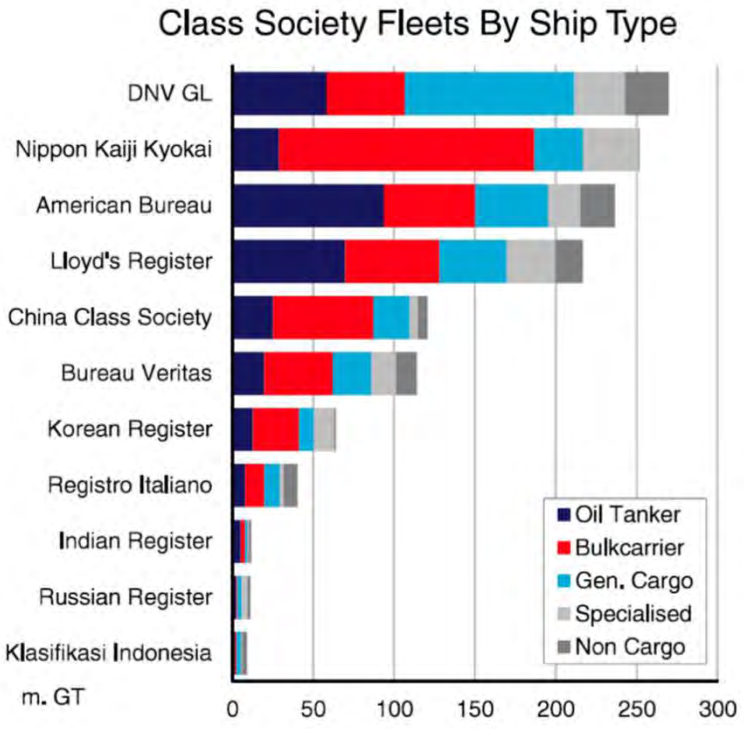
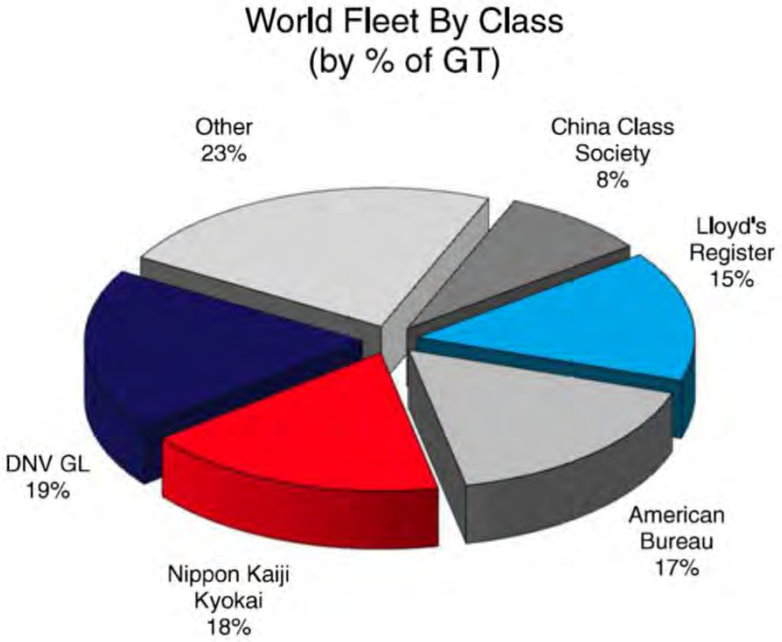
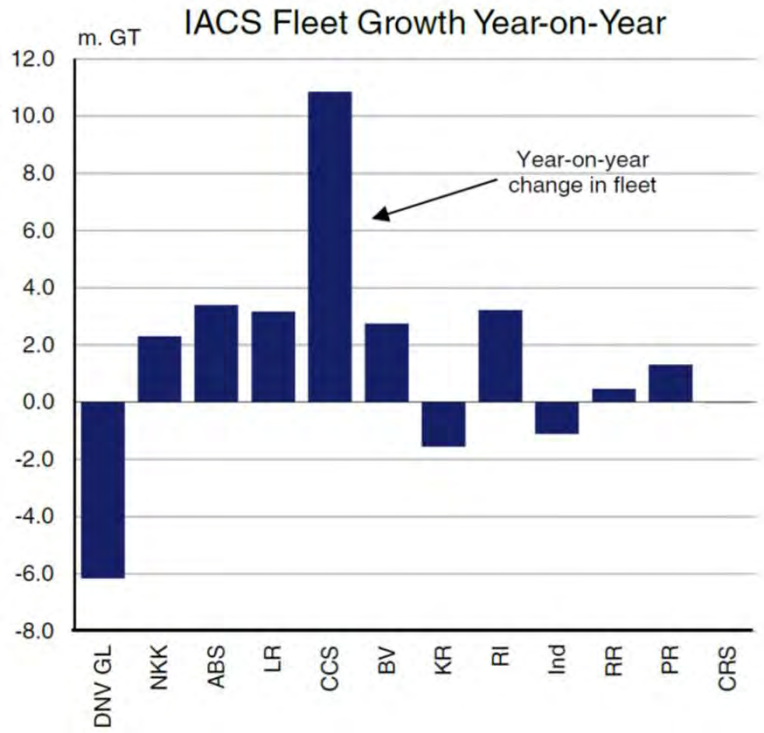




Source Clarksons



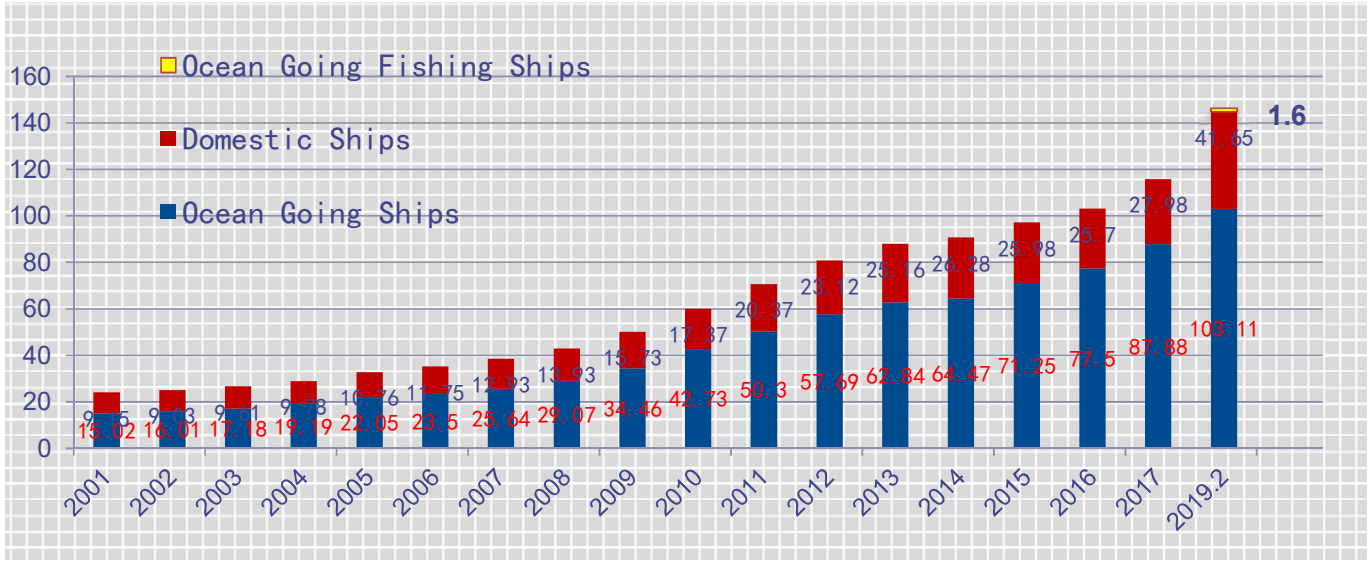
Class Societies	01 Mar 19		Fleet Growth Year-on-Year	
	No.	m.GT		
IACS Members				
DNV GL	8,781	269.9	*DOWN…*	*-2.2%*
Nippon Kaiji Kyokai	8,378	251.8	*UP BY…*	*0.9%*
American Bureau	7,291	236.6	*UP BY…*	*1.5%*
Lloyd's Register	6,697	216.9	*UP BY…*	*1.5%*
China Class Society	4,734	120.7	*UP BY…*	*9.9%*
Bureau Veritas	7,638	114.1	*UP BY…*	*2.5%*
Korean Register	2,387	64.1	*DOWN…*	*-2.4%*
Registro Italiano	3,444	40.3	*UP BY…*	*8.7%*
Indian Register	1,360	11.6	*DOWN…*	*-8.7%*
Russian Register	2,382	11.2	*UP BY…*	*4.3%*
Polski Register	337	4.7	*UP BY…*	*38.9%*
Croatian Register	301	1.7	*DOWN…*	*-1.2%*
Total IACS Membe	**52,709**	**1,284.1**	***UP BY…***	***2.2%***
Share of World Tota	*55%*	*95%*		

Source Clarksons

General Review of Main Business – Fleet Growth

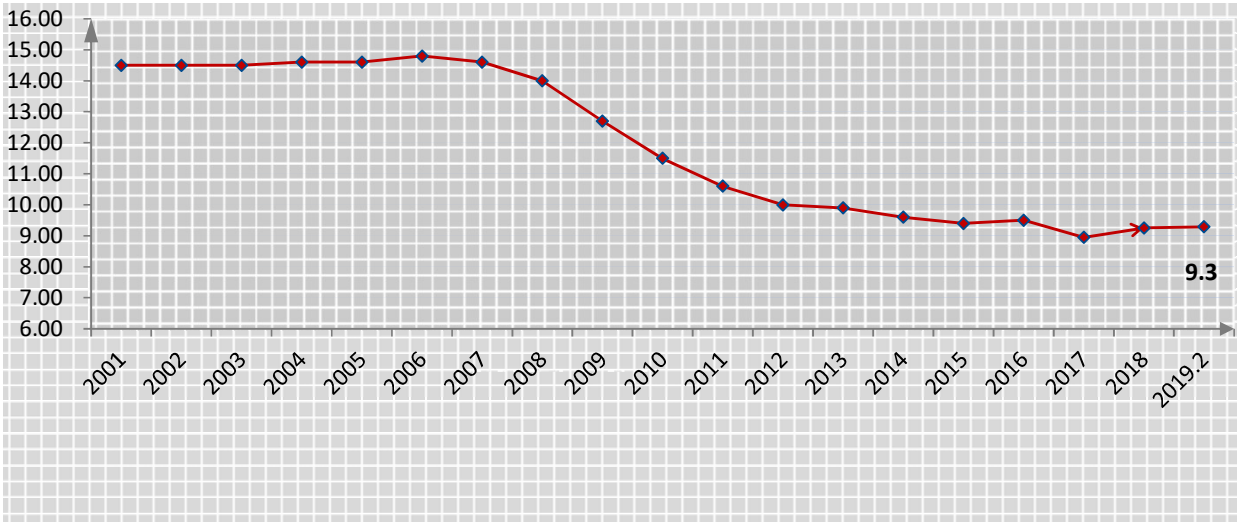
In Sep. 2018

CCS Ocean Going Fleet exceeded 100 million GT

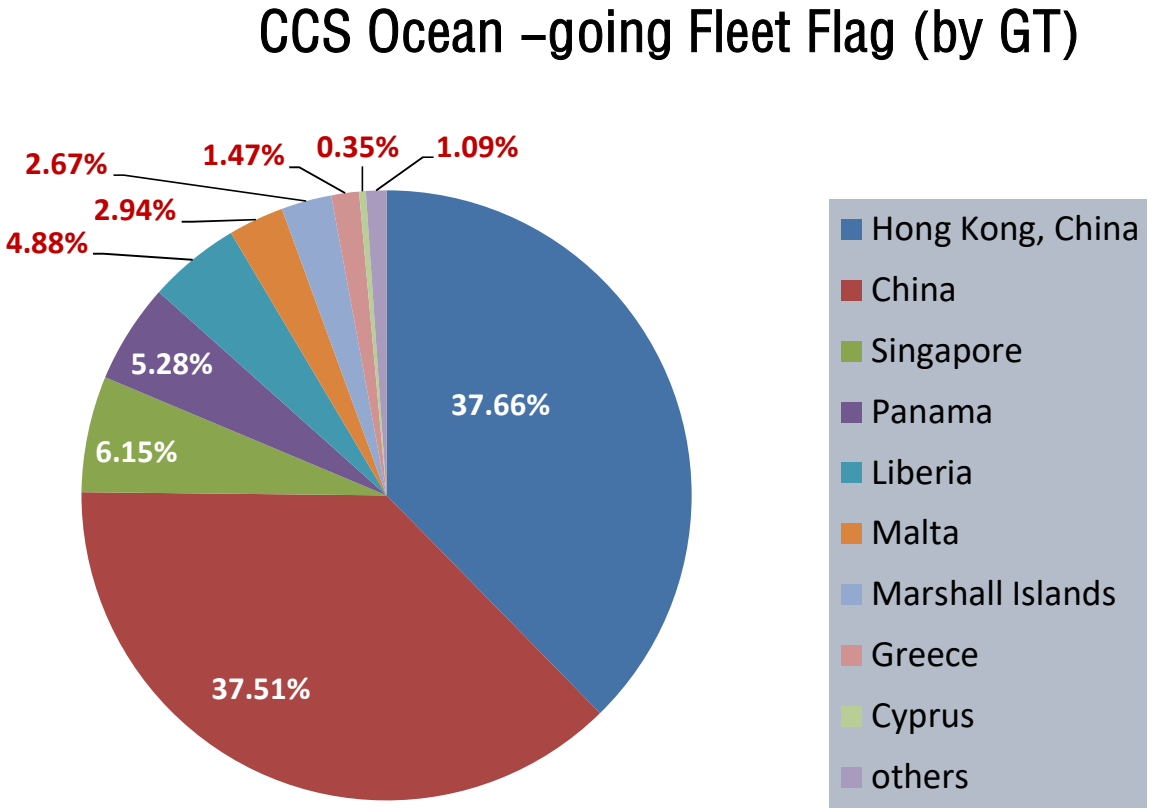


Fleet Growth (2001– 2019.Feb)

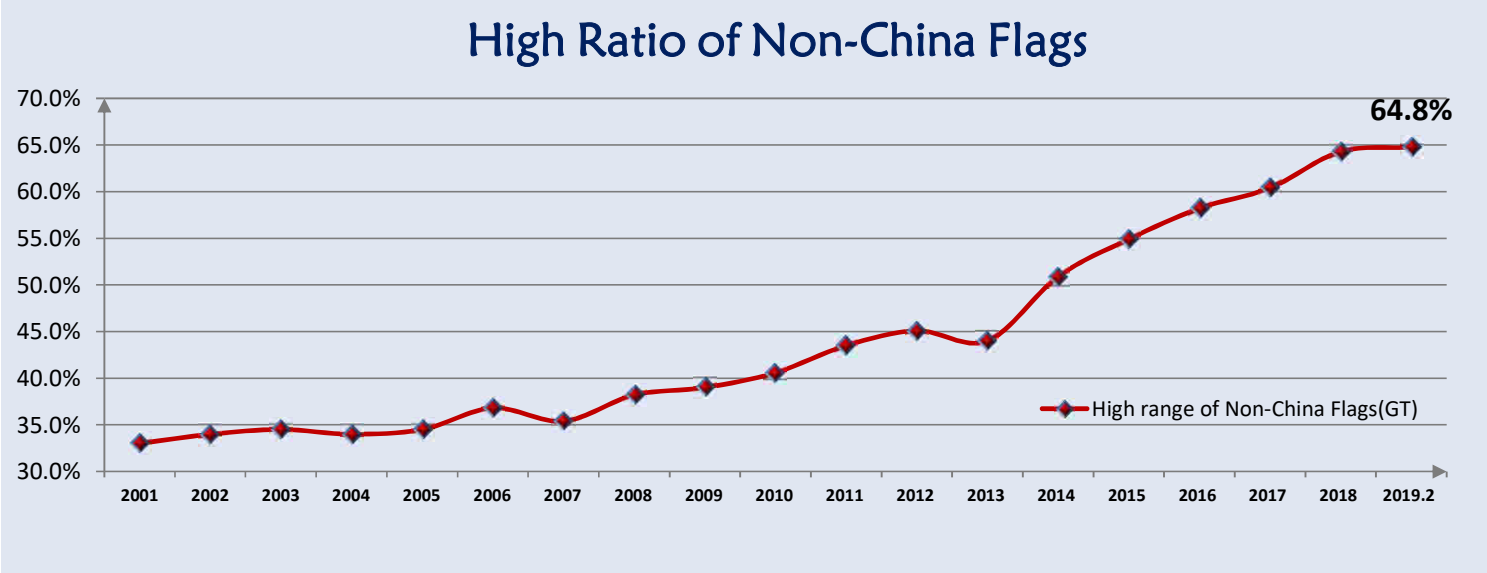
The Youngest Ocean– going Fleet of IACS Members(Age. Years)



Fleet Growth (2001– 2019.Feb)



Fleet Growth (2001– 2019.Feb)



General Review of Main Business –Service Network

- 114 offices in the world, established new offices in Stockholm, Copenhagen office, Istanbul Paris
- office ; Undergoing and planning offices include St Petersburg, Santiago, Accra .

General Review of Main Business
–Flag States Authorization

- **Authorized by 45 states and regional governments.**
- **2018 New statutory authorization obtained from Bangladesh**

CCS Europe

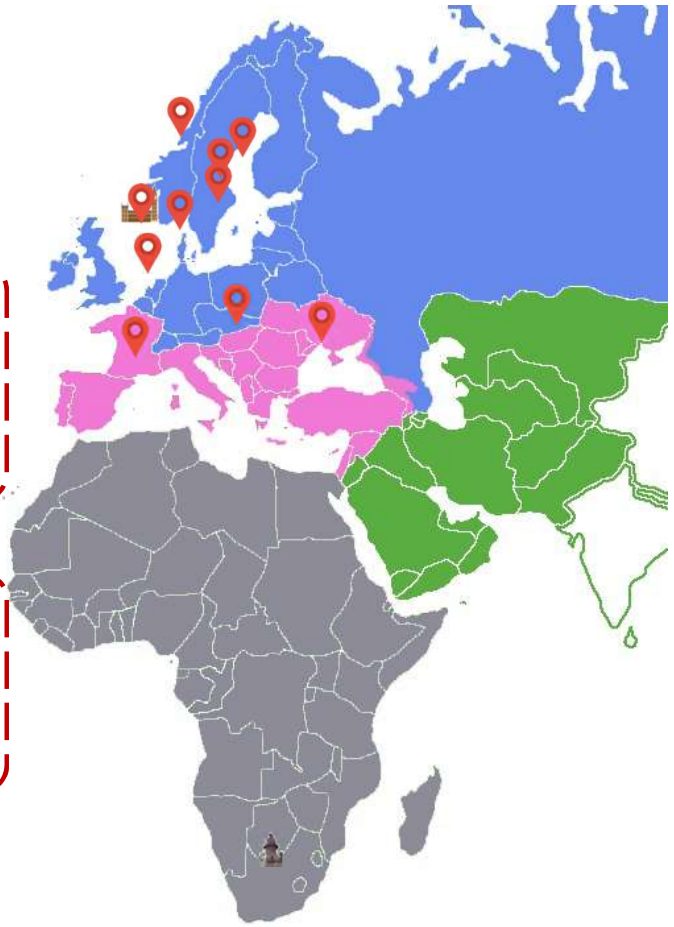
There are Hamburg and Athen branches with 14 offices, 44 surveyors

Hamburg Branches

Hamburg, Düsseldorf, Stuttgart, London, Rotterdam, Gothenburg, Bergen, Stockholm, Gepenhagen

Athen Branches

Athen, Milan, Barcelona, Paris, Istanbul



First Transocean Transport of LNG ISO Tanks and Related Experiments: *Practice & findings*

Dr.-Ing. Leshan ZHANG

China Classification Society Europe GmbH

lszhang@ccs.org.cn

1. Brief on LNG ISO tank container
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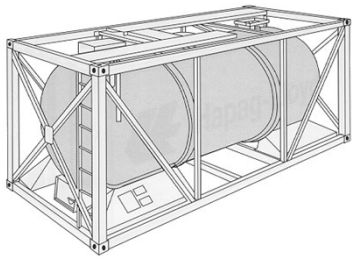
ISO 1496 - 3 Standard



Frame body

Frameless body

Design Code	RID/ADR IMDG regulations for ISO-type T75; ASME code 8 div1
Regulations	IMDG / RID / ADR / TIR / CSC / UIC / TC impact / US DOT / Frame ISO 1496/3
Type	T75 UN Portable Tank, ML1 Frame Design

40 foot

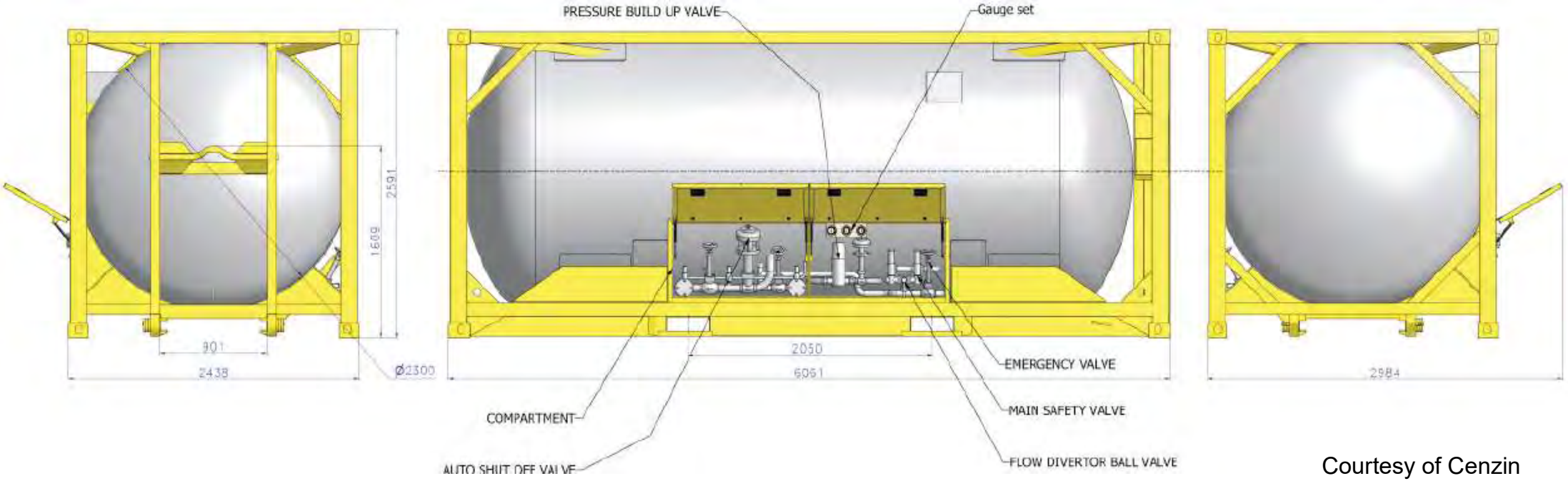
Dimensions (l,w,h)	12192 x 2438 x 2591 mm	40 ft x 8 ft x 8 ft 6 inch
Tare weight	12.500 - 13.200 kg	27.600 – 29.100 lbs
Max Gross Weight	36.000 kg	79.400 lbs
Capacity	45.500 – 47.000 L	12.000 – 12.400 gallon [US, liquid]
MAWP	10 Barg	145 PSIG
Temperate Range	-196 to +20 Celsius	-321 to 68 Fahrenheit

20 foot

Dimensions l x h x b	mm	6.058 x 2.438 x 2.591
Code Type		22T7
Type		UN T75
Approvals		CSC; UN; RID/ADR; IMDG
Maximum working pressure	bar	10,3
Tare weight	kg	7400
Maximum gross weight	kg	36000
Suitable for		LIN; LNG
Storage capacity nominal	ltr	19.720
Flange connection		DN 65 PN 40

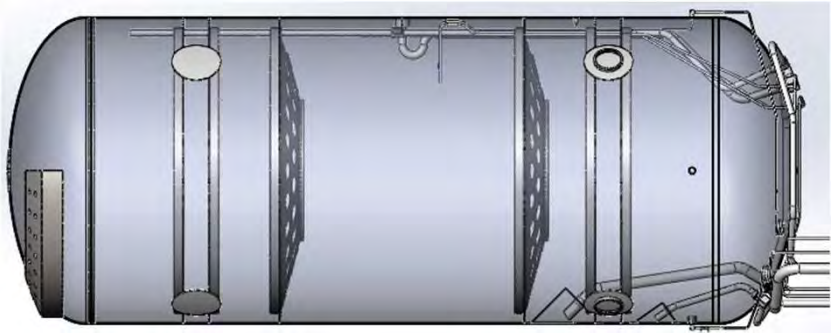
Typical Components for a Vacuum Insulated Tank Container

1.Inner tank (*for storage*)
2.Outer shell (*for vacuum insulated*)
3.Support components (*load transfer*)
4.Piping (*inlet/outlet line; functional line*)
6.Safety & functional attachments (*pressure relief device , instruments,etc.*)
7.Frame

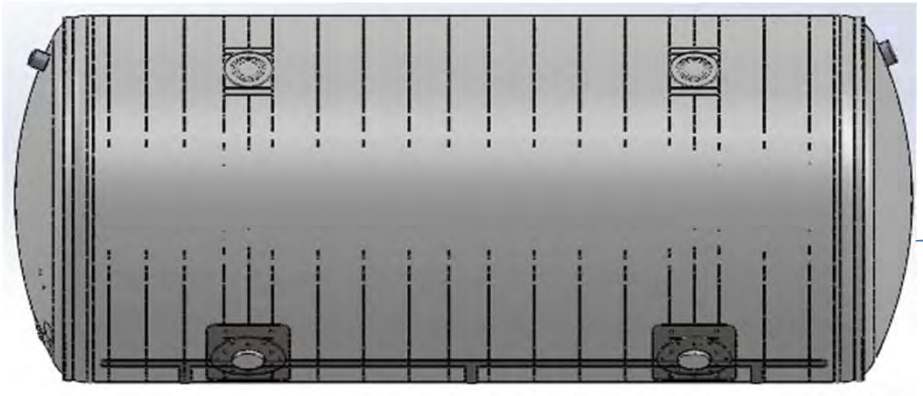


Courtesy of Cenzin

Typical Components for a Vacuum Insulated Tank Container



Inner tank



Outer shell

ISO 1496 - 3 Standard

Static test

Test No. 1 - Stacking
Test No. 2 - Lifting from the four top corner fittings
Test No. 3 - Lifting from the four bottom corner fittings
Test No. 4 - External restraint (longitudinal)
Test No. 5 - Internal restraint (longitudinal)
Test No. 6 - Internal restraint (lateral)
Test No. 7 - Rigidity (transverse)
Test No. 8 - Rigidity (longitudinal)
Test No. 9 - Load-transfer area test
Test No. I0 - Walkways (where provided)
Test No. 11 - Ladders (where provided)
Test No. 12 - Pressure test

Dynamic longitudinal impact test

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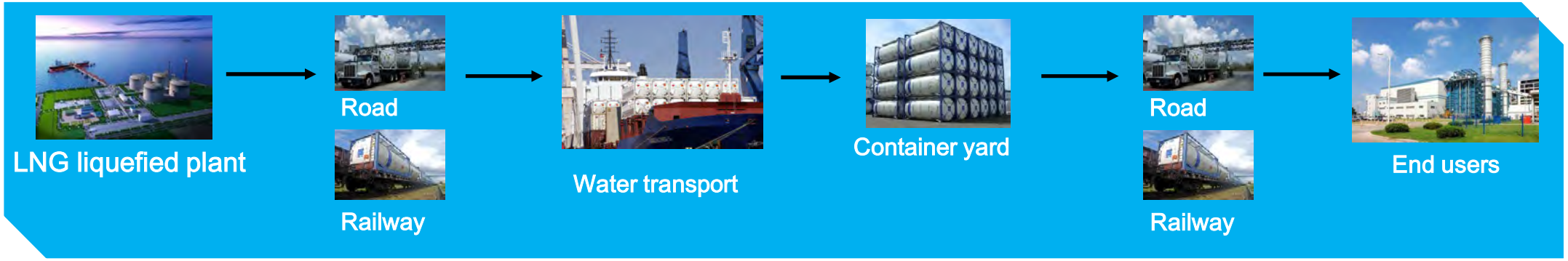
Drivers for transport of LNG in ISO tanks ?

The advantages:

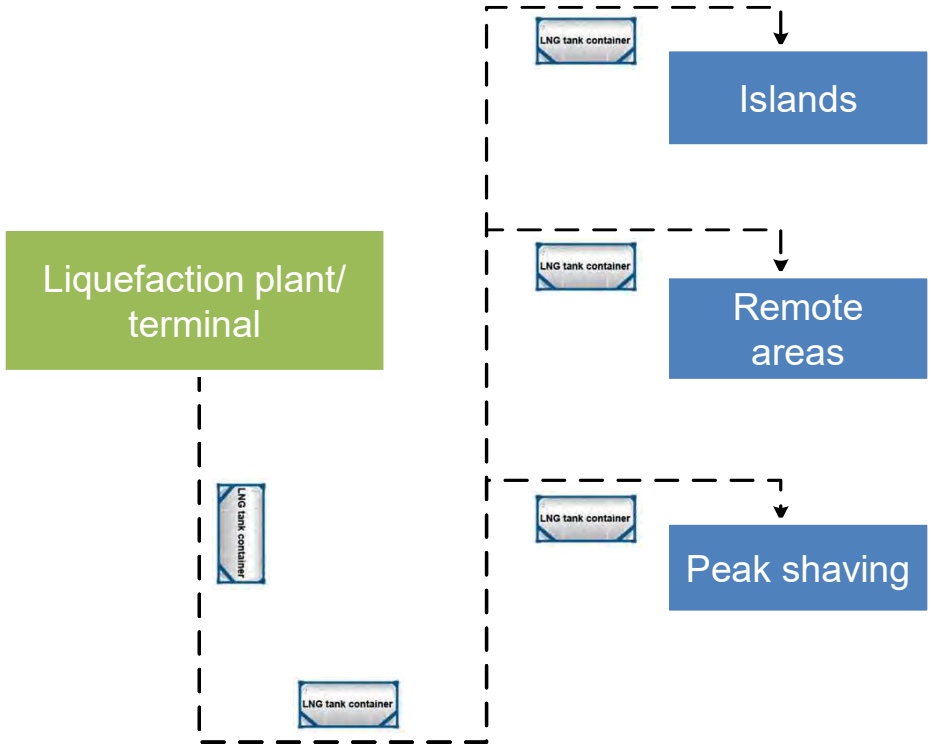
- One contract;
- One insurance policy;
- One-time payment;
- **“Door to door” service**;
- Low initial investment by using of existing containerships and ports.

- Make LNG trading more flexible, more players can come into LNG game;
- supplying final LNG consumers as an alternative for gas delivered by conventional piping. This is the method of gas delivery diversification which guarantees the energy independence;
- Elaborate the LNG value chain. (artery + blood capillary)



Typical Applications

Virtual pipeline

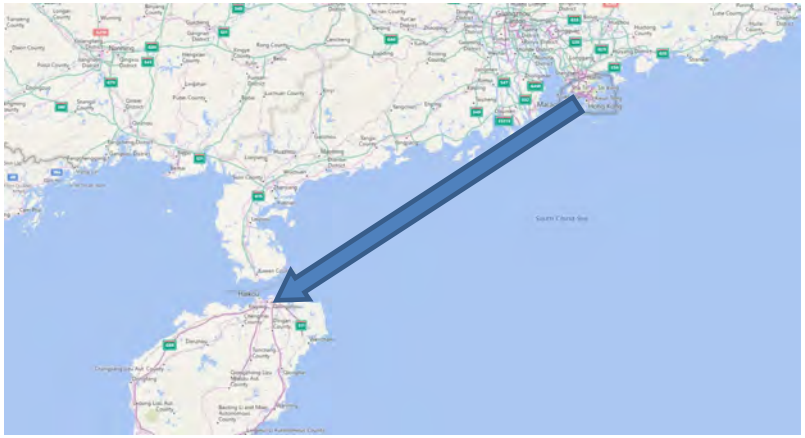


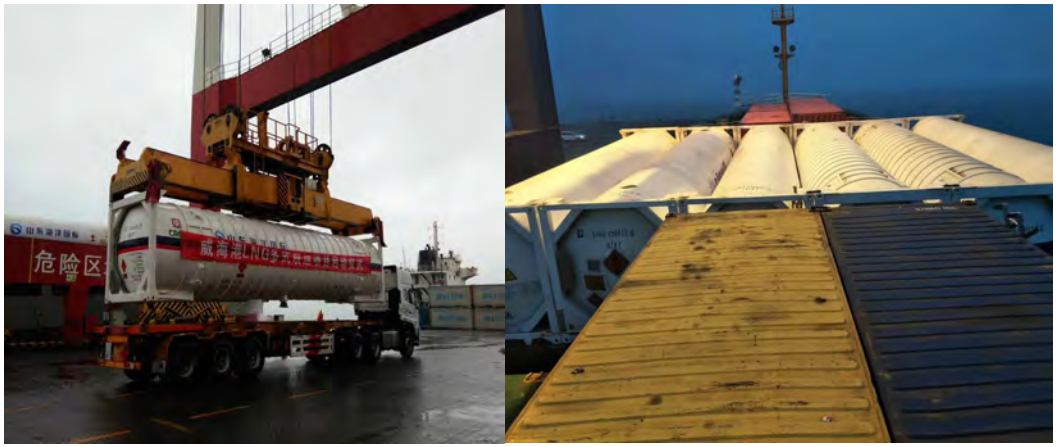
Marine application

Portable fuel tank

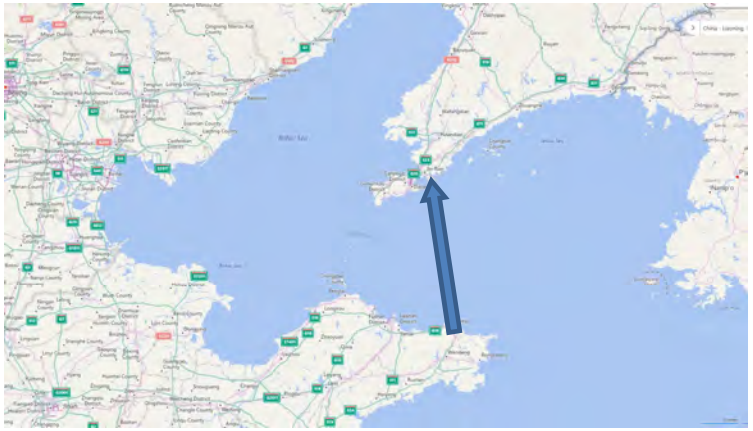
Pilot Projects — **China**

Dongguan-Haikou



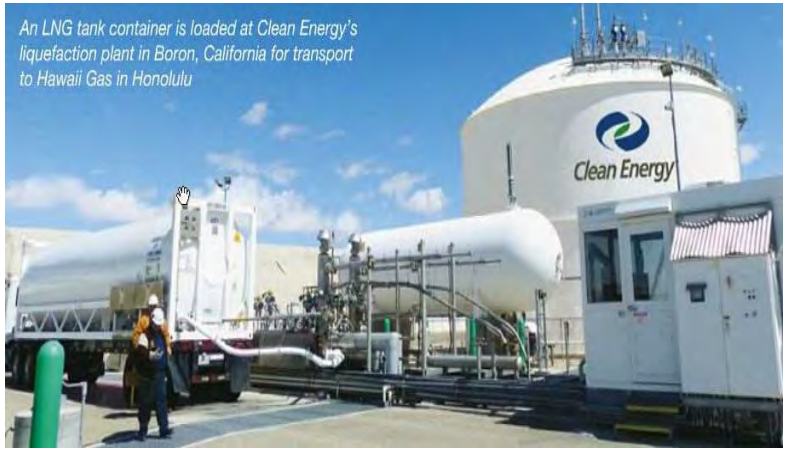


Weihai-Dalian



Pilot Projects — America

Time	2014.3
Seller	Clean Energy
Buyer	Hawaii Gas
Transportation mode	Truck + containership (2231 nm) + Truck
Itinerary	Boron-Los Angeles-Hawaii-Honolulu
Application	Power supply
Planning number	38 containers
Current Number	2 containers



An LNG tank container is loaded at Clean Energy's liquefaction plant in Boron, California for transport to Hawaii Gas in Honolulu

Time	Since 2014, Multi-year contract
Seller	Crowley Maritime
Buyer	Coca-cola
Transportation mode	Truck + containership (1144 nm) + Truck
Itinerary	Jacksonville-Puerto Rico
Carrier	Carib Energy （Crowley Maritime）
Application	Factory production

Pilot Projects — **Portugal**

Time	2014.4
Seller	Gaslink Gas Nature (Sousa Group)
Buyer	Madeira Electricity Company
Mode of transportation	Truck(150km) + containership(960km) + Truck(40km)
Itinerary	Portugal Sines-Madeira
Application	Power supply
Producer	Chart
Number & capacity	14 Containers, 500m^3 in total, 2 layers
Contract time	8 years
Haul cycle time	12 days
Annual consumption	30,000 tons

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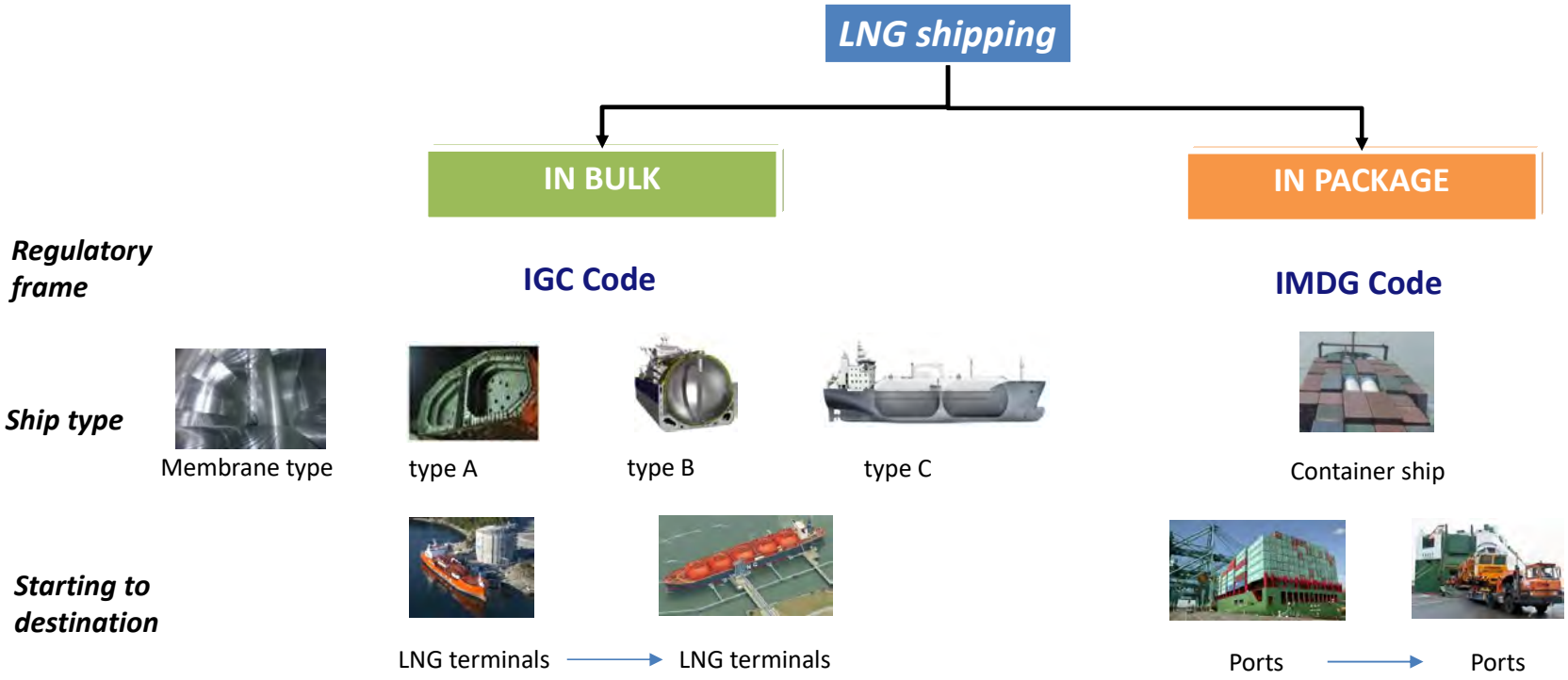
Regulation framework for LNG shipping



Provisions requiring that dangerous goods are correctly and safely:

- Classified and identified
- Packed
- Marked, labelled and placarded
- Documented
- Stowed on board the vessel
- Segregated from other goods with which they may react dangerously

Regulation framework for LNG shipping in ISO tanks

Safety requirements for transportation of tank containers

Ship

SOLAS II-2/Reg.19

- Water supplies;
- Sources of ignition;
- Detection system;
- Ventilation;
- Personnel protection;
- · · ·

Tank container

IMDG Code

Manufacture & filling

- Tank container requirements (T75 Guidance)
- Special tank container requirements TP5 (initial filling ratio)

Stowage

- Stowage on deck (category D)
- **Holding time** should be **calculated** and the duration of voyage must not exceed the holding time, otherwise, it cannot be shipped on board.

Doubts and problems

REQUIREMENTS

- holding time: for a specified degree of filling, from establishing the initial filling condition until the pressure has risen, due to heat leak, to the set pressure of the pressure-limiting device. (ISO 21014)
- The actual holding time shall be calculated for each journey in accordance with a procedure recognized by the competent authority, on the basis of the following (IMDG 4.2.3.7):
  - the reference holding time for the refrigerated liquefied gas to be transported
  - the actual filling density and pressure;
  - the lowest set pressure of the pressure-limiting device(s)

COMMOM PRACTICE

- LN2 test to get the static boil-off rate;
- Conversion to get the static BOR for LNG;
- Calculate the reference holding time based on thermal equilibrium

DOUBTS & PROBLEMS

- The calculation is based on LN2 test and several times conversion, so the result is accurate and reliable enough?
- The test and calculation is only for static condition, so what about the dynamic condition ?

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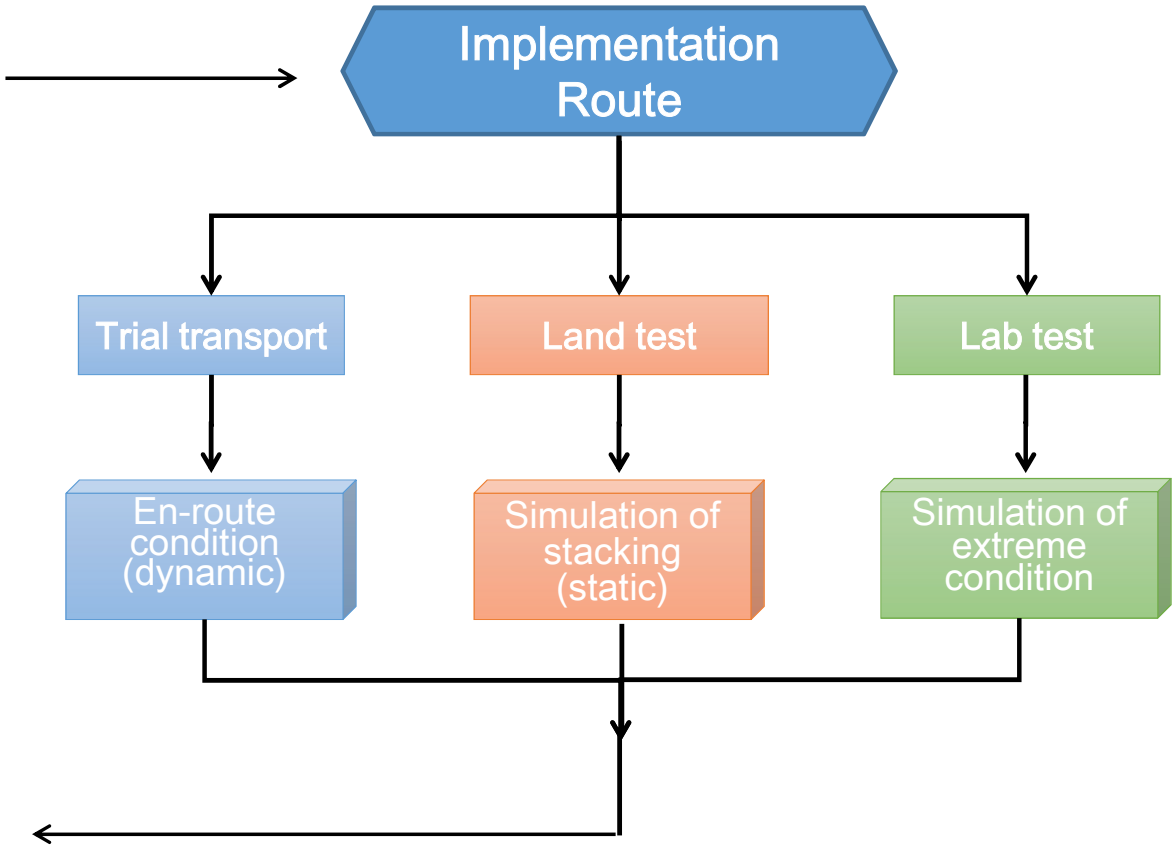
Scheme design

GOAL

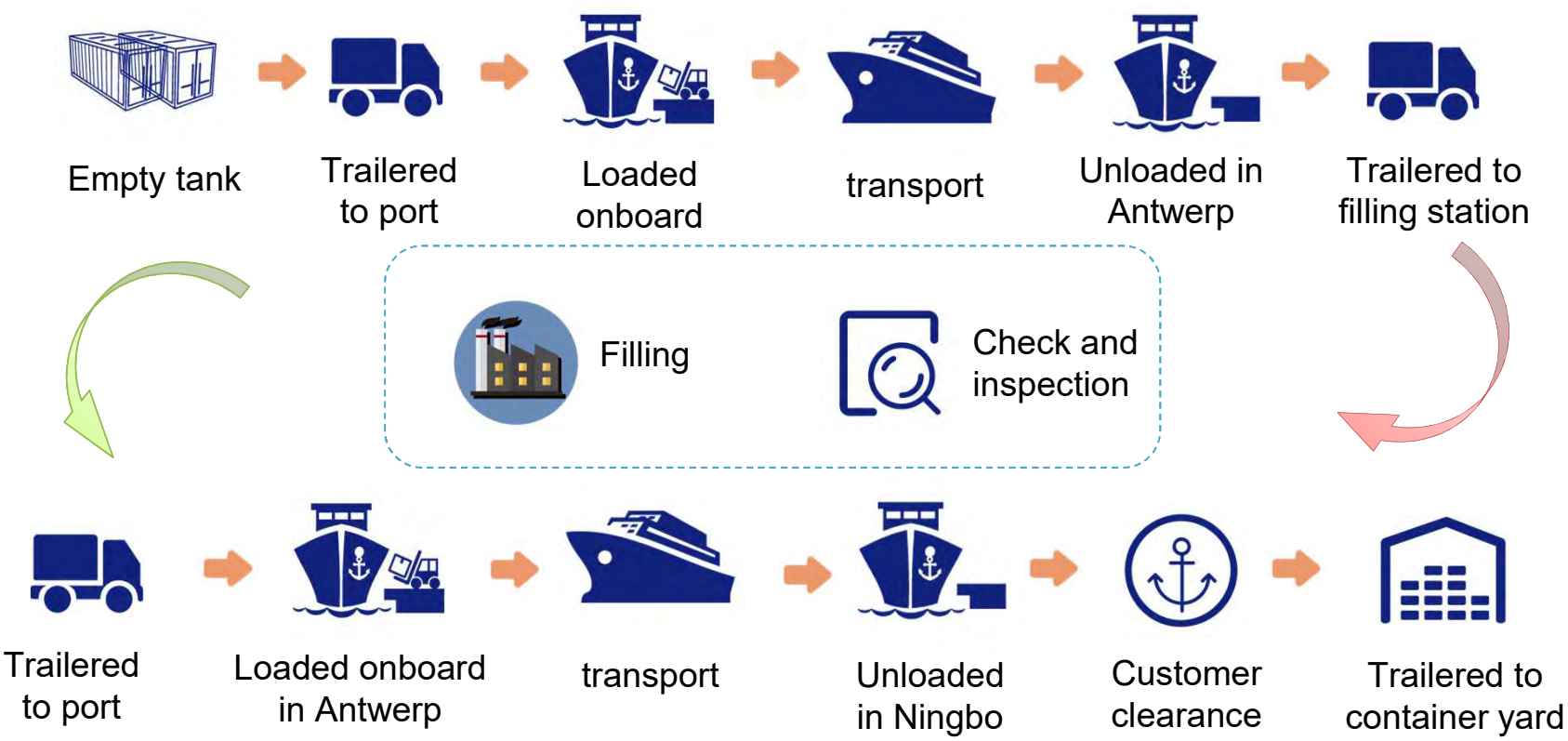
- Verify the feasibility of long distance transport of LNG ISO tanks;
- Find out and compare the pressure / temperature change trend against time under static, dynamic and extreme condition;
- Find out the real holding time under static and dynamic condition;
- Compare the real holding time and calc
- Establish a model to predict the holding time based on real time data collection.



Trail transport (Europe-China)

- 4 40 feet ISO tanks (No.SIMU810001，No.SIMU810007，No.SIMU810019 and No.SIMU810020) shipped by Maersk Line；
- Each tank equipped with an intelligent system capable of monitoring and recording real time temperature, pressure and level data.

Flow of the trail transport



Land test to simulate stacking in container yard

Empty tanks trailered to site

Deployment and LNG filling

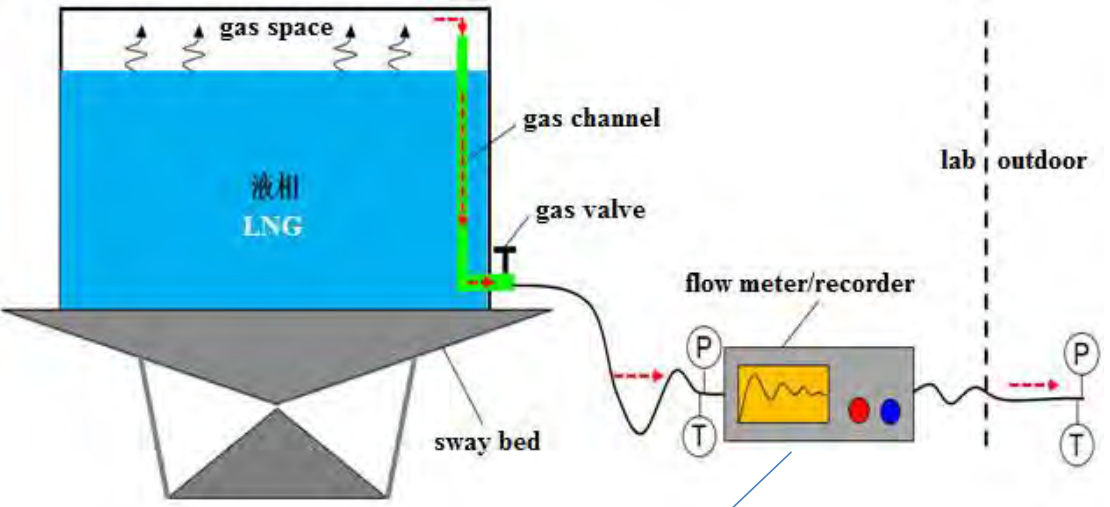
Settlement

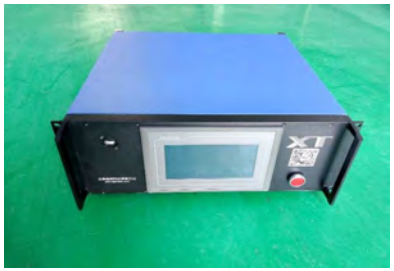
Monitoring and record

Safety watch

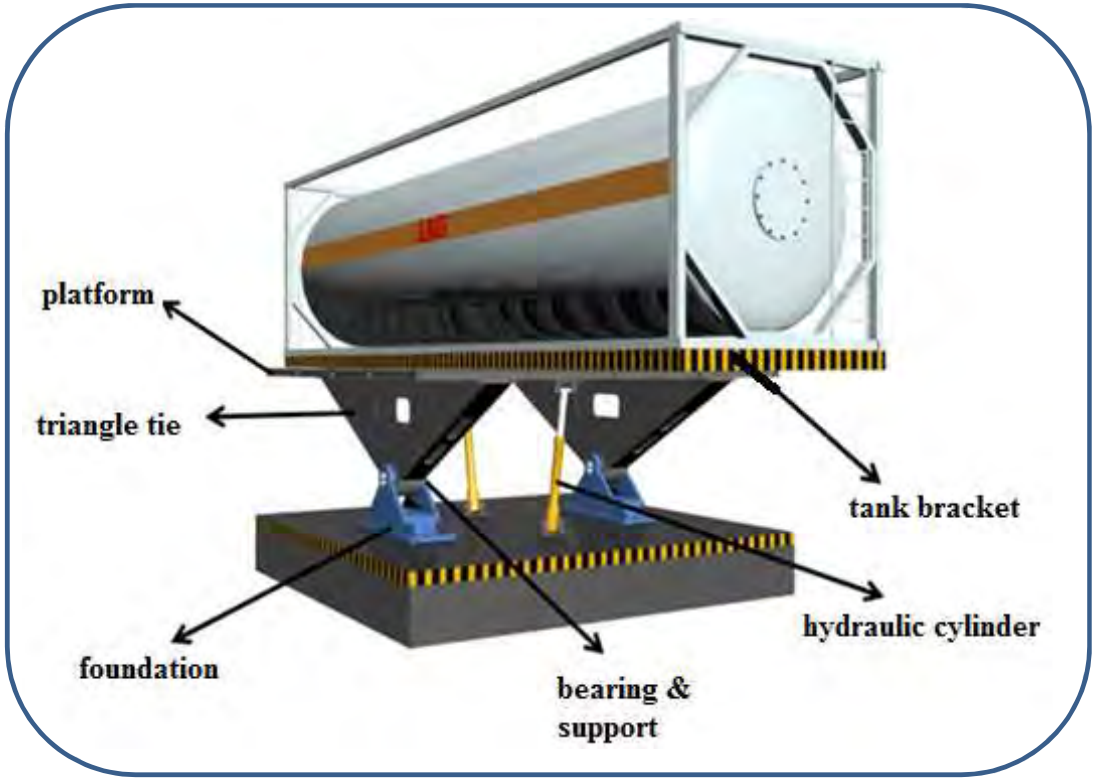
Emergency drill

Lab test to simulate the extreme condition





Gas flow meter and recorder




SINOCHEM
SINOCHEM JN ENERGY

Lab test to simulate the extreme condition

- Sea states simulated by the sway bed

Condition	Sea state level	Encountering probability	Ship motion parameter		Motion excitation
			Amplitude (degree)	Frequency (Hz)	
LC 1	3	10^{-1}	0.5	0.1	$\theta = -\frac{\pi}{180}\cos(0.2\pi \cdot t)$
LC 2	4	10^{-1}	1	0.09	$\theta = -\frac{\pi}{45}\cos(0.18\pi \cdot t)$
LC 3	5	10^{-1}	6	0.08	$\theta = -\frac{11\pi}{180}\cos(0.16\pi \cdot t)$
LC 4	8	10^{-4}	11.2	0.06	$\theta = -\frac{1\pi}{18}\cos(0.12\pi \cdot t)$
LC 5	> 8	10^{-6}	14.5	0.05	$\theta = -\frac{1\pi}{12}\cos(0.10\pi \cdot t)$

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Finding 1: the feasibility of long distance transport proven

	Empty tanks	Heavy tanks
Port of origin	Ningbo Port	Antwerp
Destination	Antwerp	Ningbo Port
Shipper	COSCO Shipping	Maersk
Duration	29 D	30 D at sea + 15 D stack and on road

LNG filling data

Tem.	-159℃	MARVS	4.83bar
Density	440.6 kg/m³	Mass	17220 kg (86%)

LNG discharged to end user

Tem.	-148.8℃	Discharged mass	16900 kg
Pressure	1.6 bar	Heel cargo	300 kg

Finding 2: the ISO tank technology proven as reliable

LN2

Tank no.	MARVS (MPa)	Aver. Ambient temp. (℃)	Actual holding time (D)
8100100	0.75	11.04	78.89
8100121	0.75	10.35	69.30
8100245	0.75	9.17	68.64
8100029	0.75	13.32	119.28
8100060	0.75	11.79	91.12

LNG

Tank no.	MARVS (MPa)	Aver. Ambient temp. (℃)	Actual holding time (D)
8100116	0.75	11.53	113.23
8100097	0.75	13.08	129.19
8100230	0.75	13.52	121.53
8100034	0.75	17.24	174.79
8100055	0.74	17.03	145.96

Finding 3: calculated holding time is not accurate enough

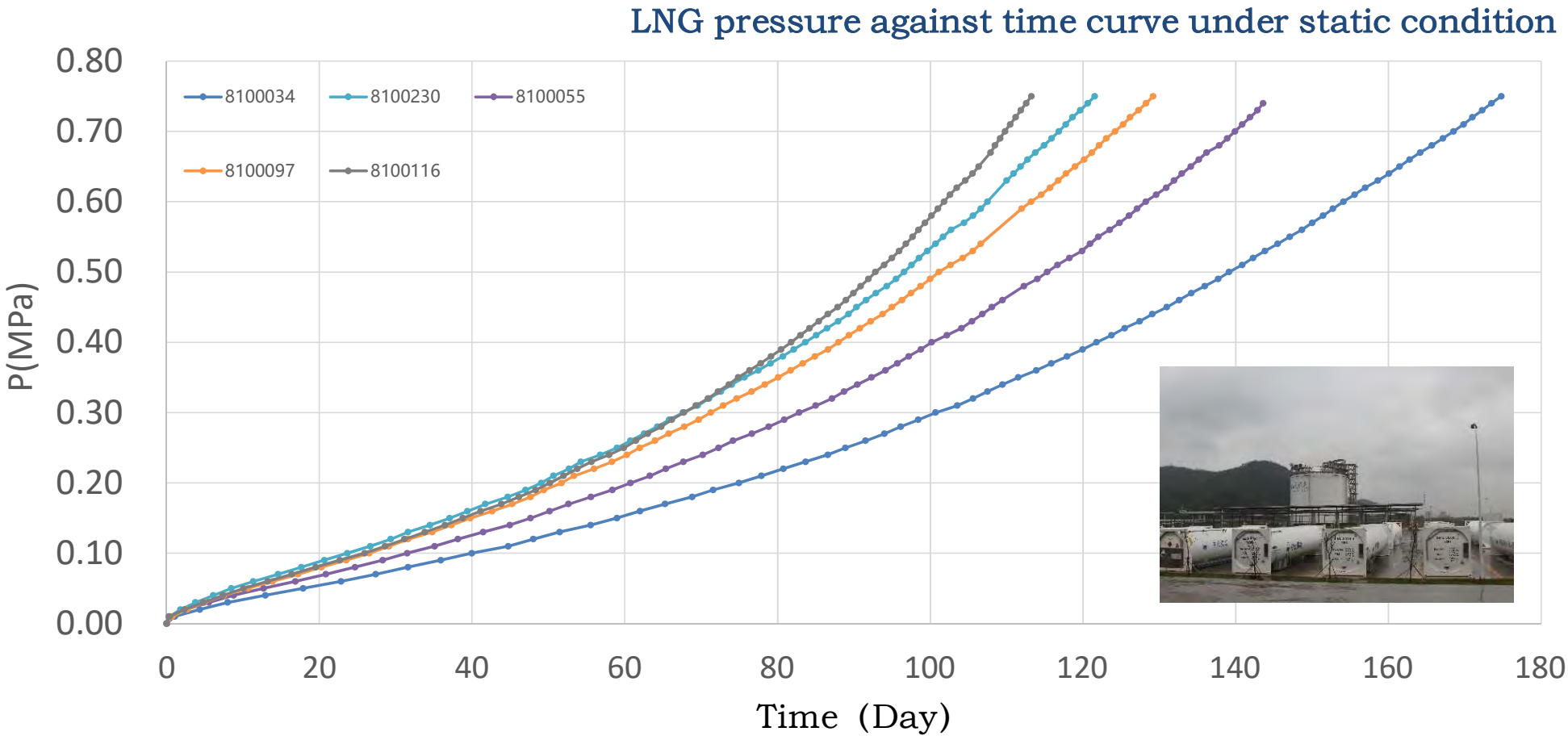
Tank No.	Filling medium	Actual holding time (days)	Calculated holding time (days)	Deviation
8100116	LNG	113.23	168.00	0.67
8100097	LNG	129.19	165.20	0.78
8100230	LNG	121.53	171.00	0.71
8100224	LNG	156.08	235.00	0.66
8100034	LNG	174.79	199.00	0.88
8100055	LNG	145.96	159.00	0.92

ANALYSIS

- The calculated holding time is based on the thermal equilibrium condition, i.e. ideal condition.
- Actually, there are effects from thermal stratification and uneven heat flow.
- That's why the actual holding time is always shorten than the calculated holding time.

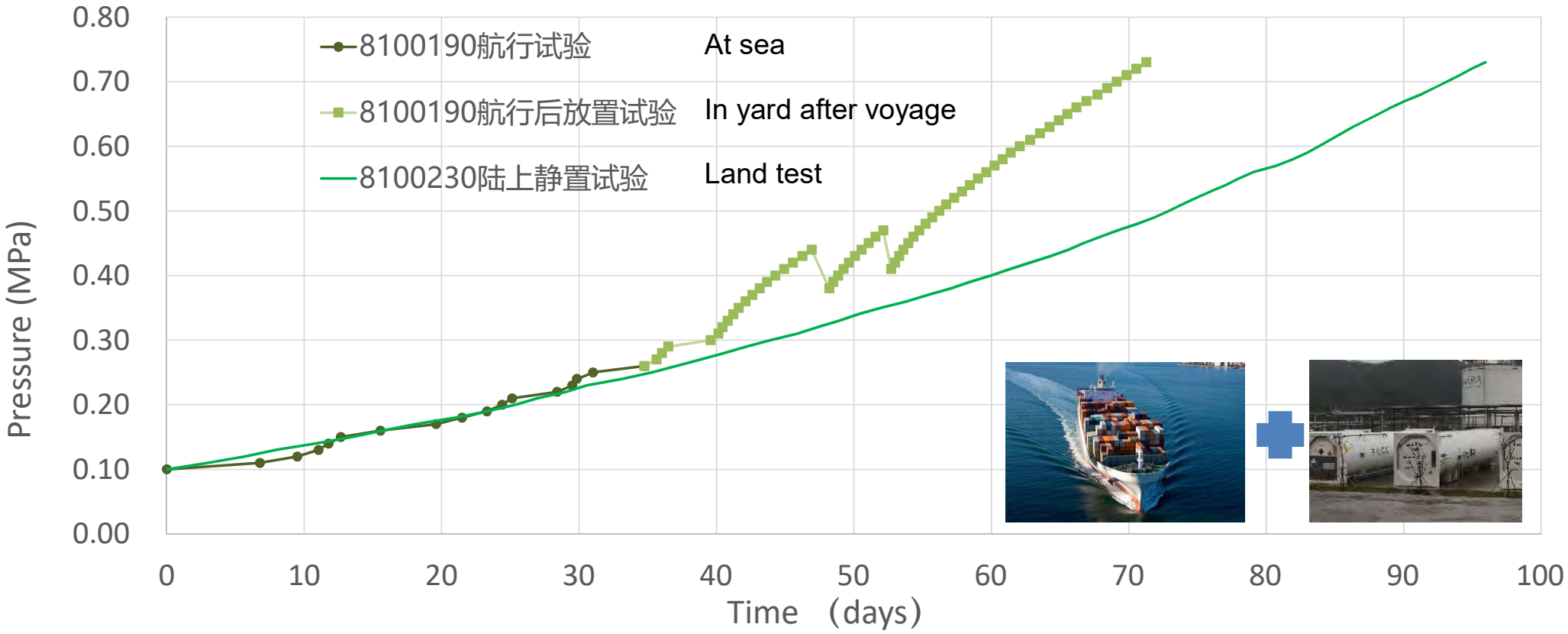
A correction factor of 0.6~0.9 is recommended to be applied on the calculated holding time.

Finding 4: pressure change trend is similar despite different tanks



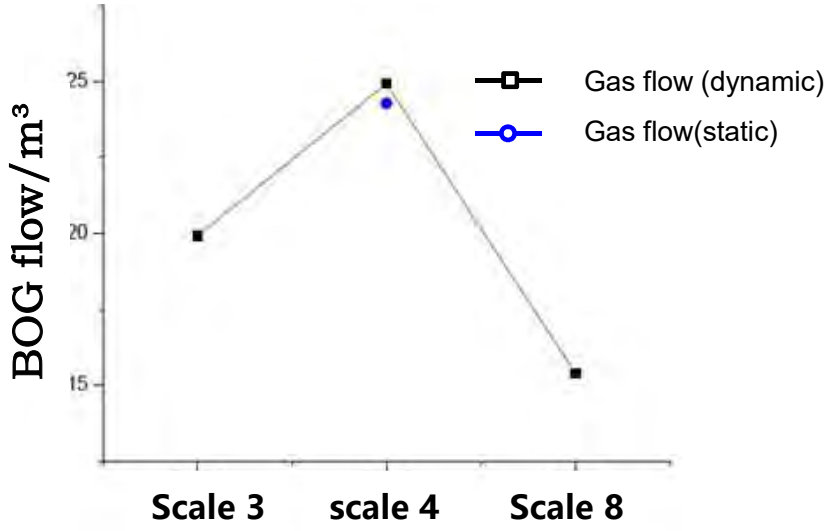
Finding 5: pressure escalate slightly faster under static condition

Finding 6: pressure change dramatically in yard after shipping

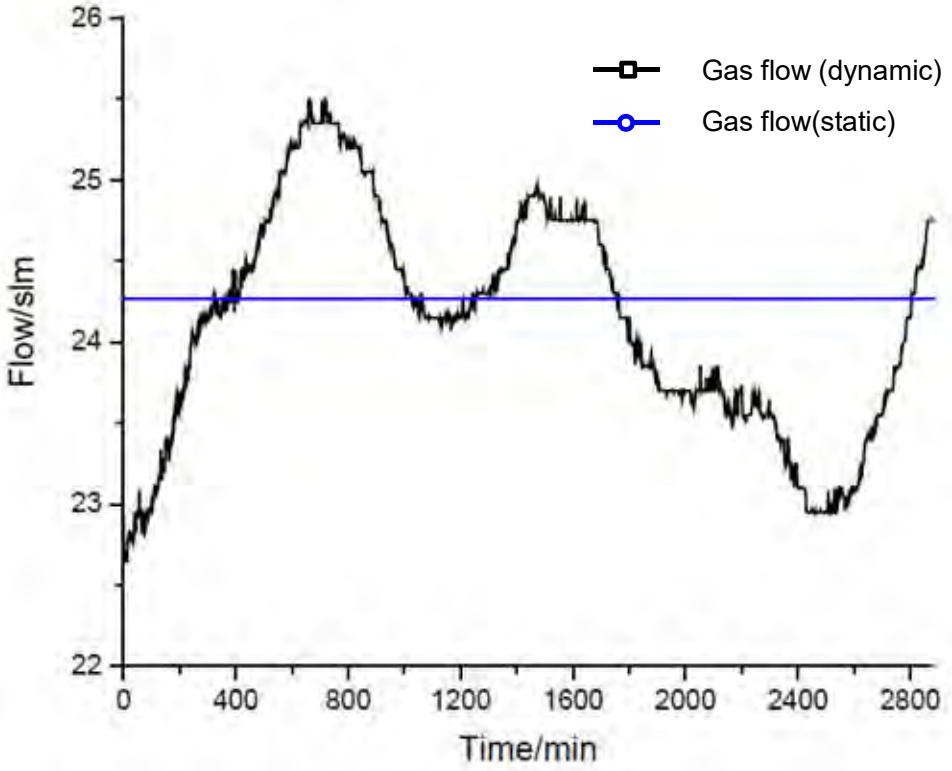


Finding 7: BOR change is limited under extreme condition

- The boil-off rate may increase under moderate sway condition, but the extent is very limited;
- The BOR even descend under relatively stable or adverse condition.



BOG flow comparison
(under scale 4 sea state v.s static condition)



Finding 8: a remaining holding time prediction system developed

A remaining holding time prediction system was developed based on collected data and analysis.

Smart phone APP

Conclusion

- LNG ISO tank containers provide final gas consumers an alternative solution, by which the energy independence will be further guaranteed.
- With the dramatic progress of ISO tank technology, the feasibility of trans-ocean and long time transport is proven as practical and reliable;
- The calculated holding times, which attained from the current method based on thermal equilibrium assumption, deviate the actual holding times by 10-40% , this should be taken into account when planning the transport;
- The movement of ISO tanks, even under extreme condition, poses very limited effect on the boil-off rate;
- A remaining holding time system is of great use to ensure the transport safety;
- The pressure change trend in empty tank (with limited volume of LNG for cold-keeping) need to be further studied.

Courtesy of COSCO Shipping

Safety，Environmental protection，Create value for clients & society

For more details, please contact

GAN Shaowei, China Classification Society

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