *complete secondary barrier necessary*
- *pressure/ temperature control system necessary*
- *highest energy demand for pressure/ temperature control*

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## IMO Type C Independent Tanks

*semi-refrigerated (typically between 4 and 9 bar)*

- *no secondary barrier necessary*
- *pressure/ temperature control system necessary*
- *lower energy demand for pressure/ temperature control*

*fully pressurized (approximately 18 bar)*

- *worst space utilization*
- *no secondary barrier necessary*
- *no pressure and temperature control system necessary*
- *no energy demand for pressure/ temperature control, but heavy and material intensive*

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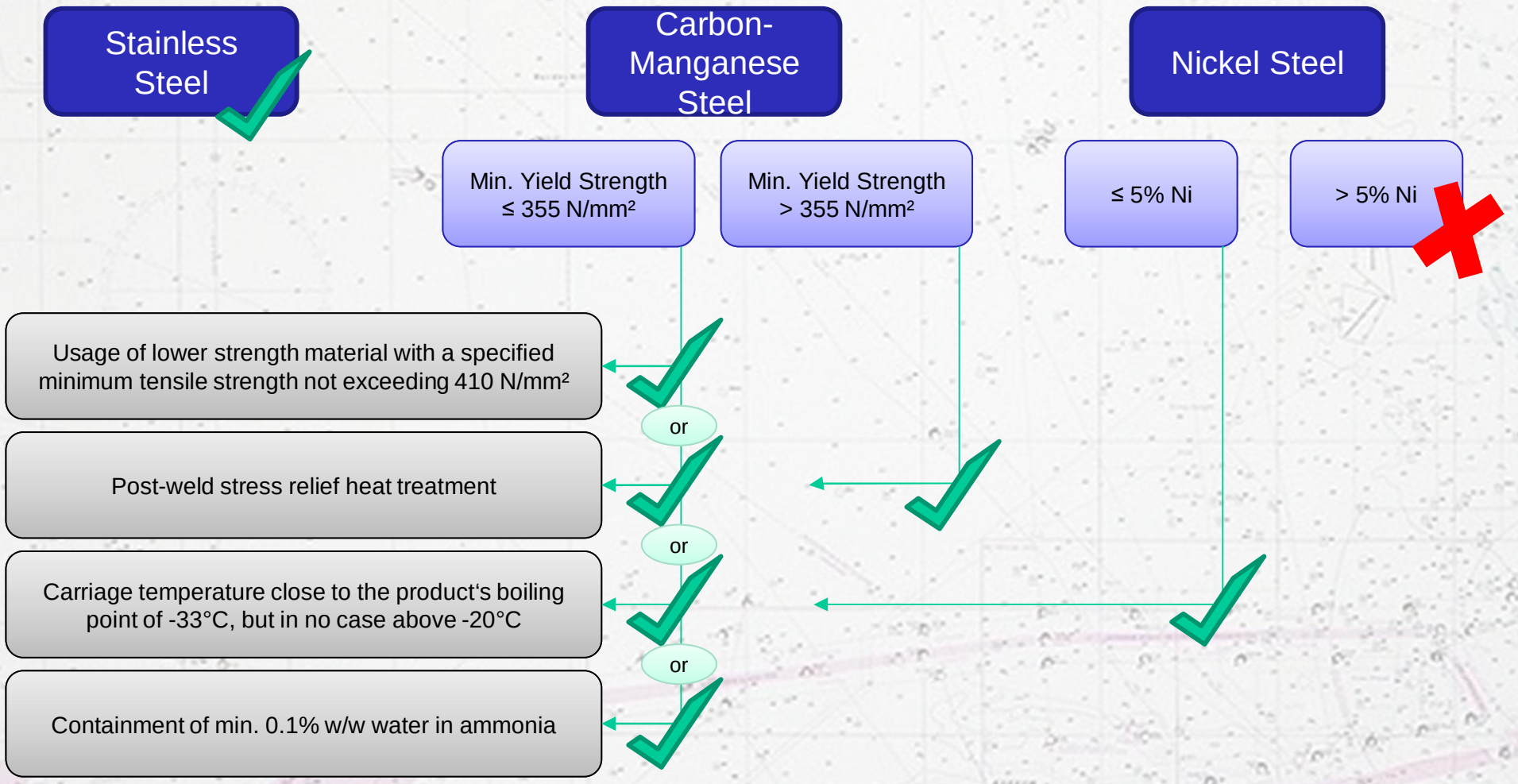
# Suitable materials for the storage and processing of $NH_3$

*Anhydrous ammonia may cause stress corrosion cracking in containment and piping systems made of carbon-manganese or nickel steel*

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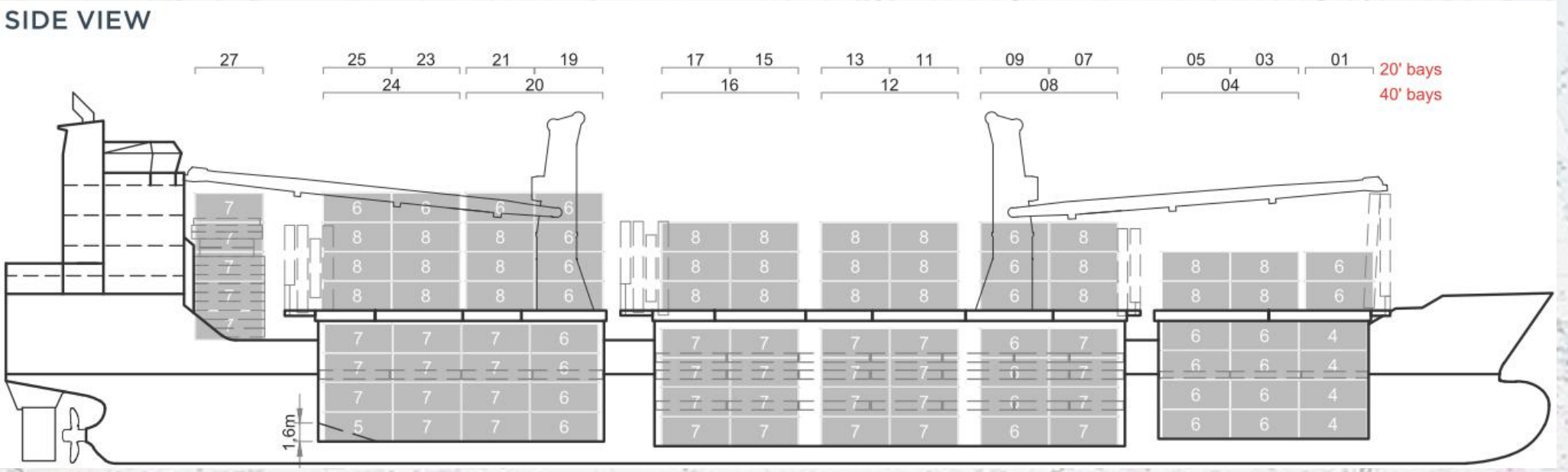
# Base vessel

## 12,700 dwt MPP “FRATERNITY”

| | |
|---|---|
| *Lpp* | *130.00 m* |
| *B* | *21.00 m* |
| *Draft* | *8.00 m (ssw)* |

| | |
|---|---|
| *Main engine* | *MAK 6M43 5,400 kW* |
| *Fuel capacity* | *total abt. 1,100 m³* |

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# Necessary tank sizes (exemplary)

| | Temp. | Pressure | Density | LHV | Tank | MARVS | Loading Limit | Volume |
|---|---|---|---|---|---|---|---|---|
| MGO, reference | | | 835 kg/m³ | 42.700 kJ/kg | | | 98,0% | 1.100 m³ |
| Ammonia | -33,7 °C | 1,0 bar(a) | 682 kg/m³ | 18.600 kJ/kg | | | 100,0% | 3.028 m³ |
| | | | | | | | | |
| Ammonia, fully refrigerated | -33,7 °C | 1,0 bar(a) | 682 kg/m³ | 18.600 kJ/kg | Type A | 1,7 bar(a) | 98,0% | 3.090 m³ |
| Ammonia, semi-ref | -10,0 °C | 2,9 bar(a) | 652 kg/m³ | 18.600 kJ/kg | Type C | 3,2 bar(a) | 93,2% | 3.249 m³ |
| Ammonia, semi-ref | 0,0 °C | 4,3 bar(a) | 639 kg/m³ | 18.600 kJ/kg | Type C | 4,8 bar(a) | 91,1% | 3.324 m³ |
| Ammonia, semi-ref | 20,0 °C | 8,6 bar(a) | 610 kg/m³ | 18.600 kJ/kg | Type C | 9,5 bar(a) | 87,0% | 3.481 m³ |
| Ammonia, fully pressurized | 45,0 °C | 17,8 bar(a) | 571 kg/m³ | 18.600 kJ/kg | Type C | 19,6 bar(a) | 81,2% | 3.729 m³ |

# General options for refitting purposes/ tank integration

## A) Conversion of existing structural tanks to IMO type A tanks

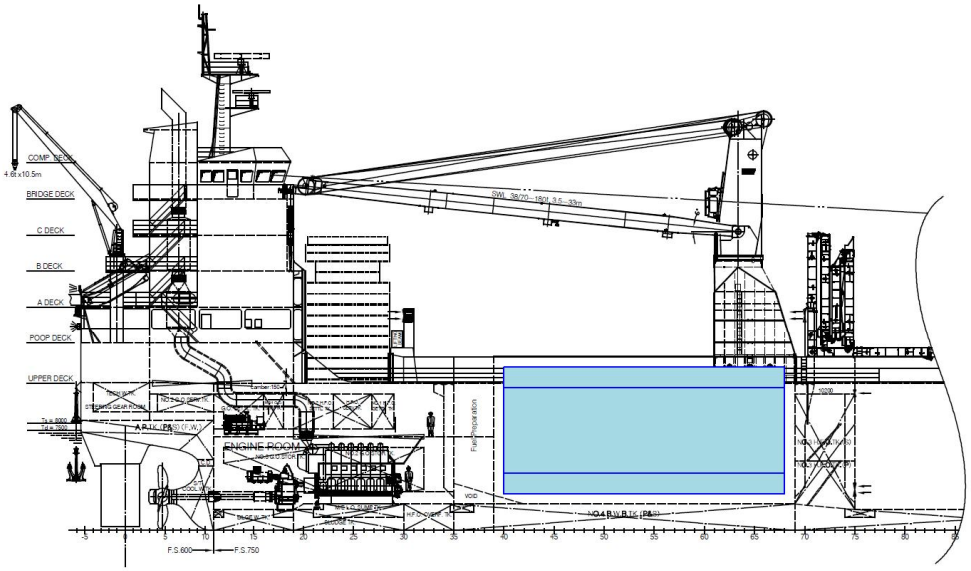
*This is considered as a theoretical option, only.*
*For smaller tank volumes and depending on the actual tank arrangement it may be checked on a case by case basis.*
*Furthermore, a certain amount of MGO is necessary as pilot fuel and as fuel for the auxiliary engines.*

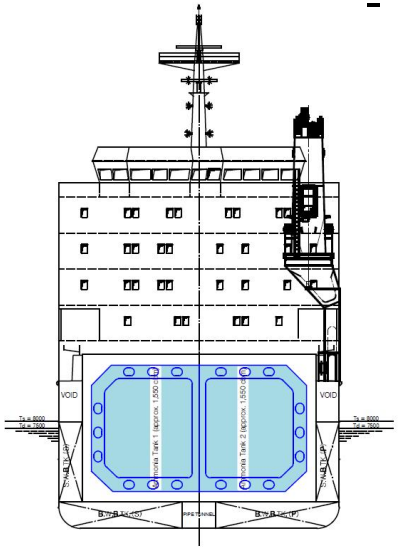
## B) Integration of IMO type A or IMO type C tanks in e.g. former cargo holds or on deck etc.

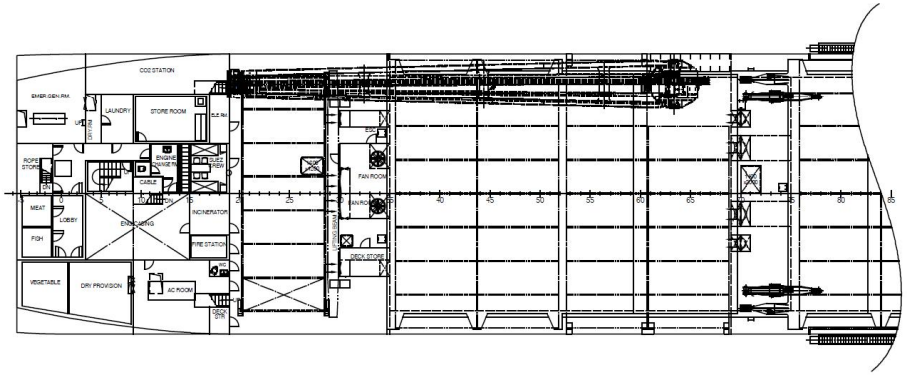
*For this study an IMO type A and an IMO type C (0°C, MARVS 5 bar(a)) have been selected as a basis.*

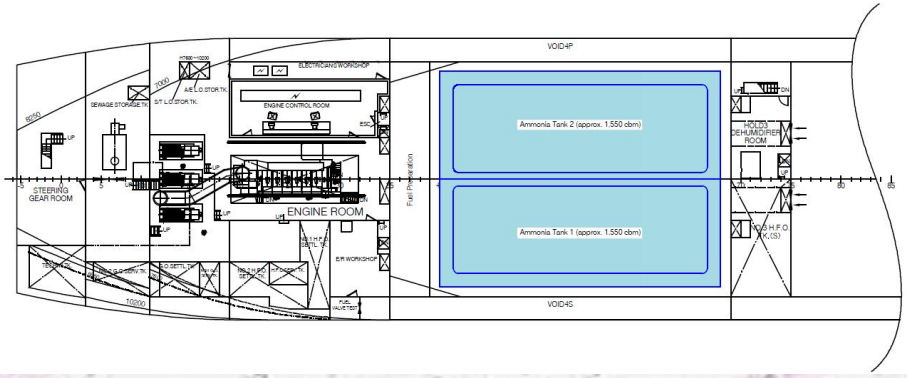
# Options for refitting purposes

## B1) Integration of IMO type A tanks in e.g. former cargo holds or on deck etc.



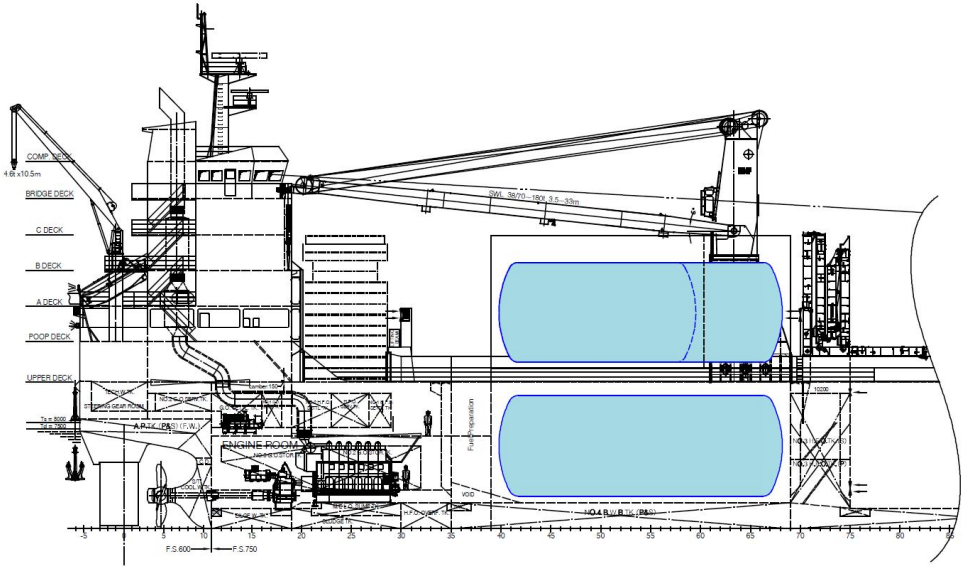

IMO Type A Tanks

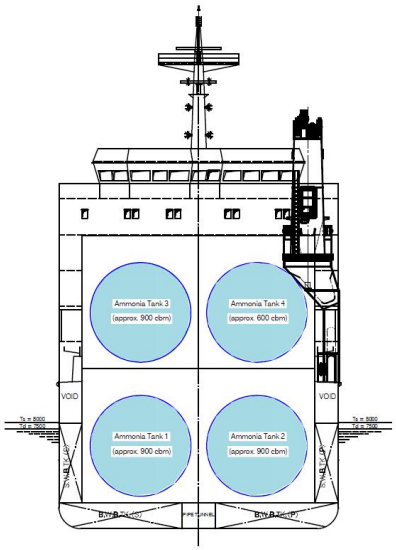
(-33°C, MARVS 0.7 bar(g))

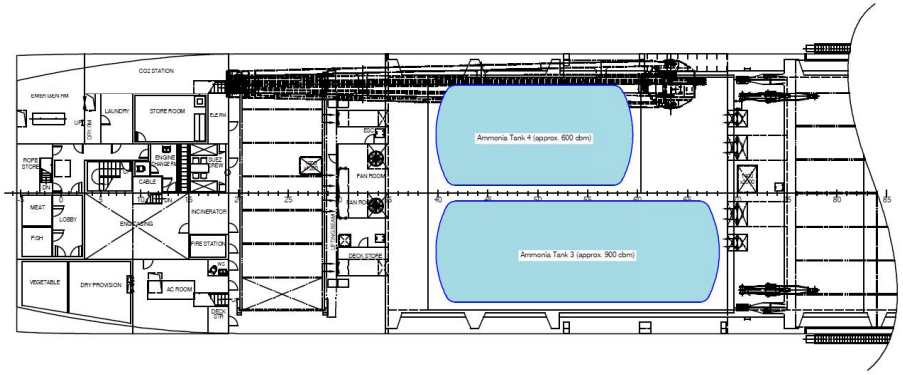
- *Complete secondary barrier necessary*
- *Pressure/ temperature control system necessary*

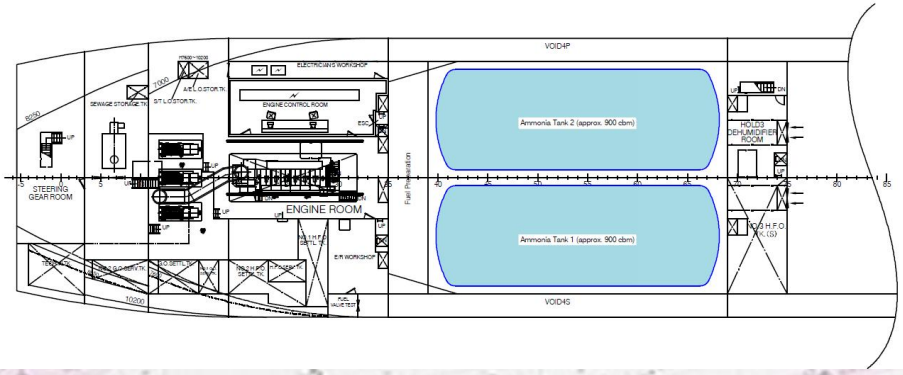
# Options for refitting purposes

## B2) Integration of IMO type C tanks in e.g. former cargo holds or on deck etc.




### IMO Type C Tanks

(0°C, MARVS 4 bar(g))

- *Design limitations due to material requirements*
- *Higher flexibility with regard to delivered fuel*
- *Pressure/ temperature control system necessary, but lower energy demand than for type A tanks*

# Options for refitting purposes

## Fuel Preparation

*close to tank(s) and ER*

## Bunkering station(s)

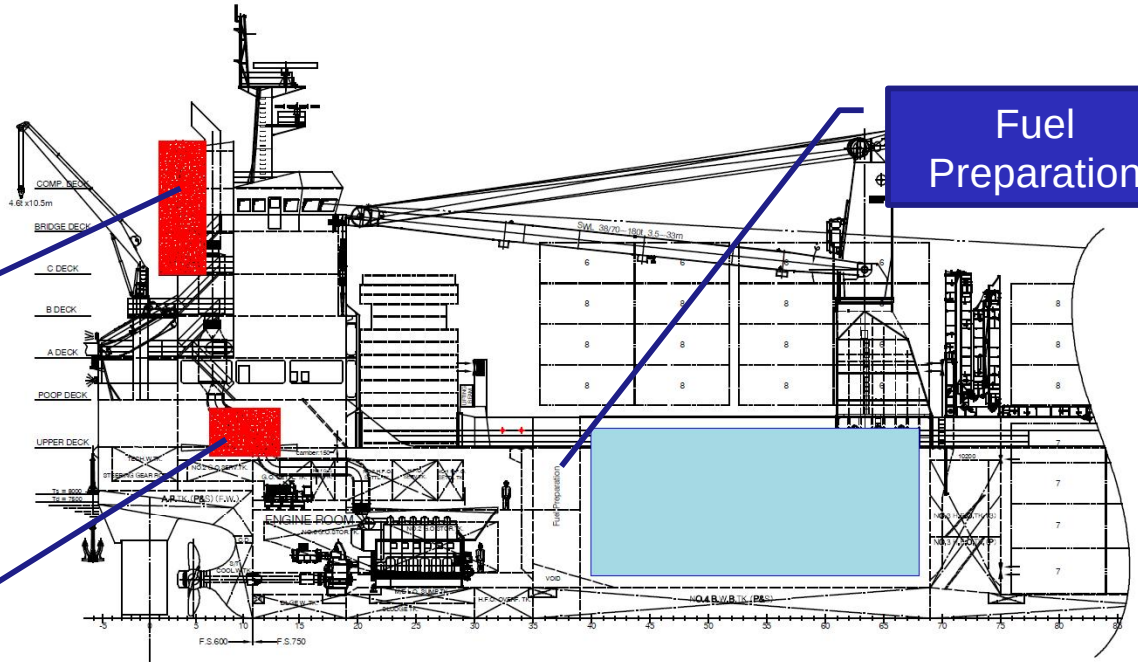
*on open deck in close vicinity of the tank(s)*

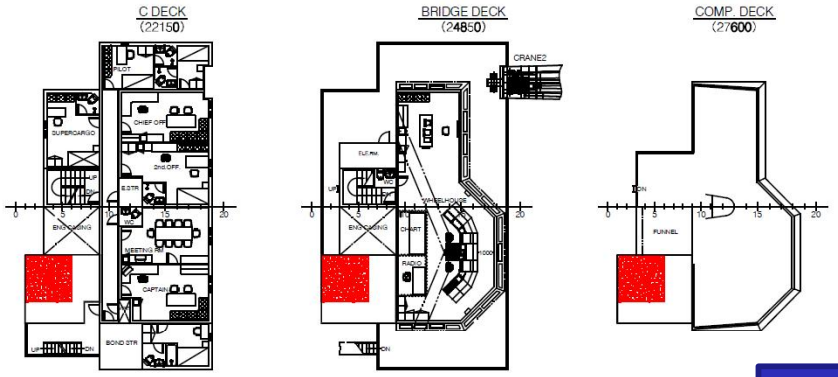
## Combustion Aftertreatment

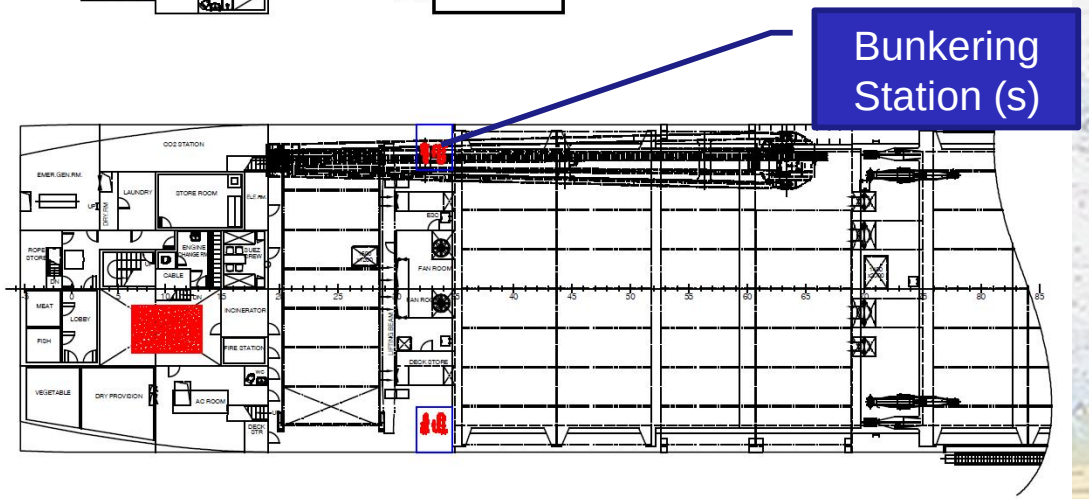
*$N_2O$ Cat.*

*SCR Cat.*

*Slip Cat.*

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# Interim conclusion

*Re-fitting ammonia tanks having a volume comparable to 1,100 m³ fuel oil does not seem to be economically reasonable for vessels like MV "FRATERNITY".*

*An ammonia re-fit may only be reasonable as long as less endurance or more frequent bunkering is acceptable.*

*Installing ammonia tanks in front of the deckhouse seems to be a feasible solution for this kind of vessels, but…*

- *endurance is reduced to abt. 20% of before*
- *toxic ammonia is stored in direct vicinity of the accommodation*
- *handling of hazardous zones is possible but challenging*
- *tank protection against damages during cargo operations is necessary*
- *IMO type A tanks would need a complete housing*
- *COG is affected negatively*

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# Re-fitting possibility for MV “FRATERNITY”

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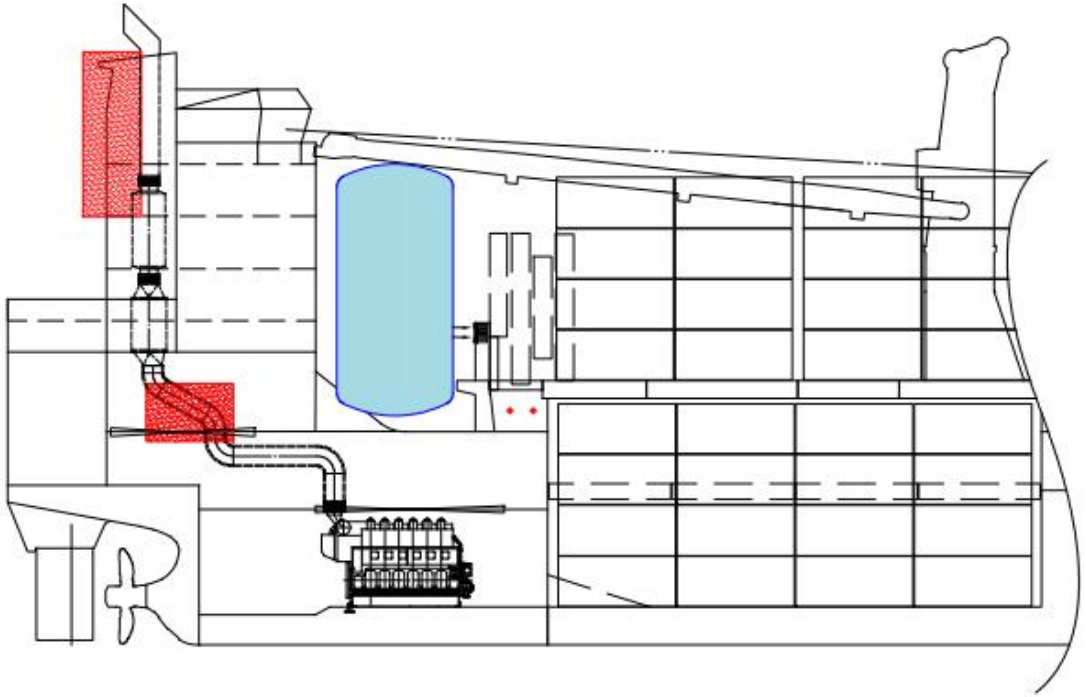
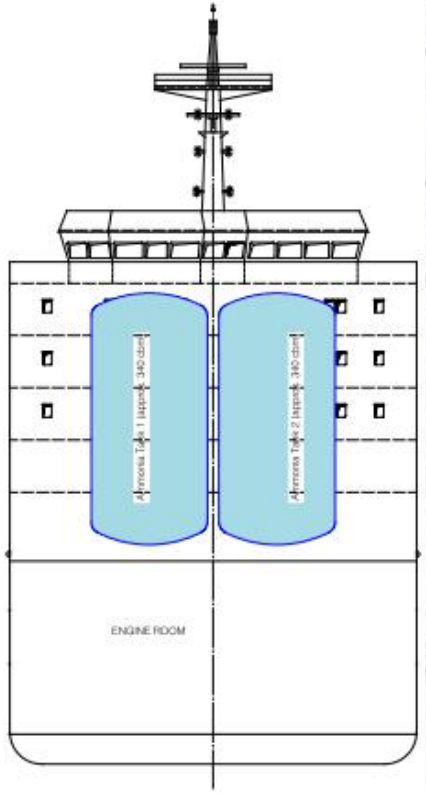
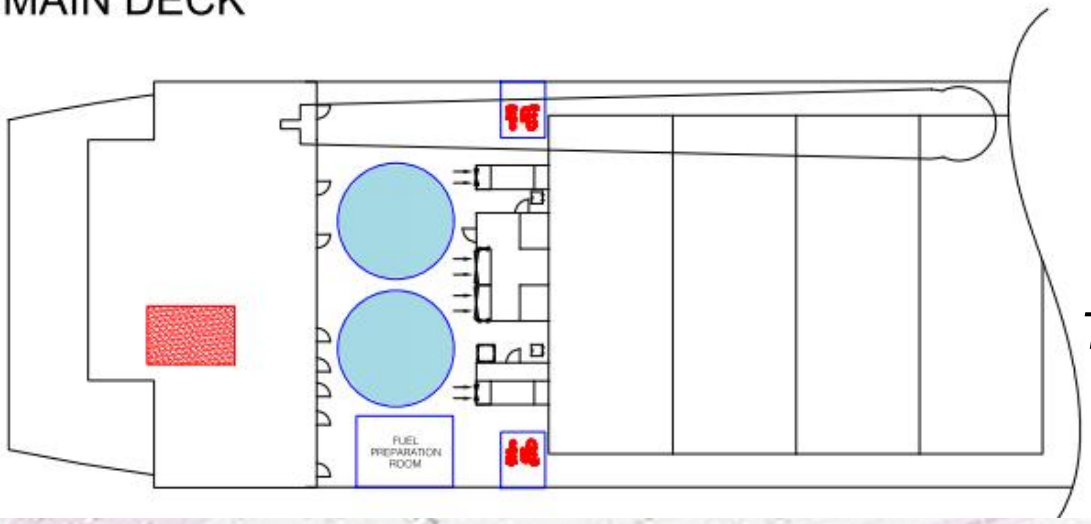
SIDE VIEW






MAIN DECK




*Ammonia tank capacity:*

*abt. 680 m³*

*equivalent to approx. 220 m³ MGO*

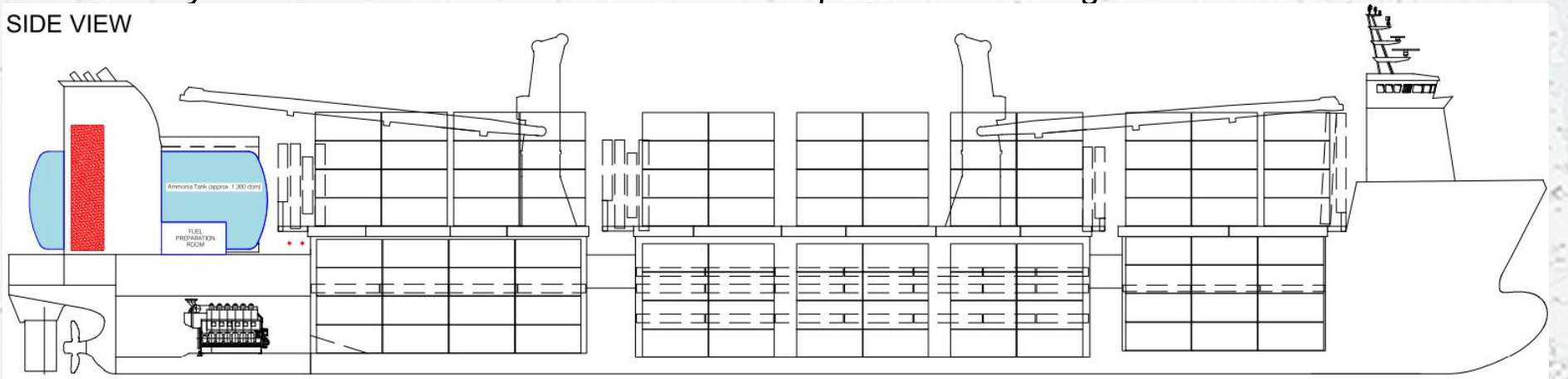
*This may probably lead to the conclusion that newbuildings could be a more reasonable option.*

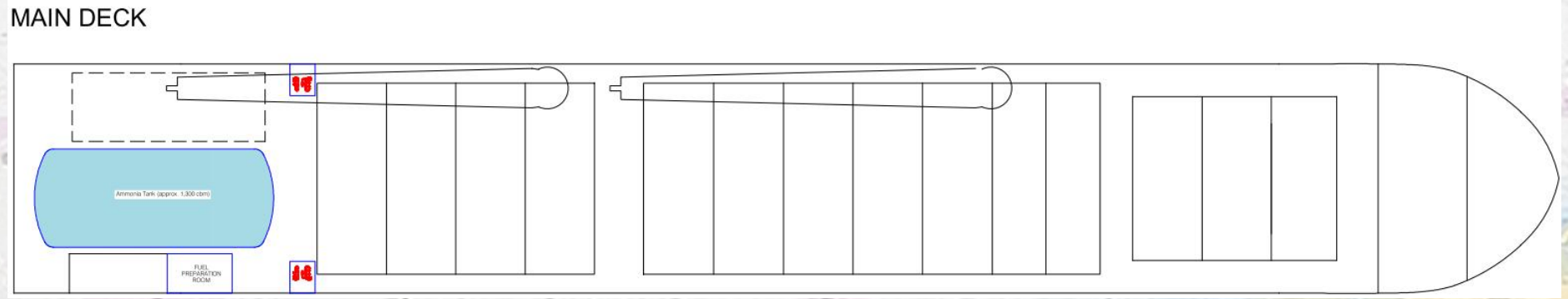
# Newbuilding using ammonia as fuel

*As ammonia has a low energy content it will require larger tanks for storage. Therefore a vessel designed for using ammonia as fuel compared to a vessel using conventional fuels will always either*

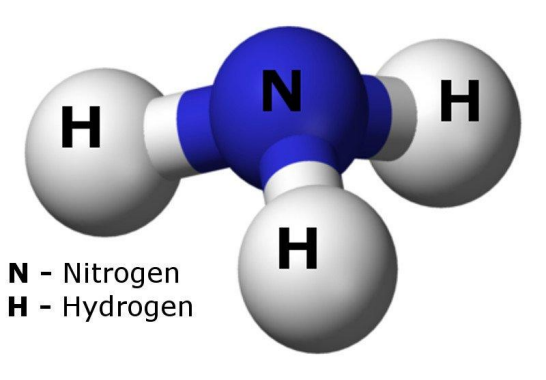
- *be larger*
- *have a decreased cargo capacity*
- *have a reduced endurance/ need more frequent bunkering*

*In addition vessel arrangements will vary significantly depending on the chosen containment system, fuel pressure, fuel temperature, prime mover etc.*
*Due to the toxicity of ammonia it would be sensible to separate fuel storage and accommodation.*



# $NH_3$ Challenges & Ideas




Political Impact
- $CO_2$ reduction

$NH_3$ Colour Scheme *

Infrastructure
- Production towards Use

- Health & Safety
  Rules & Regulations

Demand and Competition
with other industries:
- *For 2012: 650 Mio t Ammonia-fuel demand (energy base) for all ships
  - ➢ 170 Mio t production in 2018

Cradle-to-Grave
- OPEX – CAPEX
  - Energy
  - Emissions

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* Source DNV

# Thanks for your patience !
# Still time for a question ?

*An ammonia-fuelled ammonia gas carrier.*
*Photo courtesy of NYK Line*

*Three 40.000 cbm LPG/Ammonia carriers ordered at Yangzijang by Hartmann Group; HB Hunte Design*

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