MOVE THE WORLD FORWARD

MITSUBISHI HEAVY INDUSTRIES GROUP

MHI-MME WHRS - STG

Environment friendly and economical solution

MITSUBISHI HEAVY INDUSTRIES MARINE MACHINERY & ENGINE CO., LTD.

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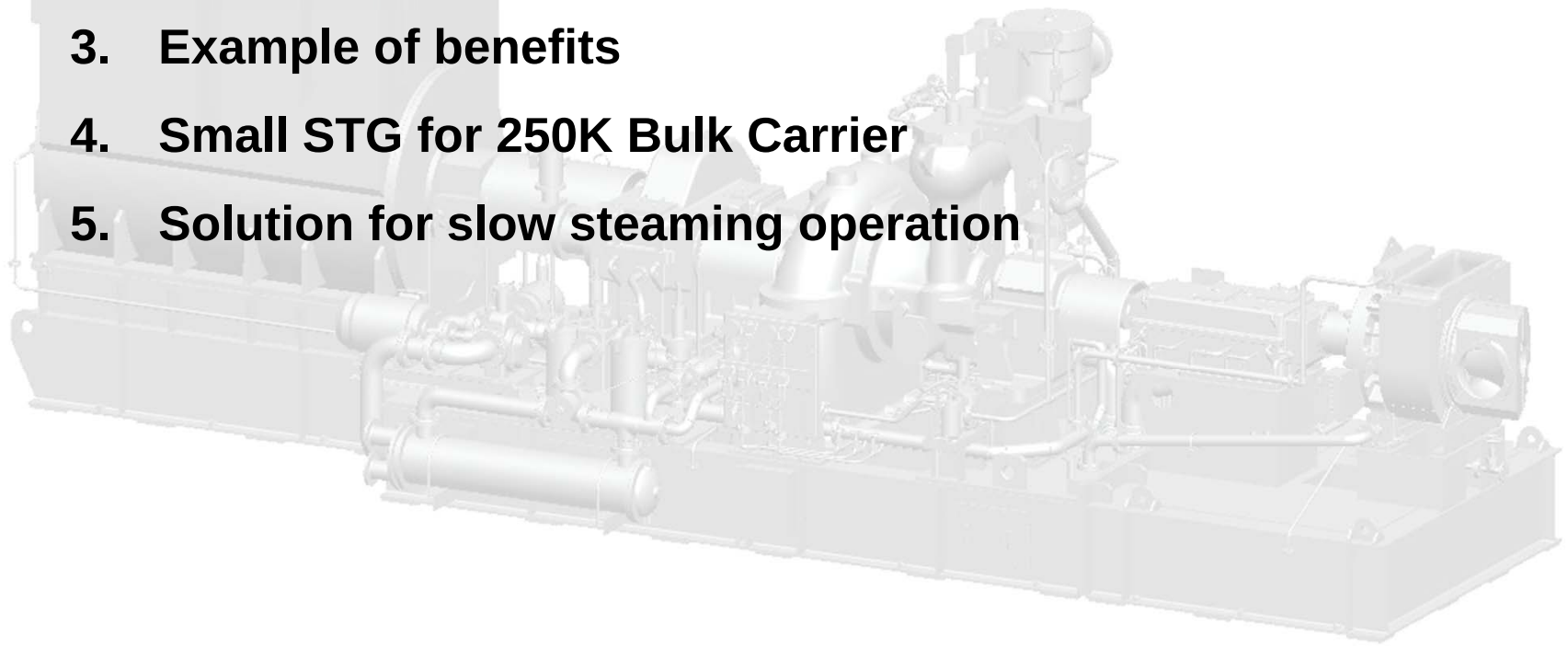
MARINE MACHINERY & ENGINE CO., LTD.



Overview

MITSUBISHI HEAVY INDUSTRIES MARINE MACHINERY & ENGINE CO., LTD.

MHI-MME's WHRS-STG offers solutions of ;

Environment Friendly

- Reduction of emission gas
- Saving fuel consumption

Economical

- Saving total fuel consumption
- Lower maintenance & running cost

Efficient

- Reduction of power or stop of D/G
- Optimized thermal efficiency of total plant incl. M/E, D/G and A/B.

… by Efficient waste heat recovery,
Large output,
Optimum load sharing control

Easy

- Easy maintenance, basically maintenance free, no continuous worn part, consumable parts, oil consumption.
- Easy operation, full automatic remote control / monitoring
- Easy installation, supplied as a complete package

- High reliability and safety by proven design, technology, and rich experience
- Effective solution for environment and economical
- Effective feedback for higher reliability and easier operation

- Regulations for emission
- Oil price

* WHRS : Waste Heat Recovery System

1. Outline, WHRS-STG system

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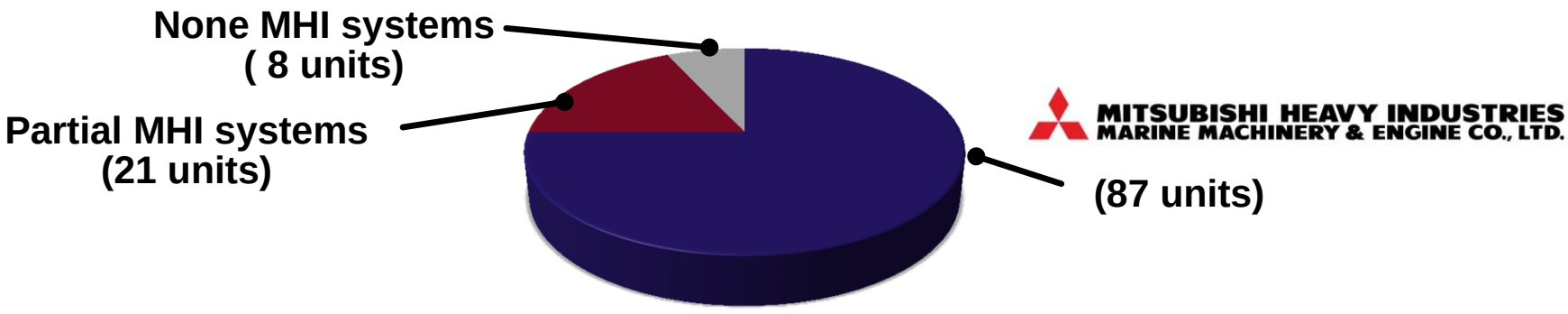
Production record (WHRS-STG)

As of Dec.28, 2016

Kind of Ship	Capacity	Main Engine Type	Contract	Delivered	Gen. Output
Container	8,500 TEU	Wartsila 12RT-flex96C	12	12	6,000 kW
Container	4,500 TEU	MAN B&W 6S80ME-C9	22	22	3,100 kW
Container	7,450 TEU	MAN B&W 9S90ME-C Mk8	16	16	3,700 kW
Container	13,000TEU	MAN B&W 12K98ME-7	9	9	7,000 kW
Container	18,000 TEU	MAN B&W 8S80ME-C9.2(x 2skegs)	20	20	6,000 kW
Ore Carrier	250,000 DWT	MAN B&W 7S80MC-C Mk7	1	1	1,700 kW
Container	15,000 TEU	MAN B&W 9S90ME-C10.2	11	11	2,700 kW
Container	18,800 TEU	MAN B&W 10S90ME-C10.2	6	6	3,000 kW
Container	19,630 TEU	MAN B&W 7G80ME-C9.5(x 2skegs)	11	0	4,600 kW
Total			108	97	



1. Outline, WHRS-STG system

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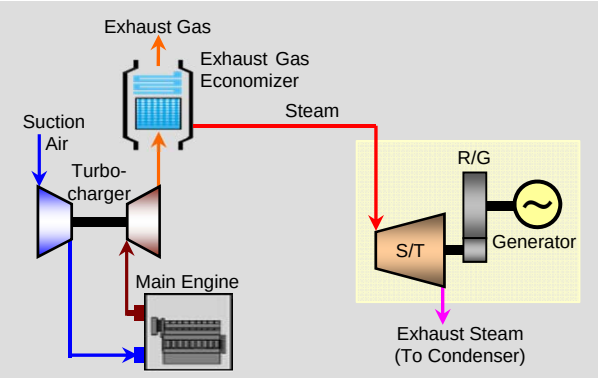
MHI-MME / WHRS

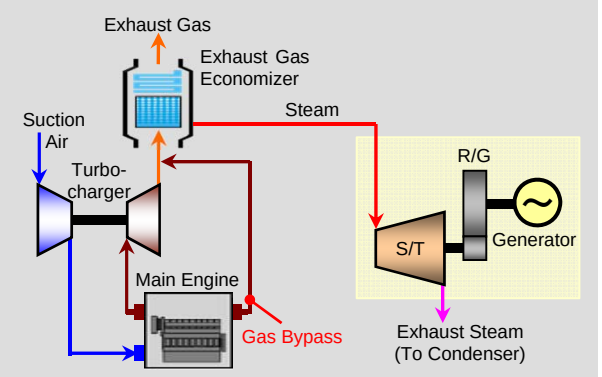
Eco - TG System (Without gas bypass)

This is a conventional system which all exhaust gas after TC is led to the Economizer.
The steam turbine power is not so great amount.



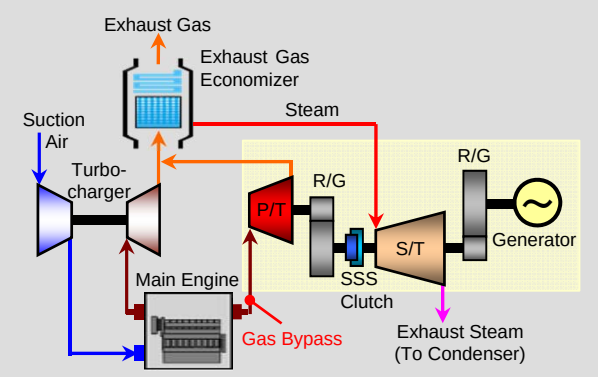
Eco - TG System (With gas bypass)

With extracting an exhaust gas partially from main engine to economizer, this system realized more amount of power generation by increasing economizer steam amount and temperature.
The power generation amount is **1.5 to 1.8 times** more than above system.



STG System (Super Turbo Generating)

The exhaust gas partially extracts from main engine exhaust gas manifold then it drives an Exhaust Gas Power Turbine, which is connected to steam turbine with SSS Clutch. **2.4 to 2.8 times** more power generation than conventional one.



1. Outline, WHRS-STG system

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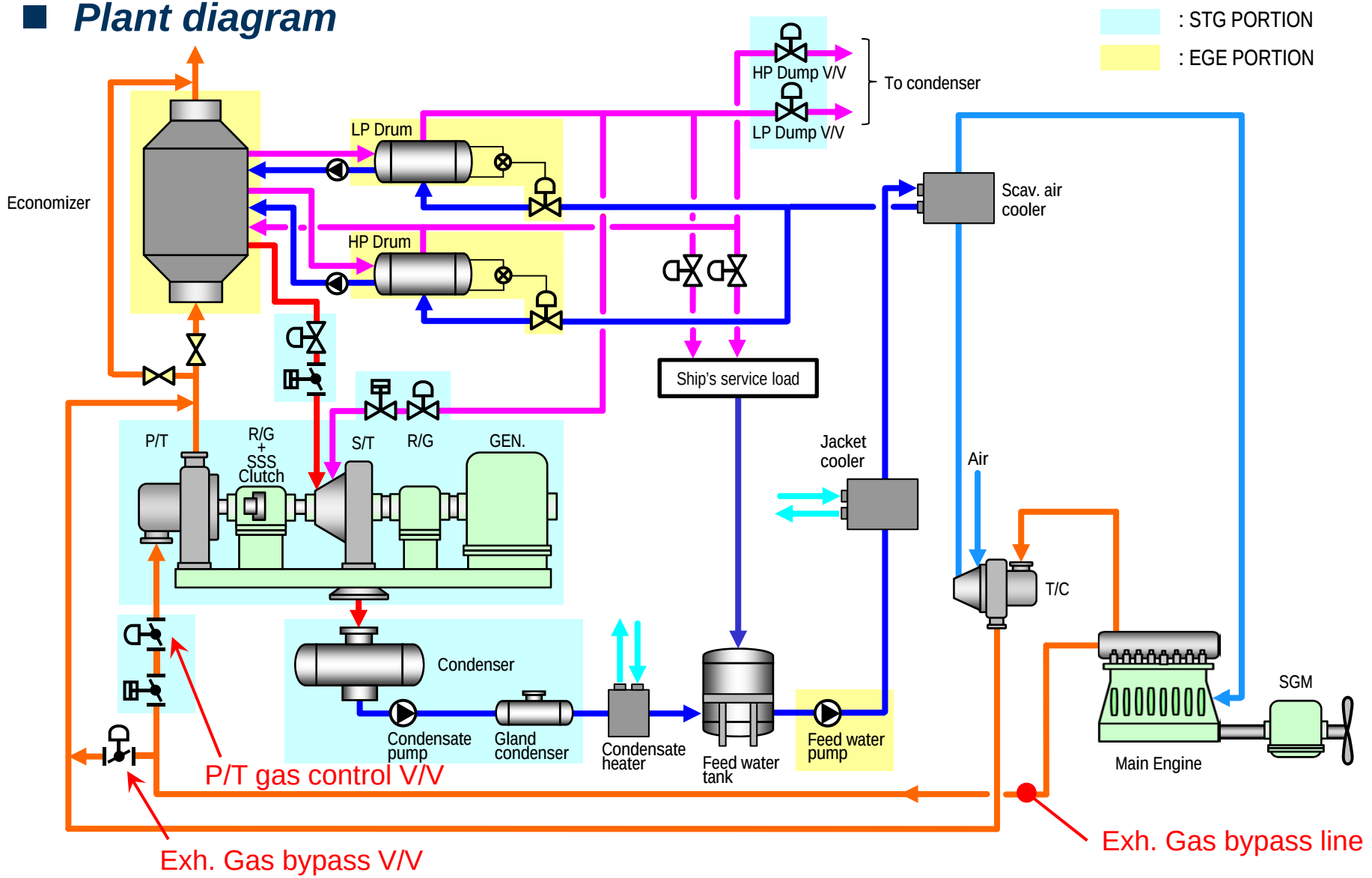
Plant diagram



1. Outline, WHRS-STG system

MITSUBISHI HEAVY INDUSTRIES
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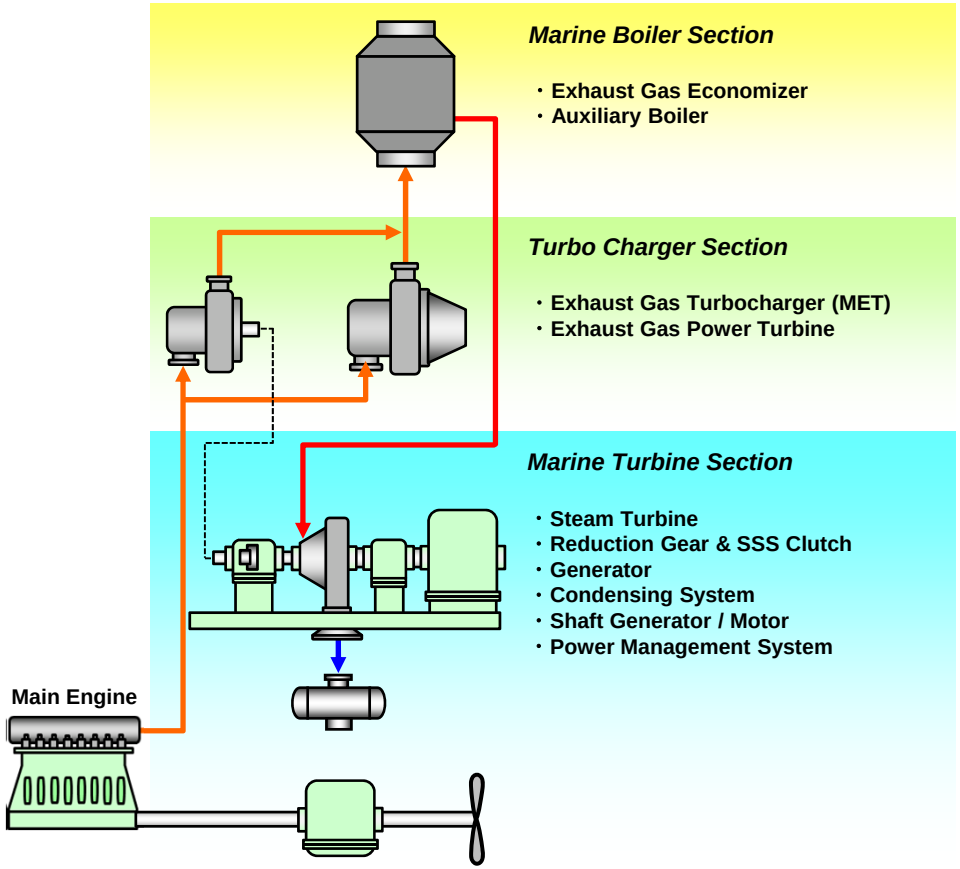
■ *Single Responsibility for whole system*

- ☑ Coordination of whole system by MHI
- ☑ Competitive performance
- ☑ One window & support to ship owner after delivery



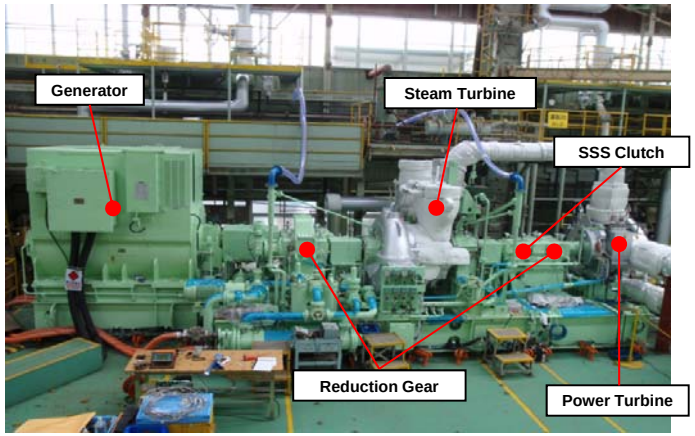

Exhaust Gas Economizer


Exhaust Gas Power Turbine


Turbocharger (MET)


Steam Turbine


Shaft Generator / Motor



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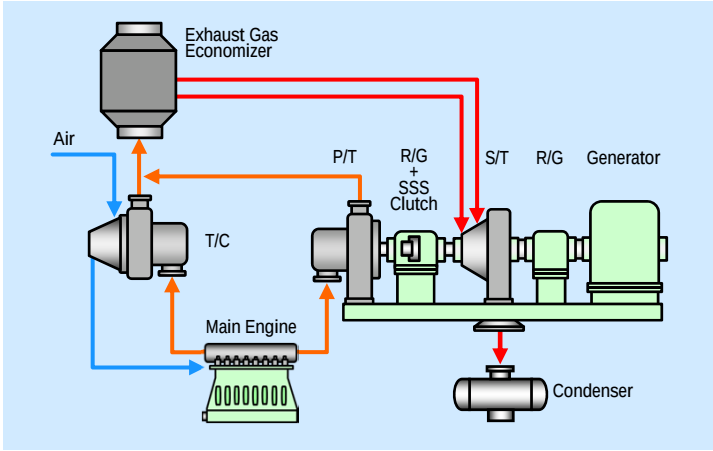
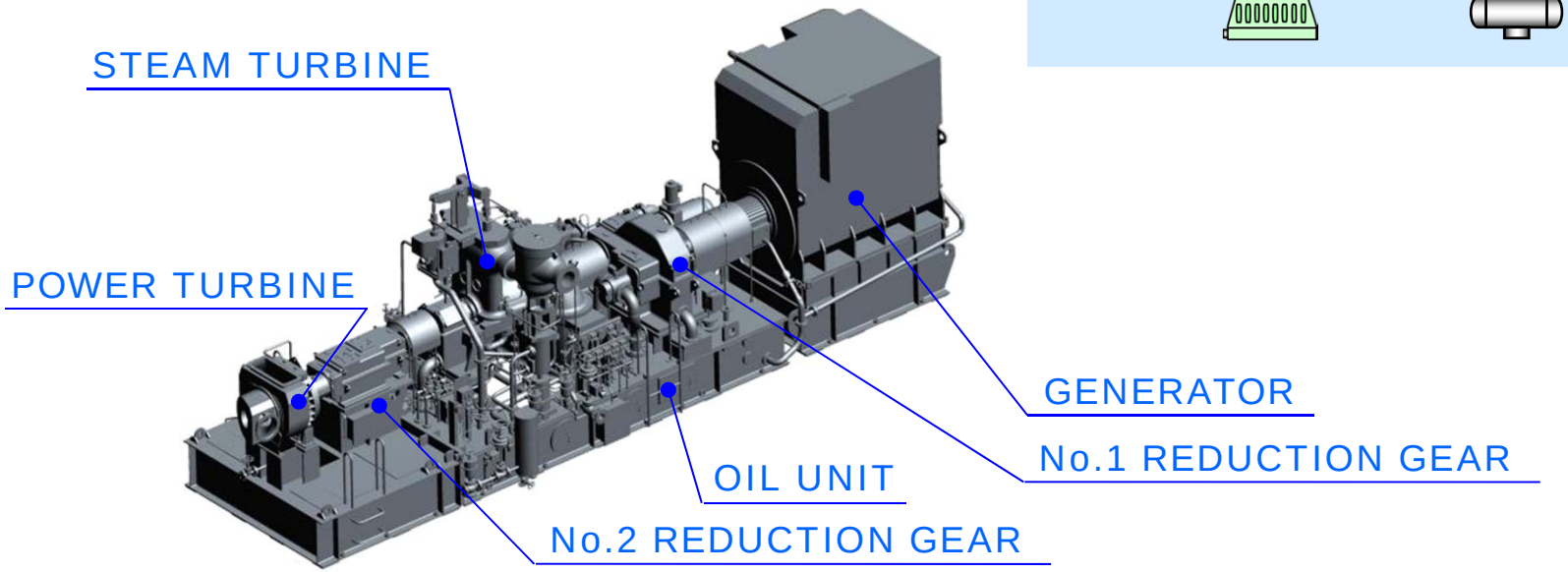
Configuration of STG unit

The Steam turbine, Power turbine and Auxiliary equipment with lubricant system are installed on the common skid and the Power turbine torque is transmitted to the Steam turbine through the SSS clutch





☑ **WHRS can be installed all kind of ships**

2. Feature, WHRS-STG system

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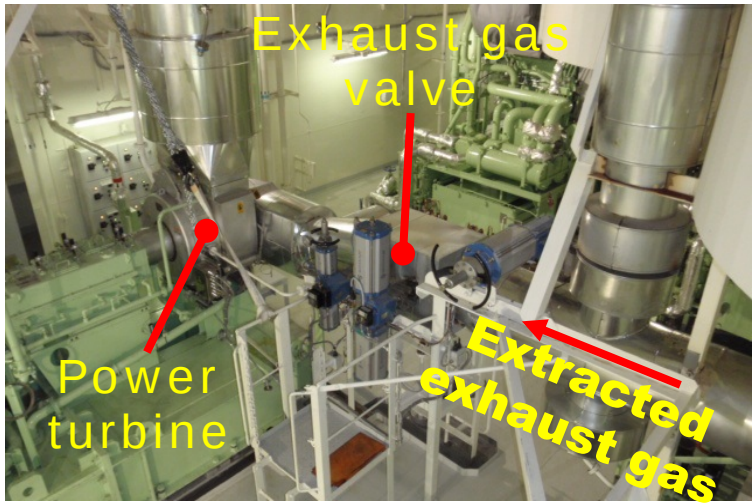
Onboard installation

- ☑ Full package & Easy installation
- ☑ High thermal efficiency
- ☑ High reliability

STG52/42 overview (Onboard installation)



Exhaust gas valve arrangement

Exhaust gas extraction

2. Feature, WHRS-STG system

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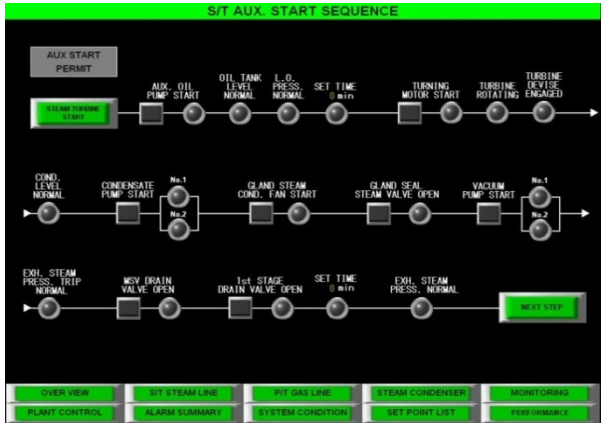
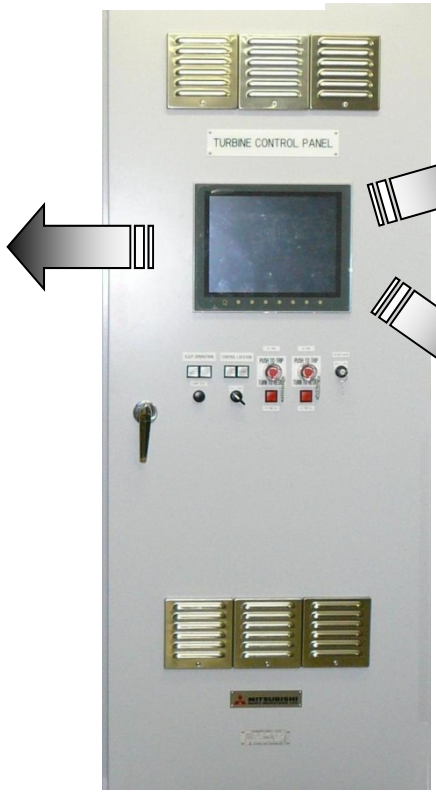
■ *Turbine control panel*

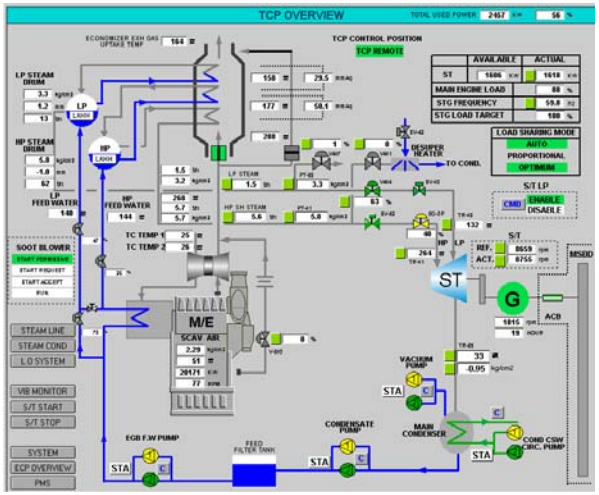
- ☑ Full automatic
- ☑ Plant monitoring system
- ☑ Performance diagnosis



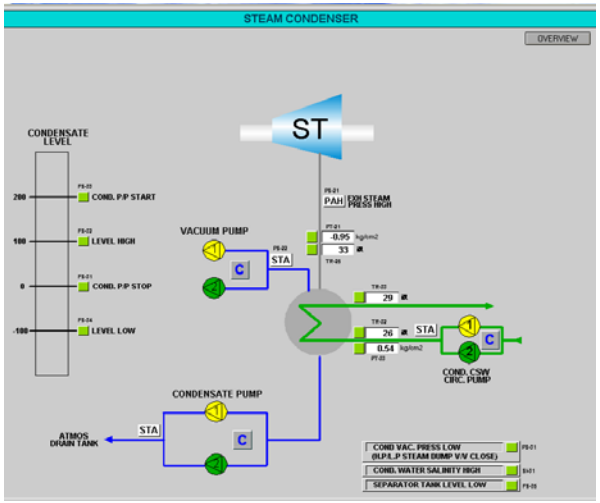
Monitoring screen of S/T start sequence



Turbine control panel overview



Monitoring screen of Whole plant



Monitoring screen of power turbine

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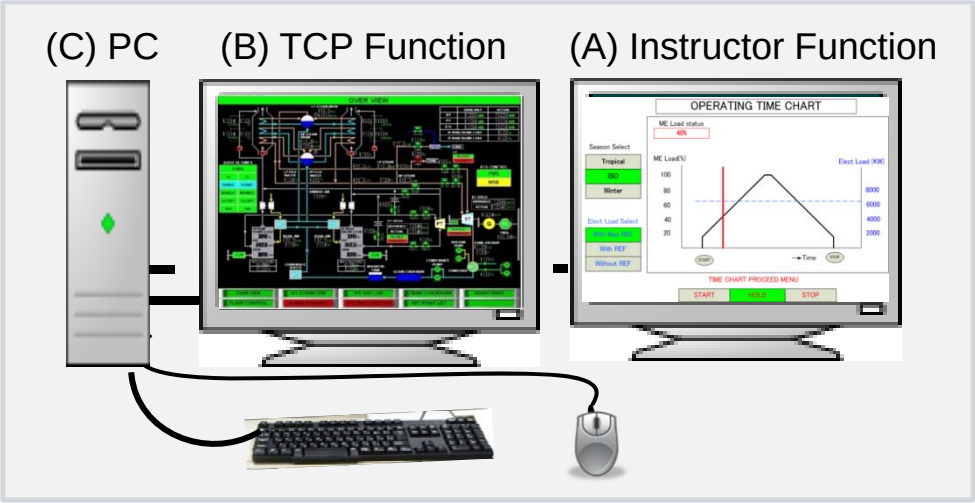
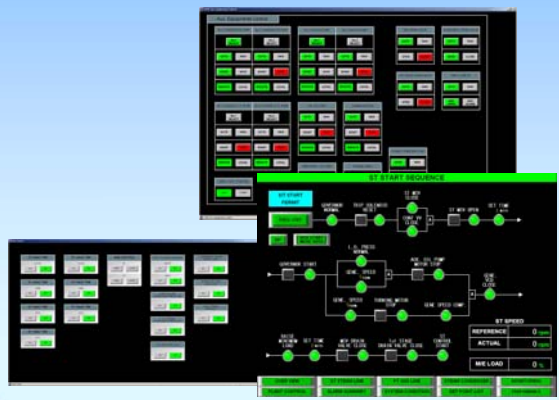
Simulation technology – Crew Training Simulator

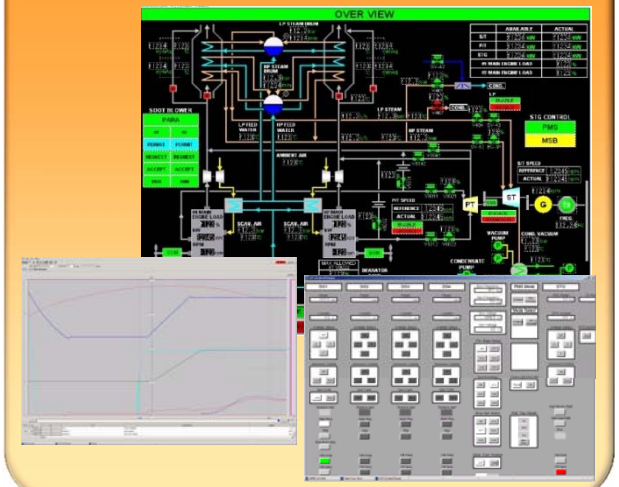
- Plant simulation technology is applied
  - Model of system of related equipment & panels
  - Dynamic system behavior
- To be familiar with WHRS/TCP concept and to learn operation of WHRS/TCP in office with easy handling
- Condition setting to start can be selected in Operating time chart
- Monitor dynamic plant reaction (Trend monitor)



Operation display,
Auto seq. operation, etc…



Plant status, Trend data, etc…



3. Example of benefits

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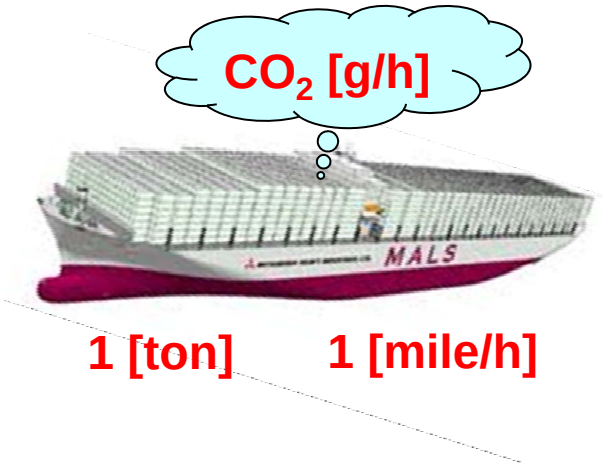
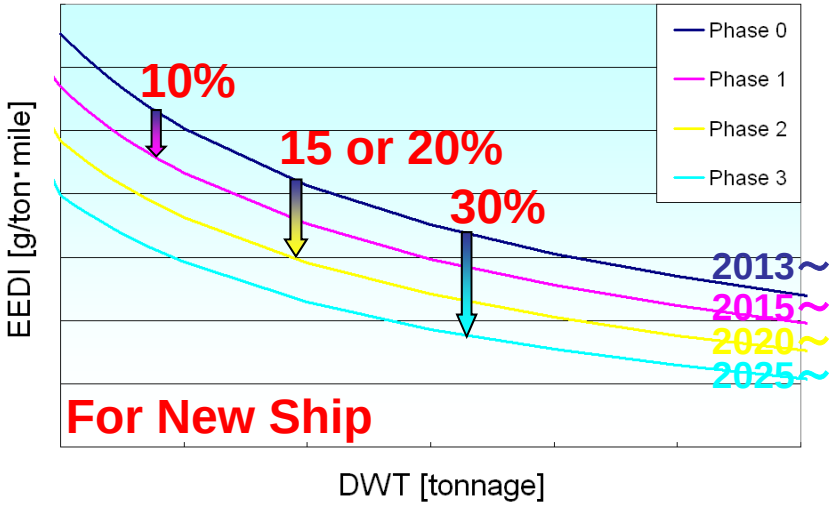
■ *EEDI / IMO (MEPC) regulation*

EEDI : Energy Efficiency Design Index

$$\mathrm{EEDI} = \frac{\mathrm{CO_2\ emission\,[g/h]}}{\mathrm{Capacity\,[ton]} \times \mathrm{Speed\,[mile/h]}}$$



Regulation



How does the EEDI reduce?

- Slow steaming operation
- Improvement of ship shape and propeller
- Air lubrication system

- Derating engine
- WHRS
- Gas fuel engine
- Renewable energy

3. Example of benefits

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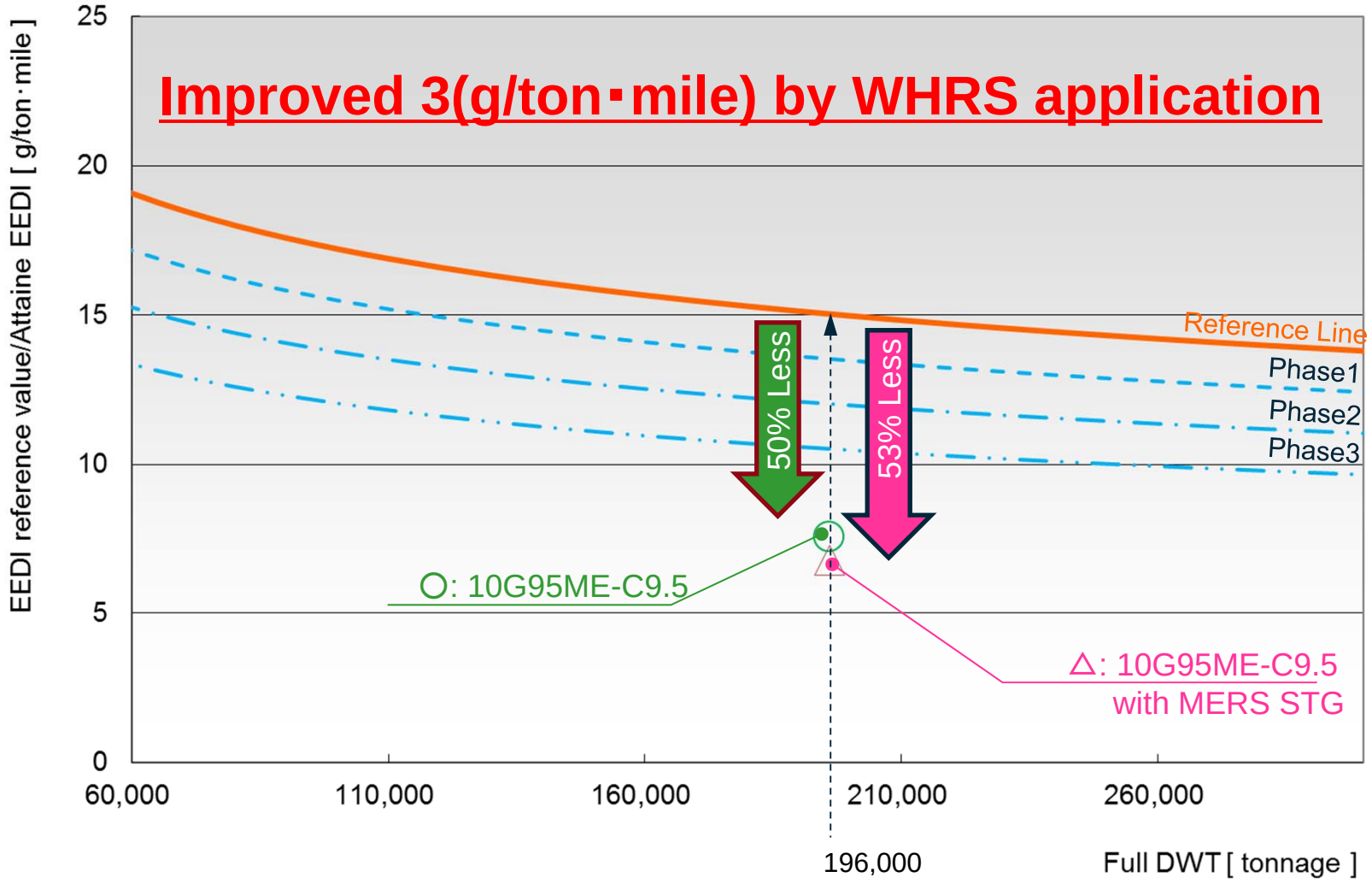
18,000TEU class C/V EEDI estimation



3. Example of benefits

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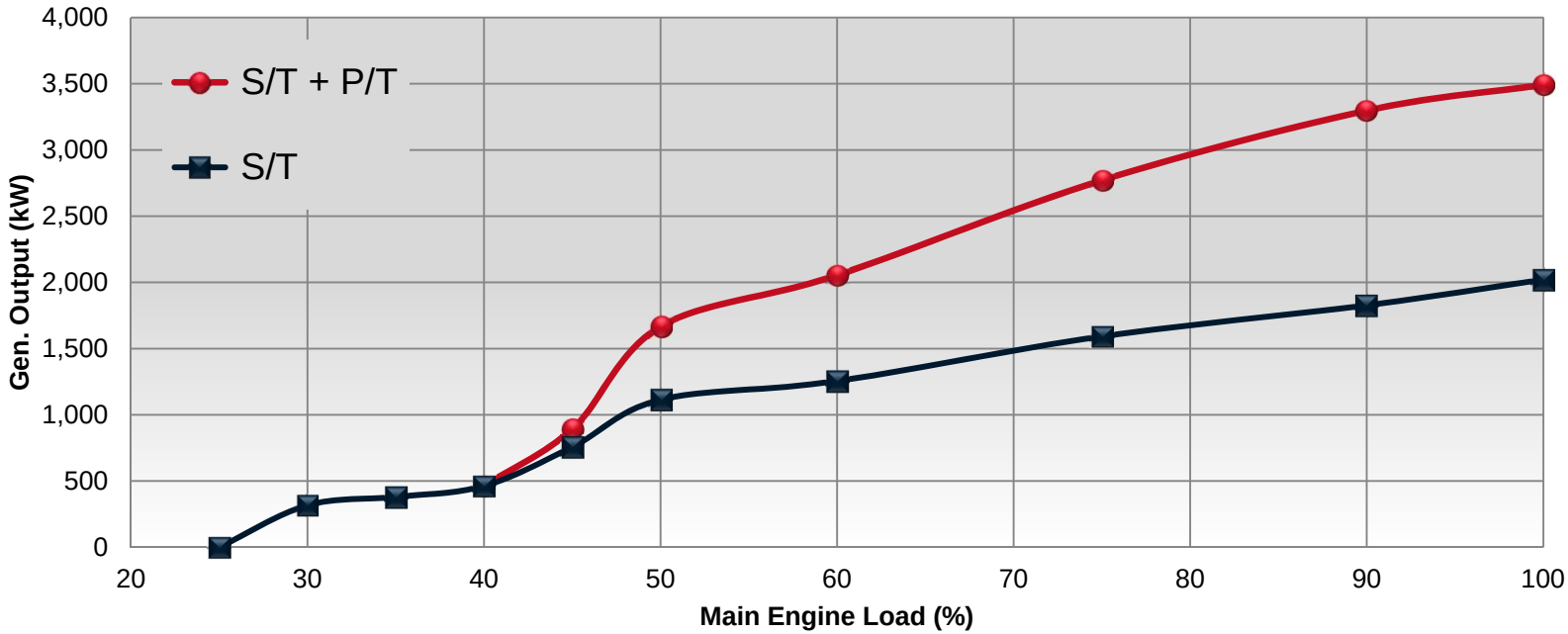
STG output

Main engine : 10G95ME-C9.5 (SMCR : 59,000 kW x 78.4 r/min), Tier2

Ambient Condition		ISO									
M/E Load (%)		**100**	**90**	**75**	**60**	**50**	**45**	**40**	**35**	**30**	**25**
Output from P/T	(kW)	1,472	1,469	1,179	798	552	136	0	0	0	0
Output from S/T	(kW)	2,021	1,827	1,592	1,255	1,114	757	463	380	317	0
Gen. Output	**(kW)**	**3,492**	**3,297**	**2,771**	**2,054**	**1,667**	**893**	**463**	**380**	**317**	**0**



3. Example of benefits

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Saving fuel cost

Summary:

HFO price : 400 US$

Annual Operation Time: 7,000hrs (21 knots(75%load))

M/E type [SMCR x rev.]	10G95ME-C9.5 [59,000 kW x 78.4 r/min]
SMCR (100 % M/E load) speed	23 knots
Fuel consumption without WHRS	62,096 tons
Fuel consumption with WHRS	58,654 tons
Saving fuel consumption	**3,442 tons**
Saving fuel cost	**1,475,137 US$**

3. Example of benefits

MITSUBISHI HEAVY INDUSTRIES
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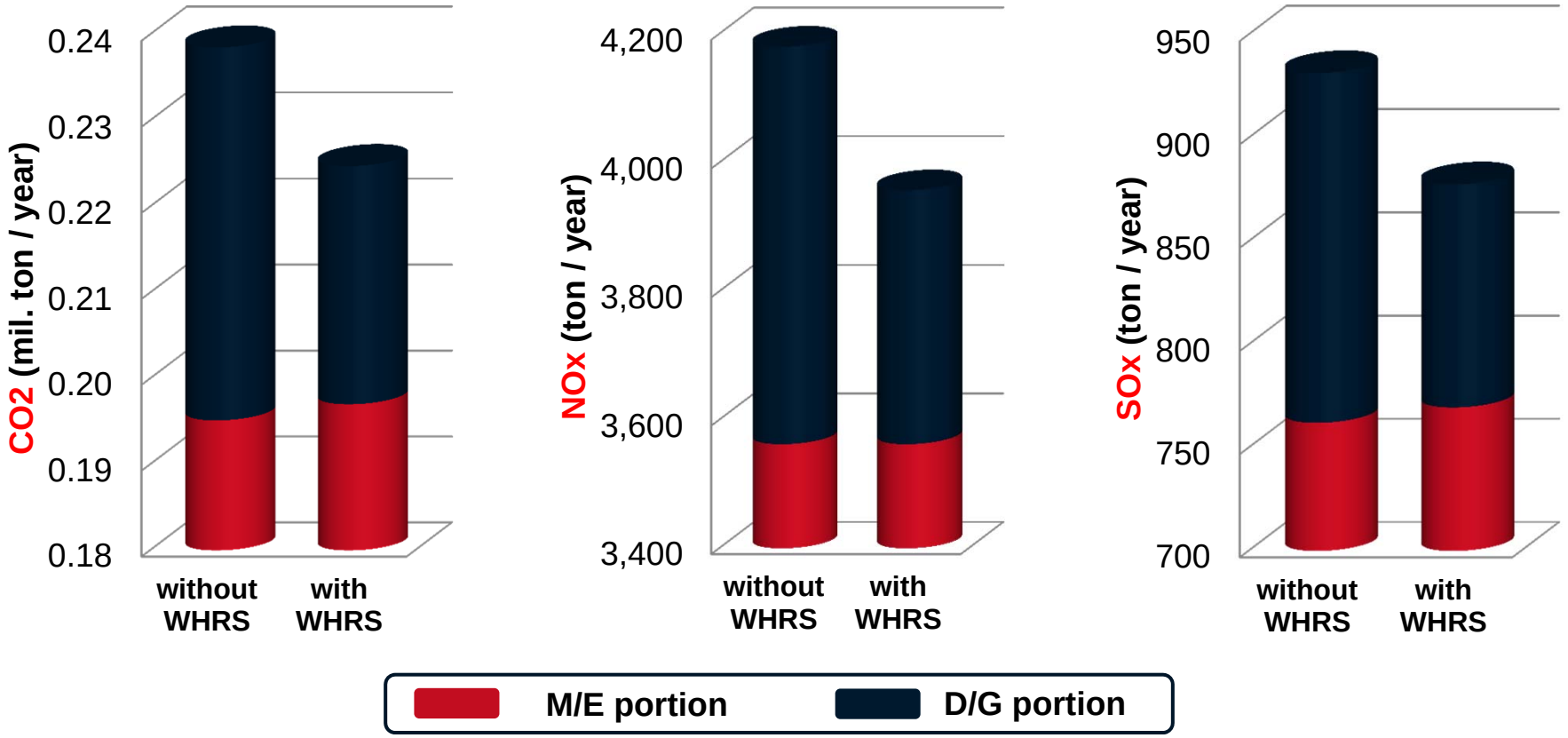
Reducing emission gas

Main engine : 10G95ME-C9.5 (SMCR : 59,000 kW x 78.4 r/min), Tier2

- Vessel speed : 21kt (abt. 75% SMCR)
- Annual operating time : 7,000 Hr



4. Small STG for 250K Bulk Carrier

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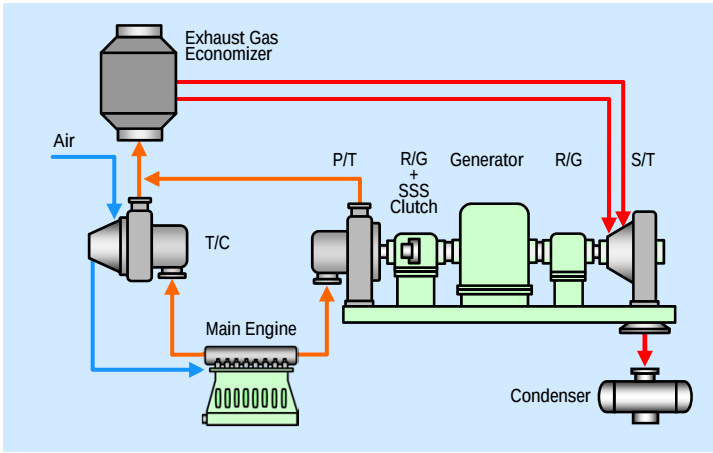
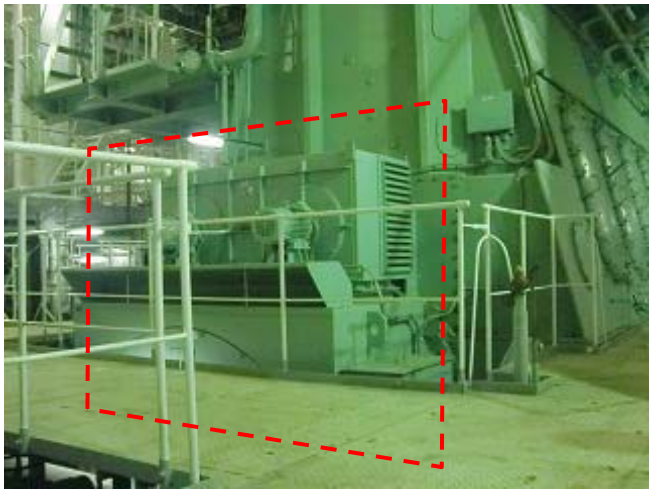
STG arrangement & Shaft Motor in Engine Room

250K Bulk Carrier



STG (AT42C + MPT33A)



Shaft motor

All auxiliary engine can stop when over than ME 55% load, the demand can be supplied by WHR power, and surplus power can be utilized to SGM(Power Take In) to save ME FOC

4. Small STG for 250K Bulk Carrier

MITSUBISHI HEAVY INDUSTRIES MARINE MACHINERY & ENGINE CO., LTD.

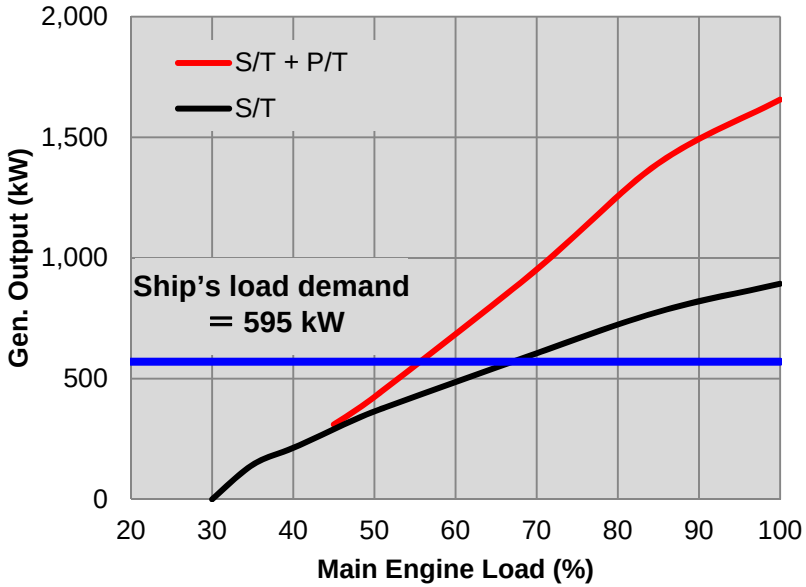
Test result

- M/E Output: 17,850kw@85%MCR
  (7S80MC-C : 21,000kw@100%MCR)
- Ship demand: 595kw

- WHRS(STG) installed
  Generated: 1,392 kw at 85%
- SM(Shaft Motor) installed

- All DG stop
- SM(Shaft Motor): 796kw
  to assist Main Engine

Total save fuel about "8%"
(481,000 US$/year (400 US$/ton))



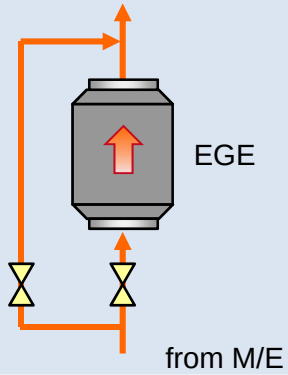
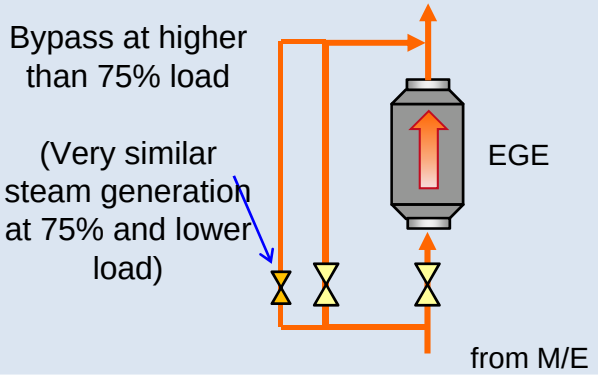
Estimated STG power (ISO)

5. Solution for slow steaming operation

MITSUBISHI HEAVY INDUSTRIES MARINE MACHINERY & ENGINE CO., LTD.

■ *(1) Part load optimization design concept*

☑ Part load optimization design concept

	(a) Conventional des.	(b) Part load optimum des.
EGE Exh.Gas line configuration * EGE : Exh.Gas Economizer		
EGE design point	ISO 90%	ISO 75%
Heat transfer area	100%	79%
Installation space	100%	80%
Weight	100%	85%
Exh.gas velocity (at same M/E load)	100%	133% ✓ Soot blowing at lower M/E load
EGE start point	M/E load 30%	M/E load 22%

5. Solution for slow steaming operation

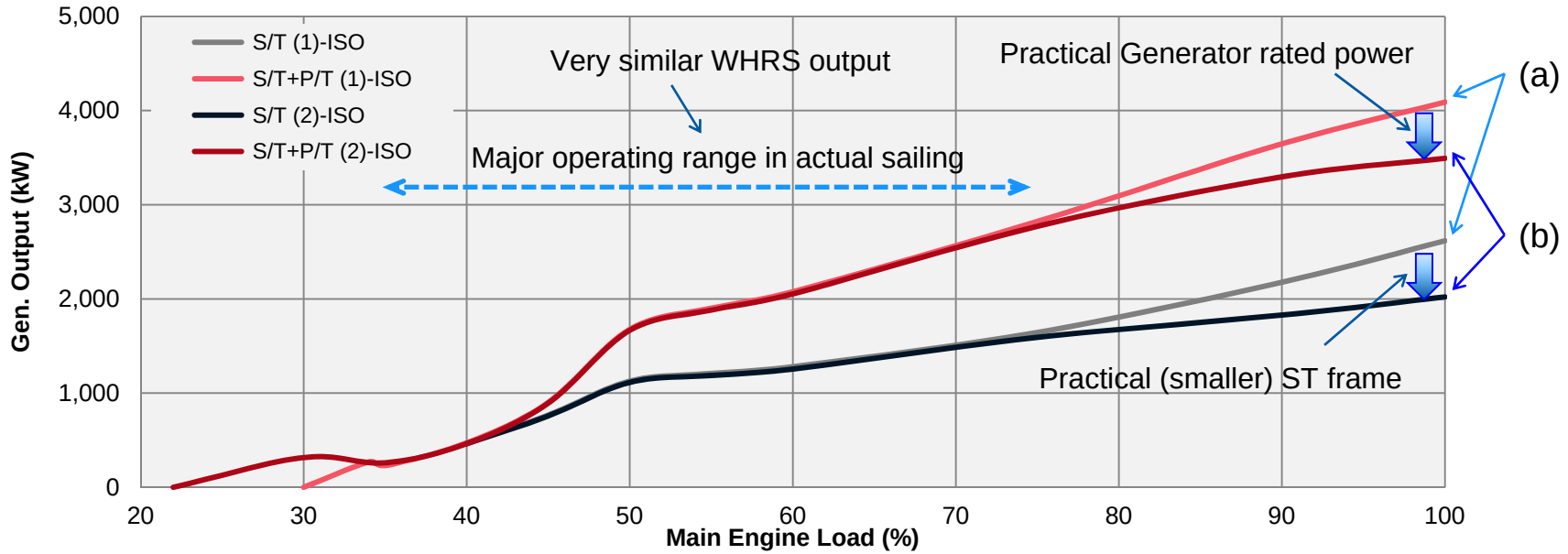
MITSUBISHI HEAVY INDUSTRIES MARINE MACHINERY & ENGINE CO., LTD.

(1) Part load optimization design concept

(a) EGE design point ISO 100% (Conventional design)

(b) EGE design point ISO 75% (Exh.Gas bypass at higher load than 75% to maintain M/E back press.)

- Benefit by concept (b)
  - Smaller EGE (installation space and weight)
  - Soot blowing at lower load due to higher velocity of Exh.Gas
  - Very similar WHRS output at 75% and lower load expected as major loads in actual sailing
  - Lower investment by practical Generator rated power and selection of ST frame



* Main engine : 10G95ME-C9.5 (SMCR : 59,000 kW x 78.4 r/min)

5. Solution for slow steaming operation

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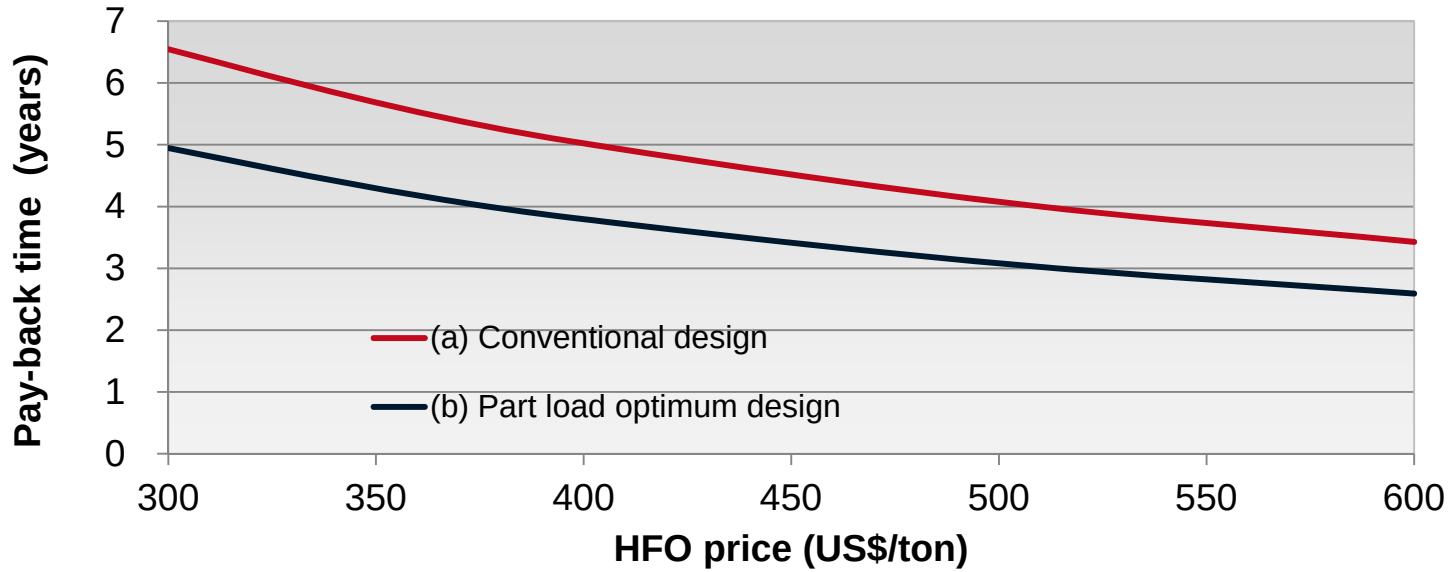
■ *(1) Part load optimization design concept*

HFO price (IFO380) : 400 US$/ton
Total operating days : 250 days (75% load : 50%, 55% load : 50%)

M/E type [SMCR x rev.]	10G95ME-C9.5 [59,000 kW x 78.4 r/min]	
EGE Design	(a) Conventional design	(b) Part load optim. des.
Fuel consumption without WHRS	48,350 ton	48,350 ton
Fuel consumption with WHRS	45,850 ton	45,900 ton
Saving fuel consumption	2,500 ton	2,450 ton
Saving operating cost	1,074,960 US$	1,053,730 US$



5. Solution for slow steaming operation

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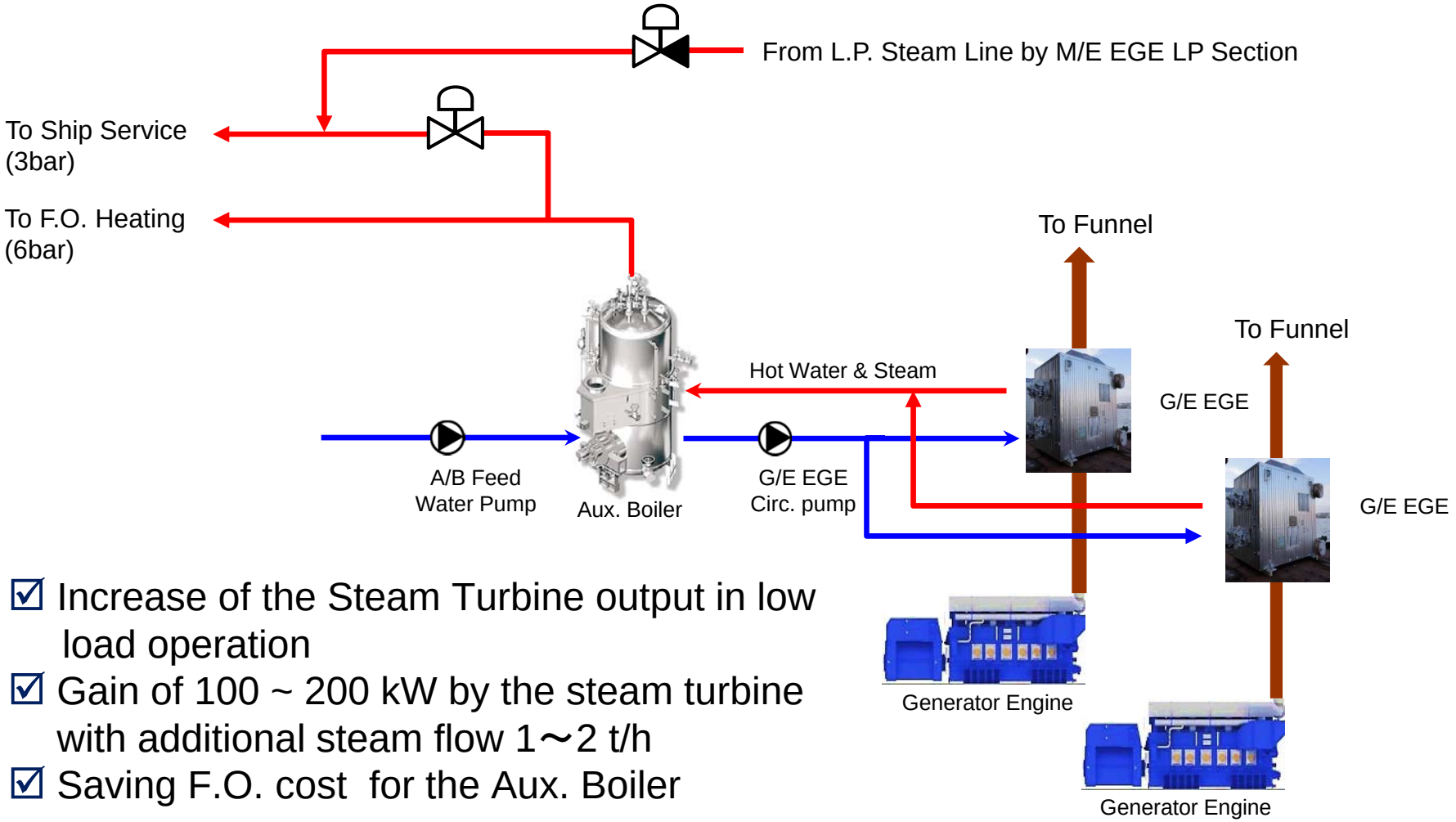
■ *(2) Waste heat recovery of Aux. Engine*

☑ Utilized Aux. Engine Exh. gas Energy for large container ship



☑ Increase of the Steam Turbine output in low load operation

☑ Gain of 100 ~ 200 kW by the steam turbine with additional steam flow 1～2 t/h

☑ Saving F.O. cost for the Aux. Boiler

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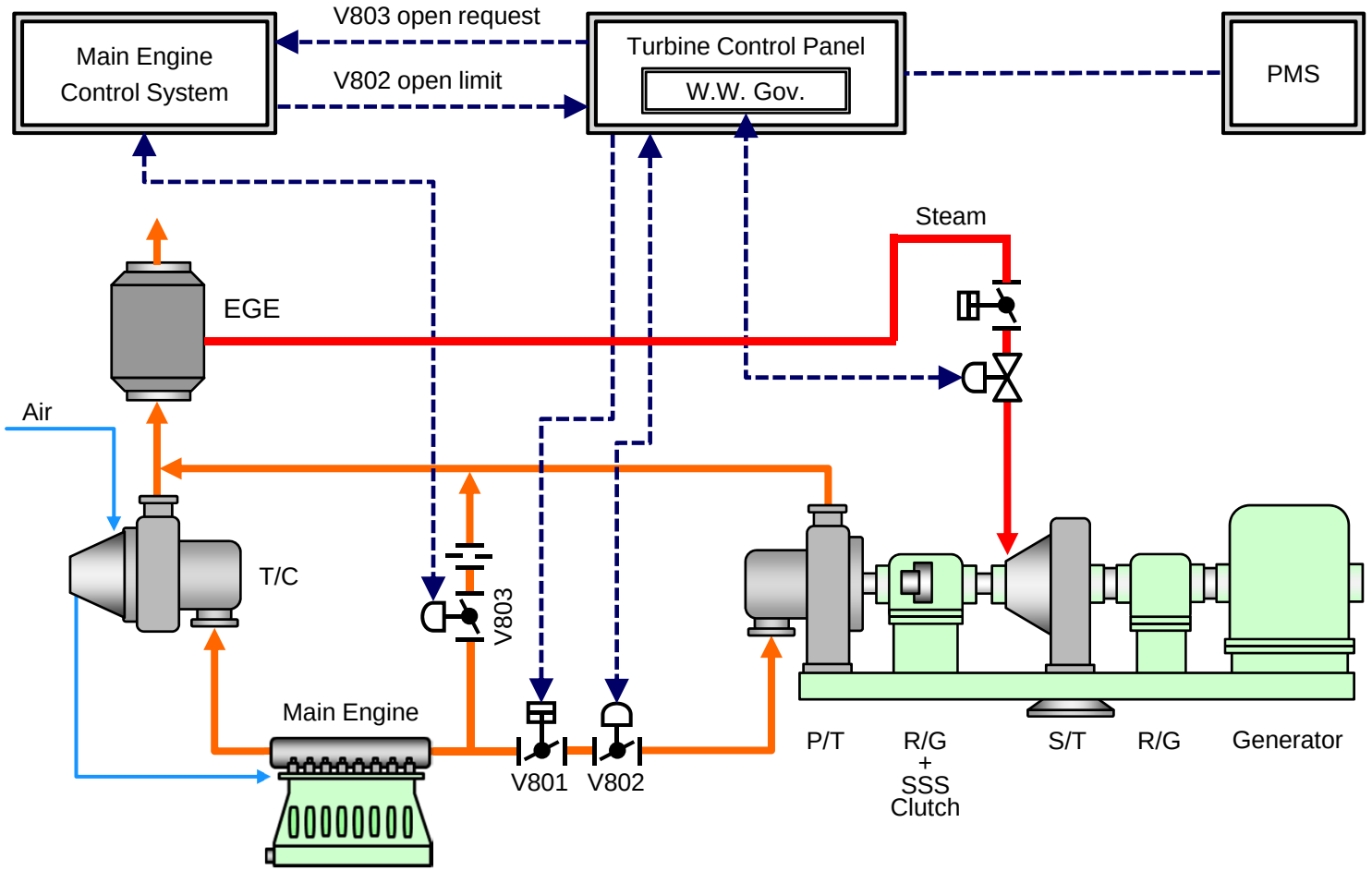
(3) Increase of steam generation

☑ Increase of steam generation in low load operation



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