DAIHATSU

Multi-Gas-Fuel Engine

November 3, 2015

DAIHATSU DIESEL MFG. CO., LTD.

Contents

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1. Outline of DK-26
   1) Marine Propulsion and Genesets Diesel Engine
2. DF engine of DAIHATSU DIESEL
   1)Line-up
   2)DF Engine – Design Feature & Test result
3. Future technology for DF and GAS engine
4. Summary

1.Outline of DK-26

Engine specification

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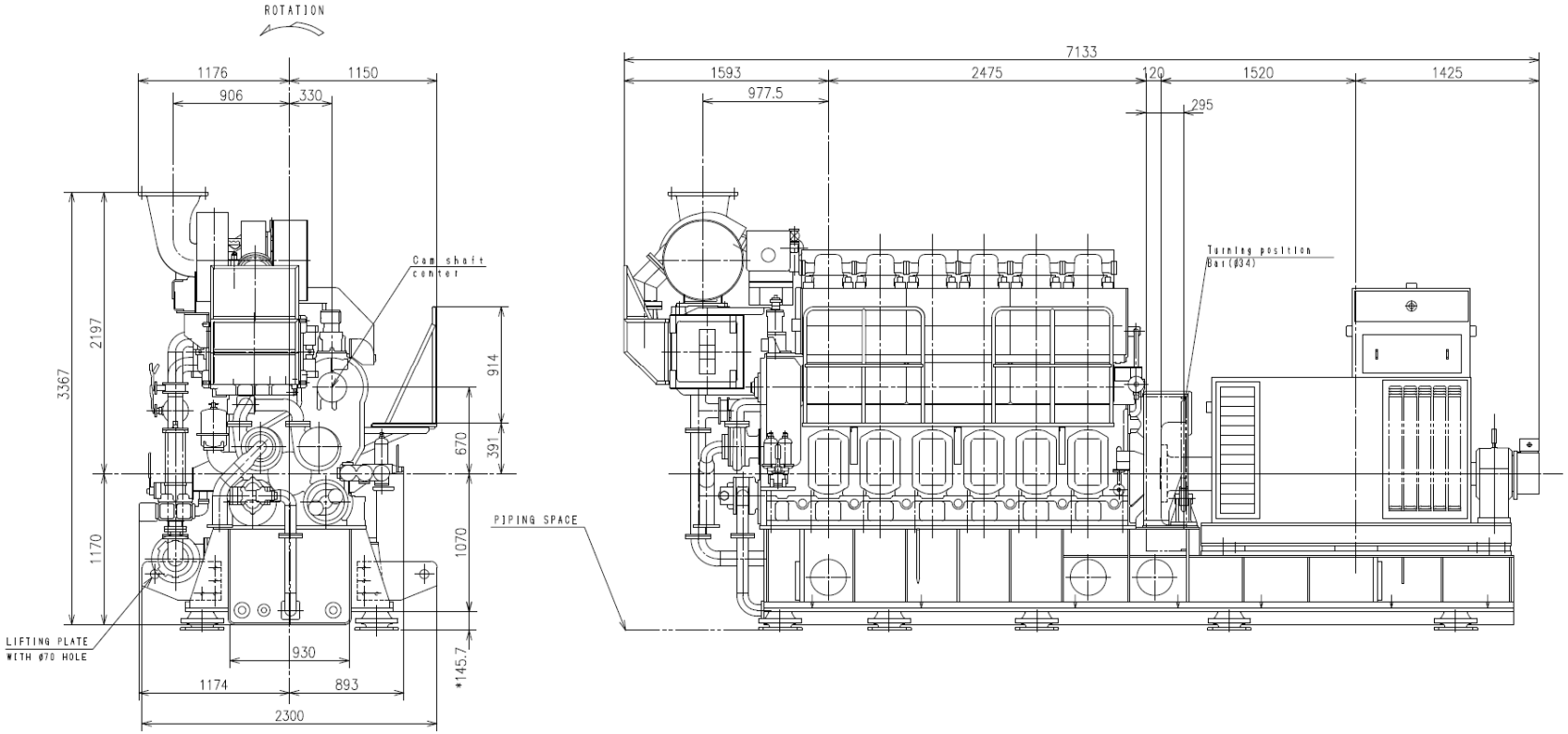

Engine Model	6DK-26
Quantity of Cylinder	6
Cylinder Bore x Piston Stroke	260mm x 380mm
Engine rated output	1570kW (2135PS)
Engine Speed	720 min-1
Mean effective pressure	2.16Mpa
Mean piston speed	9.12m/s
Maximum pressure	≦ 17Mpa

Generator	
Generator capacity	1837.5 kVA
Generator rated output	1470 kW
Power factor	0.8 lagging
No. of poles	10
Voltage Phase Frequency	AC 450V 3-phase 60Hz
Quantity of DG set	One (1) set / plant
Parallel running	None

1.Outline of DK-26

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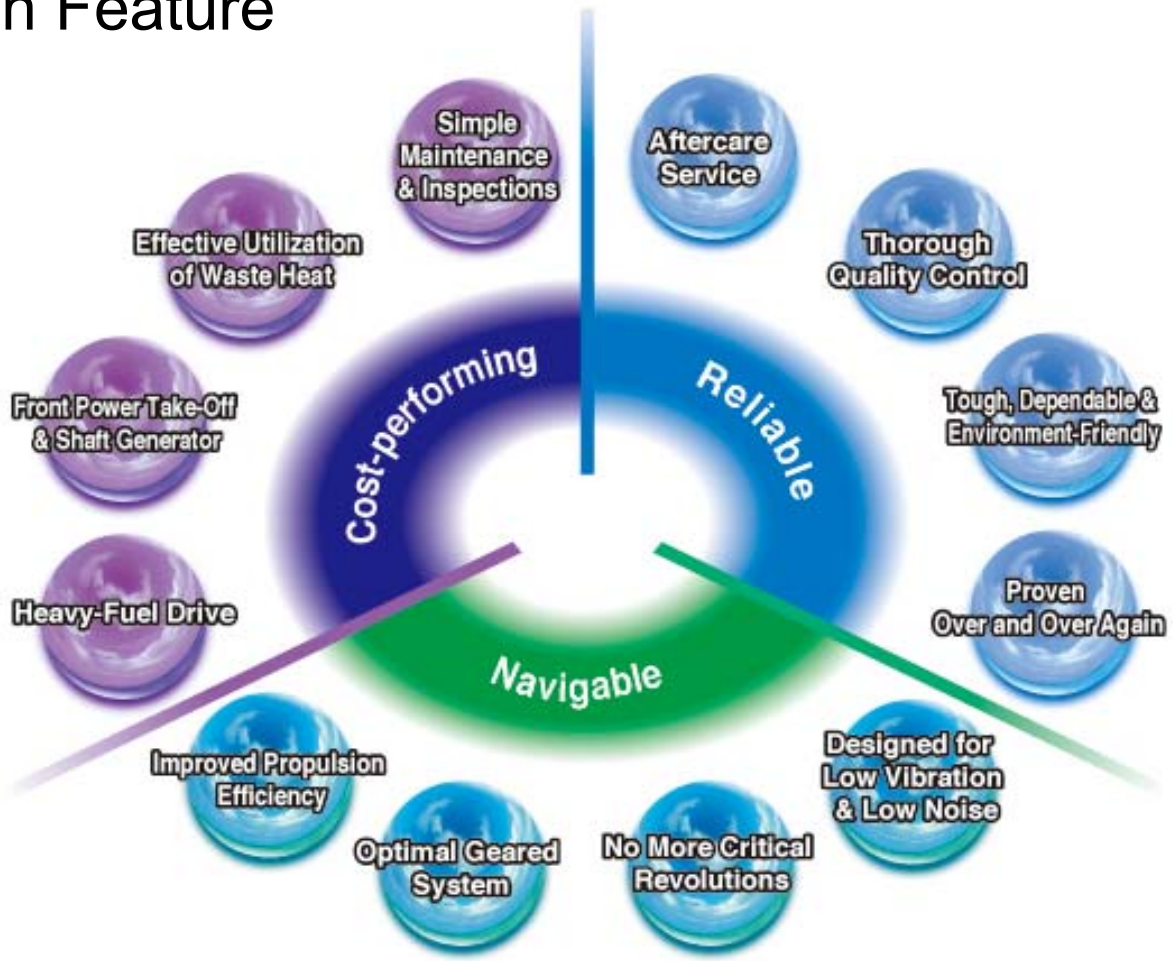
1. Main Feature



1. Outline of DK-26

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Ship type	Passenger Ferry	Tanker	Steel Transport Cargo Ship
Ship name	Ferry TAIYO / 410GT	SEIMEI / 749(G/T)	ARITA MARU / 499(G/T)
Ship Yard	IZUTSU SHIPYARD Co., Ltd.	KOIKE SHIPBUILDING & SHIPPING Co., Ltd	MATSUURA SHIPBUILDING Co., Ltd.
Engine	**6DKM-26(L)×2**	**6DKM-26(L)×1**	**6DKM-26(L)×1**

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DAIHATSU Group

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DAIHATSU Group Philosophy

The DAIHATSU Group
aims to establish itself as
"a global loved around the world" and as
"a corporate group with confidence and pride"
through meeting the challenge of innovative
automobile manufacturing
at the forefront of our era.

1907 HATSUDOKI Manufacturing Co., Ltd

Manufactured 6.0hp GAS Engine

1951 DAIHATSU Motor Co., Ltd

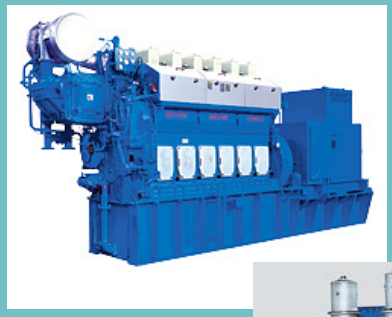
The production of diesel engine for diesel locomotive of Japan National Railways

Development of the world's smallest displacement diesel engine for of passenger car

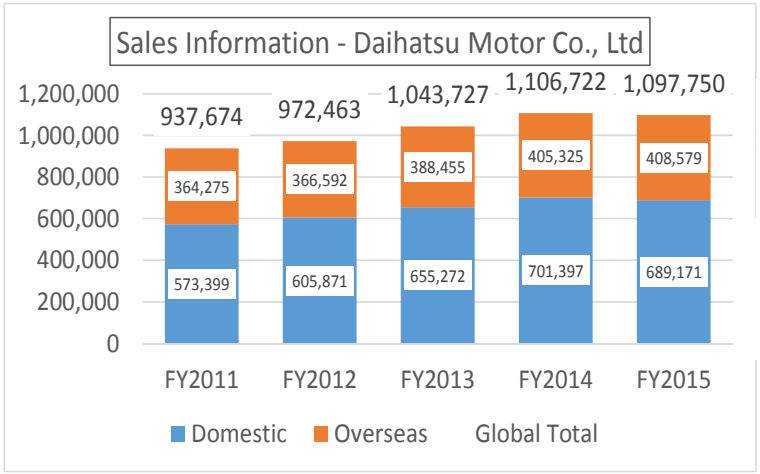
HATSUDOKI: Mover , Engine / 発動機 / 发动机

1966 **Daihatsu Diesel MFG Co., Ltd.**

Main Products : Diesel Engine for Marine Use
Gas Engine & Gas Turbine for Land Use



Main Products : Passenger Car (around 1.1 mil vehicles / year)



Ayla

Mira

History of DAIHATSU DIESEL GAS Engine

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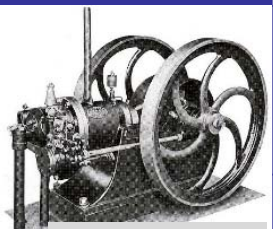
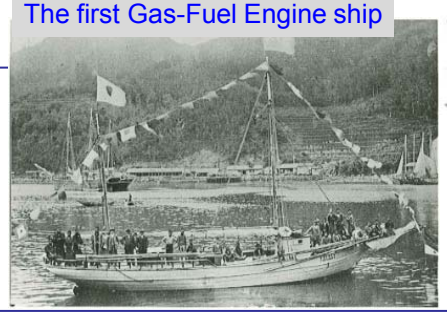
Year	Event	Remarks
1907	6.0hp Gas Engine was manufactured in MOVER(HATSUDOUKI) MFG. Co., Ltd	 6.0hp Gas Engine
1908	15.0hp Gas engine was installed to Passenger boat in Nagasaki, Japan *The first Gas-Fuel Engine ship in Japan.*	The first Gas-Fuel Engine ship 
1966	Established DAIHATSU DIESEL MFG Co., Ltd	
1983~	Launched Spark Ignition type GAS Engine with Three-way Catalyst	GK28G – Shin Umeda Bld. Osaka 
2005	Developed Lean burn Gas engine with Micro-Pilot ignition system Launched “MD20G”, “MD36G”, “GK28G”	
2013	Developed Dual Fuel Engine “DE28DF” with Micro Pilot ignition system	 DE28DF

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2-1. GAS fuel engine line-up

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Engine Model			6DE28DF	6GK28G	6MD20G	6MD36G
Engine Type			Dual Fuel	Gas	Gas	Gas
Ignition Type			Micro Pilot	Micro Pilot	Micro Pilot	Micro Pilot
Bore x Stroke		[mm]	Φ280 x 390	Φ280 x 390	Φ200 x 300	Φ360 x 480
Cylinder No.		[-]	6	6	6	6
Firing Order		[-]	1-2-4-6-5-3	1-2-4-6-5-3	1-2-4-6-5-3	1-2-4-6-5-3
Engine Speed		[min-1]	720	720	900	600
Rated Output		[kWe]	1,730	1,500	815	2,760
BMEP		[MPa]	2.0	1.8	2.0	2.0
NOx Emission	Gas mode	[-]	≦TierⅢ	(Land use only)		
	Diesel mode	[-]	≦TierⅡ	—		
Main Fuel	Gas mode	[-]	Natural gas	Natural gas		
	Diesel mode	[-]	MDO or HFO	—		
Pilot Fuel (Gas mode)		[-]	MDO or MGO (1% of total heat value)	Gas Oil		
Market Release			2015	2007	2005	2006

2-2. DF Engine – Certification

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Type Approval

NIPPON KAIJI KYOKAI

TYPE APPROVAL CERTIFICATE

Certificate No. TA14611M

This is to certify that Type Approval of the undermentioned dual fuel engine designed by DAIHATSU DIESEL MFG. CO., LTD., has been granted in accordance with the current "Rules for the Survey and Construction of Steel Ships" of this Society on the basis of the drawing approval and the result of type approval test for 6DE(M)28DF(L) carried out at DAIHATSU DIESEL MFG. CO., LTD. Moriyama First Factory, Japan on 20th-24th October 2014.

This certificate is issued to

Approval No.:	**14DD024B**	
Product Description:	**Vertical, In-line, 4-stroke, Trunk Piston Type Dual Fuel Engine with Turbocharger & Intercooler, Electronically Controlled**	
Model Designation:	**6DE(M)28DF(L)**	
Intended Purpose	**Main Engine / Generating Engine**	
Kind of fuel	**Natural gas and Fuel oil**	
Number of Cylinder:	**6**	
Cylinder Bore x Stroke:	**280 mm x 390 mm**	
Max. Continuous Output:	**1730 kW at 720 rpm**	**1730 kW at 750 rpm**
Max Firing Pressure:	**17.7 MPa**	
Mean Indicated Pressure:	**2.15 MPa**	**2.06 MPa**
Mean Effective Pressure:	**2.00 MPa**	**1.92 MPa**

Issued at Tokyo on 13 November 2014.

Y. Shibata
General Manager
Machinery Department

Statement of Compliance

STATEMENT OF COMPLIANCE FOR
ENGINE AIR POLLUTION PREVENTION

Statement No. KB15MM00193

Issued under the provisions of the Protocol of 1997, as amended by resolution MEPC.176(58) in 2008, to amend the
INTERNATIONAL CONVENTION FOR THE PREVENTION OF POLLUTION FROM SHIPS, 1973,
as modified by the Protocol of 1978 related thereto (hereinafter referred to as 'the Convention')

by **NIPPON KAIJI KYOKAI**

Engine manufacturer	Model number	Serial number	Test cycle(s)	Rated power (kW) and speed (rpm)	Engine approval number
Daihatsu Diesel Mfg. Co., Ltd.	6DE28DF	DETN628F 1601	D2,E2	1,730 kW 720 rpm	15MM00193

THIS IS TO CERTIFY:

1. That the above-mentioned marine diesel engine has been surveyed for pre-certification in accordance with the requirements of the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines 2008 made mandatory by Annex VI of the Convention; and
2. That the pre-certification survey shows that the engine, its components, adjustable features, and technical file, prior to the engine's installation and/or service on board a ship, fully comply with the applicable regulation 13 of Annex VI of the Convention.

This statement is valid for the life of the engine subject to surveys in accordance with regulation 5 of Annex VI of the Convention, installed in ships.

Issued at Tokyo on 4 September 2015 .

(Y. SHIBATA)
General Manager of Machinery Department
NIPPON KAIJI KYOKAI

2-2. DF Engine – Design Concept

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6DK-28 (Diesel engine)

Reliability & Durability

6GK28G(Gas engine)

Gas combustion technology

6DE28DF(DF engine)

Reliability & Durability

Gas combustion technology

2-2. DF Engine – Design Concept

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- Ensure the reliability required as a marine engine.
- Safety design that meets the requirements of the "gas safety machinery spaces" of the IGF Code
- NOx emission rate, complies with
  IMO NOx Tier III Regulations in GAS mode,
  IMO NOx Tier II Regulations in Diesel mode.
- Realize the mode switching during operation:
  Diesel mode ⇔ Gas mode (Both direction)
- Ensure transient response performance during load fluctuation

2-2. DF Engine – Design Concept

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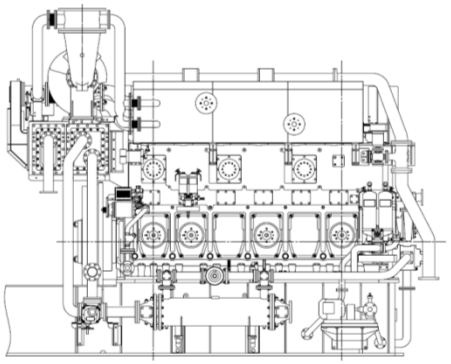
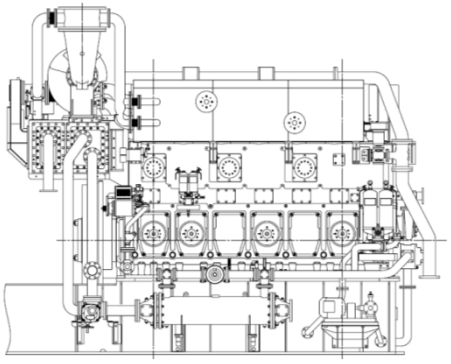


Gas mode

99% **Natural gas**

1% **MDO or MGO**
(For ignition source)



Diesel mode

99% **MDO or MGO or HFO**

1% **MDO or MGO**
(For injectors cooling)

2-2. DF Engine – Design Concept

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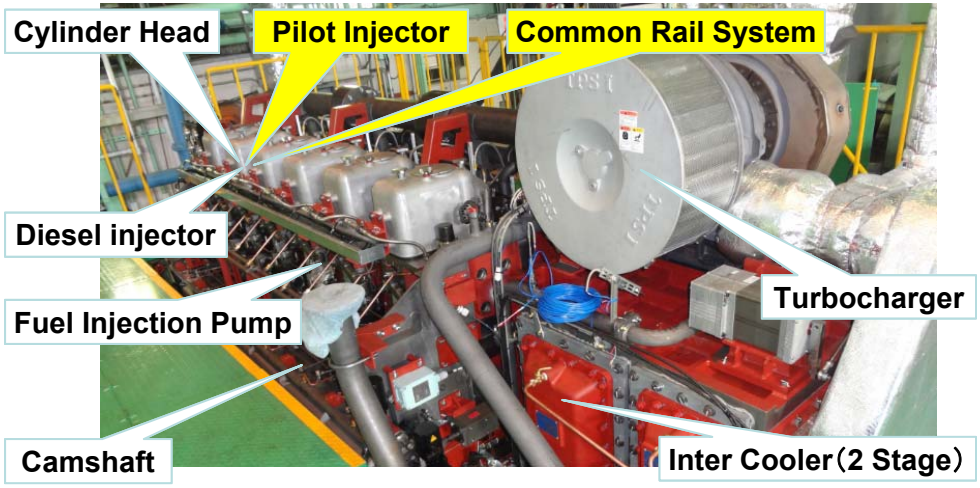
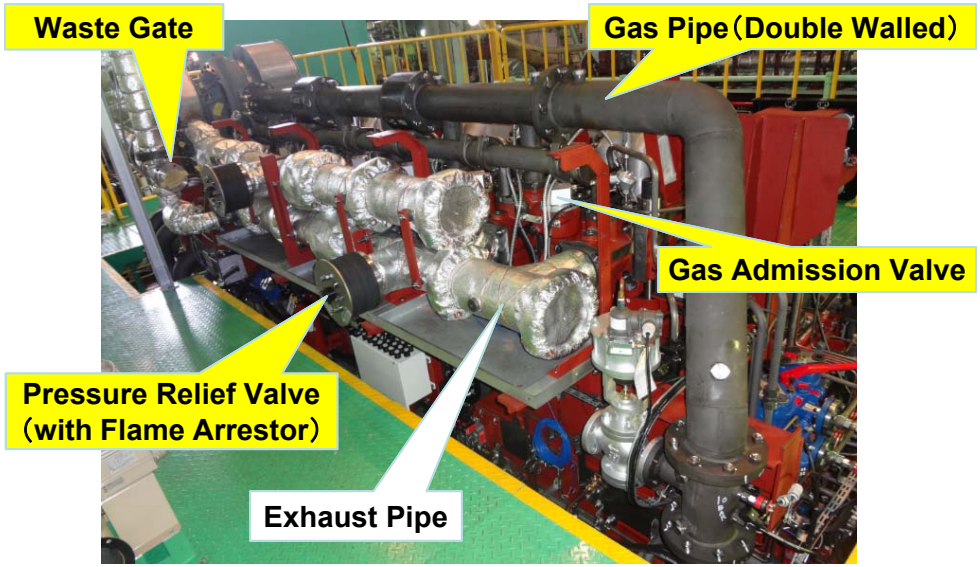
Parts commonality





DF exclusive Parts & Component
(major additional component)

Parts & Component	Remarks
Gas admission Valve	Gas supply
Gas Pipe（Double wall）	Safety regulation
Pilot Injector	Fuel injection for Ignition & fuel supply system
Common Rail system	
Pressure relief valve	Safety regulation
West Gate	A/F Control
Engine Control Panel	Control unit

Not-common parts of Diesel engine

Parts & Component	Remarks
Cylinder Head	MP Injector, etc.
Diesel Injector	Diesel Mode
Fuel Injection pump	
Camshaft	VVT
Exhaust pipe	Transient performance
Piston & Liner	GAS mode
Intercooler	Single stage →Two stage

2-2. DF Engine – Test Result

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Short Video of DF Engine

1. DE28DF Engine Structure

Gas Valve Unit
Double walled gas pipe and Cylinder pressure sensor
Micro Pilot Injector and Common Rail, Gas admission valve
V V T (variable valve timing device)

2. Operation Mode Switch : Diesel mode ⇒ Gas mode

3. Operation Mode Switch : Gas mode ⇒ Diesel mode

2-2. DF Engine – Test Result

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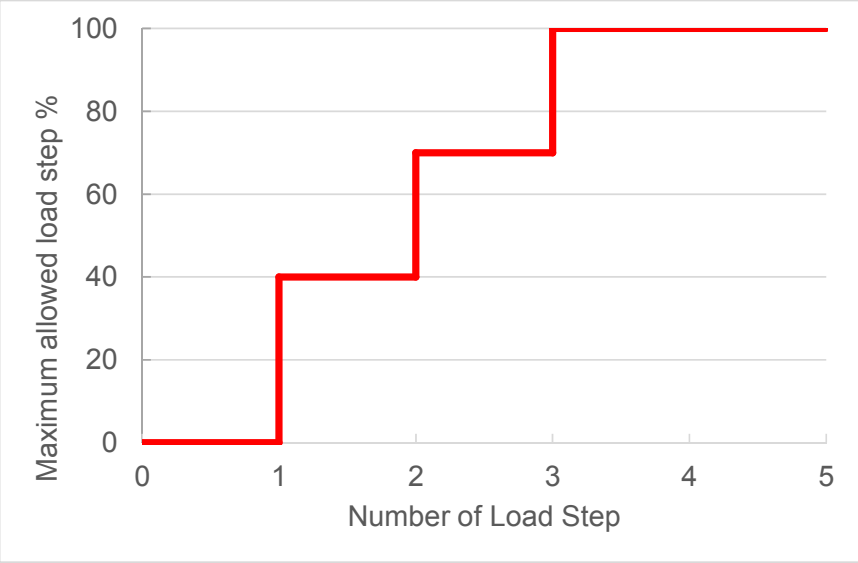
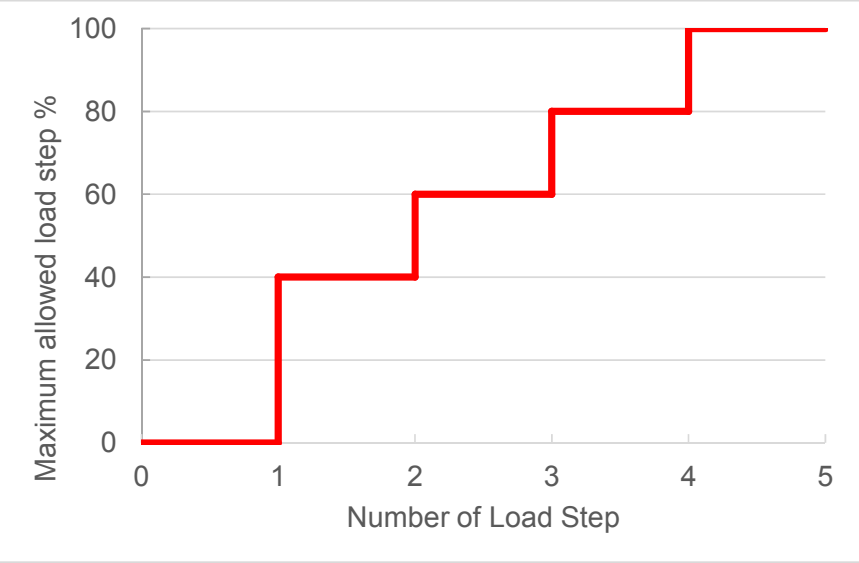
Load Step

Load Application (Diesel Mode)



Load Application (GAS Mode)



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3. Future Technology

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LNG Tank System

1st Step

Member	NIPPON KAIJI KYOKAI (ClassNK) The Cooperative Association of Japan Shipbuilders Kobe Shipping Co., Ltd Higaki Shipbuilding Co., Ltd. Sanwa Dock Co/. Ltd Izumi Steel Works, Ltd. Daihatsu Diesel Mfg. Co., Ltd.
Joint Research Theme	**The trial design relates to a small LNG carrier and bunker ship with a natural gas fueled engine**

Main Specification of trial design ship	
Design Pressure	3,500m3 LNG carriers and bunker ship
Assumed coastal road	Keihin - Kushiro (605 miles) (LNG transport)
Navigation area	Coastal areas (non-international)
Speed	13.0 knots
Propulsion system	Electric propulsion system
Fuel	Natural gas
Cargo tank system	IMO Type C Independent Tank

3. Future Technology

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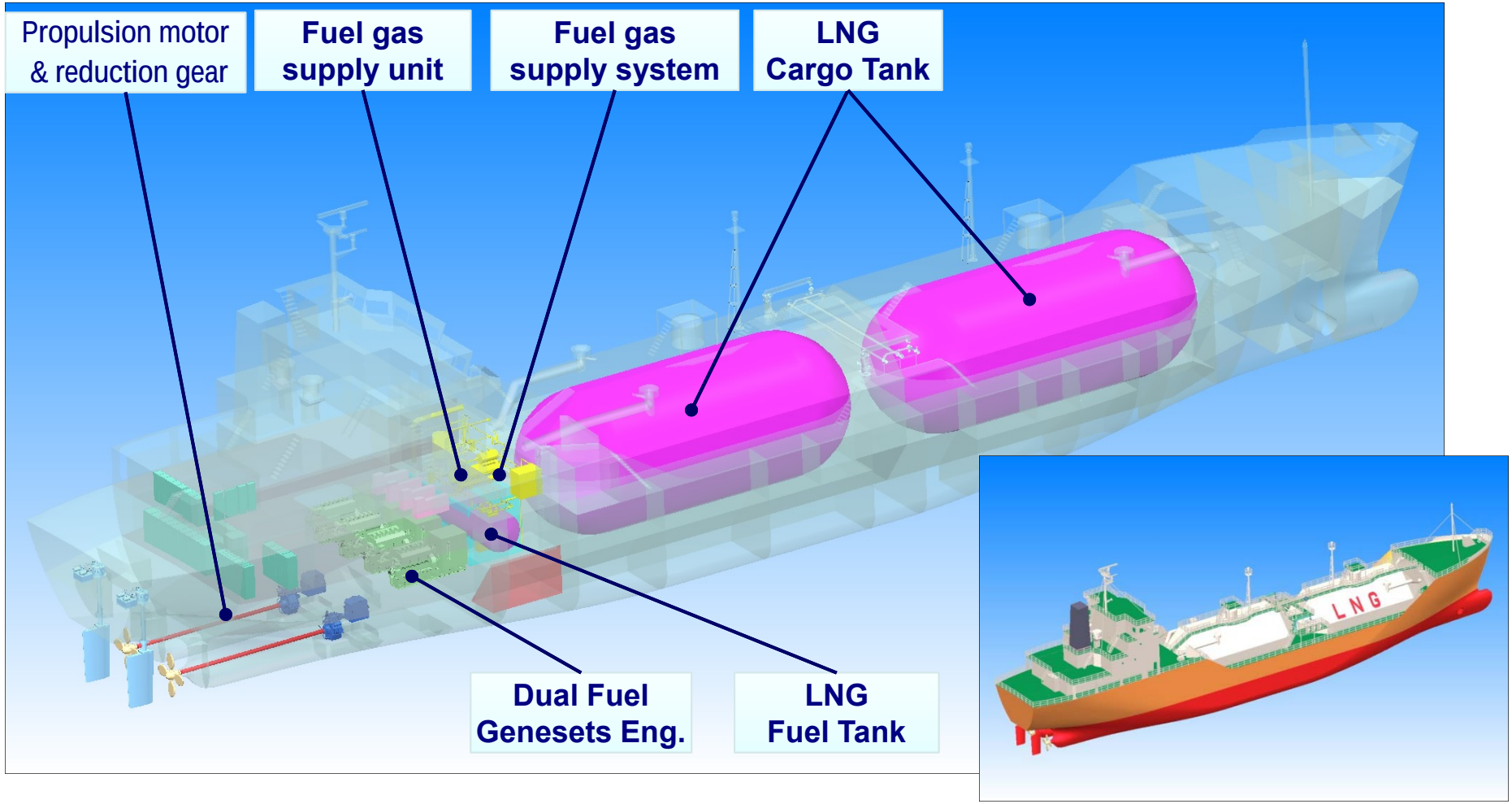
LNG Tank System

1st Step



Nippon Kaiji Kyokai environment seminar
- Natural gas fuel ship Special 2014. 9.25-26

This project was carried out with the support of ClassNK as part of the ClassNK Joint R&D for Industry Program.

ClassNK R&D PROJECT

3. Future Technology

LNG Tank System

2nd Step

Type	Cylindrical with Both Ellipsoidal Heads, IMO Type C Independent Tank
Capacity	27m3 (Operation Usage : 22m3)
Dimension	Outer Dia.=3.2m Length=6.1m
Design Pressure	1.0 Mpa
Heatproof Temp.	-196℃～+40℃
Material	SUS304
Thermal Insulation	Perlite vacuum insulation

Joint Research with NK and Izumi Steel Works, Ltd.
(Supported by Ministry of Land, Infrastructure, Transport and Tourism as "Next generation marine environment-related technology development support project")

3. Future Technology

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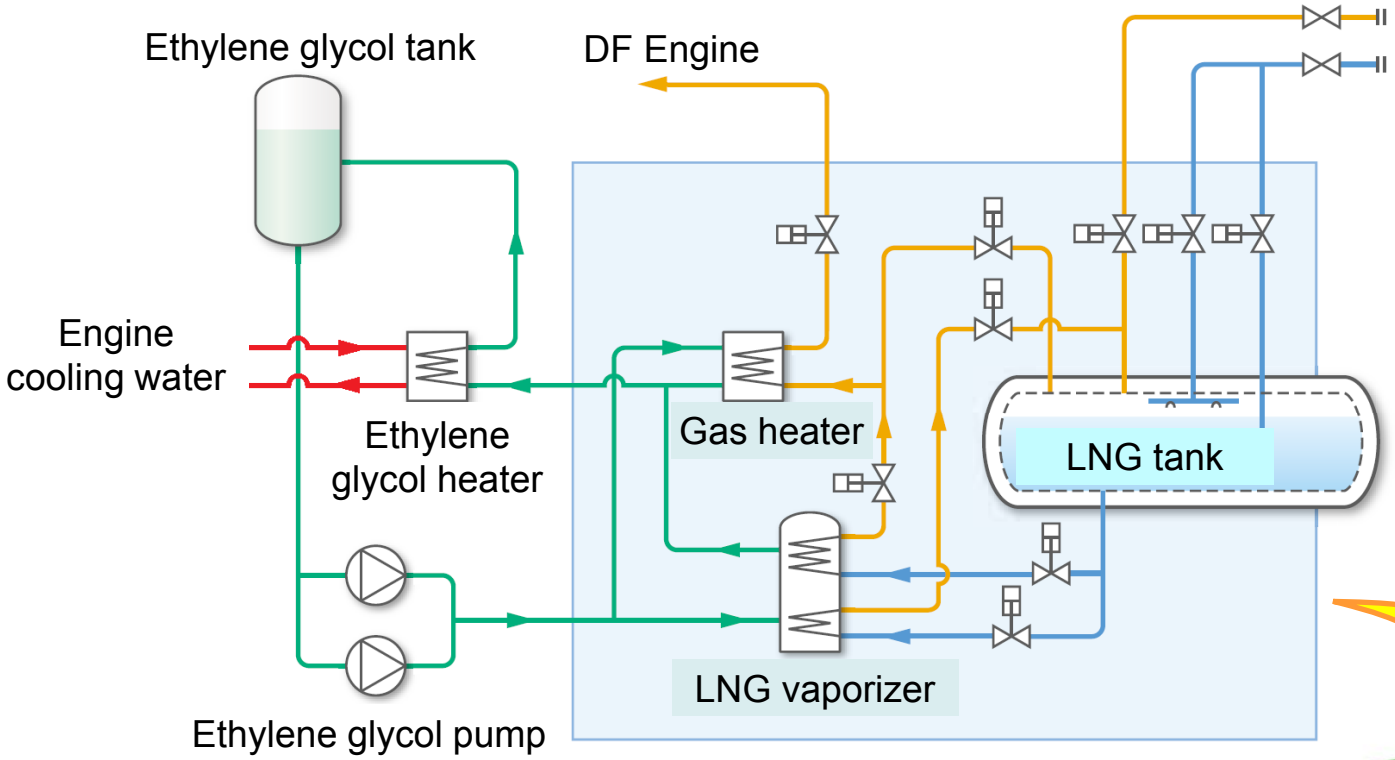
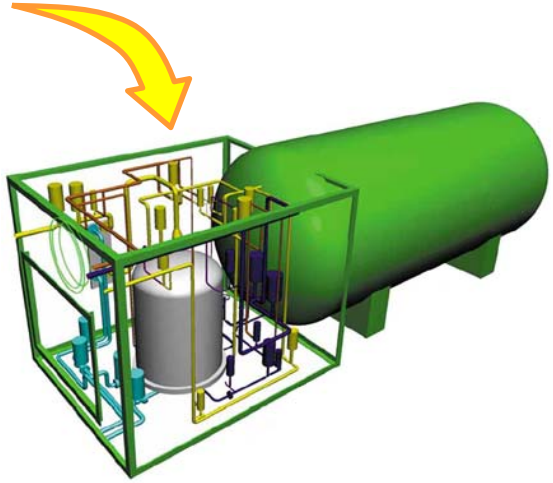
LNG Tank System

2nd Step



TANK connection Space



The fuel tank pressurized with the gasified LNG, and pumping the LNG to the vaporizer (No need LNG transfer pump)

3. Future Technology

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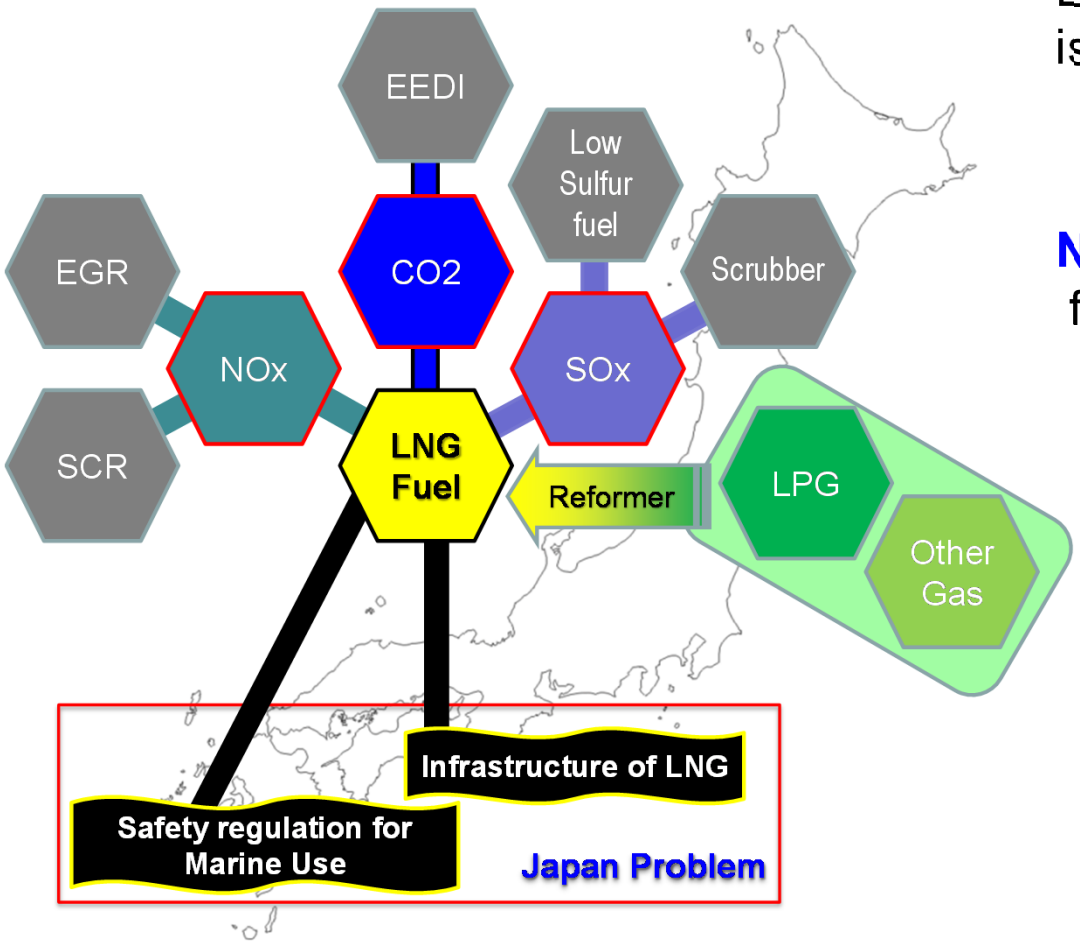
Multi-Gas



LNG Gas fuel for environmental issues, is one of good solution

Not technical problem
for spreading LNG fuel vessel in Japan

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4. Summery

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- Daihatsu Diesel Mfg.(DDK) developed 6 cylinder 280mm bore DF engine. 6DE28DF main structure is based on DK-28 engine which has reliability and durability confirmed by more than 1000 delivered engines.
- In addition, 6DE28DF engine has to ensure high operability both Diesel and Gas mode, such as Operation Mode Switch and Load Step.
- DDK became the first in Japan to acquire Type approval of DF engine from ClassNK.
- DDK continue to evaluate the original LNG tank system towards the high-efficiency LNG supply system.
- DDK is considering to study relationship between the Engine combustion and the gas composition for the compact gas reformer.

Thank you very much for your attention