SNAME UK Collegium

London
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LNG Fuelled Vessels

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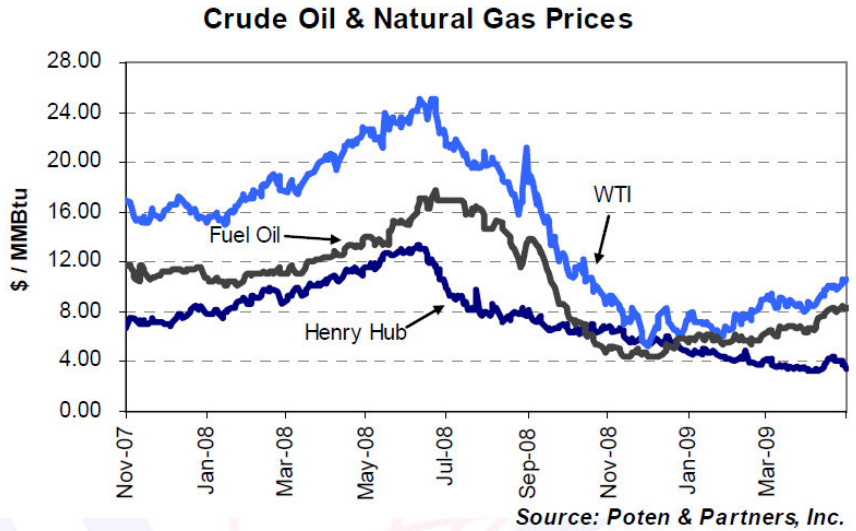
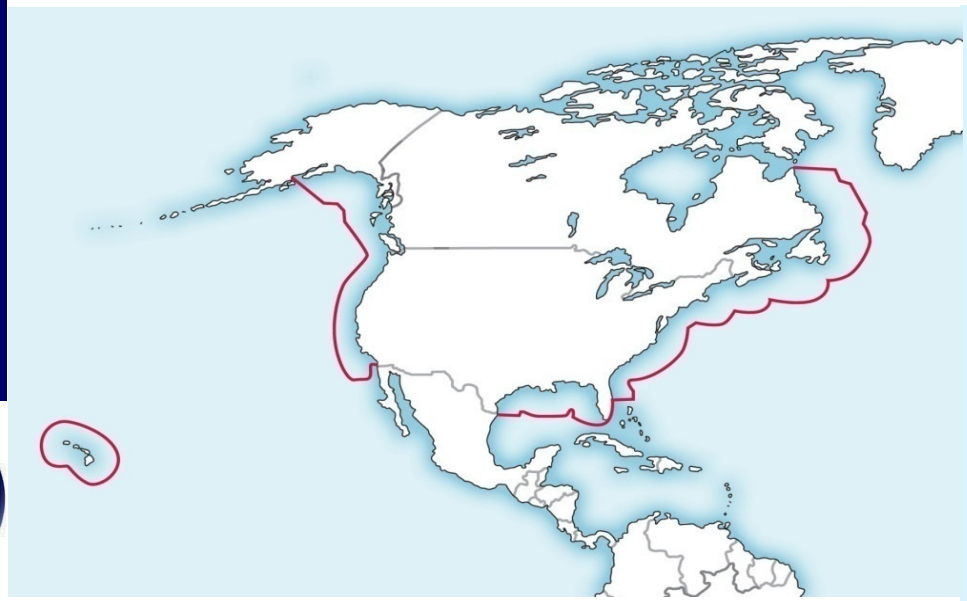
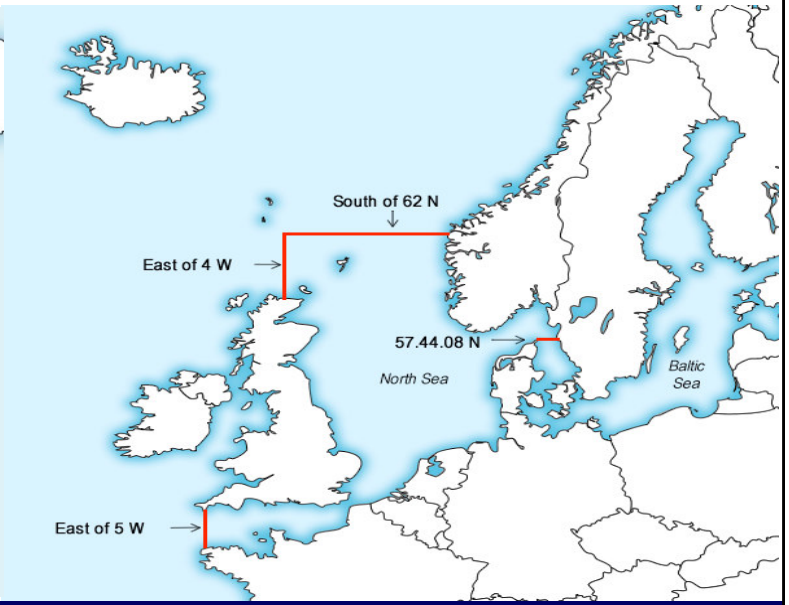
ABS

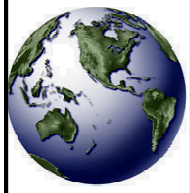
Motivation

- **Emissions**
  - NOx, SOx and GHG
- **Economics**
  - Fuel price uncertainty
  - Carbon regulations



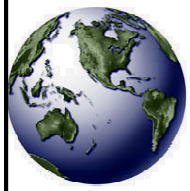






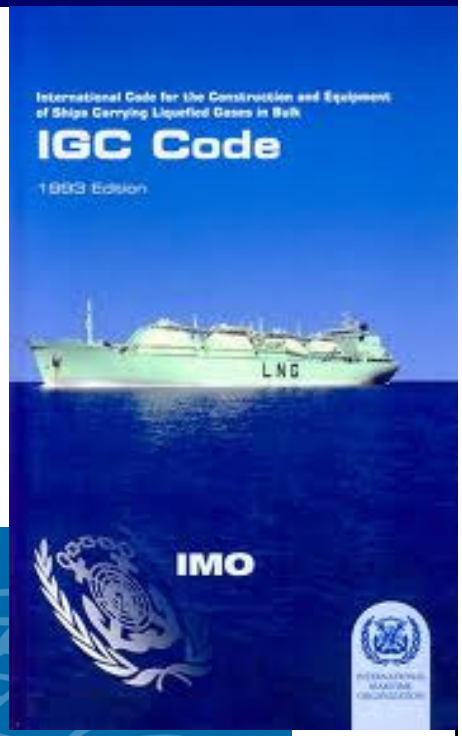
Application

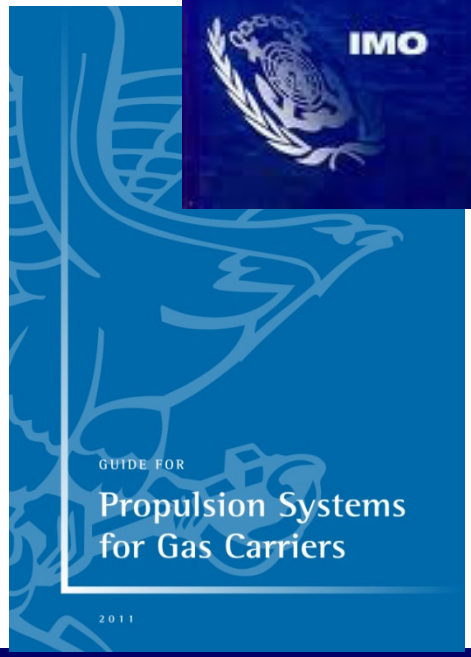
- **Goals**
  - Sulfur and nitrogen oxides emission compliance
  - GHG emissions – statutory and actual (methane slip)
  - Fuel-savings (possible rise in fuel prices, availability of own fuel)
- **Concept**
  - Use of gas in ECAs only
  - 100% gas use or dual fuel
- **Equipment**
  - Range of available powers
- **Fuel Availability**
  - Infrastructure, ownership and competition



Regulatory Framework

- IMO Interim Guidelines on Safety for Natural Gas-Fueled Engine Installations in Ships (IMO Res. MSC.285(86))
- IMO International Code for Safety for Ships Using Gases or Other Low Flashpoint Fuels (IGF Code) (draft)
- International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
- ABS Guide for Propulsion Systems for Gas Carriers
- ABS Guide for Propulsion and Auxiliary Systems for Gas Fueled Ships
- Additional requirements may be imposed by flag Administrations

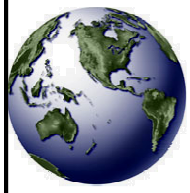




ABS Gas Fueled Ships Guide

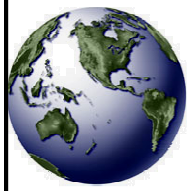
- The new ABS Guide has been aligned where appropriate to incorporate relevant aspects of IMO Resolution MSC.285(86) and can be applied to all vessel types, (except gas carriers) regardless of size.
- The Guide is to be applied in association with relevant IMO documents, ABS Rules and additional flag requirements, as applicable.

Non-Gas Carriers	Gas Carriers
• MSC.285(86) [IGF Code from 2014] • ABS Publication 181: • ABS Guide for Propulsion and Auxiliary Systems for Gas Fueled Ships • SVR	• IGC Code • ABS Publication 112: • ABS Guide for Propulsion Systems for LNG Carriers • SVR



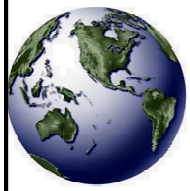
ABS Gas Fueled Ships Guide Arrangement

- The ABS Guide is arranged with the following Sections:
  - Section 1 – General
  - Section 2 – Ship Arrangements and System Design
  - Section 3 – Gas Fuel Storage
  - Section 4 – Fuel Bunkering System
  - Section 5 – Fuel Gas Supply System
  - Section 6 – Re-liquefaction System
  - Section 7 – Gas Combustion Units
  - Section 8 – Dual Fuel and Single Gas Fuel Engines
  - Section 9 – Gas Turbines
  - Section 10 – Surveys After Construction



Key Design Issues

- Overview – IGC Code Principles
- Key design issues
  - LNG Fuel Tank Location
  - BOG Management
  - Inert Gas vs Ventilation of Tank Hold Space
  - Double Wall Vent Piping for Enclosed Passageway
  - Gas Pipe Location
  - HP Gas Pipe Requirements
  - Bunker Station
  - Redundancy of Main Engine
  - FO Tank Arrangement



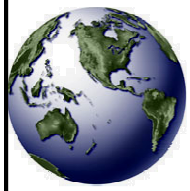
ABS Gas Fueled Ships Guide
Ship Arrangements

- Gas fuel storage tanks can be located on deck or in enclosed spaces.
- Requirements for tank connection space are given which are typically to be applied to smaller vessels with Type C LNG fuel tanks where the tank connection space incorporates vaporizers, valves, etc. forming part of the fuel gas supply system.
- Engine block and bleed and regulating valves typically located in separate GVU room.

Source: TGE

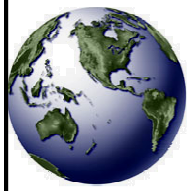
Storage Challenges

- **Low temperature**
  - Requires special materials for handling
    - Stainless steel
    - Aluminum
  - Requires insulation to keep boil-off down
  - Tank shrinkage
- **Flammable and lighter than air when warm**
  - Requires ventilation and other precautions
- **Larger volumes**
  - Higher per energy volumes and lost tank space
- **Tank location**



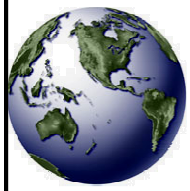
Fuel Properties

- Boiling point equals -163°C at atmospheric pressure
- Specific gravity is approximately 0.5
- Volume 1/600 gaseous form
- Flammability range is 5% to 15% by volume



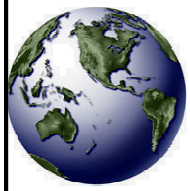
Location of tanks

- Risk of fire in adjacent space causing over pressure
  - Fuel spaces segregate from spaces containing source of ignition
  - Cargo area forward of category A machinery spaces
  - Segregated from source of ignition by a cofferdam
  - ESD system
- Risk of leaked flammable product causing fire / explosion
  - Segregated from source of ignition
  - Area classification (hazardous zones)
  - Gas detection systems
  - Inert cargo holds for Type A and means to quickly inert for Type B tanks



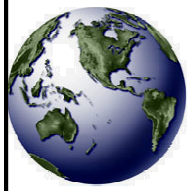
Location of tanks

- Risk of leaked cryogenic fluid leading to loss of structural integrity
  - Separation from bottom / side shell
  - Double hull in way of cargo storage
  - Full Secondary barrier
  - “leak before failure concept” with partial secondary barrier and small leak protection system
  - Gas detection
  - Temperature detection



Storage Options

- Containment types are as defined in IGC Code
  - Independent pressure tanks
  - Independent gravity tanks
  - Membrane and semi-membrane tanks

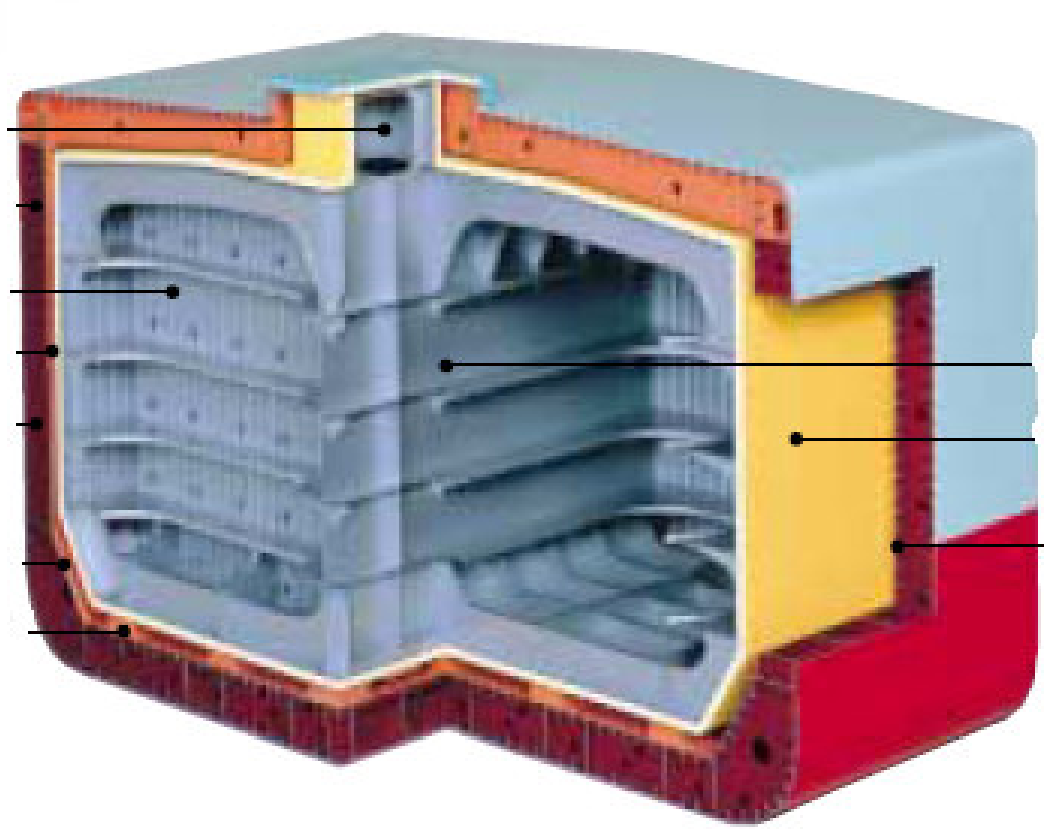


Fuel Types

- Type C Independent Tanks
  - No secondary barrier
  - Typically higher design pressures

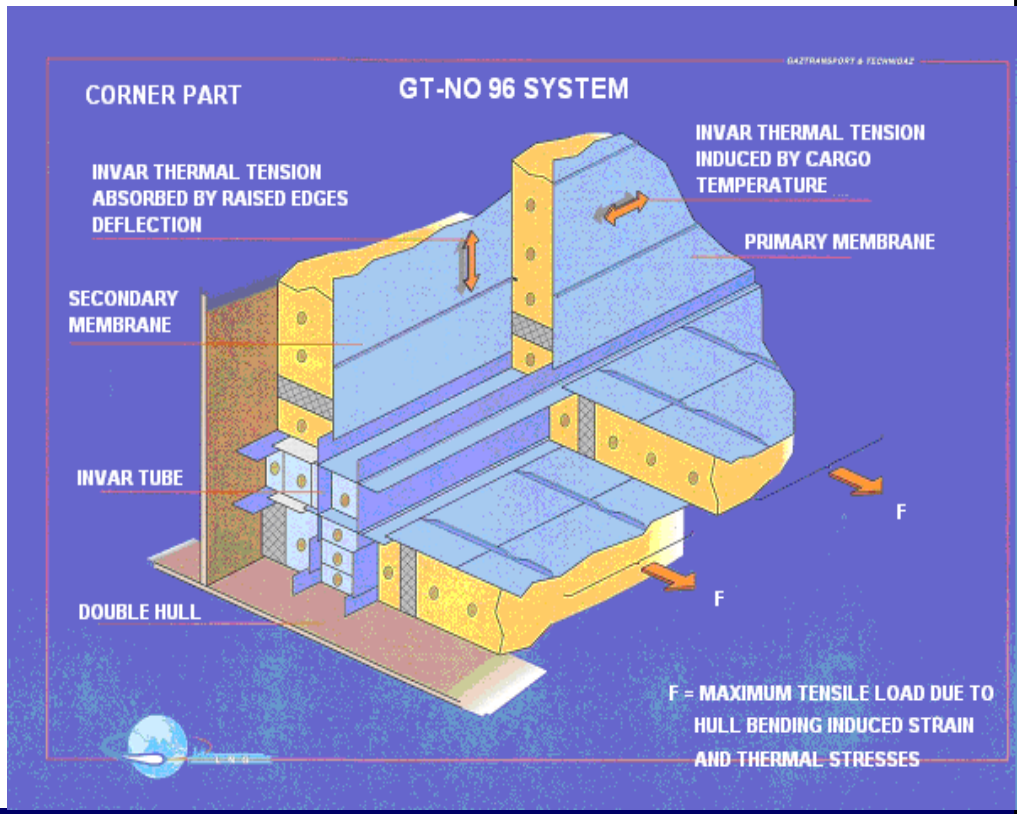
Prismatic Tanks

- Effectively utilize available space
- Require full or partial secondary barriers



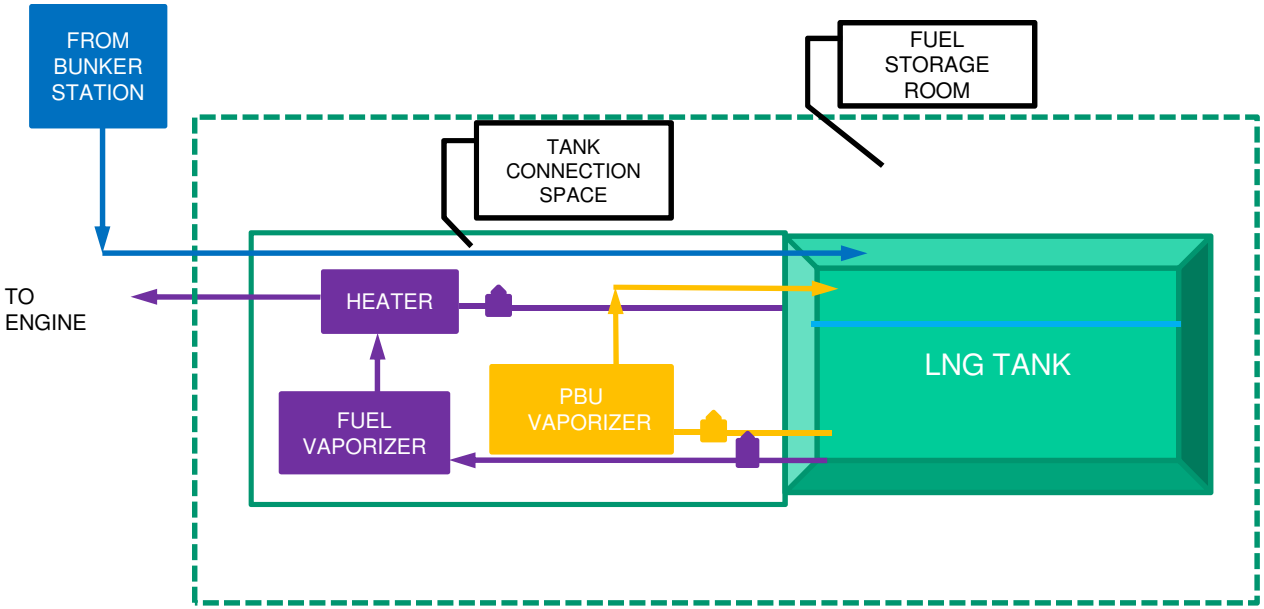
Membrane Tanks

- Effectively utilize available space
- Require full or partial secondary barriers



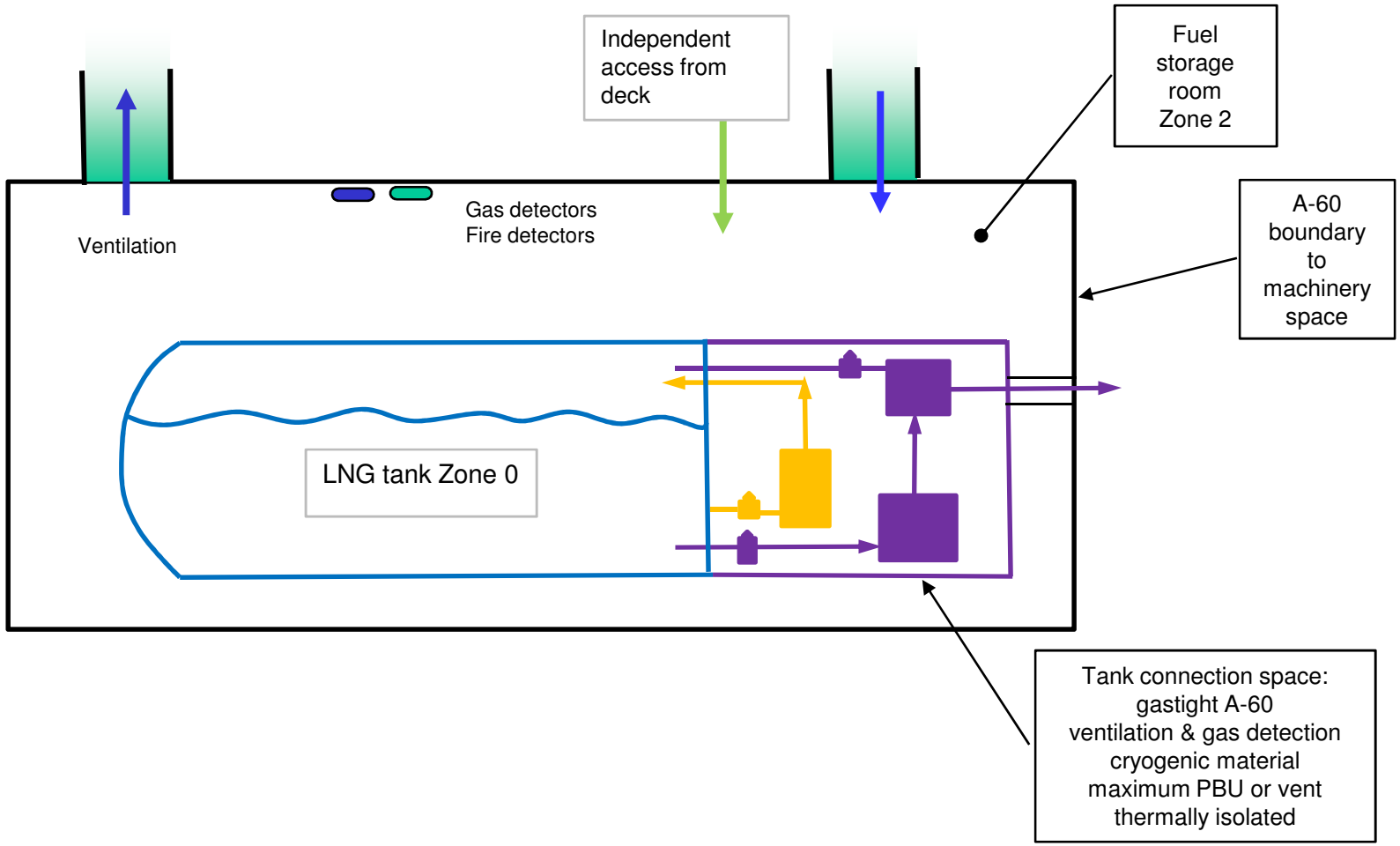
Tank Connection Space/Room

- Fuel gas conditioning and preparation to be undertaken in a space outside of the engine room.
- For smaller vessels using Type C fuel storage tanks this is typically undertaken in the ‘tank connection space’ or ‘tank room’ or ‘cold box’.



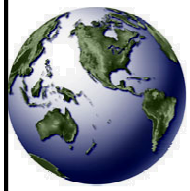
ABS Gas Fueled Ships Guide
Tank Connection Space/Room Requirements

- Gas fuelled ships Type C arrangements



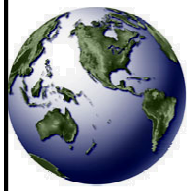
Safe utilization or disposal of NBO

- Means of pressure and temperature control is required to be available at all times even when in port or maneuvering
- System required to safely handle all natural boil off under upper ambient conditions
- Means may be
  - Refrigeration / reliquefaction
  - Pressure accumulation
  - Burning gas for propulsion / power / steam dump
  - Gas Combustion Unit

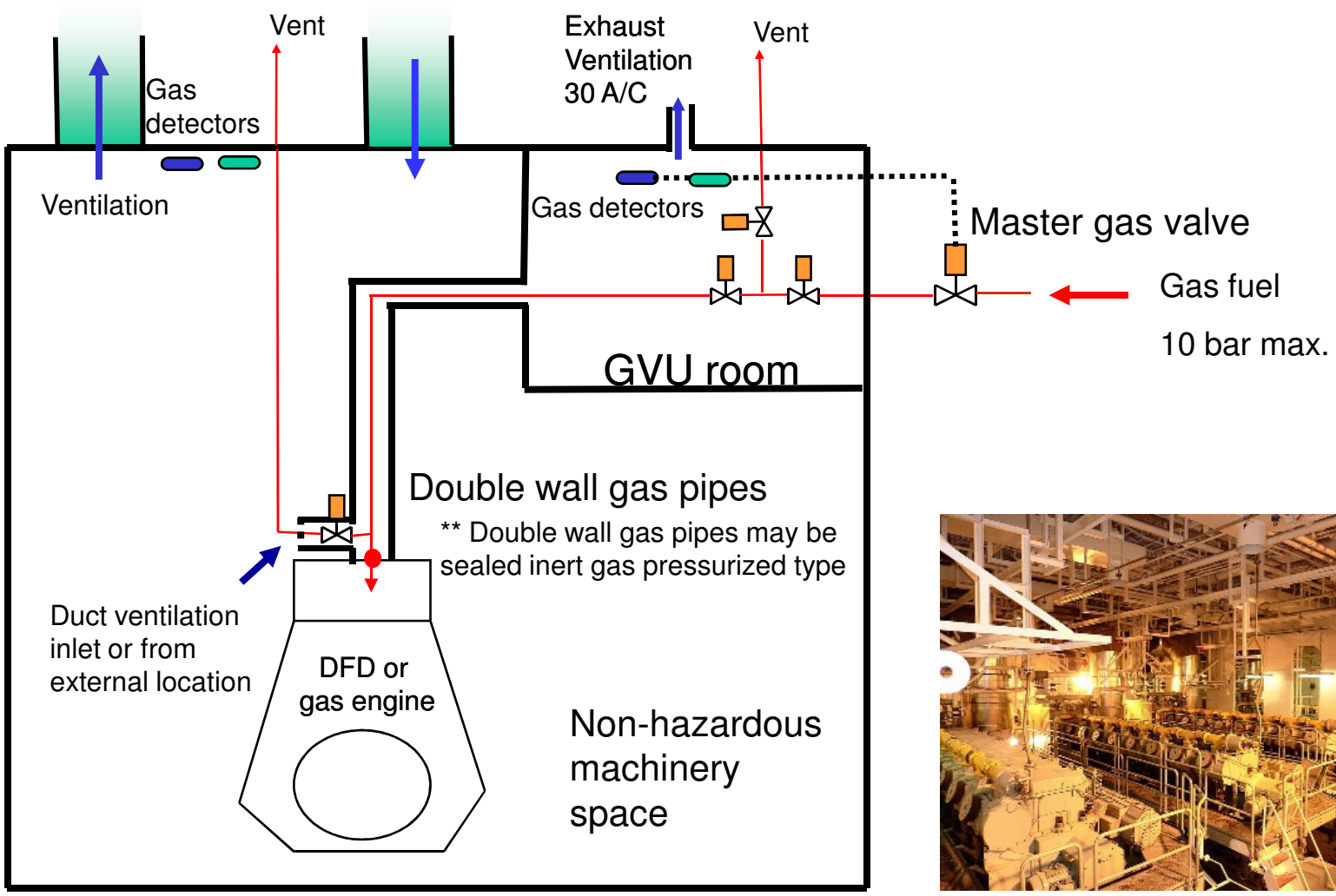


Propulsion Challenges

- Gas leak in engine room
  - High pressure gas
  - Low pressure gas
  - ESD
- Suitable redundancy
  - Getting home
  - Dynamic positioning
- Transient response
- Low power performance



Double Wall Piping Machinery Space



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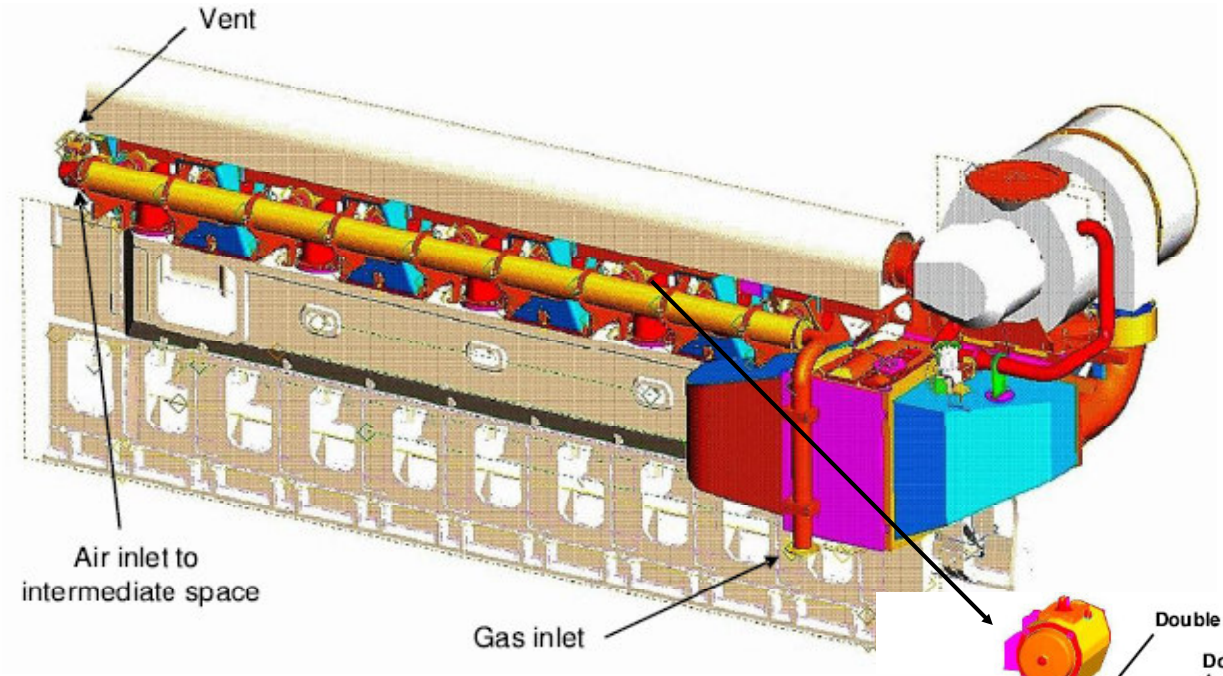
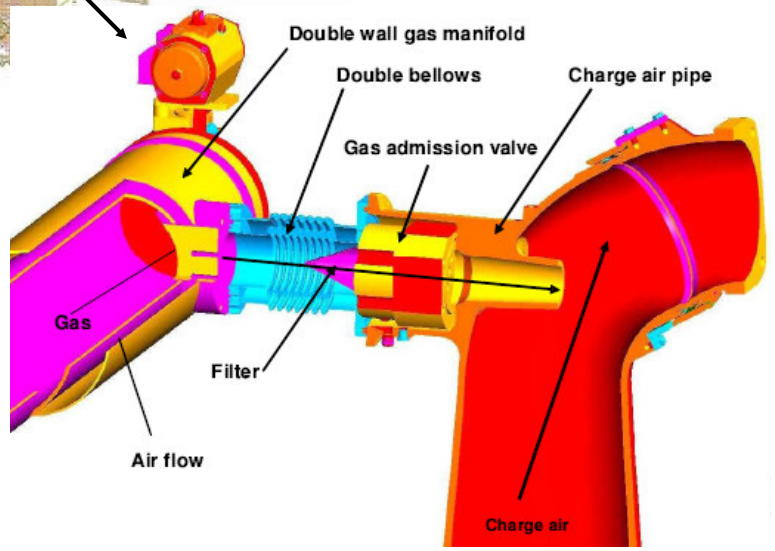
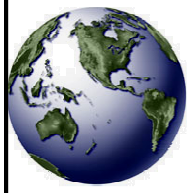




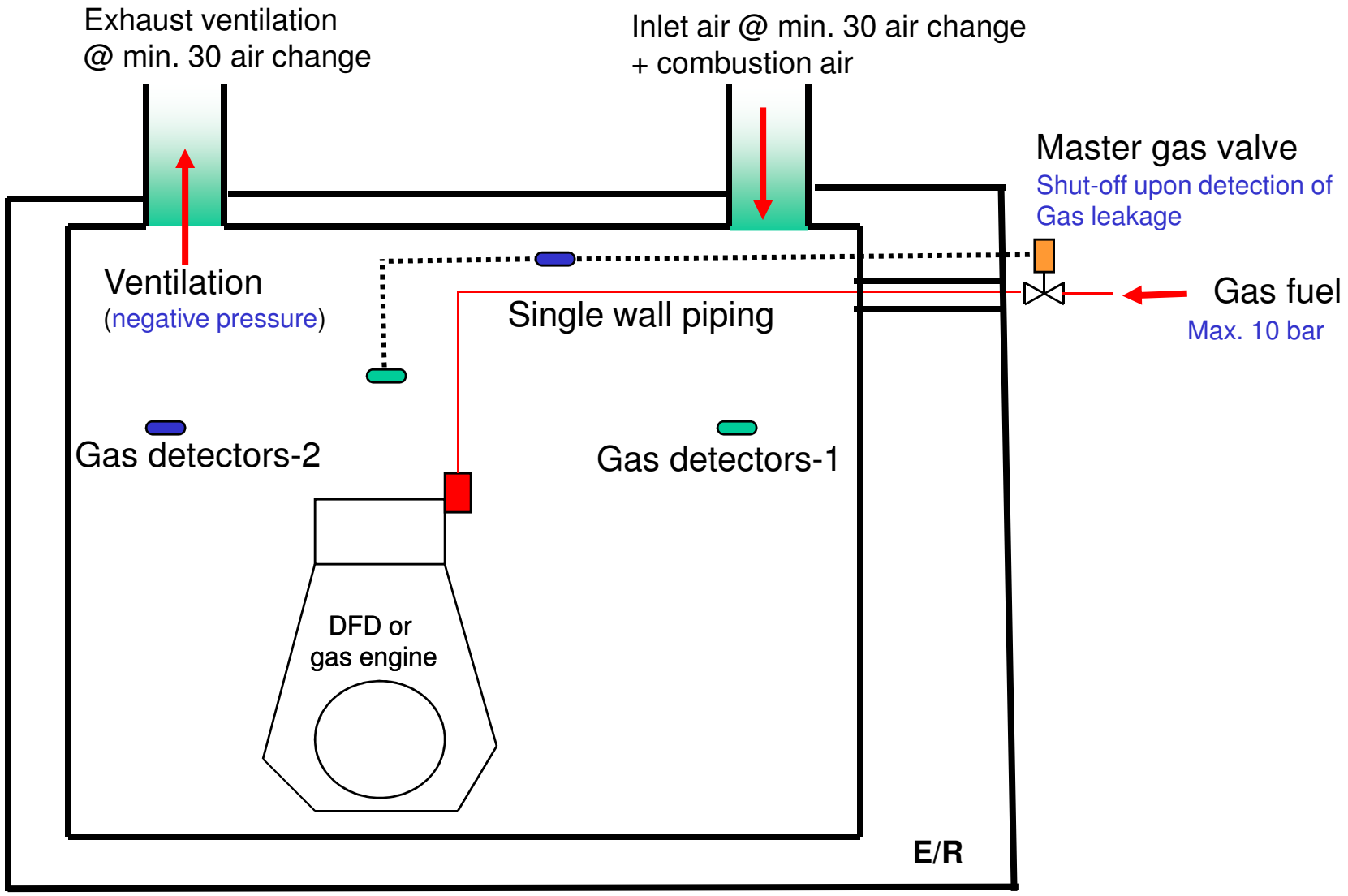
Double wall gas supply pipe

Single Wall Piping Concept

- Low pressure gas systems (<10bar) only
- Two separate machinery spaces are to be provided
- Spaces to contain only engines and minimum necessary equipment
- Alarm upon gas detection at 20% LEL
- Upon gas detection (40% LEL), shut off gas supply and shutdown the machinery space
- Electrical equipment that needs to be operational is to be of Zone-0 certified safe type (Ex-ia only) IEC 92-502
- Ventilation fans redundancy (100% fan capability maintained)
- Access to the spaces through double self-closing doors, or single self-closing door with left-open alarm
- Two independent gas monitoring systems. Locations of gas detectors to be verified by smoke tests or gas dispersion analysis

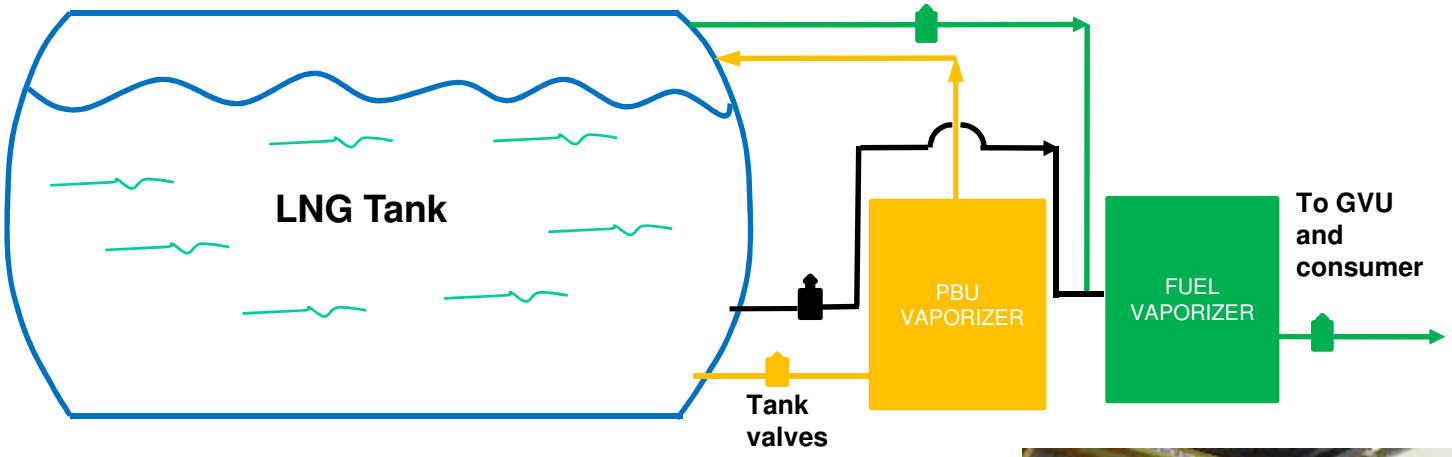


Single Wall Piping Concept



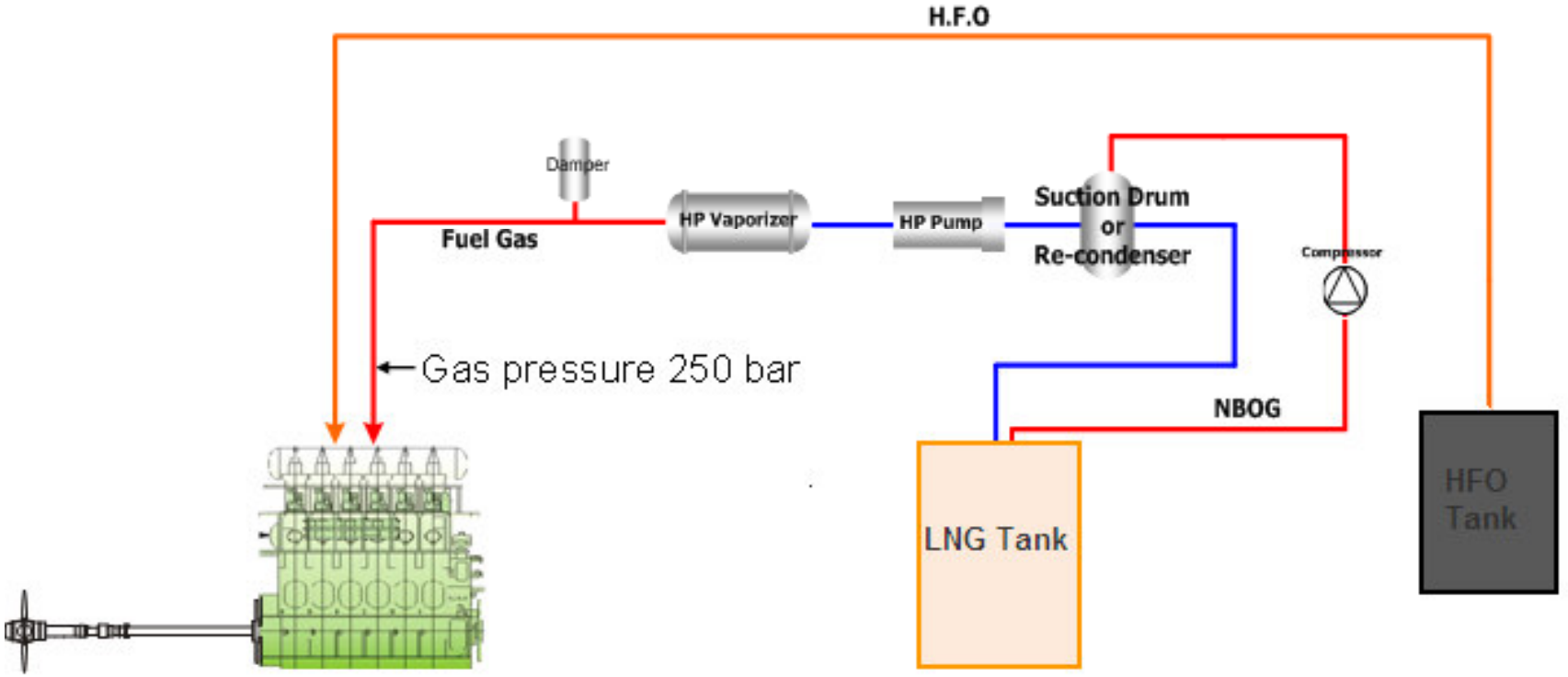
Fuel Preparation and Supply

- Typical low pressure fuel gas supply system
- Delivery pressure 4-5 bar



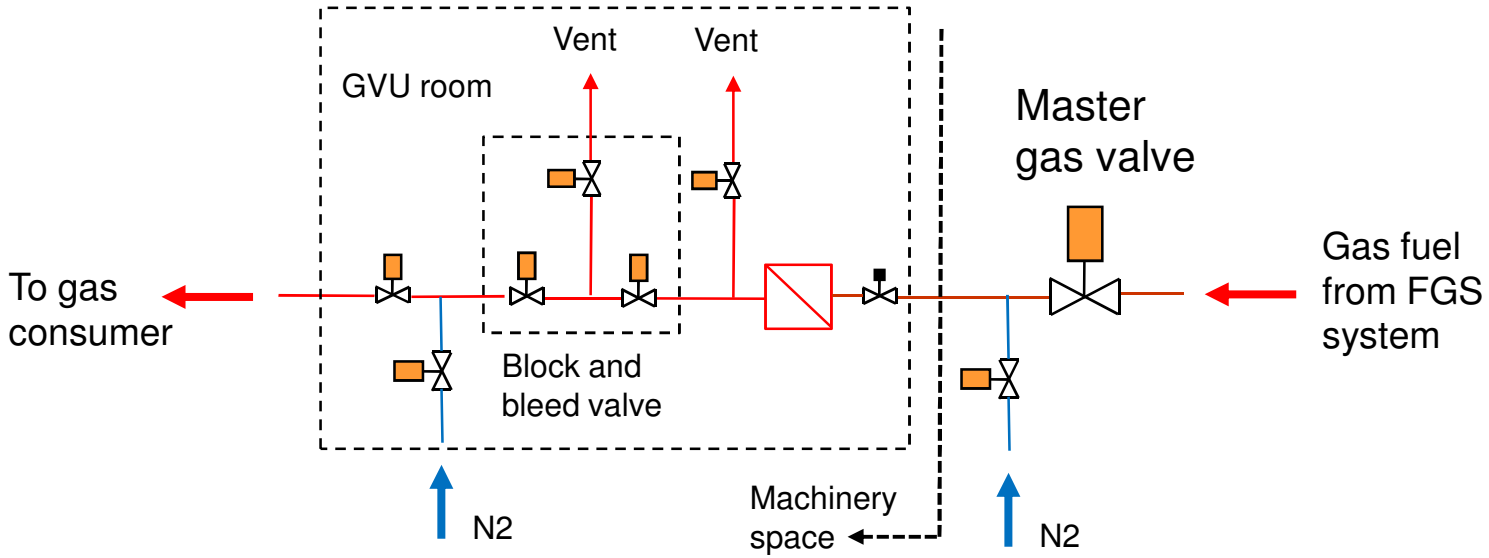
Fuel Preparation and Supply

- High Pressure slow speed DF engine may use HP compressor or HP LNG fuel gas supply system



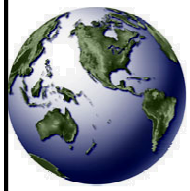
Fuel Preparation and Supply

- Master gas valve to be located outside machinery space
- Block and bleed valve required for each consumer
- Venting and purging facility



Piping and Purging Requirements

- Piping to IGC Code as per 5C-8-5 of the SVR.
- All full penetration butt welded connections fully radiographed.
- Stress analysis for -110C.
- Single wall on open deck, double wall in enclosed spaces.
- Piping to be at least 800 mm in board.
- Protection against mechanical damage.
- Not to be led through accommodation, service spaces or control stations.

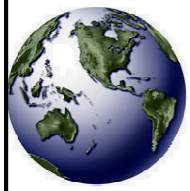


Piping and Purging Requirements

- Provided with means to purge and gas free bunkering and engine room piping.
- Nitrogen supply by generator or bottles.
- Venting to a safe location – mast.
- Fuel storage tanks with low level or pressurized connections to be fitted with ‘main tank valve’.
- Each gas consumer to be fitted with a ‘master gas valve’ and ‘block and bleed’ valves.

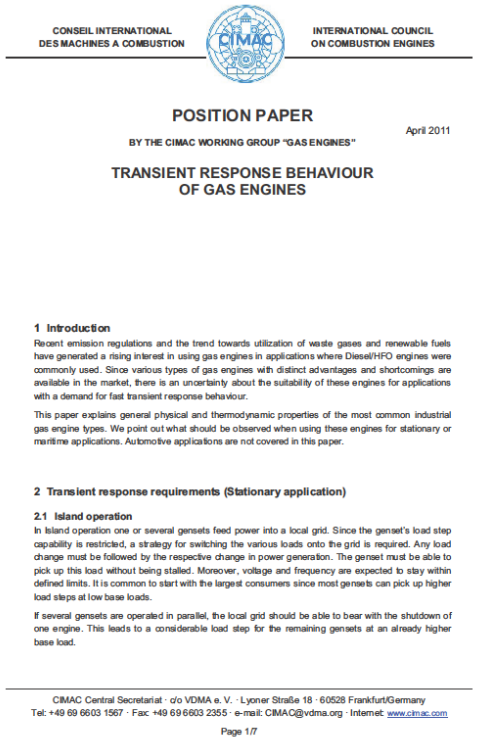
Fuel gas piping inside E/R

- Double wall pipe with annular space pressurized with inert gas at pressure higher than fuel gas pressure. Loss of pressure alarm and activate ESD
- Installed within a ventilated pipe or duct with negative pressure , gas detection loss of ventilation activate ESD
- Provision for inerting and gas freeing piping in E/R
- Master gas valve in the cargo area
- Gas detection in any fuel gas utilization spaces



ABS Gas Fueled Ships Guide
New Propulsion Challenges

- Gas leak in engine room
- Suitable redundancy
  - Getting home
  - Dynamic positioning
- Transient response
- Low power performance
- Arrangement options
  - Gas only
  - Dual fuel using dual fuel engines
  - Dual fuel using combination gas and diesel engines



CONSEIL INTERNATIONAL DES MACHINES A COMBUSTION

CIMAC

INTERNATIONAL COUNCIL ON COMBUSTION ENGINES

POSITION PAPER

April 2011

BY THE CIMAC WORKING GROUP "GAS ENGINES"

TRANSIENT RESPONSE BEHAVIOUR OF GAS ENGINES

1 Introduction

Recent emission regulations and the trend towards utilization of waste gases and renewable fuels have generated a rising interest in using gas engines in applications where Diesel/HFO engines were commonly used. Since various types of gas engines with distinct advantages and shortcomings are available in the market, there is an uncertainty about the suitability of these engines for applications with a demand for fast transient response behaviour.

This paper explains general physical and thermodynamic properties of the most common industrial gas engine types. We point out what should be observed when using these engines for stationary or maritime applications. Automotive applications are not covered in this paper.

2 Transient response requirements (Stationary application)

2.1 Island operation

In Island operation one or several gensets feed power into a local grid. Since the genset's load step capability is restricted, a strategy for switching the various loads onto the grid is required. Any load change must be followed by the respective change in power generation. The genset must be able to pick up this load without being stalled. Moreover, voltage and frequency are expected to stay within defined limits. It is common to start with the largest consumers since most gensets can pick up higher load steps at low base loads.

If several gensets are operated in parallel, the local grid should be able to bear with the shutdown of one engine. This leads to a considerable load step for the remaining gensets at an already higher base load.

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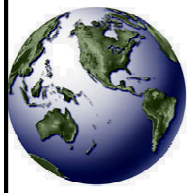
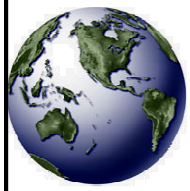


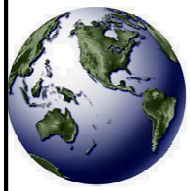
Continuity of propulsion

- Existing IGC only recognized dual fuel plants , draft IGC recognizes gas only engines
- Rapid transfer to liquid fuel required to be demonstrated
- Administration may require oil pilot fuel during maneuvering



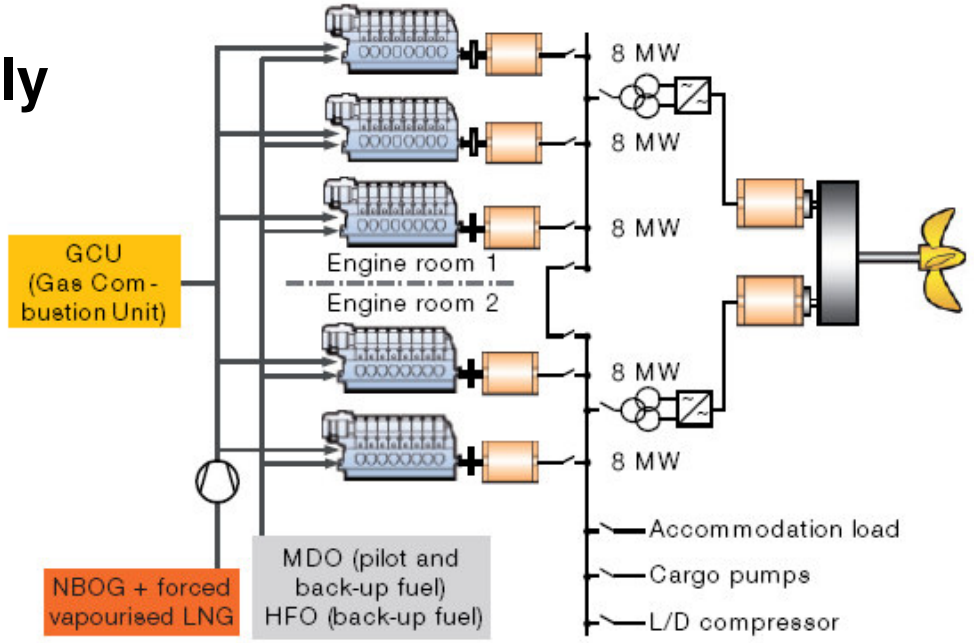
Arrangement Options

- Gas only
- Dual fuel using dual fuel engines
- Dual fuel using combined engines



Gas Engine Options

- **DFDE:** four stroke medium speed dual fuel diesel
- **DF Direct Drive:** four stroke medium speed dual fuel diesel
- **DF Two Stroke Engine:** dual fuel two stroke slow speed diesel direct drive
- **Spark Ignited Gas Only Engine:** four stroke medium speed gas engine



Prime Mover Requirements and Options

- Explosion protection for air and exhaust manifolds.
- Means to sample crankcase gas concentration and means of inerting.
- Crankcase oil mist detection.
- Exhaust system purge capability.
- Combustion monitoring – knock sensor.
- No gas admission without pilot injection or spark ignition.
- Rapid (emergency) changeover gas to fuel (DF).
- Start and stop on diesel (DF).

Source: MAN SE

ABS Gas Fueled Ships Guide
Gas Turbines

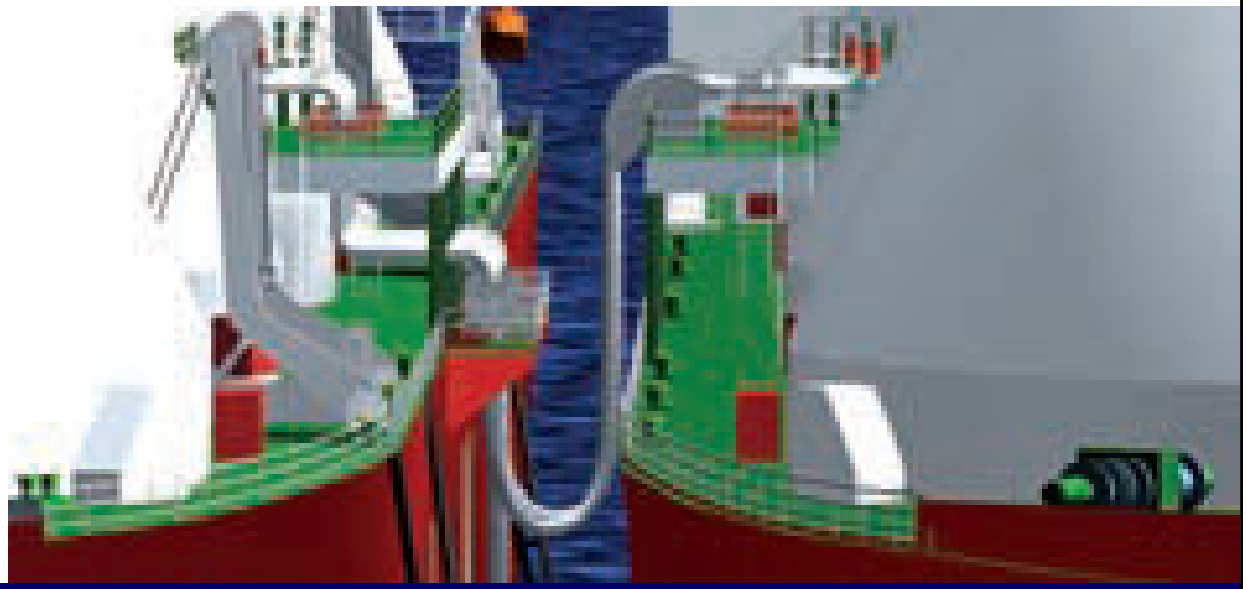
- Gas turbines to be installed in an acoustic gastight enclosure
- Enclosure to contain minimum required installed electrical equipment
- Double or single wall fuel gas piping
- Ventilation 30 air changes / hour
- Gas detection by 2 independent continuous detectors
- Enclosure considered category A machinery space for fire protection
- Gas manifold and nozzle to be vented on shutdown

ABS Gas Fueled Ships Guide
Gas Turbines

- Gas turbines used for propulsion are to have good transient response from zero to full power in both gas and liquid fuel modes
- Fuel changeover to be seamless
- Simultaneous burning of gas and liquid fuels
- Interlocked access to enclosure
- Separate intake and exhaust systems
- Anti-icing systems

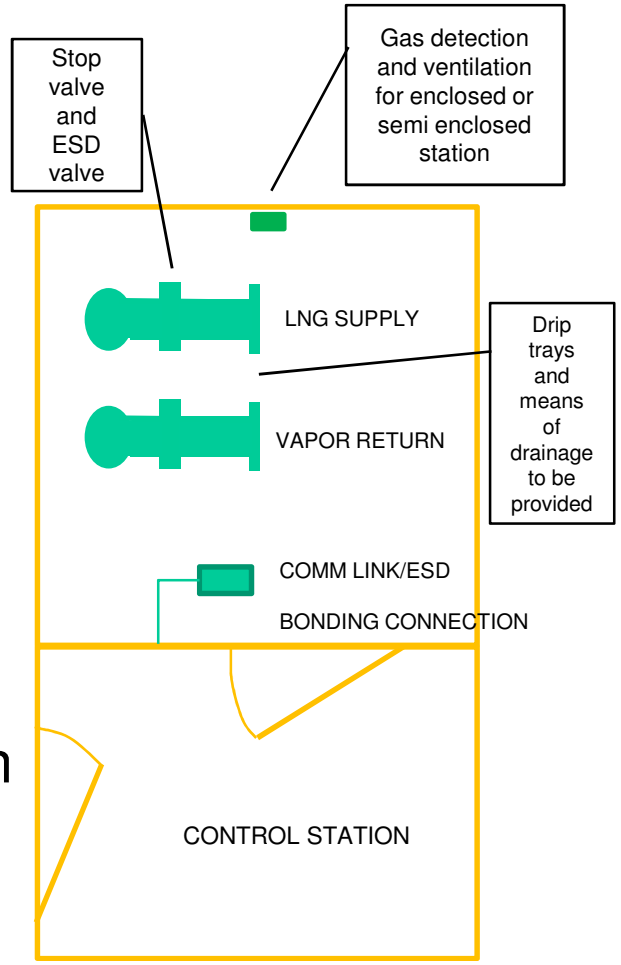
Bunkering

- Arrangement of Piping and Manifolds
- Ship-to-ship transfer



Bunker Station Requirements

- No gas is to be discharged to air during bunkering operations.
- Key bunker station requirements:
  - Sufficient natural ventilation
  - Physical separation and structural protection
  - Stainless steel drip trays
  - Class A-60 protection
  - Remote control and monitoring
  - Manual and remote ESD valves
  - Draining/purging/inerting provision
  - Ventilation and gas detection of bunkering lines



Further Considerations

- Availability of LNG fueling terminals
- Ship-to-ship transfer
- Sufficient storage space
- Emissions
  - Local regulations
  - GHG – methane slip
- Gas spec – methane number
- Transient response
- Crew training

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