LNG as marine fuel and bunkering: technology & practice

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Director

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Who we are

Founded in 1956 and headquartered in Bei Jing, China Classification Society (CCS) is the specialized organization to provide classification services.

Who we are

- A full member of the International Association of Classification Societies (IACS) and one of major international classification societies.
- Authorized by the administrations of more than 34 countries or regions to perform statutory surveys for the ships flying their flags and recognized by the United States Coast Guard (USCG) and the European Union (EU);
- 4,100 employees and over 80 forming a global service network.
- By providing high quality technical services, CCS is lending a significant support to the clients in safety management, energy saving, environmental protection and risk management.

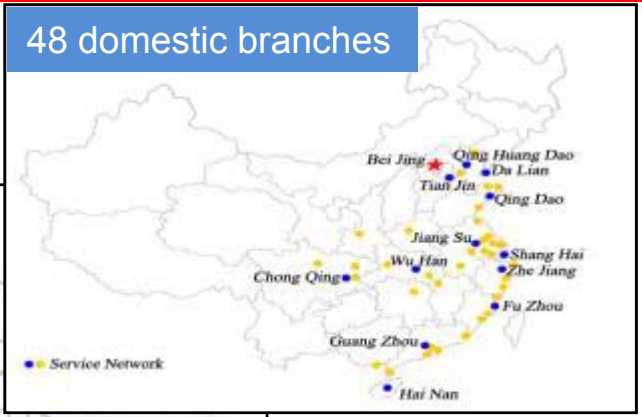
Members of IACS (partial)

CCS
Lloyd's Register
BUREAU VERITAS
DNV GL Group
ABS
RINA
ClassNK
KR KOREAN REGISTER

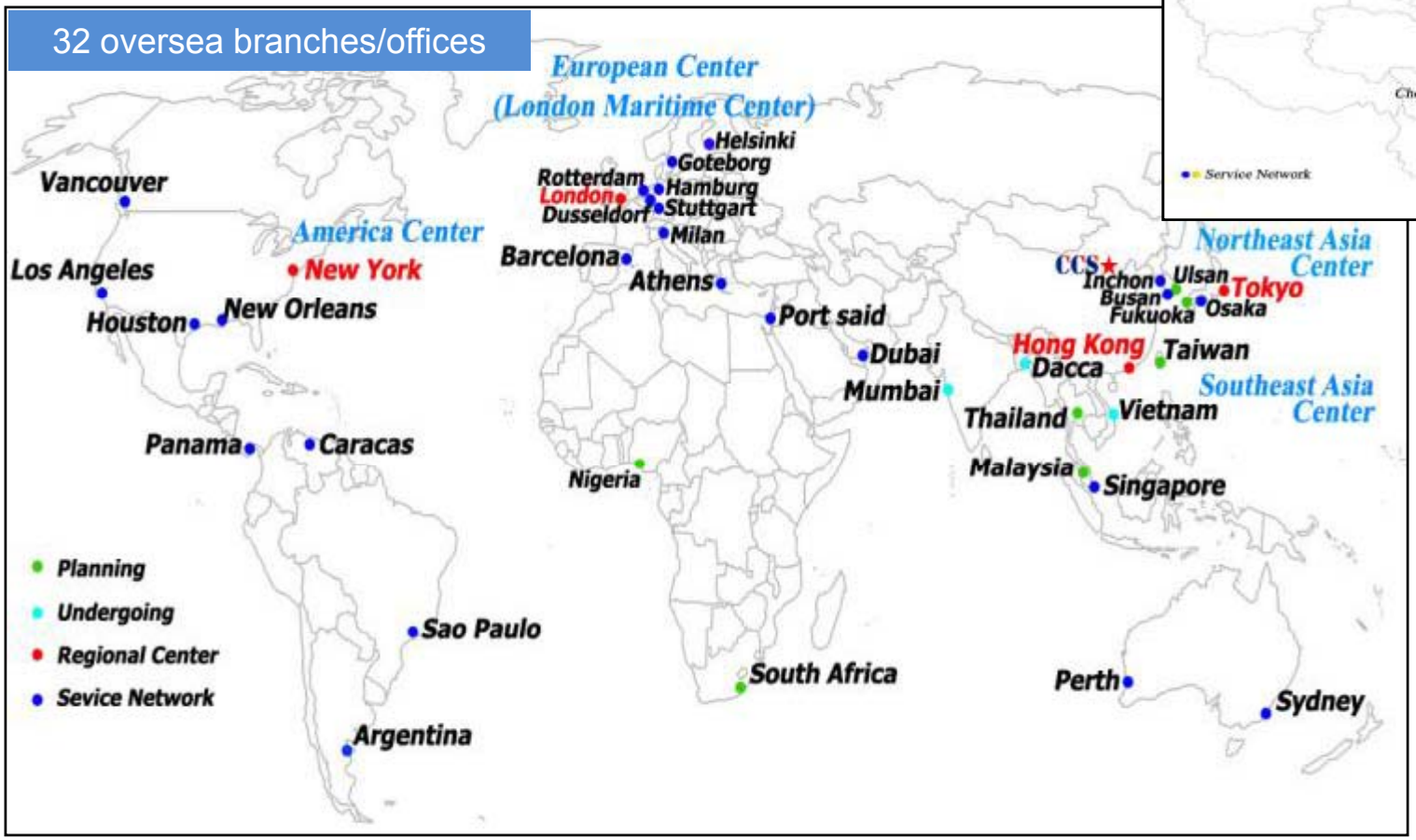
Who we are

CCS Global Service Network

48 domestic branches



32 oversea branches/offices



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- Background & environment for LNG used as marine fuel
- Status quo of LNG fuelled ships and LNG bunkering in China
- Technology development and cases study
- CCS R&D on waterborne LNG value chain
- Conclusion

1st LNG fuelled tug in China

1st LNG bunker in China

1st LNG bunkering pontoon in China

LNG value chain

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LNG value chain

Regulatory background

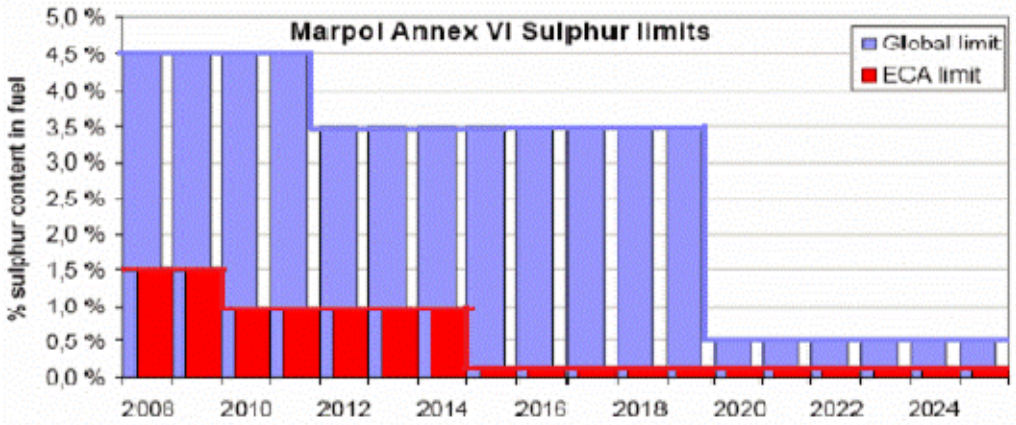
Increasingly stringent regulations on emission control

Existing regulations

- SOx
- NOx
- EEDI

Potential regulations

- Black carbon
- PM



More and more ECAs are excepted to be set up

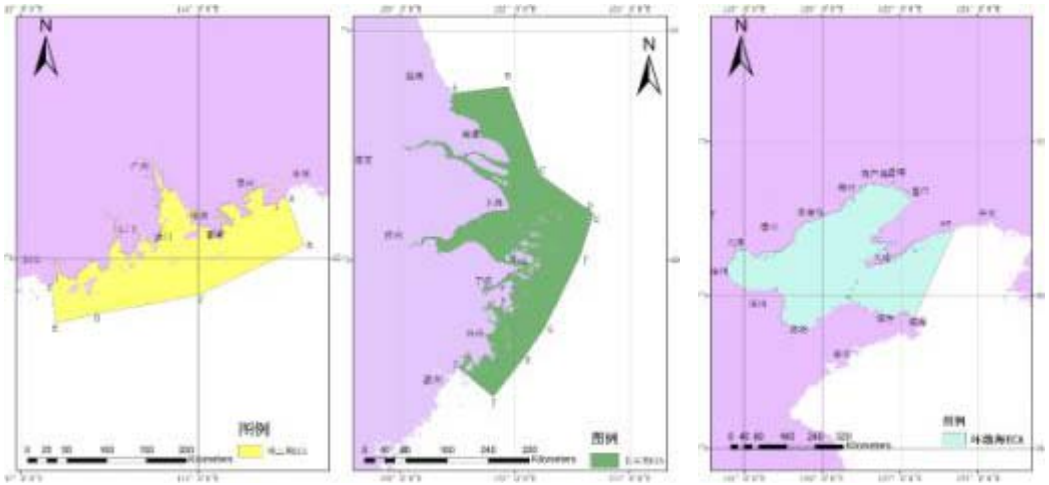
- Taking Hong Kong as an example, although it's not an international ECA today, its EPD(Environmental Protection Department) has issued the regulations requiring all ships in Hong Kong port to use low sulphur content fuel oil (< 0.5) since Jan 1, 2015.
- Other potential ECAs: Singapore, Japan, Australia.

Regulatory background

What about China?

- As the 1st step, China is now considering to set up 3 SECAs, then steadily raise the emission standards for ships navigating or mooring in the ECAs.
- This September, China Ministry of Transport issued the *Action Plan for Preventing Pollution from Ships and in Ports (2015-2020),* aiming at cutting SOx, NOx, PM emission by 65%, 20% and 30% respectively by the end of 2020 comparing with 2015 levels.

The 1st potential ECAs in China (draft)

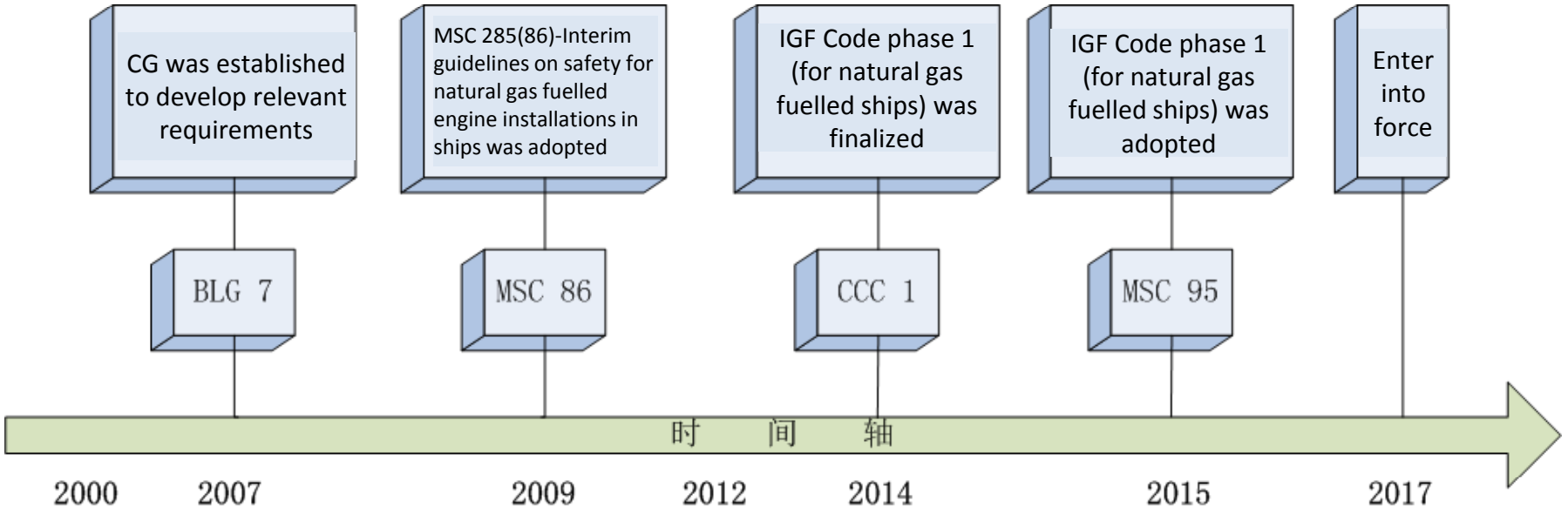


Pearl River Delta | River Yangtze Delta | Bohai Rim

Using LNG as marine fuel is an viable and practicable solution for the time being

Regulatory background

- **The Code for ships using LNG as fuel (IGF Code) is ready……**



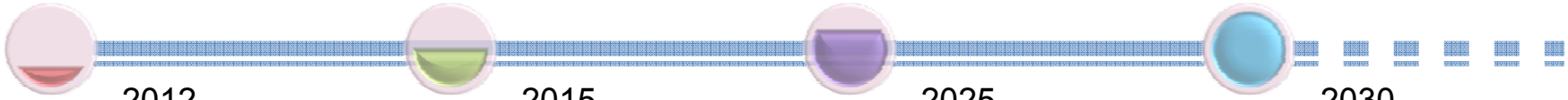
GLUTRA, the 1st LNG fuelled ship in the world

1st LNG fuelled costal ship in China

Environment for LNG fuelled ships (Europe)

Clean Power for Transport: A European alternative fuels strategy

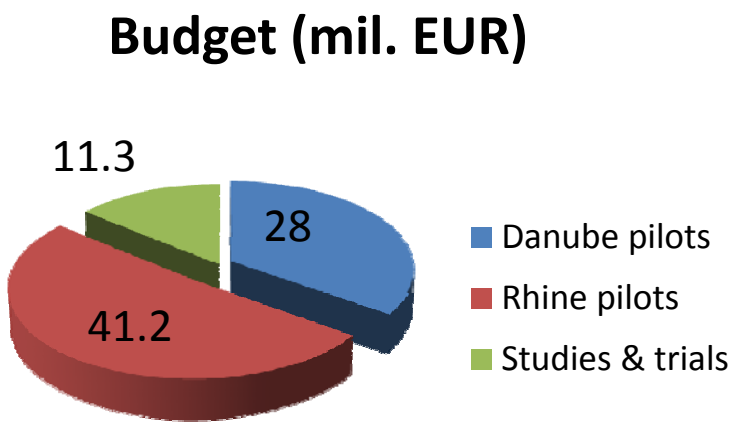
- **A Communication** laying out a comprehensive European alternative fuels strategy, for the long-term substitution of oil as energy source in all modes of transport;
- **A Directive** on the deployment of alternative fuels recharging and refuelling infrastructure;
- **An accompanying Impact Assessment**;
- **A Staff Working Document** setting out the needs in terms of market conditions, regulations, codes and standards for a broad market uptake of LNG in the shipping sector.



2012	2015	2025	2030
Final gap analysis study report by EMSA	0.1% SOx rules apply in sulphur emission control areas (SECAs)	LNG refuelling points for inland waterway transport are provided **in all maritime ports** of the TEN –T Core Network	LNG refuelling points for inland waterway transport are provided **in all inland ports** of the TEN –T Core Network

Environment for LNG fuelled ships (Europe)

The **LNG Masterplan** aims to create a platform for the cooperation of authorities and industry stakeholders with the purpose to facilitate the creation of a harmonized European regulatory framework for LNG as fuel and cargo in inland navigation and to promote the introduction of LNG as a fuel and cargo for inland shipping.



GOAL

- Identify and quantify pioneer markets and customers in the inland ports hinterland
- Analyse costs and savings/benefits of LNG use
- Transfer know-how from maritime into inland navigation sector and raise awareness
- Facilitate the creation of a harmonised European regulatory framework considering LNG as fuel and as cargo for inland navigation
- Deliver technical concepts for new and retrofitted vessels
- Elaborate supply chains to reach end-consumer
- Execute pilot deployments of vessels and terminals
- Develop a comprehensive strategy with a detailed roadmap for the implementation of LNG in line with the EU policies in transport, energy and environment
- Prepare wide-scale deployment with the help of CEF & other EU programs

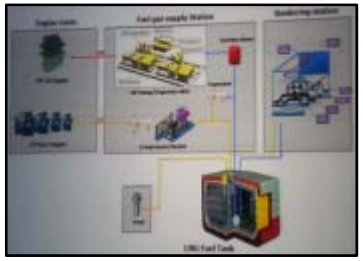
Environment for LNG fuelled ships (China)

- China has established a comprehensive Regulatory framework for ships using LNG as fuel;
- China government is now encouraging the new building ships to use LNG as fuel by subsidy policies;
- Now the China Ministry of Transport is also considering incorporating new promotion policies for ships using LNG into its 13th 5-year plan;
- The “chicken egg trap” is being steadily broken in China.

2010 2013 2014 2015

1st dual fuelled inland ship

1st dual fuelled seagoing ship

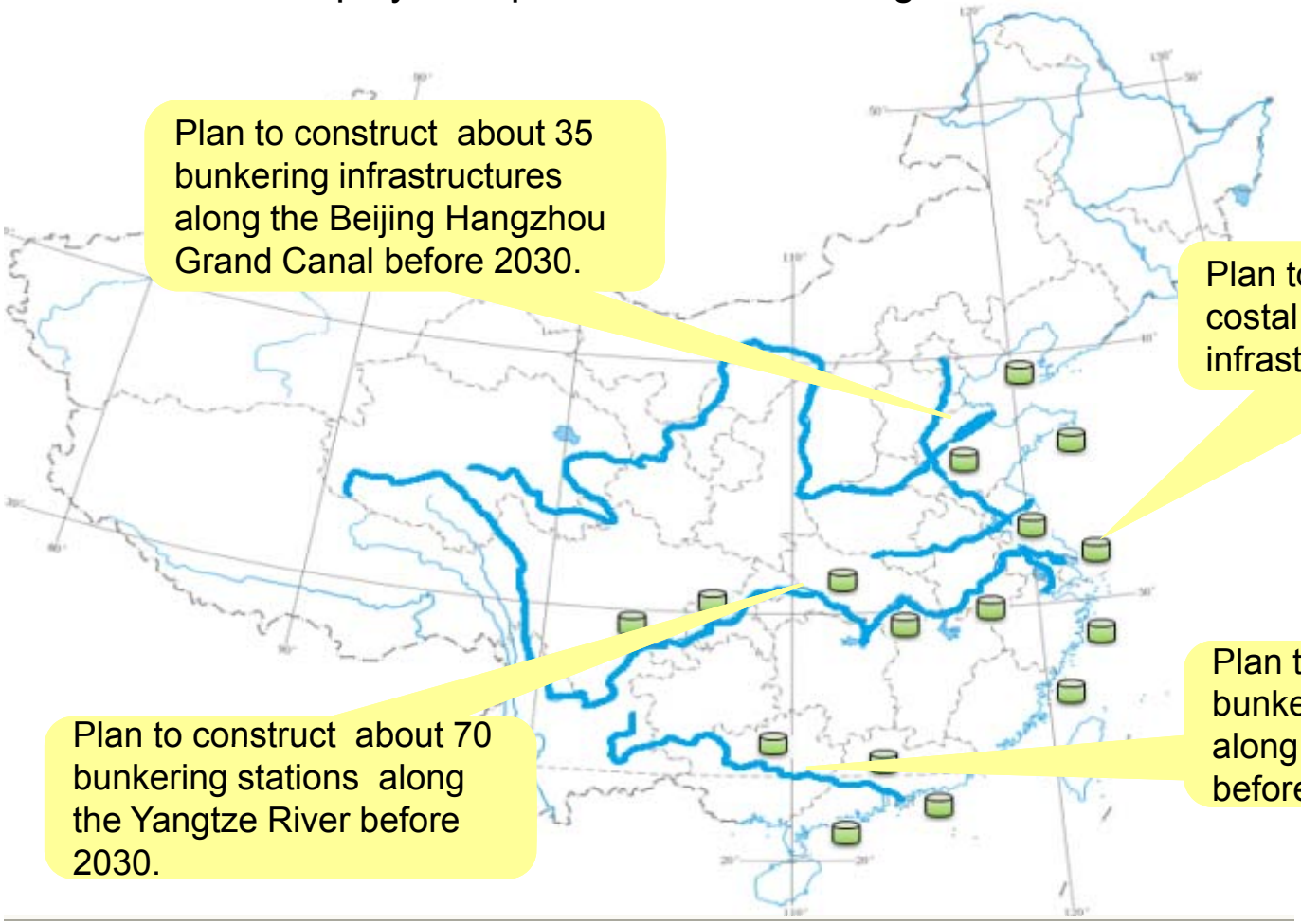


LNG ready concept for VLCC

1st pure LNG fuelled ship in Asia

Environment for LNG fuelled ships (China)

Deployment plan of LNG bunkering infrastructures in China



Brief summary

- The entry into force of 0.10% sulphur Regulation for SECAs accelerates the uptake of LNG fuel.
- The adoption of IGF Code lay a solid Regulatory foundation for the international navigation LNG fuelled ships
- China (including Hong Kong) is now planning to set up SECAs, which will "push" the ship owners to consider using LNG; on the other hand, Chinese government is actively encouraging and guiding the use of LNG through a series of policies, which will effectively promote the use of LNG as marine fuel;
- China has established a comprehensive framework of Regulations & Rules for waterborne LNG value chain, also has many successful cases of LNG fuelled ship, LNG bunkering pontoon and LNG bunkering barge, the practice proved that the safety of LNG application can be assured as long as appropriate risk control measures are used.

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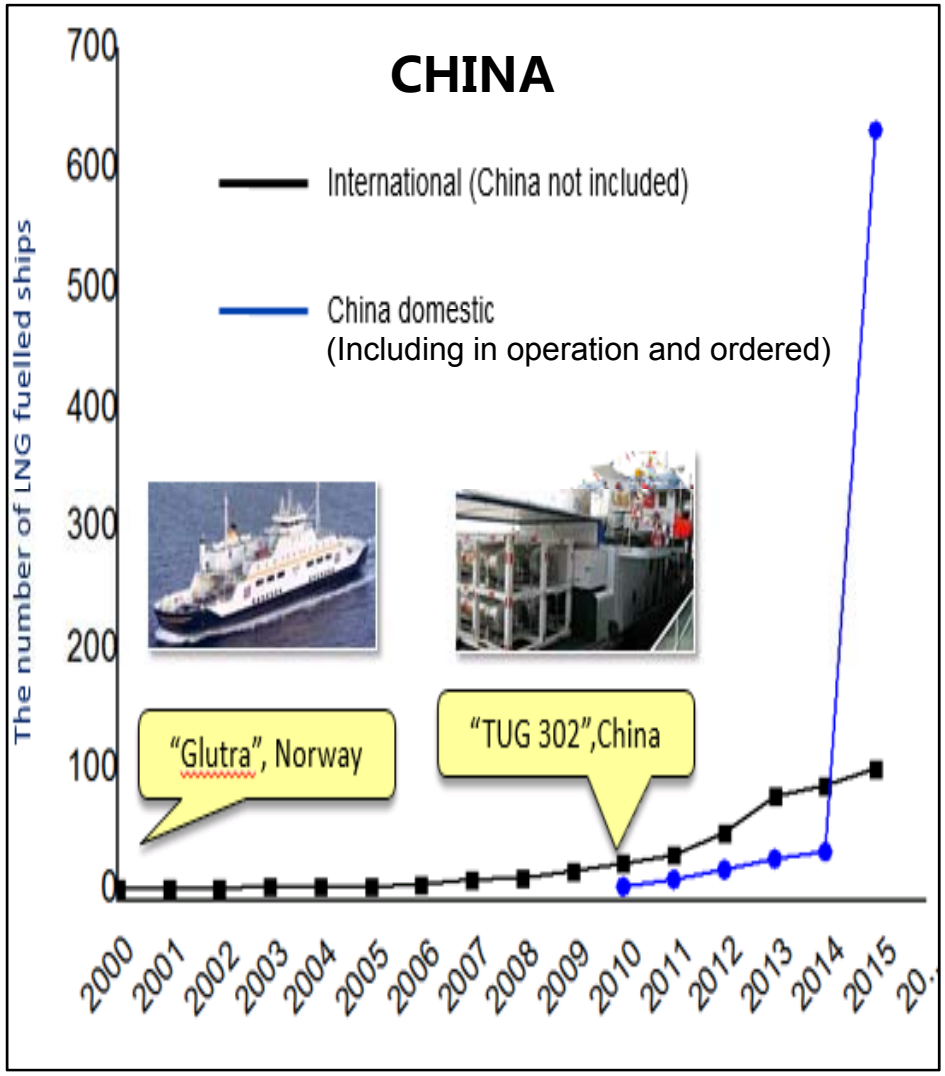
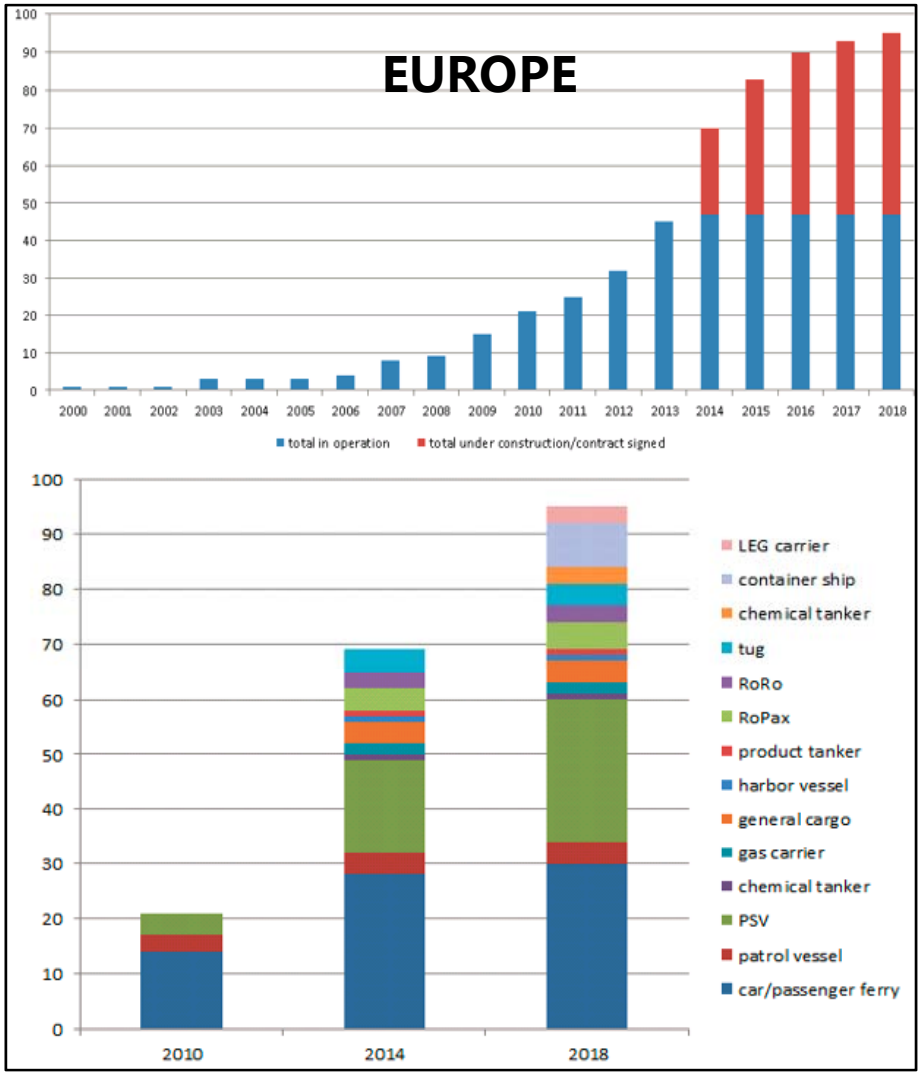
LNG value chain

Current status of LNG fuelled ships: China vs Europe

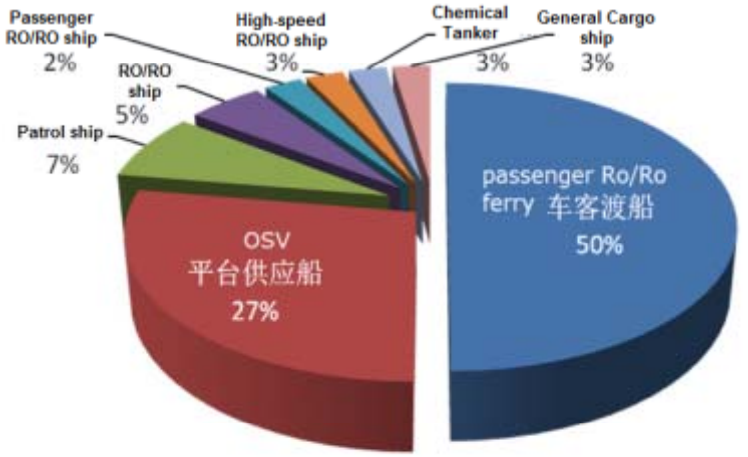




Current status of LNG fuelled ships: China vs Europe

Which types of ships are most suitable for using LNG as fuel?

- **Ships navigating on fixed route**, due to that bunkering and ship design are much easier.
  - Car/passenger ferries
  - Platform supply vessels
  - Ro-Ro
- **Ships with large open deck** which is available for arranging LNG storage tank, to reduce the cargo tank loss.
  - Oil tankers
  - Chemical tankers



LNG-fuelled fleet per segment

Oil/chemical tanker using LNG as fuel

Current status of LNG carriers: China vs Europe

EU

Permitted the inland waterway LNG transport by revising table C of ADN. LNG can be transported by type G tank vessels, maximum permissible capacity of a cargo tank shall not exceed 1000cbm, and there's no safety zone requirements for inland waterway LNG carriers.

Application for a recommendation on the use of membrane tanks for transport of liquefied natural gas on the tank vessel *Argos-GL*

Transmitted by the Government of the Netherlands

I. Introduction

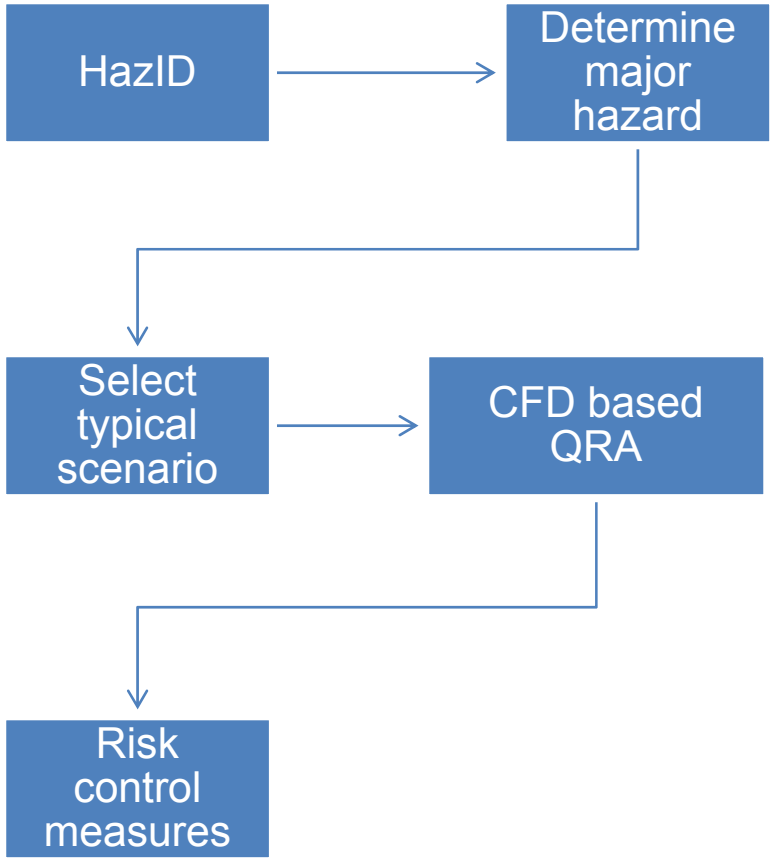
1. Several vessels are now - on a trial basis - using LNG as fuel, and it is expected that more will follow in the future. Also the development of bunkering facilities along inland waterways is making progress.

2. To support these developments the Dutch delegation has proposed to include LNG (UN No. 1972) in Table C of ADN, and developed additional regulations for the carriage of liquefied gases. These proposals have been adopted and are expected to enter into force on 1 January 2015.

Current status of LNG carriers: China vs Europe

China： a ***Research on Risk Assessment and Risk-control Measures for Inland Waterway LNG Carriers*** was conducted and the following conclusion was given:

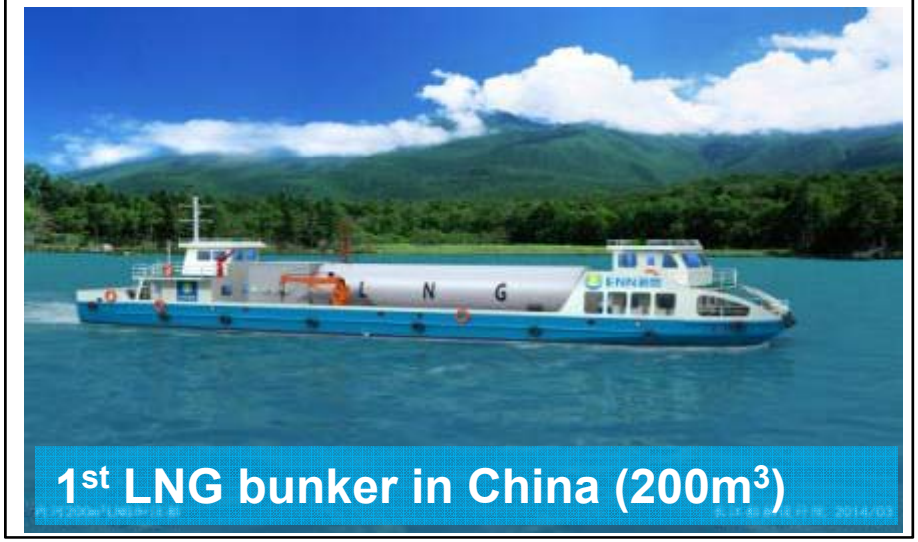
- The collision design is required for inland LNG carriers ;
- About safety zone
  - Normal condition: no safety zone requirement ;
  - Failure condition of LNG carriers: the ships shall move to emergency anchorage ASAP, fore-and aft 300m, port-and-starboard 100m is safety distance;
  - LNG leakage condition : 1100m around the ship is safety distance.
- The emergency anchorage shall be located at 1100m far away from other anchorages



Current status of LNG bunker barges: China vs Europe

- CCS has finalized the *Rules for LNG Bunkering Vessels*, which will be published this year and expected to be the 1st Rules for LNG bunkering Vessels in the world;
- The 1st LNG bunkering barge in China is now under construction;
- 4 key issues for LNG bunkering barge:
  - Quantitative risk assessment to determine the safety distance;
  - Appropriate connection (hose + dry disconnection coupling);
  - Emergency break away;
  - Safe operation procedure

1st LNG bunkering barge in the world—Seagas



1st LNG bunker in China (200m3)

Milestones of LNG fueled vessel & LNG bunker in China

- CCS issued 1st version of Guidelines for Survey of Gas Fuelled Ships in 2008;
- CCS issued updated Guidelines for Survey of Gas Fuelled Ships in 2011;
- CCS issued Rules for Natural Gas Fuelled Ships in 2013;
- CCS issued Rules for LNG Bunkering Pontoons in 2014;
- In Dec 2013, the 1st sea-going dual fuel vessel — 6500HP harbor tug “CNOOC 521”delivered, classed by CCS;
- This July, the Asia 1st pure LNG fuelled tugs was delivered, classed by CCS;
- The 1st new built LNG bunkering barge in China will be delivered this year, classed by CCS

CNOOC No.521	*CNOOC No.522*	*1100 TEU*	*LNG bunker*
			

Brief summary

- The start of using LNG as marine fuel in China is later than in Europe, but the development of LNG fuel ships in China is much faster;
- Both Europe and China has realized that the development of LNG fuelled ships depends on the whole waterborne LNG value chain, which including LNG transport, LNG bunkering, etc;
- The LNG bunkering solutions are various, which could be chosen based on specific condition. Ship to ship bunkering is a flexible solution;
- Inland LNG transport in bulk was not allowed before in Europe nor in China, but the situation is now regularly changing;

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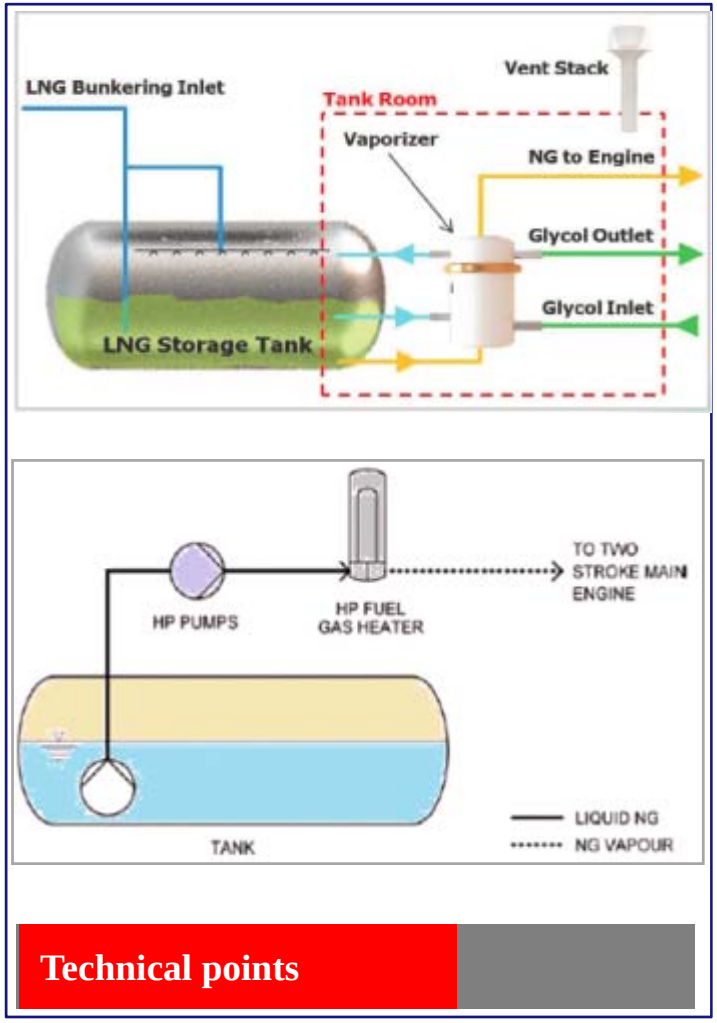
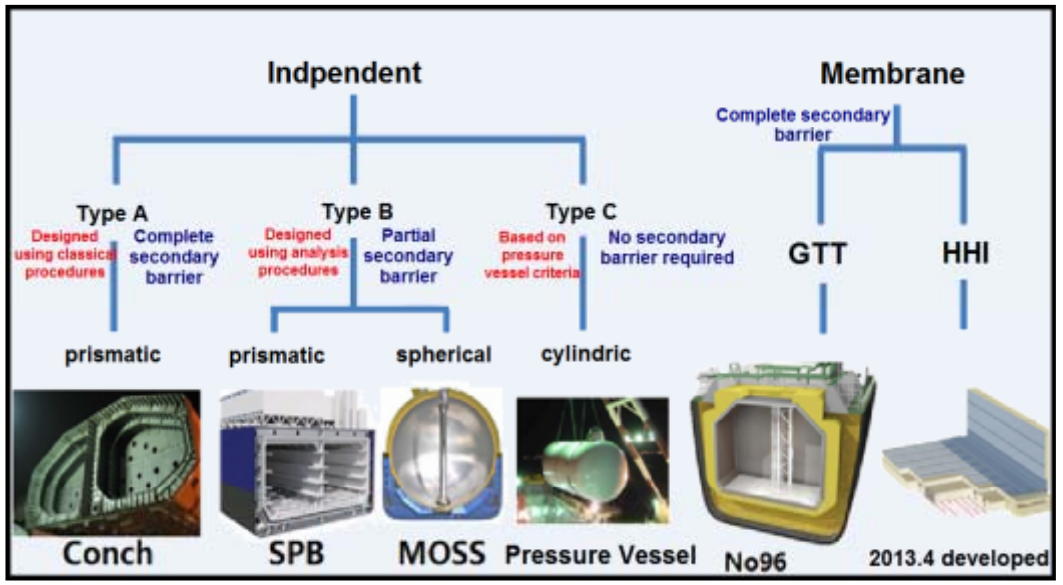


Fuel gas storage & supply system

The following common technologies/systems are used for LNG fuelled ships, LNG carriers and LNG bunkering barges, so in our R&D, they are considered “modules”:

- Fuel/cargo containment system;
- Fuel gas supply system;
- LNG power system, such as gas engine;
- LNG bunkering system or LNG cargo handling system;
- Risk assessment

Fuel gas storage & supply system



- Membrane tanks: becoming more flexible to better meet the demands from LNG fuelled ships and LNG bunkers;
- Type C tanks: upsizing (Max. volume is about 9000cbm for single tank) ;
- New opportunity for type A and type B tanks

Location of gas fuel storage tank

IGF Code (IMO MSC 391.(95))

Protective location of LNG tanks

Deterministic approach

The distance is explicitly given

Probabilistic approach

Calculating f_{CN} , then compare with the criteria

The above approaches are alternative

5.3.4 As an alternative to 5.3.3.1 and 5.3.3.3 above, the following calculation method may be used to determine the acceptable location of the fuel tanks:

.1 The value f_{CN} calculated as described in the following shall be less than [0.01][0.02] for passenger ships and [0.02][0.04] for cargo ships.[5]

.2 The f_{CN} is calculated by the following formulation:

$$f_{CN} = f_i \times f_l \times f_v$$

where:

f_i is calculated by use of the formulations for factor p contained in SOLAS regulation II-1/7-1.1.1.1. The value of x1 shall correspond to the distance from the aft terminal to the aftmost boundary of the fuel tank and the value of x2 shall correspond to the distance from the aft terminal to the foremost boundary of the fuel tank.

f_l is calculated by use of the formulations for factor r contained in SOLAS regulation II-1/7-1.1.2, and reflects the probability that the damage penetrates beyond the outer boundary of the fuel tank. The formulation is:

$$f_l = 1 - r(x1, x2, b)$$

f_v is calculated by use of the formulations for factor v contained in SOLAS regulation II-1/7-2.6.1.1 and reflects the probability that the damage is not extending vertically above the lowermost boundary of the fuel tank. The formulations to be used are:

$f_v = 1.0 - 0.8 \cdot ((H-d) / 7.8)$, if $(H - d)$ is less than or equal to 7.8 m. f_v should not be taken greater than 1.

$f_v = 0.2 - 0.2 \cdot ((H-d) - 7.8) / 4.7)$ in all other cases. f_v should not be taken less than 0.

where:

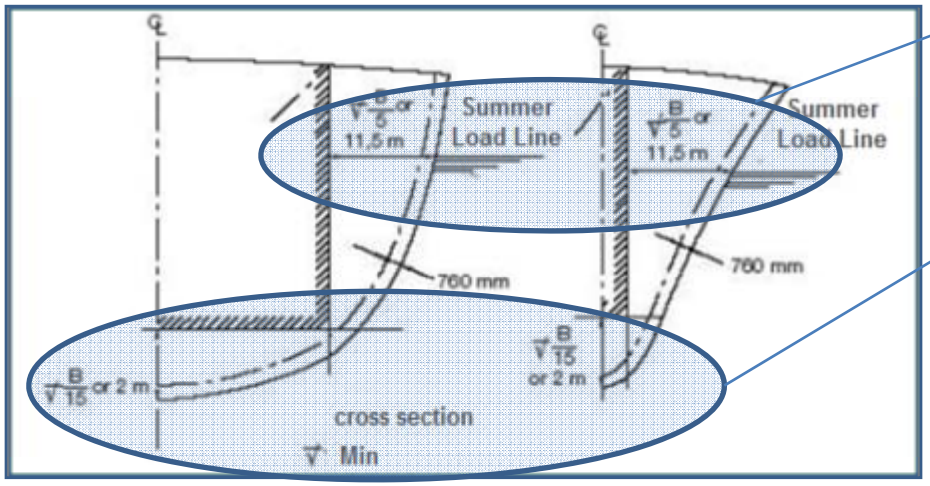
H is the distance from baseline, in metres, to the lowermost boundary of the fuel tank; and

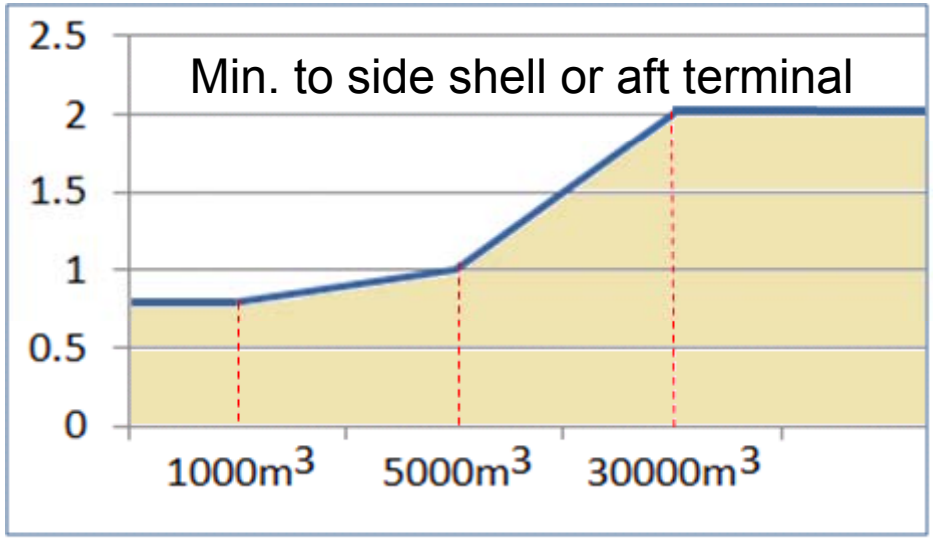
d is the deepest draught (summer load line draught).

.3 The boundaries of each fuel tank are taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its tank valves.

[5] The value fow accounts for collision damages that may occur within a zone limited by the longitudinal projected boundaries of the fuel tank only, and cannot be considered or used as the probability for the fuel tank to become damaged given a collision. The real probability will be higher when accounting for longer damages that include zones forward and aft of the fuel tank.

Deterministic approach





- To side : Min{B/5,11.5m}
- To bottom : Min{B/15,2.0m}
- Min. to side shell or aft terminal (also applied to probabilistic approach):

for V_c below or equal 1,000 m^3, 0.8 m;

for 1,000 $m^3 < V_c < 5{,}000\ m^3$, 0.75 + V_c x 0.2/4,000 m;

for 5,000 $m^3 \leq V_c < 30{,}000\ m^3$, 0.8 + V_c/25,000 m; and

for $V_c \geq 30{,}000\ m^3$, 2 m,

Vc: 100% of the gross design volume of the individual fuel tank.

Probabilistic approach

$$f_{CN}=f_l \times f_t \times f_v$$

For cargo ships: ≤ 0.04

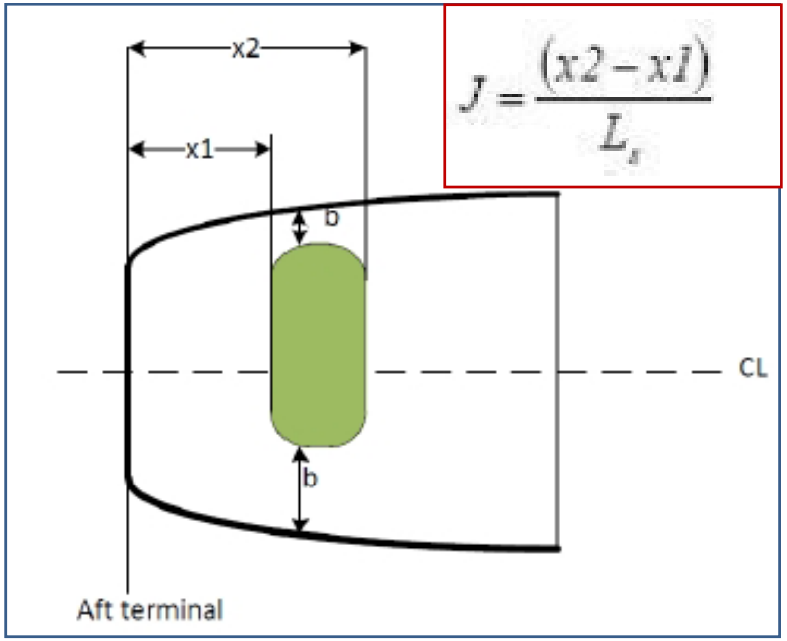
For passenger ships: ≤ 0.02

f_{CN}: damage porbobility

f_l: is calculated by use of the formulations for factor p contained in SOLAS regulation II-1/7-1.1.1.1 .

f_t: reflects the probability that the damage penetrates beyond the outer boundary of the fuel tank.

f_v: reflects the probability that the damage is not extending vertically above the lowermost boundary of the fuel tank.

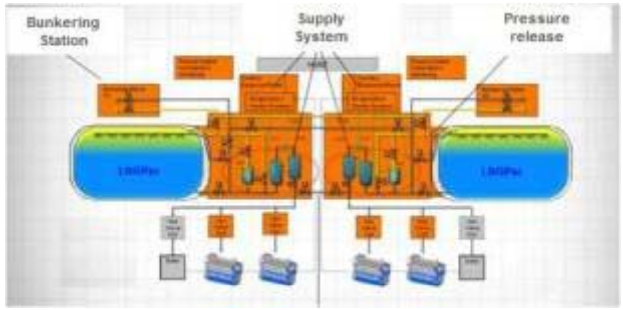


Cases of using probabilistic approach

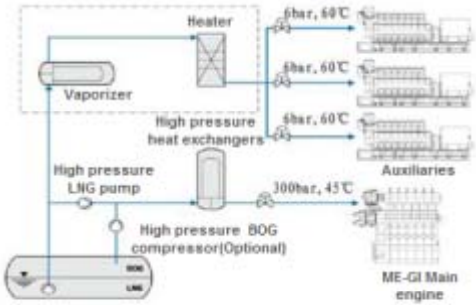
Ship types		20000 oil tanker	900TEU	2500 TEU	14000TEU
Tank type		TPYE C	TPYE C	TPYE C	membrane
Volume(m^3)		570	600	650	22000
location		Open deck	Open deck	Open deck	Below deck
parameters	length(m)	159	138.3	208	366
	beam(m)	24	22.6	29.8	51.2
	X1(m)	39	17	21.87	81.85
	X2(m)	69	30	34.87	96.8
	b(m)	4.8	4.3	3.88	2.5
	H(m)	13.2	12.5	16.4	2.3
	draught(m)	9	8	11.4	15.5
fcn		0.025	0.007	0.004	0.008

Fuel gas supply system (FGSS)

- **low pressure FGSS**
  - Gas supply pressure: below 10 bar
  - Wasilla 34DF：6~7bar
  - Guang Chai：5~8bar



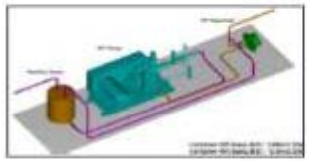
Wasilla (acquiring Hamworthy) design



TGE Marine design

- **high pressure FGSS**
  - Gas supply pressure: higher than 10 bar
  - MAN ME-GI：300~450bar

DSME



Hamworthy

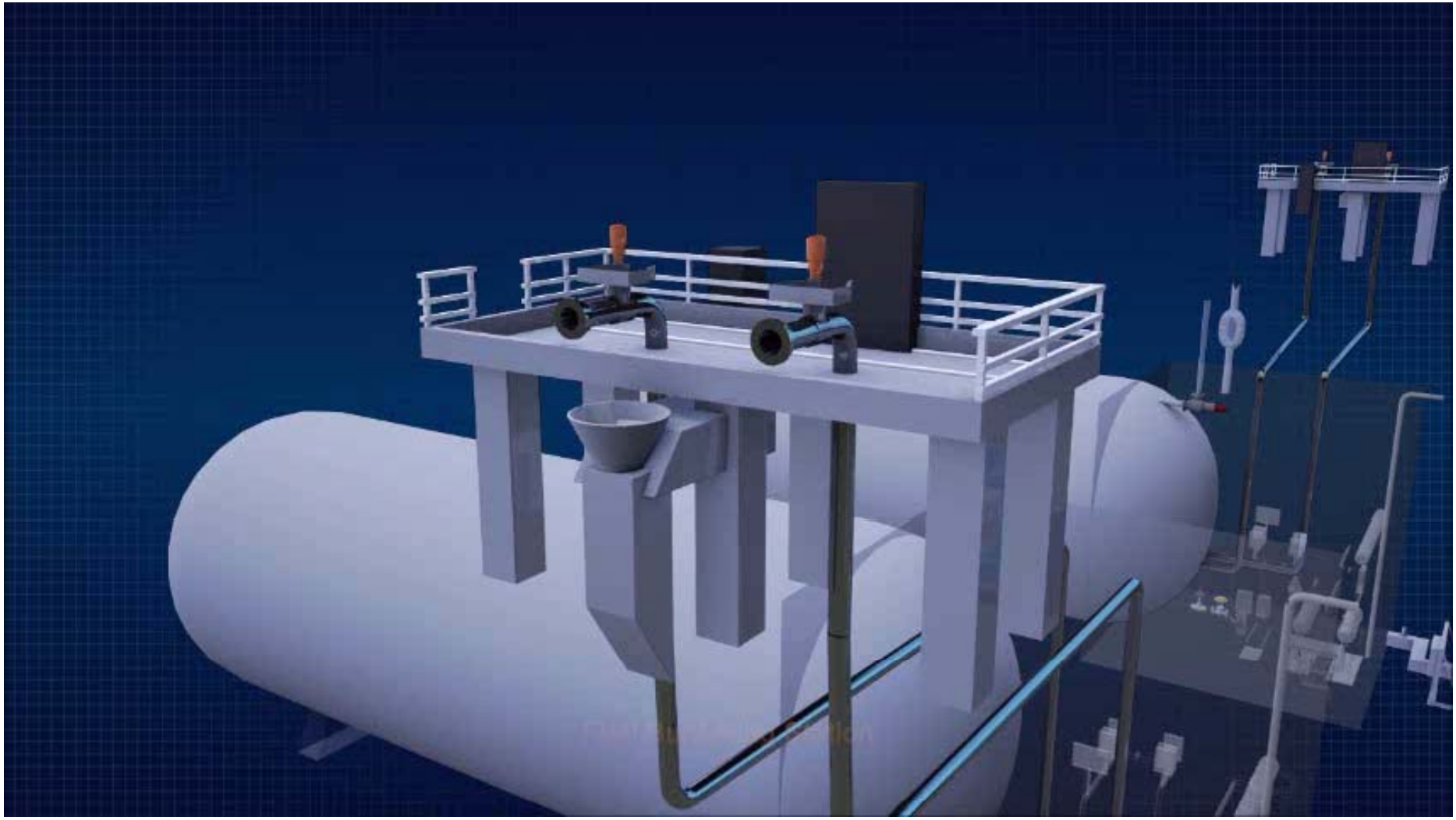
TGE

MHI

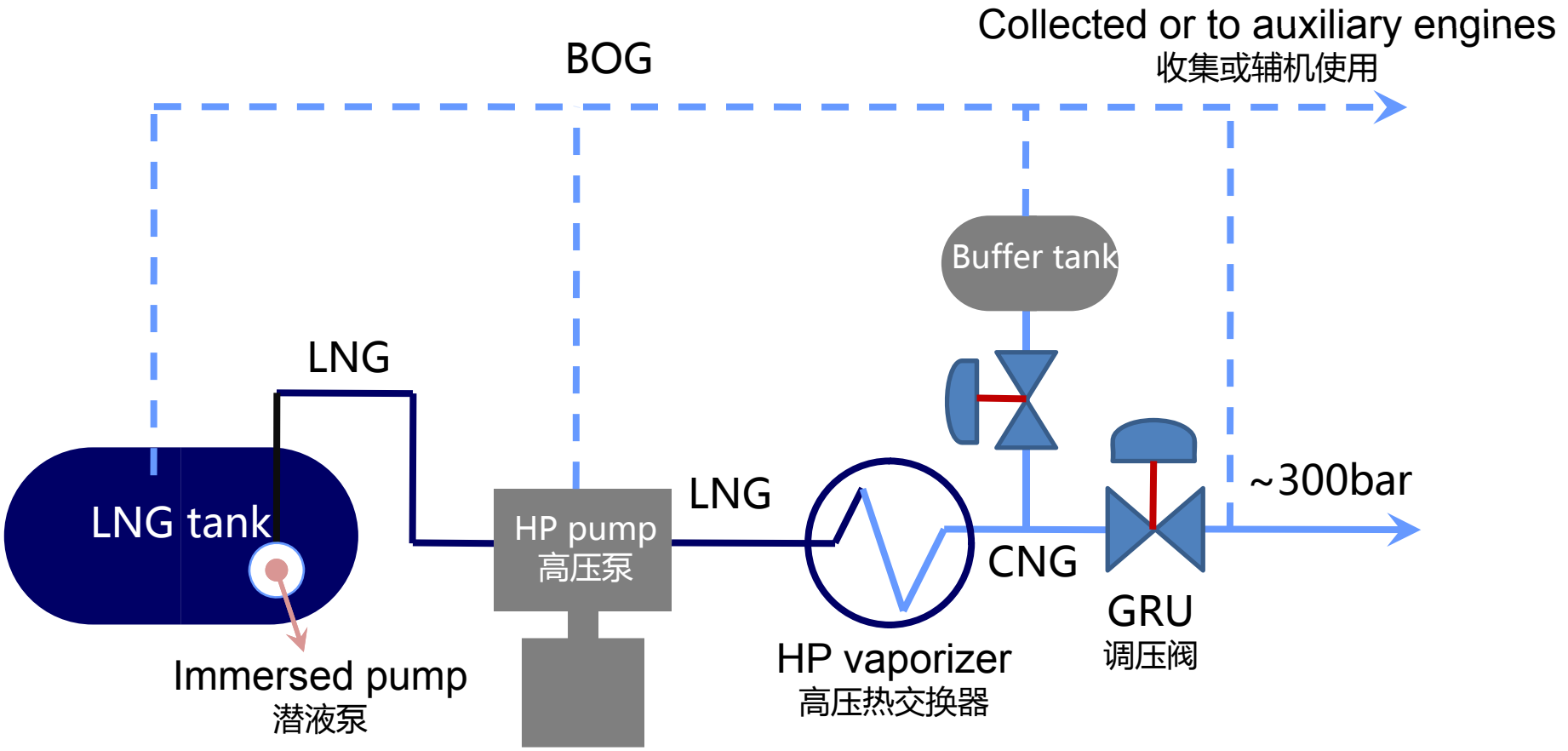
HHI

Note: non-traditional LP GFSS has arisen, e.g. a GFSS with gas supply pressure of 16 bar for Wasilla Flex50DF

Low pressure fuel gas supply system

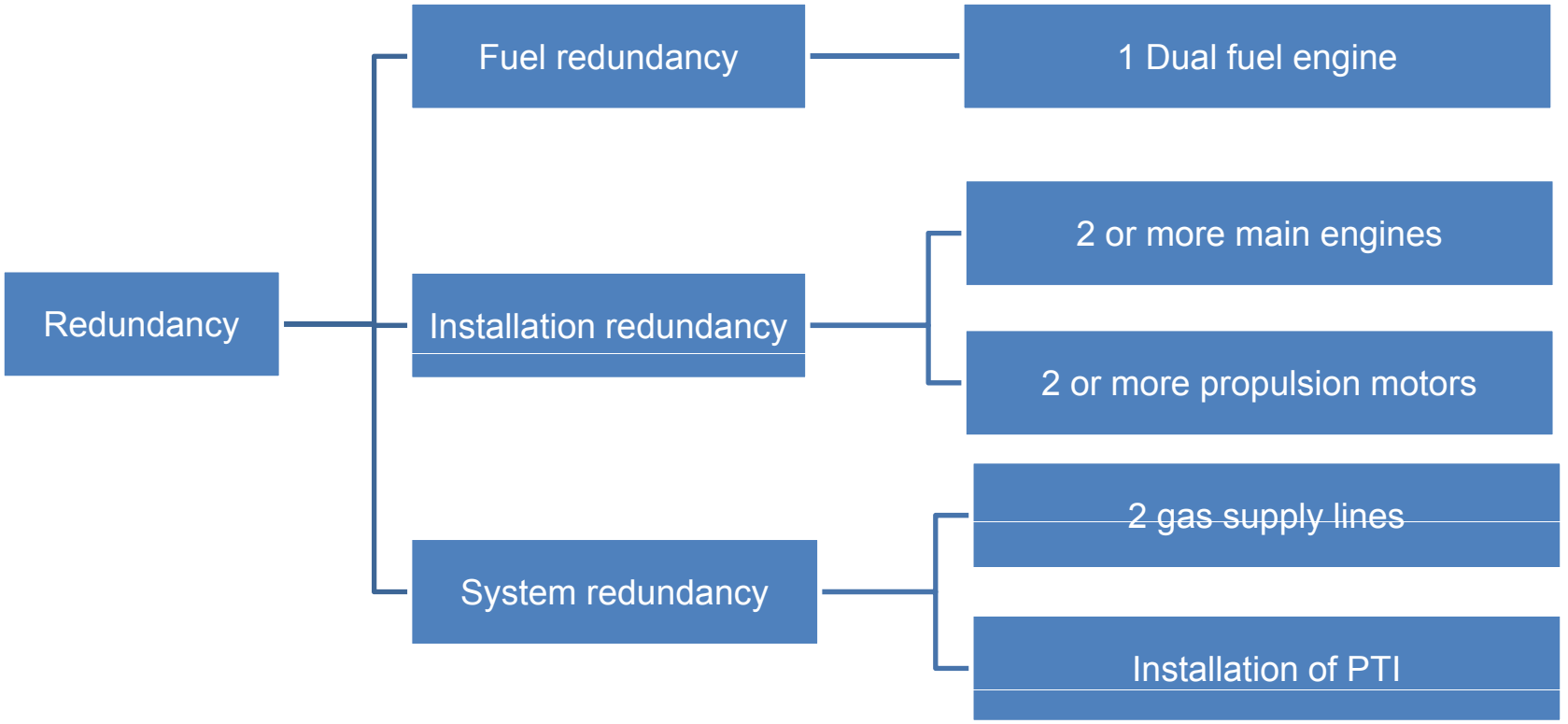


High pressure fuel gas supply system



Power system

- The risk of gas fuel leakage is higher than that of conventional oil power system
- Less operational data of onboard gas fuel engines
- Redundancy is the first choice to assure safety of power system



Gas engine

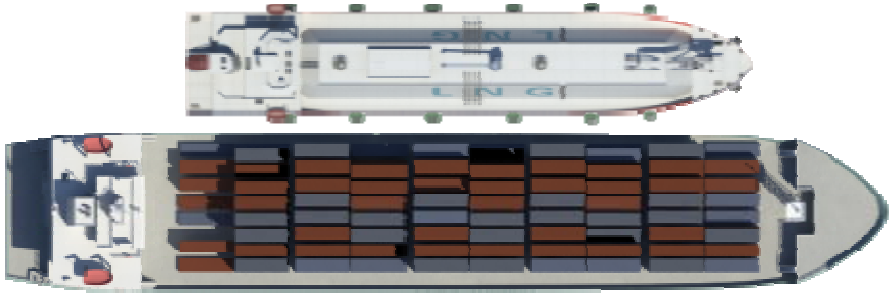
Engine type	High pressure direct injection DF	Low pressure DF
Power range	MAN: 3275 - 82400 kW	Wärtsilä: 4775 – 25800 kW
fuel flexibility	Suitable for various MNs	Methane number（MN）> 80
Fuel consumption	Relatively worse in gas mode，better in oil mode	Better in gas mode，relatively worse in oil mode
/NOx emissions	Tier II（Tier III with EGR or SCR）	Tier III
SOx emissions	SECAs	SECAs
Initial cost	Equivalent	
Gas supply system	~300bar	~16bar
Transient response characteristics	Same as diesel engine, can be coupled with FPP	Relatively worse, normally coupled with CPP or electric propulsion
Ship space occupied	large（with after-treatment equipment）	Small
Retrofit flexibility	simple	complex

Bunkering system

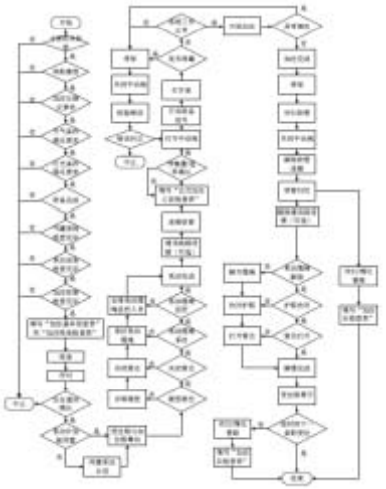
QRA (Safety Alert)

Check List

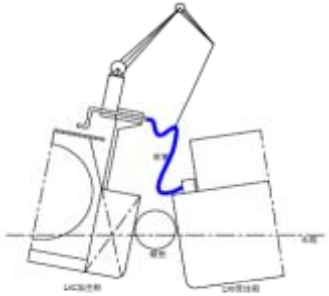
ESD & ERC



Operation procedure

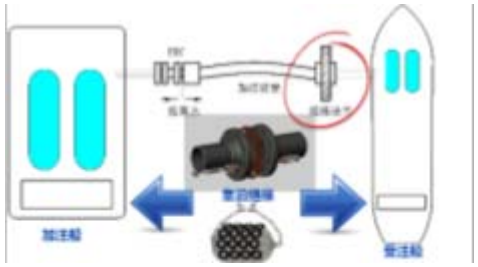


Relative motion and acceleration



Berthing and Unberthing

Insulation Connection

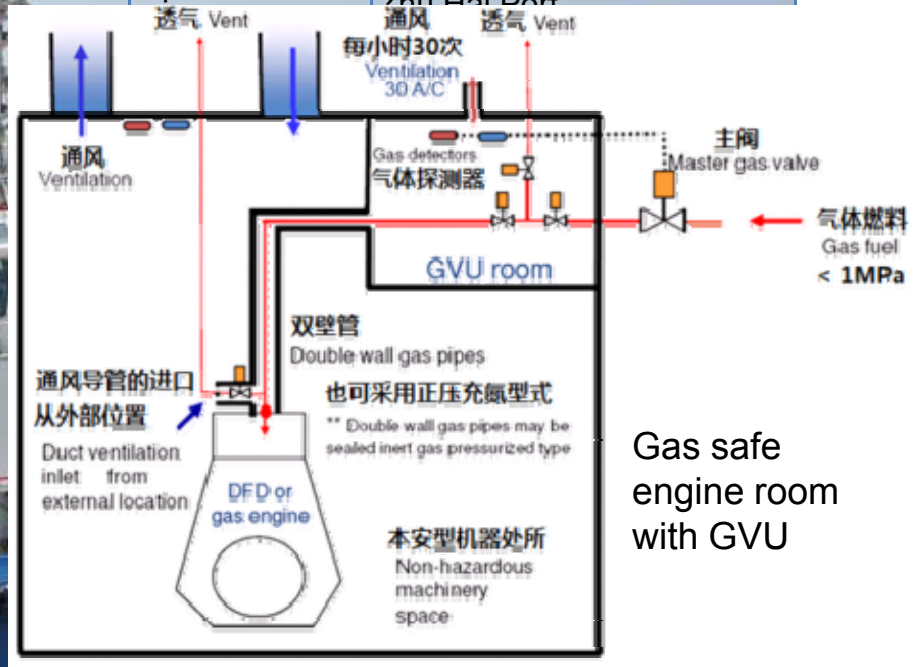


Hose Connection

Cases study

2×25 cbm LNG tanks with cold boxes

Characteristics of Hai Yang Shi You 521	
Dimension	41m ×11.6m × 6m
Engine power	dual-fuel , 6500HP
Operational	since Dec 2013, operate in Zhu Hai Port



Gas safe engine room with GVU

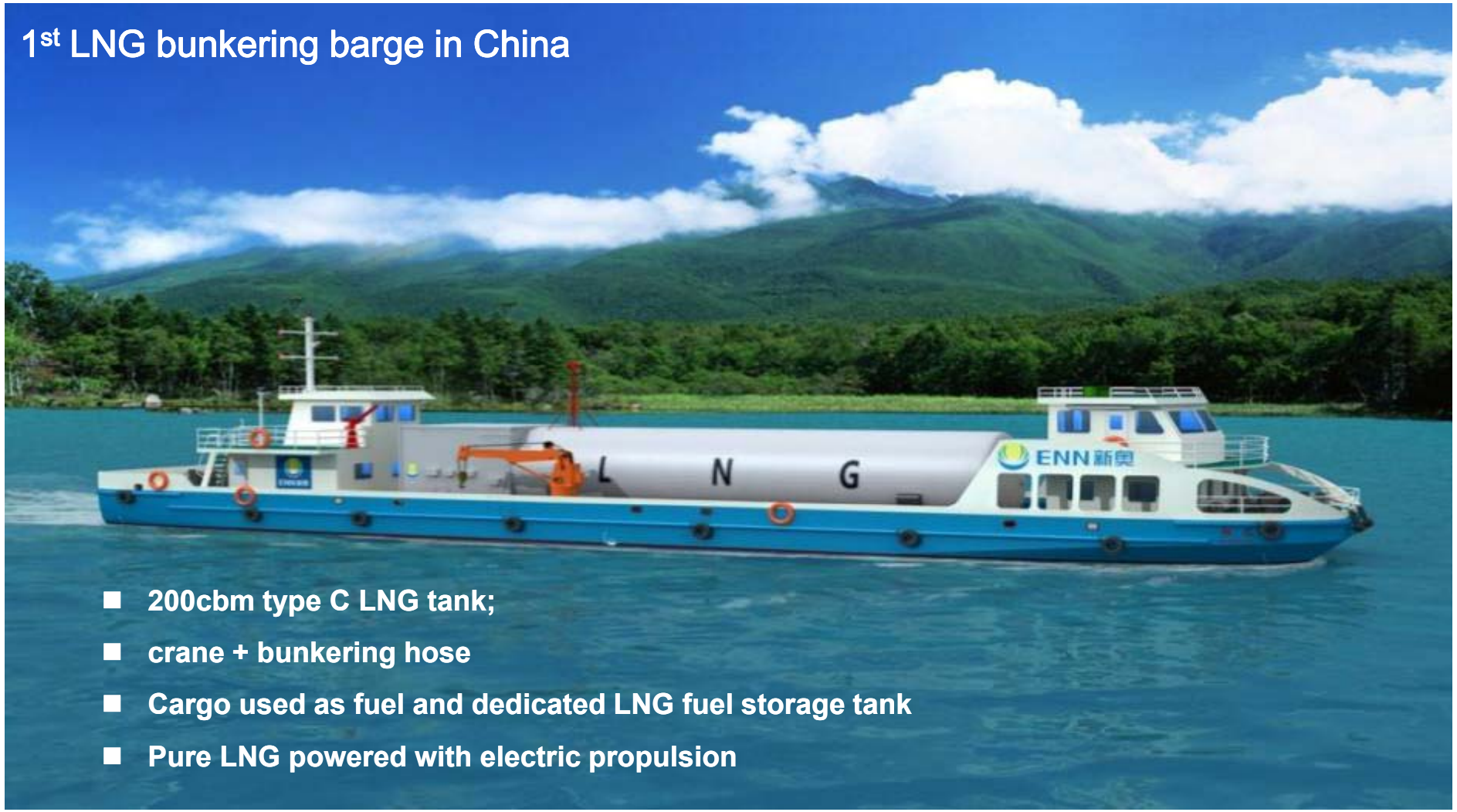
The 1st LNG fuelled seagoing vessel in China

Cases study


Gas pipe on engine
Double wall pipe
Gas valve unit
海洋石油 521
HAI YANG SHI YOU
The 1st LNG fuelled seagoing vessel in China

Cases study

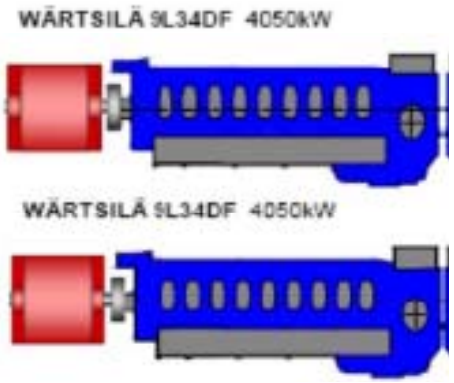
1st LNG bunkering barge in China



- 200cbm type C LNG tank;
- crane + bunkering hose
- Cargo used as fuel and dedicated LNG fuel storage tank
- Pure LNG powered with electric propulsion

Cases study

Bi-lobe type C tanks

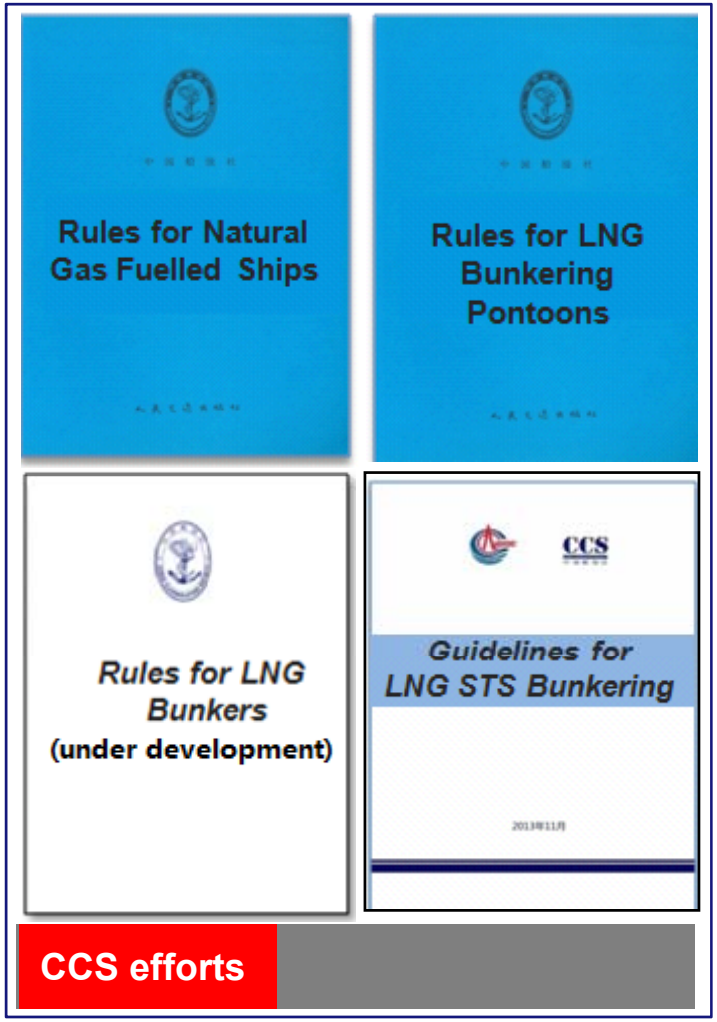


DFDE

Rudder propeller

Table of content

- Background & environment for LNG used as marine fuel
- Status quo of LNG fuelled ships and LNG bunkering in China
- Technology development and cases study
- **CCS R&D on waterborne LNG value chain**
- Conclusion



Our philosophy & methodology for R&D

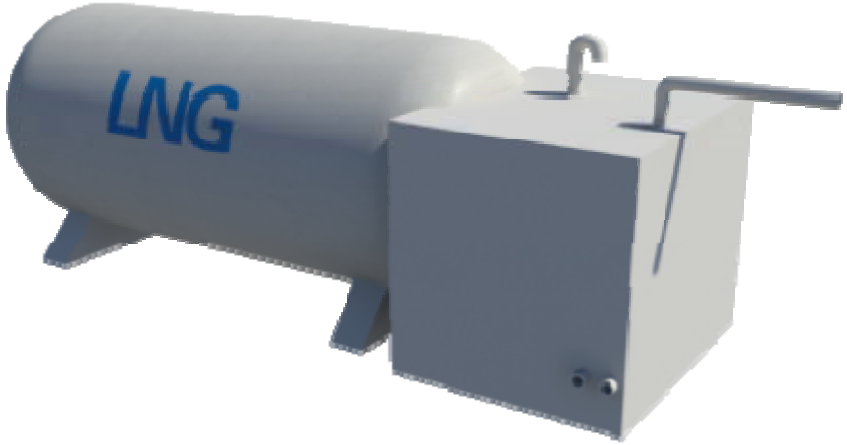
- Risk-based philosophy
  - Required by IMO GBS.
  - Required by the characteristic of LNG fuelled ships
    - Lack of experience and practice
    - LNG has its unique characteristic and hazards:
      - Cryogenic
      - Fire & explosion
      - dispersion
- Risk-based approach
  - risk analysis (theoretical analysis by simulation, such as CFD)
  - experimental verification

How do we develop Rules?

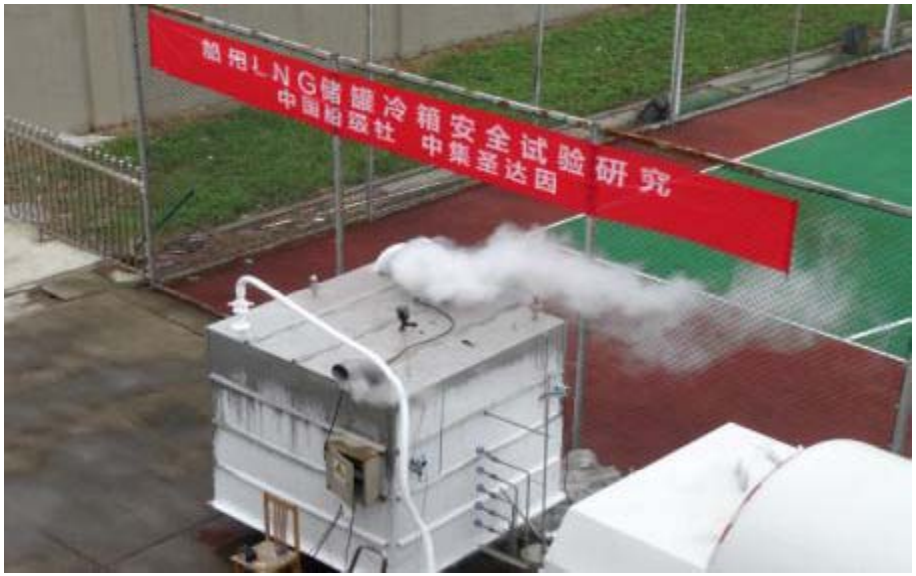
CASE: experiment study

Experimental Study on **Cold Box** to verity:

- Accumulated pressure in the box after LNG leakage
- Temperature distribution within the box
- Hi-hi level auto shut down device

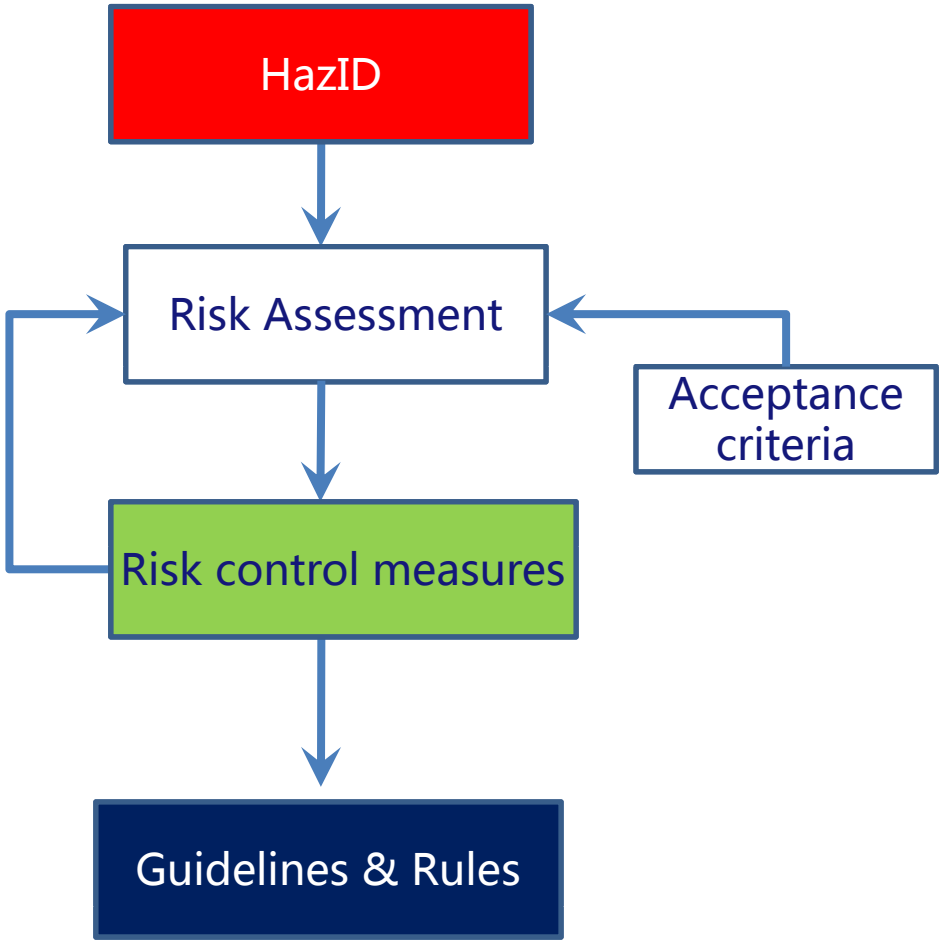


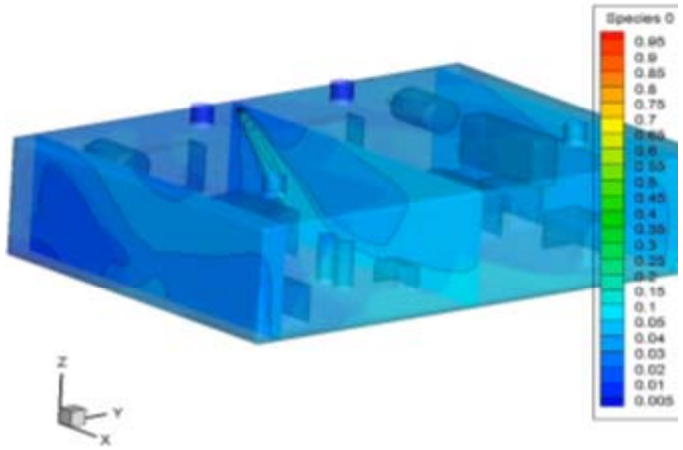
Cold box



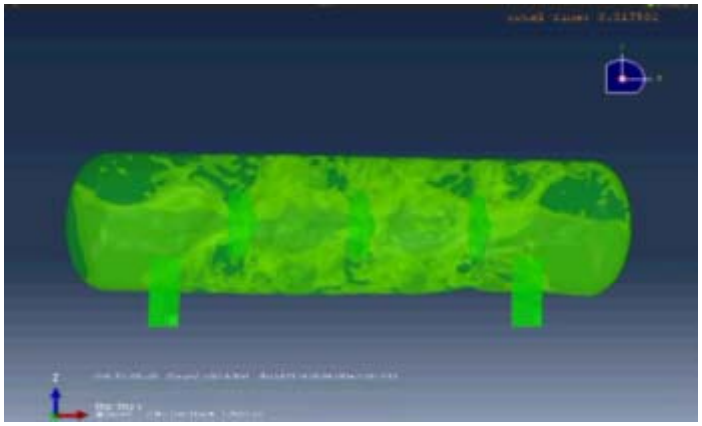
How do we develop Rules?

- **risk assessment and simulation**





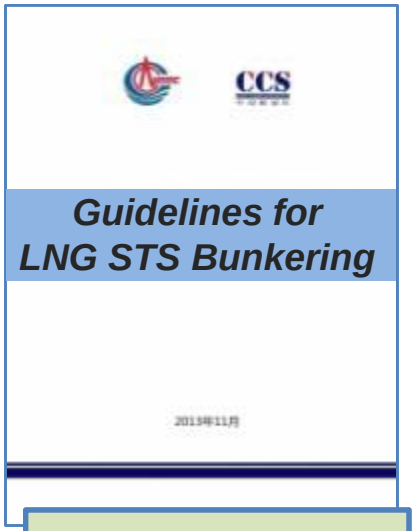
CFD gas leakage study

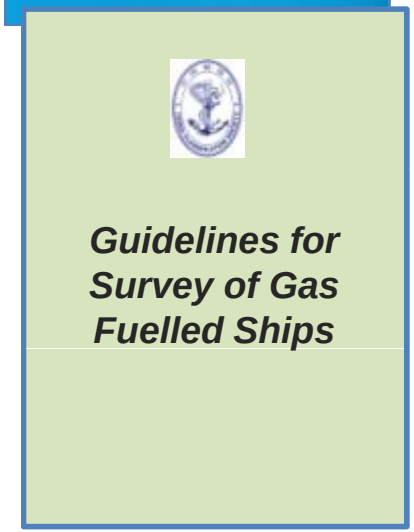


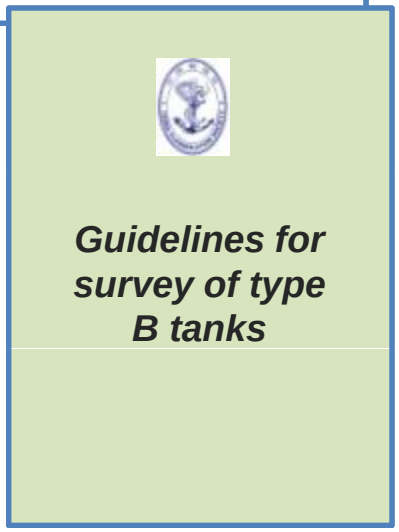
CFD Sloshing study on fuel tank

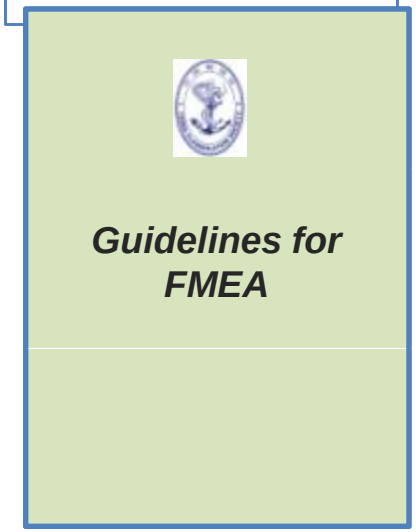
CCS Rules for Waterborne LNG value chain

Rules/Guidelines



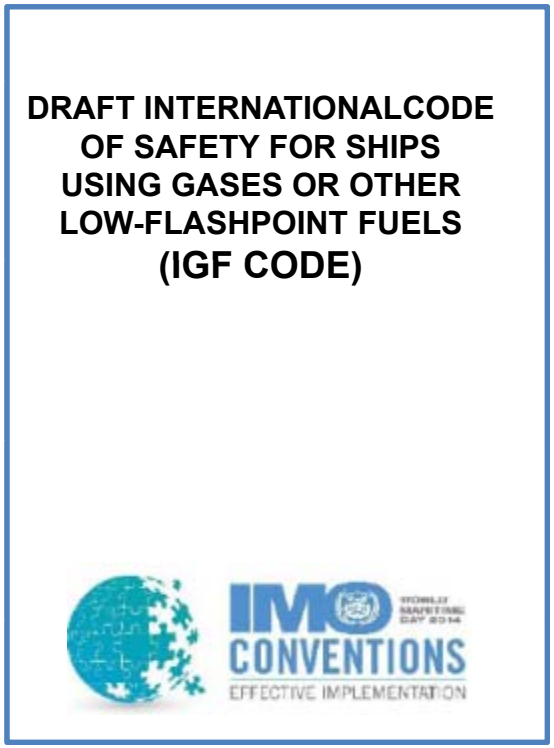






Involvement in development of international Codes/Standards

- IMO: Member of the IMO Correspondence Group (CG) on development of IGF Code, which will be adopted at MSC 95 this June ;
- ISO: Member of ISO Working Group on developing LNG bunkering guidelines (WG 8);
- IACS: Participating in 2 project teams (PTs) to develop technical requirements regarding LNG risk assessment and LNG bunkering ;
- SGMF: Association member of *Society for Gas as a Marine Fuel* (SGMF).



Integrated solutions

ENN 新奥

Zhou Shan International LNG Bunkering Infrastructure Project

- HAZID ;
- Quantitative Risk Assessment on major accident scenario;
- Risk mitigation/control measures;
- Optimization solutions on the arrangement of onshore LNG storage tanks and onshore bunkering station ;
- Safety distance for LNG STS bunkering operation.
- ……

Integrated solutions

CCS provides LNG Fuel Ready solution for different types including VLCC, VLOC,MEGA containerships.

Whether need LNG ready solution?

Based on the following analysis to decide whether LNG Ready solution is needed:

- **analysis of ship operational data**
- **concept design**
- **Economic analysis of different emission reduction solution**
- **LNG bunkering availability analysis**

How to carry out LNG ready?

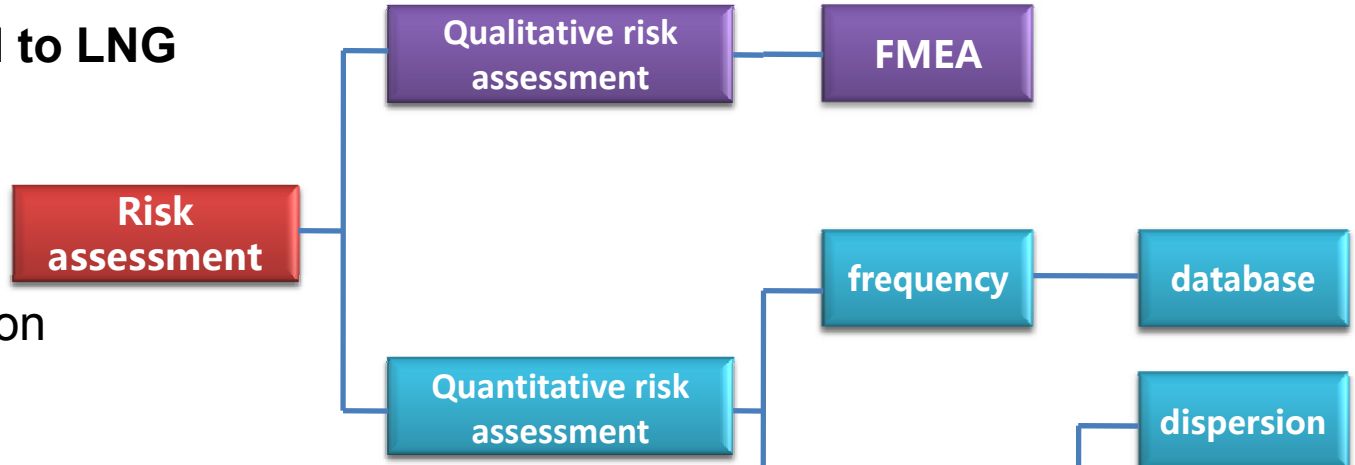
If LNG Ready solution is accepted to ship owners, then will do:

- **technical solution analysis**
  - ➢ selection of engines
  - ➢ selection of storage tanks
  - ➢ Miscellanea
- **Financial analysis**

Quantitative risk assessment (QRA)

Special risk related to LNG

- cryogenic
- dispersion
- Fire & explosion



IGF Code

4.2 Risk assessment

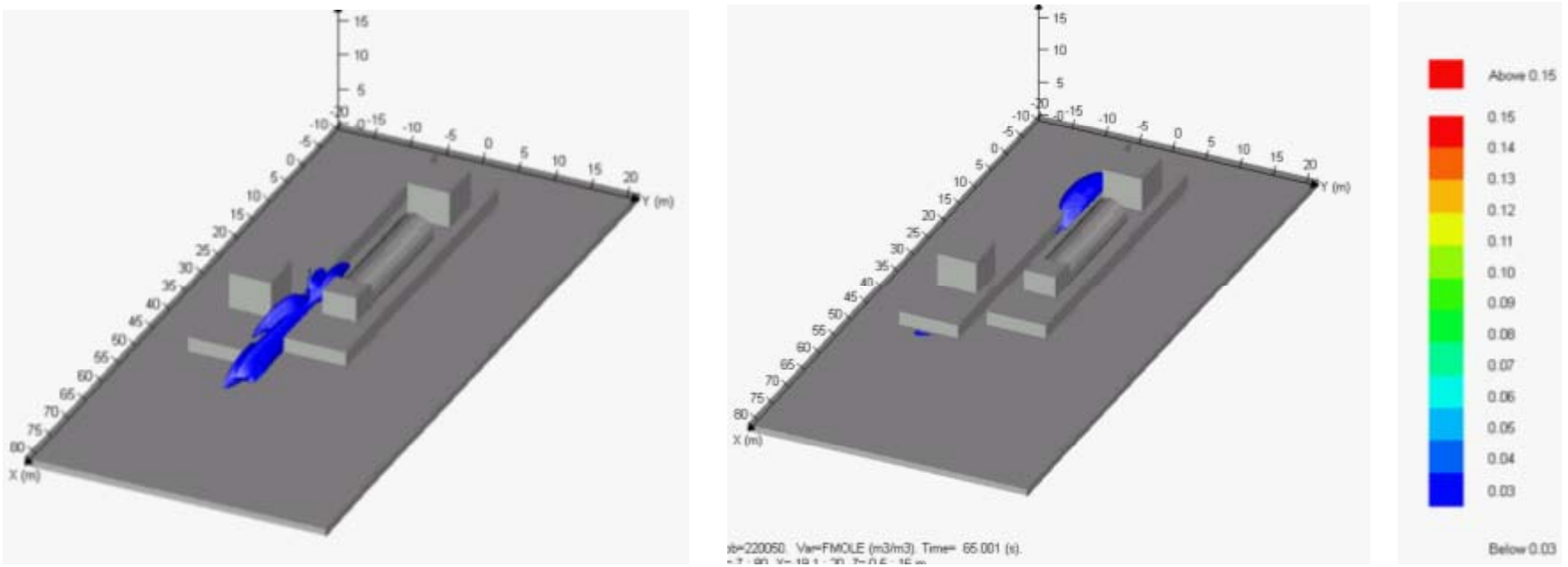
4.2.1 A risk assessment shall be conducted to ensure that risks arising from the use of low-flashpoint fuels affecting persons on board, the environment, the structural strength or the integrity of the ship are addressed. Consideration shall be given to the hazards associated with physical layout, operation and maintenance, following any reasonably foreseeable failure.

4.2.2 ····· Details of risks, and the means by which they are mitigated, shall be documented to the satisfaction of the Administration or its recognized organization acting on its behalf.

Quantitative risk assessment (QRA)

CASE: ENN 200cbm LNG bunker barge

Scenario: Φ25mm LNG pipe rupture during STS bunkering, LNG leaks between two ships for 30 seconds



Simulation on LNG dispersion after leakage during bunkering

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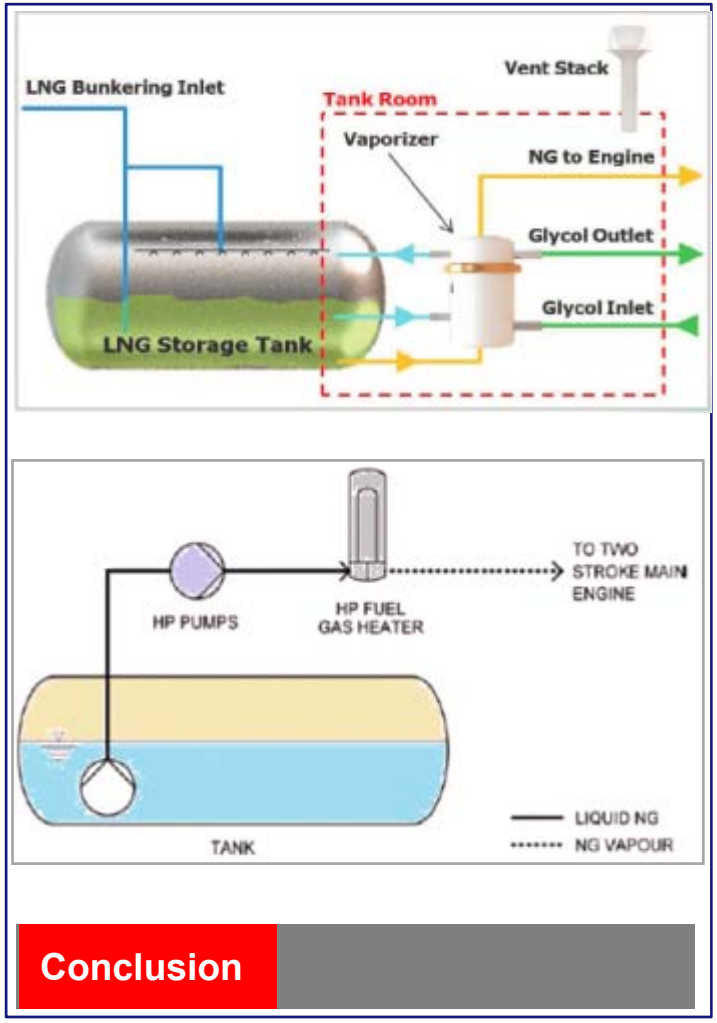


Players for waterborne LNG value chain in China

Regulatory framework development

Water Transport Bureau

Cryogenic equipment

Gas handling

Oil majors & energy enterprises

Academics

Gas engine

Ship owners

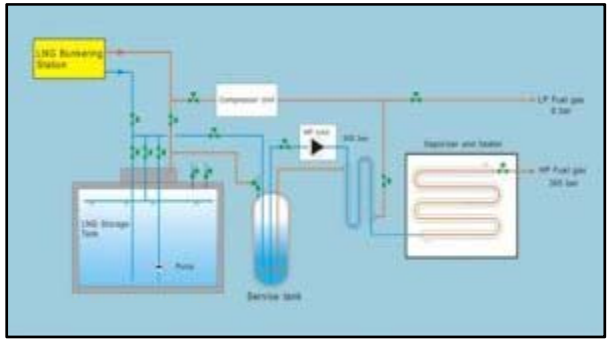
Design of LNG fuelled vessels and bunkers

Conclusion

- The marine LNG technology is mature, the practice of LNG fuelled ships has proven that the safe and reliable operation of LNG fuelled ships can be assured by technical, administrant and operational means.

- The Industry in China is able to provide necessary products and services to support the development of LNG fuelled ships.

- China Classification Society is willing to provide technical service on waterborne LNG value chain for our clients with our R&D



Thank you for your kind attention

For more details, please contact
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TEL: (86) 139 7138 1647