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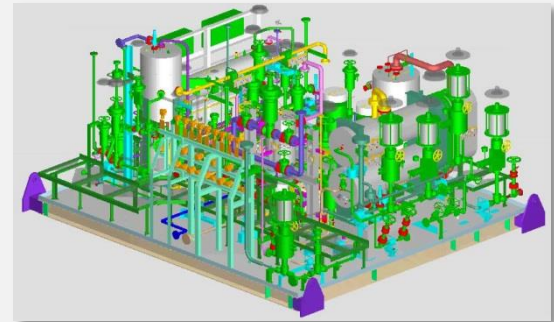
The world 1st LNG-fuelled containership

Focusing on DSME FGSS Technology: HiVAR®



Contents

- 1 Introduction
- 2 HiVAR[®] System Development
- 3 Reference Project Status
- 4 Conclusion



The World 1st LNG-fuelled Containership



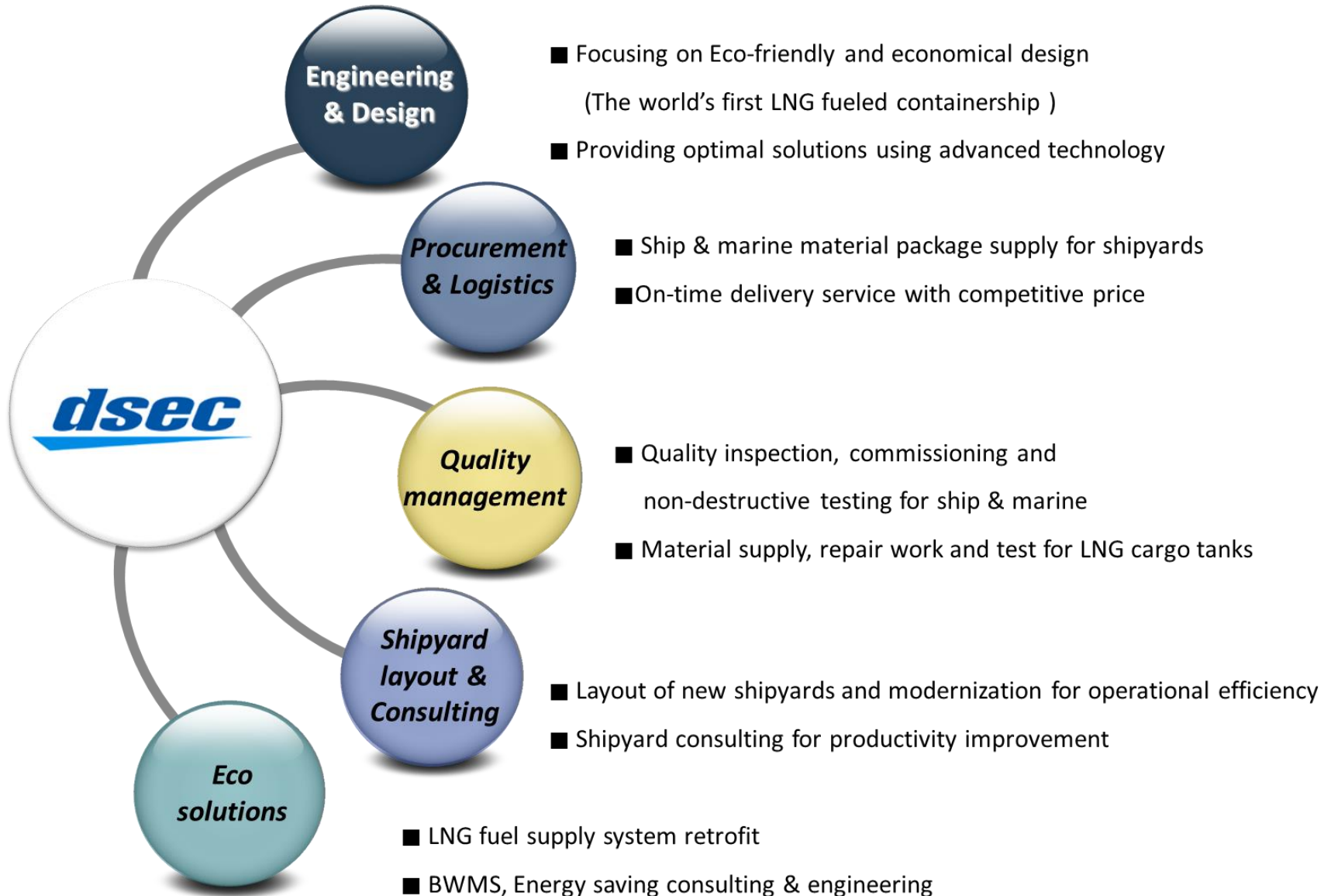
TOTE Maritime's LNG-powered containerships have been awarded the 2013 'Next Generation Shipping' award at Nor-Shipping. - 4 Jun 2013 -

- Built by **NASSCO** Shipbuilding Company
- Designed and Purchased by **DSEC**
- Fuel Gas Supply System by **DSME**

** DSEC is a subsidiary of DSME*

Company name	Daewoo Shipbuilding & Marine Engineering Co., Ltd.
Date of incorporation	October 11, 1973
Revenue	Over 13 billion USD (2013)
Yard	4 million m ³
Employees	30,000 (including affiliates)
Major Products	Commercial Vessels
	Specialty Vessels
	Offshore & Onshore Plants
Website	http://www.dsme.co.kr/





The World 1st LNG-fuelled 3,100 TEU Containership



Cow Containers



FGSS (DSME – HiVAR)



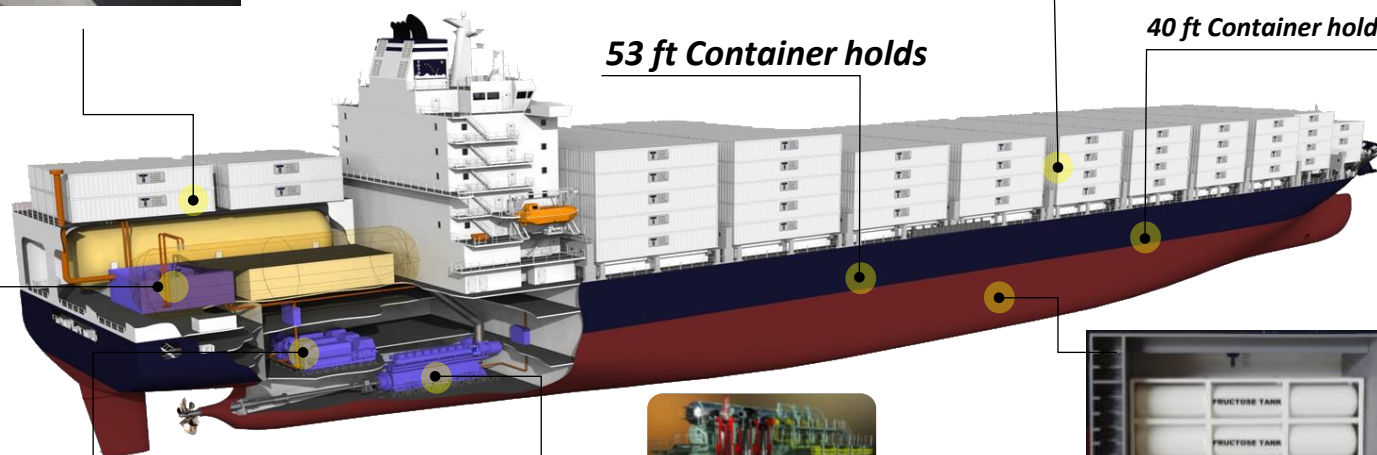
MAN DFDG



40/45/53 ft Container on deck

53 ft Container holds

40 ft Container holds



MAN ME-GI ENGINE

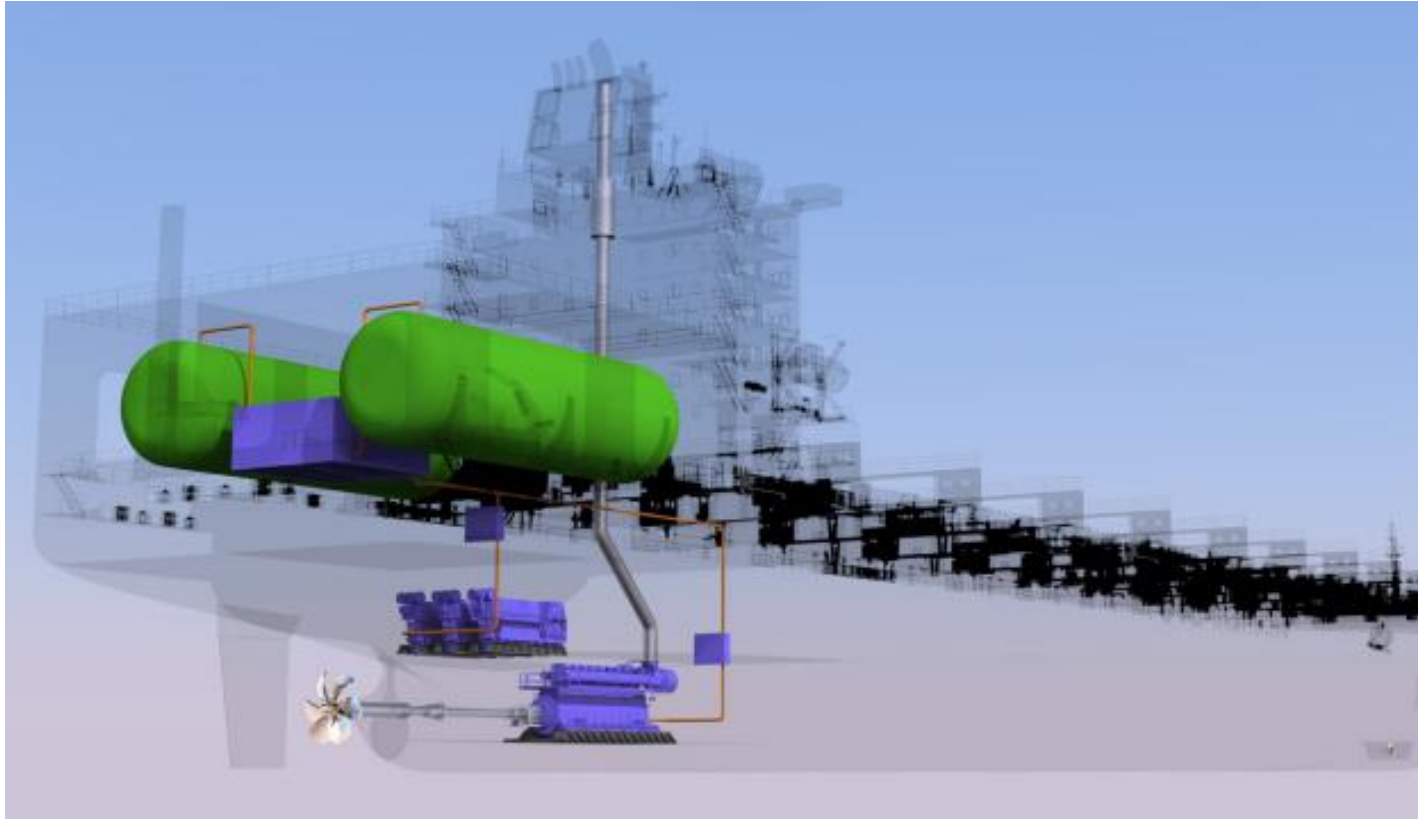


Fructose Tanks

Designed by DSEC

Principle Dimension	L x B x D (approx. 233.0 x 32.2 x 18.3 m)	Main Engine	ME-GI Engine
Deadweight	31,830 MT (at 10.5 M of design/scantling draft)	BWMS	Electrolysis type
Cruising Range	10,000 NM (LNG 4,000 NM + FO 6,000 NM)		
Cargo Capacity	<ul style="list-style-type: none"> 3,100 TEU (Incl. Reefer : 266 sockets and Cow-container: 4 FEU) 1,100 m³ Fructose tanks Various containers (40, 45 and 53 ft) in hold and on deck 		

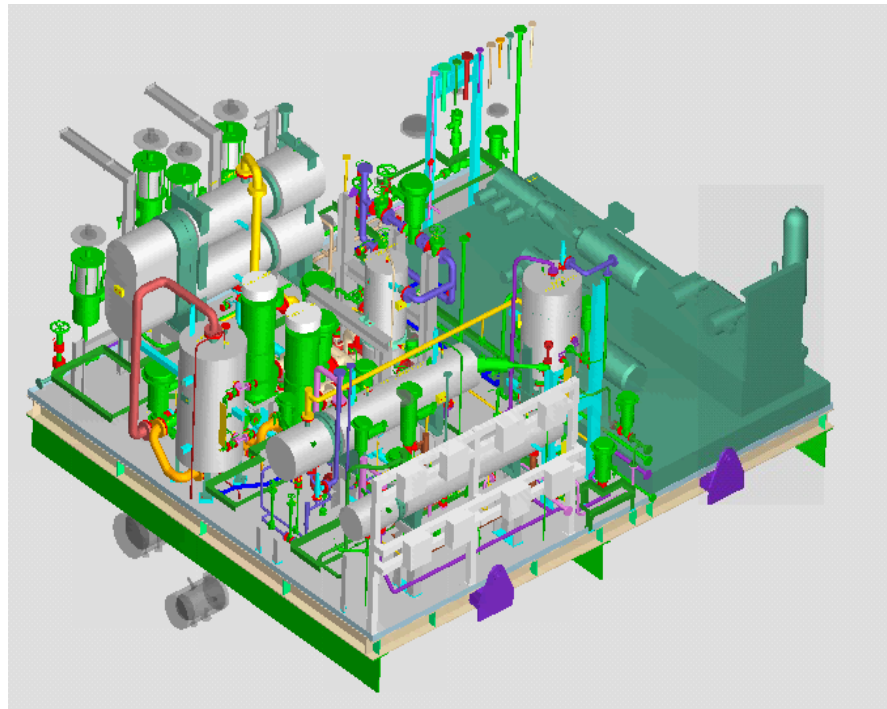
Scheduled delivery for the first ship: Q4 2015 / Scheduled delivery for the second ship: Q1 2016



→ The World 1st LNG-fuelled Containership

→ MEGI engine + New FGSS technology (DSME HiVAR®)

HiVAR[®] System Development

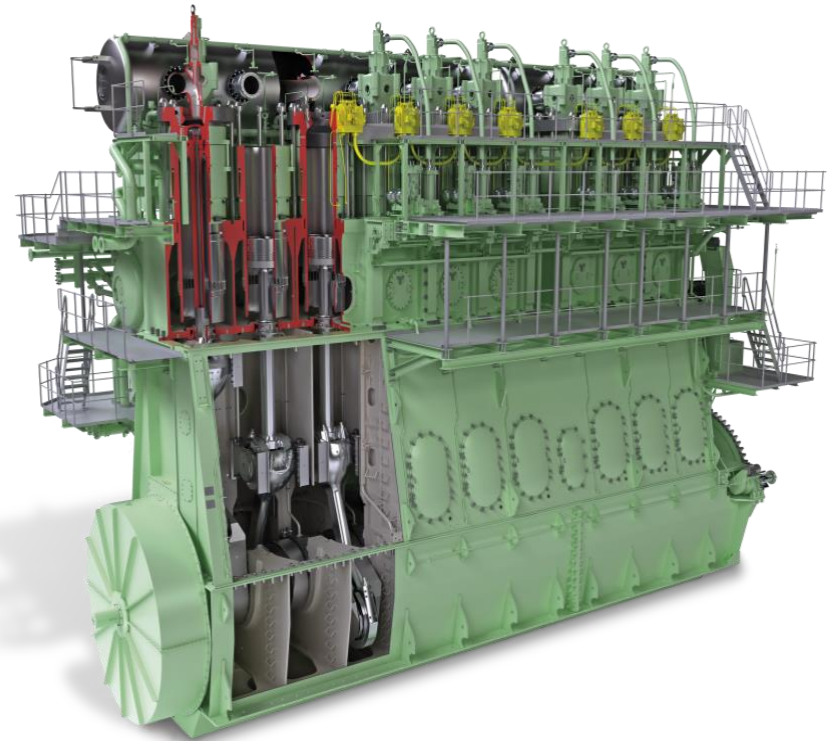


Why the ME-GI Engine?



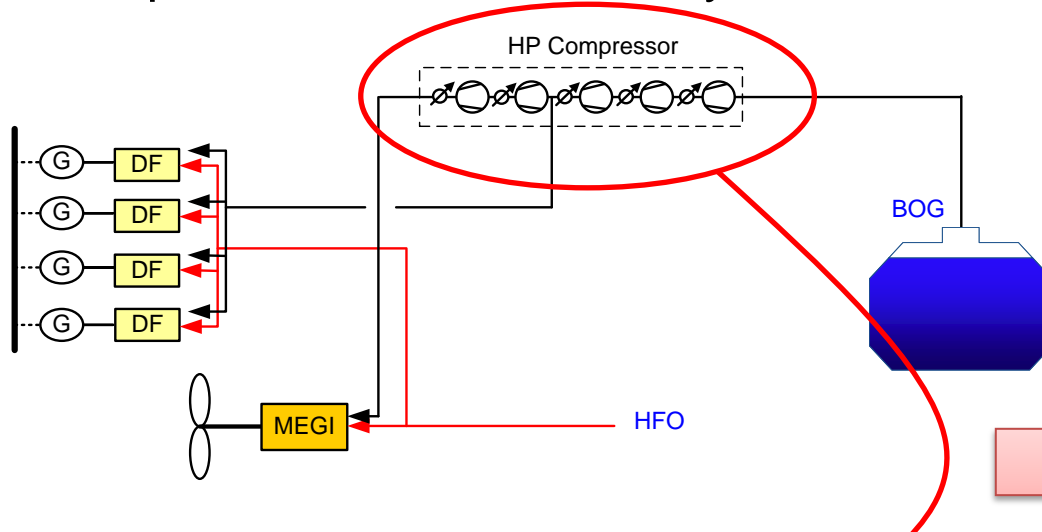
The ME-GI is derived from the industry's standard MC and ME engine.

- Proven design, **>20,000** engines in service.
- **Diesel cycle** high fuel efficiency **~50%** versus much lower for other engine types.
- High fuel flexibility – burn **all** gas grades **without derating**. Burns **all fuel types**.
- High **reliability** – same as fuel engines.
- **No derating** because of **knocking** danger.
- **Negligible methane slip**.
- **Only demonstrated AND ordered 2 stroke dual fuel engine.**
- **A robust gas combustion – unchanged load respons – unaffected by ambient condition**

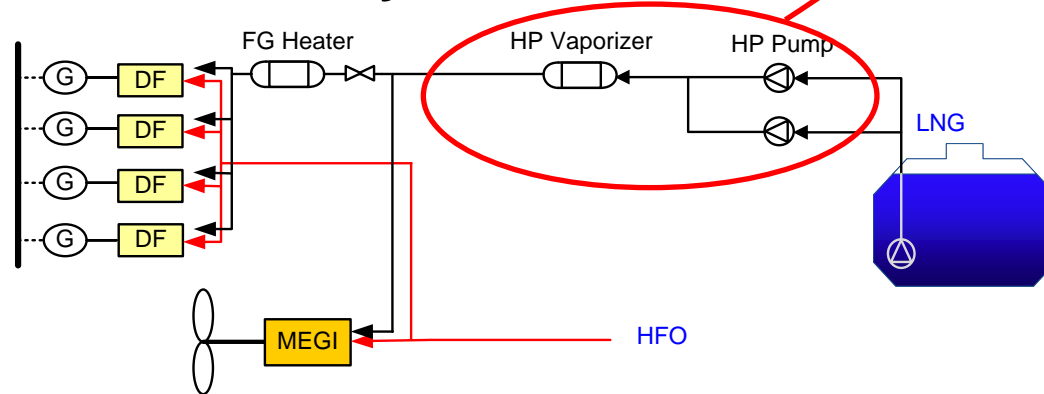


- quote from MAN Diesel & Turbo -

✓ Compressor Driven FGSS System



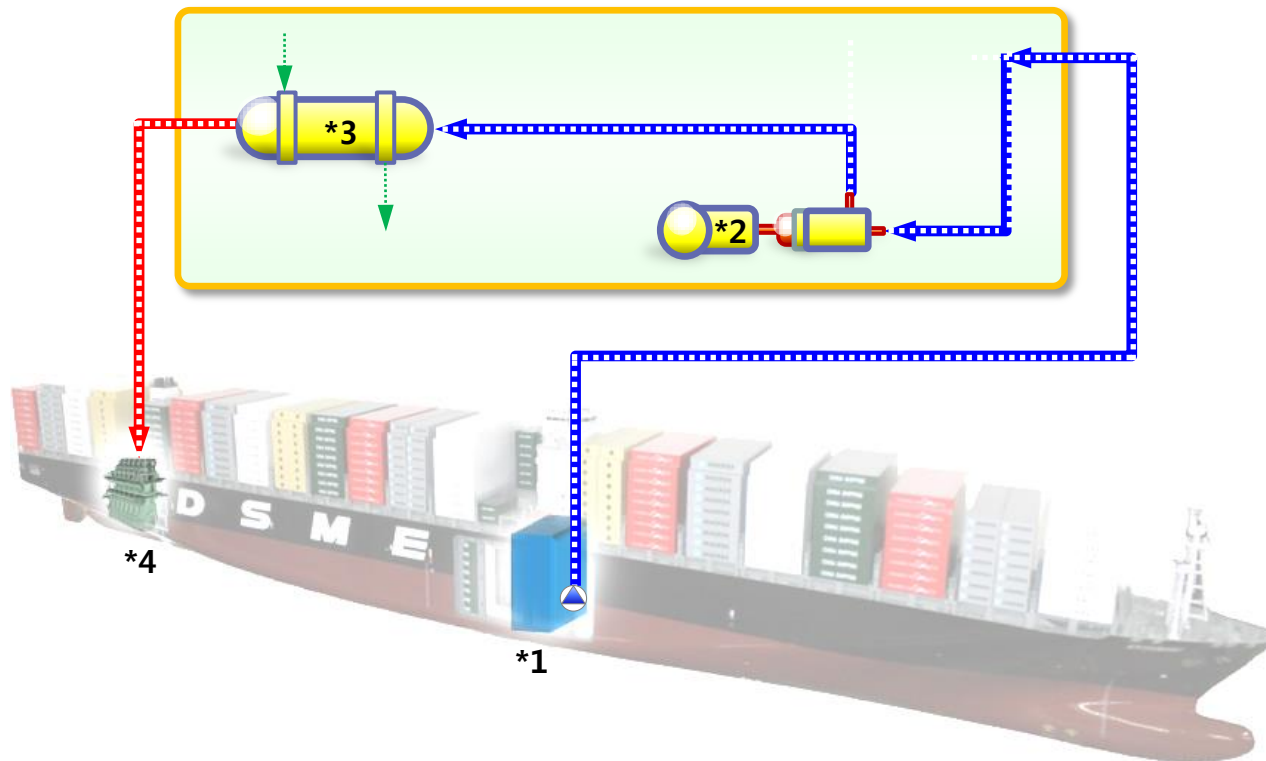
✓ DSME HiVAR® System



- CAPEX
- OPEX
- SIZE
- Operation
- Maintenance

❖ Conceptual process flow diagram of DSME HiVAR[®] FGSS

DSME FGSS



DSME HiVAR[®] FGSS

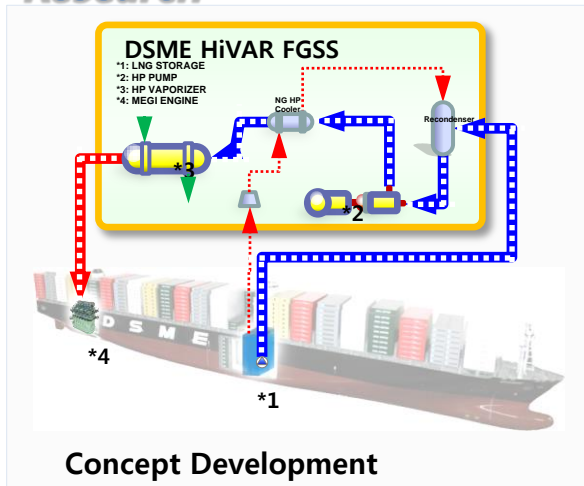
- HP Pump + HP Vaporizer
- 330 bar Design Pressure
- Compact Size
- Low Power Consumption
- Low Noise & Vibration
- Easy Maintenance

Power Consumption Comparison (for reference)

HP Compressor System	HP Pump + HP Vaporizer
1500 kW	100 kW

Year	Event
2007	HiVAR® Concept Development (DSME's Patent)
2010	HiVAR® FGSS test skid fabrication completed
2011	1st MEGI engine demonstration in MDT, Copenhagen
2012	2nd MEGI engine demonstration in MDT, Copenhagen
2012	TOTE/NASSCO project (world 1 st ME-GI containership) Teekay ME-GI LNGC ordered (world 1 st ME-GI LNG Carrier)
2013	HiVAR® FGSS license agreement with MDT for application to QG retrofit project
2014	16 ME-GI LNG Carriers ordered (DSME)

Research



Development



Application



❖ DSME Intellectual property rights

Patent List of DSME FGSS

• International Patent Application

- ✓ Several patents applied since June 2008
- ✓ Designated States : EP*(Granted), Singapore(Granted), China, United Arab Emirates

• United States Patent

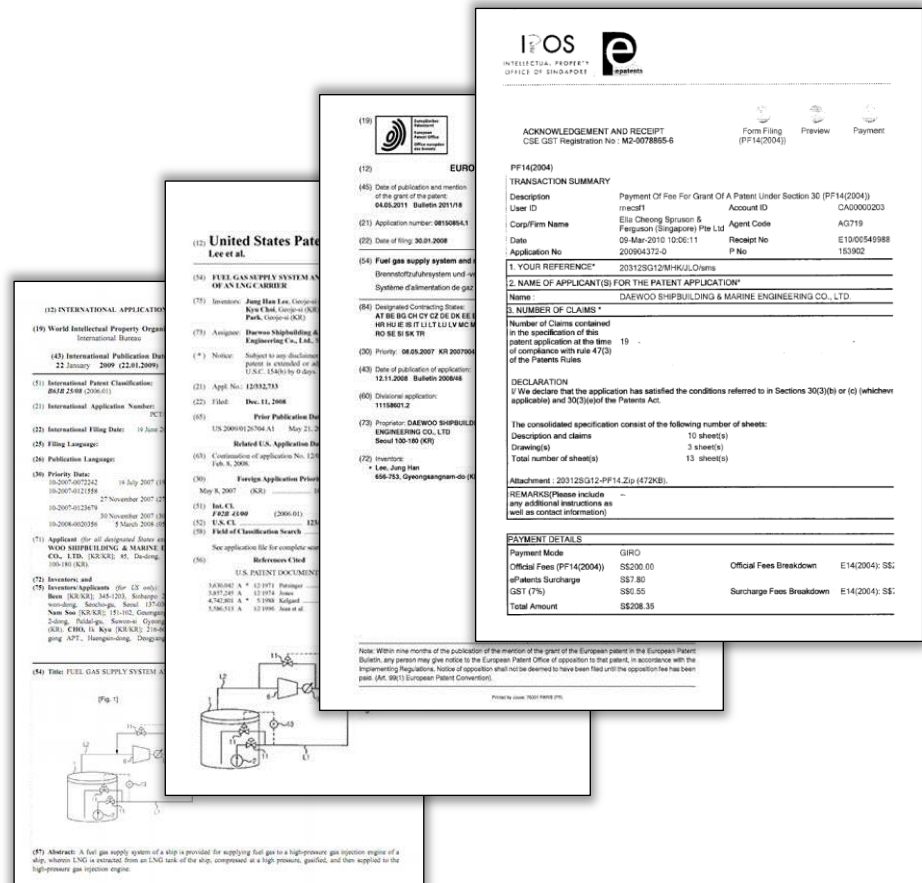
- ✓ Several patents applied since Dec 2008

• Patented or Patent Application in Korea

- ✓ Several patents applied since May 2007

※ EP : United Kingdom, Norway, Sweden, Germany, Belgium, France, Denmark, Greece, Switzerland, Finland

- High pressure **fuel gas supply** using **HP pump** and **HP vaporizer** is subject to intellectual and industrial property rights protected by national and international legislation.
- Registered to many countries including US and EU. (Previous arts have been exhaustively checked before registration.)
- It would be general protocol among world esteemed companies that patents and related development efforts are fairly respected.
- DSME **won a patent suit** for LNG fuel system at the **European Patent Office (EPO)** in 2014



The collage shows three patent-related documents:

- United States Patent Application:** A document titled "FUEL GAS SUPPLY SYSTEM OF AN LNG CARRIER" by Lee et al., dated 22 January 2009. It includes a detailed description of the system and a schematic diagram (Fig. 1) showing the fuel gas supply system of a ship.
- European Patent Application:** A document titled "FUEL GAS SUPPLY SYSTEM AND BRENNSTOFFSYSTEM UND VERBUNDENES ALIMENTATIONSSYSTEM" by Lee et al., dated 08.09.2007. It includes a detailed description of the system and a schematic diagram (Fig. 1) showing the fuel gas supply system of a ship.
- DSME IPOS Acknowledgment and Receipt:** A form titled "ACKNOWLEDGEMENT AND RECEIPT" from the Intellectual Property Office of Singapore (IPOS). It includes details of the patent application, the applicant (DAEWOO SHIPBUILDING & MARINE ENGINEERING CO., LTD.), and the payment of fees.

❖ Approvals for DSME FGSS


AIP & HAZID for 14,000 TEU CTN : GL, BV
 AIP & HAZID for 7,450 TEU CTN : ABS
 AIP & HAZID for 318K VLCC : ABS, DNV, KR, LR
 AIP & HAZID/HAZOP for LNGC : ABS

AIP (Approval in Principle) for MEGI Fuel Gas Supply System for LNGC (Apr. 2009)

Concept Appraisal for MEGI High Pressure Fuel Gas Supply System (Jul. 2010)

DSME MEGI High Pressure Fuel Gas Supply System – Drawing and Test Procedure for Prototype Test Unit (Dec. 2010)

Electronically published by ABS Busan.
 Reference 439743, dated 02-APR-2009.



DAEWOO SHIPBUILDING & MARINE ENGINEERING CO., LTD.
 85 DA-DONG, JUNG-GU, SEOUL, KOREA

Reference: JYK/439743
 Project Number: 1693549
 Date: 2 April 2009

Attn: Mr. Nam-Soo Kim / Principal Engineer – Cargo & Hull Painting Design, SHIPM Team

Drawings for Approval in Principle:

- DSME-HP-001 Rev.A "Arr't of Cargo Compressor & Electric Motor Room"
- DSME-HP-002 Rev.A "Pipline & Instrument Diagram of ME-GI Engine Fuel Gas Supply System - H1VAR"
- DSME-HP-003 Rev.A "Overall Process Flow Diagram - H1VAR"
- DSME-HP-004 Rev.A "Pipline & Instrument Diagram of D-Reli II Redundantation Plant"
- DA-720-M001 Rev.A "Arr't of High Pressure Fuel Gas Pipe in E/R"
- DA-720-M002 Rev.A "Schematic Pipline Diagram for Main Engine in E/R"

Gentlemen:


We have your above referenced email transmittal of 6 March 2009 requesting our review for an Approval in Principle and with regard thereto have to advise that, insofar as our requirements for classification are concerned, the arrangements as indicated appear to be satisfactory in association with following notes:

- Our review is limited to the information indicated in the subject plans only.
- It is our perspective that there are no high innovative features in the proposed design and its concept. Accordingly, the existing and/or extension of the applicable Rules and Regulations may cover the proposed design.
- We also referred to the technical report of the relevant risk assessment workshop held in year 2008 in Houston for the amelioration of the recommendations and note that some relevant recommendations are reflected. However, it is our understanding that due considerations on the remaining recommendations will be made on the detail design for construction.
- We are unable to verify the plans in detail since the specific statuses of the fluid conditions and all associated systems are not shown completely. However, it is our perspective that the submitted plans as indicated appear to be satisfactory.
- Drawings for construction are to be submitted for our approval separately.

... conf'd to Page 2/2 ...

ABS PACIFIC DIVISION
 8th Floor, Kyosho Life Insurance Bldg., 18-7, 4-Ka, Chongang-Dong, Chung-Ku, Busan, 600-737, Korea
 Tel: 82-51-469-8371, Fax: 82-51-462-4830, Website: www.aabs.or.kr

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Marine Design Appraisal Document

Document no: LRG 2491562
 Issue number: 1
 Page 1 of 1

Date: 15 July 2010

Quote this reference on all future communications
 DAPFENG/RMS/WF 2491562

DAEWOO SHIPBUILDING & MARINE ENGINEERING CO., LTD.
 MEGI HIGH PRESSURE FUEL GAS SUPPLY SYSTEM – CONCEPT APPRAISAL

- The document listed in paragraph 1 of the appendix has been examined for compliance with the design requirements of Lloyd's Register's Rules and Regulations for the Classification of Ships, 2010 Parts 5 and 6, and the Rules and Regulations for the Construction and Classification of Ships for the Carriage of Liquefied Gases in Bulk, 2010 and is assigned an appraisal status as indicated subject to the satisfactory resolution of the matters referred to below and highlighted in red on the plans.

Drawing No.	Rev.	Title	Status
DA301D016	0	Process Flow Diagram of ME-GI High Pressure Fuel Gas Supply System (H1VAR)	AQ


- As the engine has also the ability to operate on fuel oil, there is no requirement for the glycol water system to have any form of redundancy. However, if redundancy was to be considered, the header tank, electrical heater and vaporizer can be considered dormant items of equipment and only the glycol circulation pump would need to have standby capability.
- It is proposed that the process flow diagram should also include details of the means of dealing with the boil-off gas when the high pressure fuel gas supply system is out of action due to breakdown or maintenance.
- As the glycol water tank is fitted with a gas detector and, in the event of a tube failure, possibly contain cargo gas then the vent outlet is to be taken to the safe location in accordance with Chapter 8 of the IGC Code or, be lead to the existing cargo vent mast.
- If the gas compressor motors are to be located in a gas dangerous space then they are to be of a suitably certified safe type.
- The glycol side of the vaporizer is also to be fitted with suitable pressure relief arrangements. The size of the relief device or devices is to be able to vent the volume of gas associated with the catastrophic failure of a single tube.
- It is noted that both low and high pressure relief valves vent into the same discharge header. Where relief valves having different operating pressures discharge into a common header, consideration needs to be given to the effect of the backpressure which will exist in the header during simultaneous operation. The design of

FINAL ACCEPTANCE OF ACTUAL TESTED DEFENSE ON SATISFACTORY SURVEY AND TESTING

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Form SHBMAN (2008.02)



DAEWOO SHIPBUILDING & MARINE ENGINEERING CO., LTD.
 85 DA-DONG, JOE CITY, KYUNGNAM KOREA

Reference: YGK/jyk/661399
 Project Number: 2375608
 Class Number: None
 Date: 8 December 2010

Attn: Mr. J. Y. Ya / principal Engineer – Ship/Plant System R&D

Shipyards, Facility: DSME MEGI High Pressure Fuel Gas Supply System (H1VAR)
 - Drawings and Test Procedure for Prototype Test Unit
 Drawgs. as per list
 Your Ref.: DSME-RD-ABS-FGS-1002

Gentlemen:

We have your above referenced transmittal of 29 May 2010 and emails of 29 June 2010 and 3 September 2010 submitting the subject drawings. We have reviewed Drawing No. DA301D011 for the compliance with applicable requirements in the 2010 Steel Vessel Rules and the ABS Guide for Propulsion System for LNG Carriers as well as the HAZID and AIP results for the H1VAR project, as applicable, as per the agreed scope identified in our fax of 18 May 2010. With regard thereto we offer the following comments:

A. General Comments

- Our review of the subject drawings has been limited to the application of the H1VAR system for the test facility which is understood to be intended solely as a prototype unit to be used to facilitate future development of onboard ship applications.
- Our review has also been limited to the restricted information and details provided in the submittal.

B. Regarding our review of Drawing No. DA301D011, "Piping & Instrumentation of ME-GI High Pressure Fuel Gas Supply System (H1VAR)" we offer the following comments regarding ABS requirements:

- Since the Ethylene Glycol has generally been used for the Glycol water and the freezing point of the ethylene glycol is minus (-) 113 Degree C, arrangements should be provided to ensure that the glycol water is supplied to the vaporizers and adequate flow firmly established prior to LNG being supplied to the vaporizers so as to avoid any freezing of the Glycol water (i.e. the Glycol supply should be established first and the LNG supply should be carefully regulated to prevent the glycol water from freezing, which could block the equipment and cause damage).
- The materials of all piping components (pipes, valves, fittings, etc.) would need to comply with requirements identified in 5C-8-6 of the Rules.
- The pressure ratings, standards of construction and materials of all valves, fittings, etc. would need to be suitable for the application and pressure as well as comply with all other requirements and restrictions identified in 4-6-2 of the Rules.
- Each size and type of valve, expansion bellows and hose, if any, would require design review and prototype test as per 5C-8-5/3 thru 7 of the Rules.

ABS PACIFIC DIVISION
 8th Floor, Kyosho Life Insurance Bldg., 18-7, 4-Ka, Chongang-Dong, Chung-Ku, Busan, 600-737, Korea
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FGS SKID



Verification: DSME FGS System - Integration Test with Engine



ENGINE CONTROL SITE



FGS SKID SITE

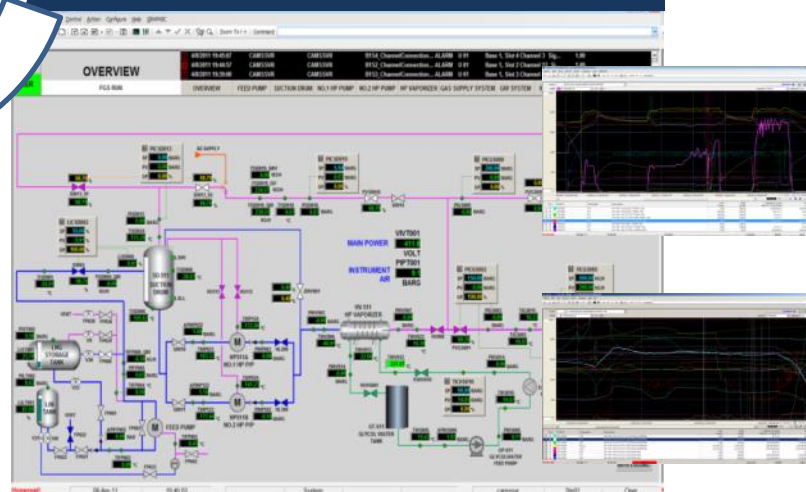


ENGINE SITE



OVERALL
SYSTEM
INTERATION
TEST

LOAD TEST with ENGINE



Verification: Announcement of ME-GI & FGS Development Completion



- On 18th of May 2011, MAN Diesel & Turbo (MDT) and DSME jointly announced the development of ME-GI engine and its application to commercial ships.
- Successful demonstration run of ME-GI engine and FGS system was performed at MDT research center in Copenhagen.



↑ **Presentation of DSME FGS System**

Demonstration run of ME-GI Engine →

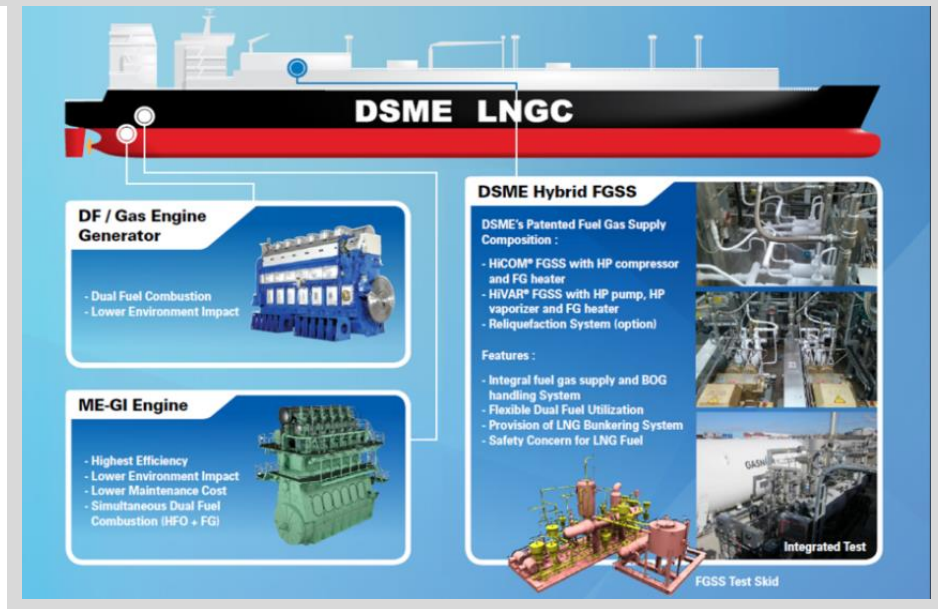


Applications: The World 1st LNG-fuelled Ships

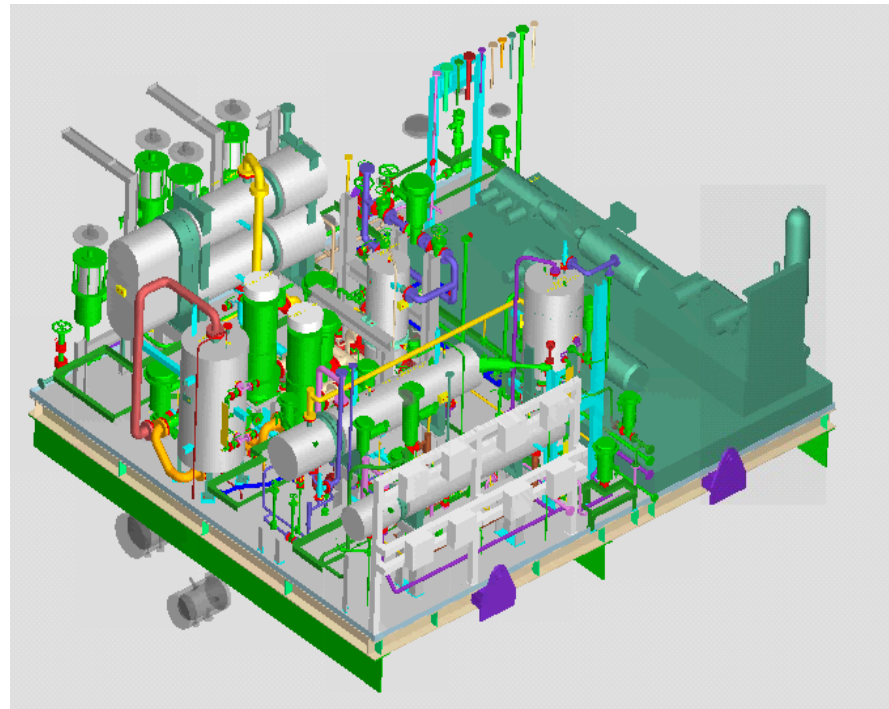


- TOTE 3,100 TEU Containership
- The World 1st LNG-fuelled Containership
- **DSME HiVAR® System**
- Under Construction
- Scheduled delivery in Q4 2015 / Q1 2016

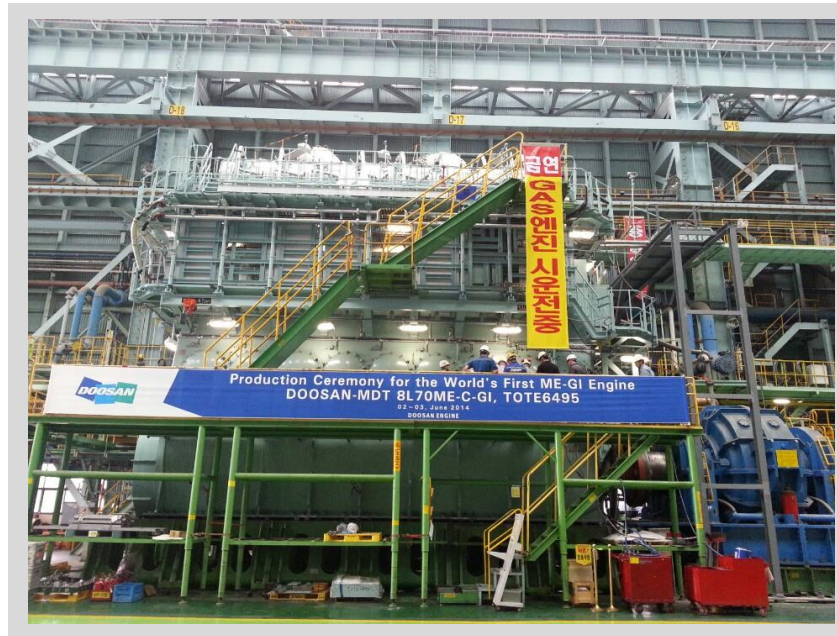
- Teekay 173K LNGC
- World's 1st ME-GI LNG Carrier
- **DSME's Hybrid FGSS (HiVAR® + HiCOM®)**
- Under Construction by DSME
- To be Delivered in 2015



Status of the Reference Project



Successful Test of TOTE ME-GI Engine + FGSS



- Official Engine Trial (1st: Jun 2014, 2nd: Oct 2014)
- Engine Delivery to NASSCO Shipyard
- FGSS Operation by DSME R&D Engineers
- Good performance and reliable operation of HiVAR®

First Engine Test Result (TOTE project)



Conclusions on the FAT test results done at Doosan:

- ME-GI concept available and confirmed
- Performance and emissions overall meet expectations
- Operation of the pilot fuel injection confirmed to 3.4% Guaranteed 5%
- Operation on low load on gas confirmed to 10% Guaranteed 15%
- Service: Q4 2015

- quote from MAN Diesel & Turbo -

- DSME **first** suggested HiVAR[®] system and has patents, which utilizes **HP pump** and **vaporizer** to supply high pressure gas to engine
- DSME has developed HiVAR[®] system **for 7 years** including idea & design development, system verification and realization for commercial application
- The **world 1st LNG-fuelled** containership and **all of LNG carriers with ME-GI engine** have adopted **DSME HiVAR[®] system**
- The ME-GI engine trial with FGSS for TOTE project was **successfully completed**
- DSME HiVAR[®] technology has contributed to **development of shipbuilding industry** by accelerating **LNG marine fuel** market growth

Thank You

