MHI-MME
WHRS - STG

Environment friendly and economical solution
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Overview

- **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

**Production record (WHRS-STG)**

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

As of Dec.28, 2016

- None MHI systems (8 units)
- Partial MHI systems (21 units)
- (87 units)
1. Outline, WHRS-STG system

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

**Plant diagram**

- **STG PORTION**
  - Condenser
  - S/TR/G+SSS Clutch
  - P/T
  - R/G GEN.
  - Condensate pump
  - Gland condenser
  - Feed water pump
  - Feed water tank
  - Economizer
  - LP Drum
  - HP Drum
  - T/C
  - Exh. Gas bypass line
  - Exh. Gas bypass V/V
  - P/T gas control V/V
  - Jacket cooler
- **EGE PORTION**
  - Main Engine
  - SGM
  - Scav. air cooler
  - Ship's service load
  - HP Dump V/V
  - LP Dump V/V

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1. Outline, WHRS-STG system

**Single Responsibility for whole system**

- Coordination of whole system by MHI
- Competitive performance
- One window & support to ship owner after delivery
2. Feature, WHRS-STG system

### 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

- **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

- **Turbine control panel**
  - Full automatic
  - Plant monitoring system
  - Performance diagnosis

- Monitoring screen of Whole plant
- Monitoring screen of S/T start sequence
- Turbine control panel overview
- Monitoring screen of power turbine
2. Feature, WHRS-STG system

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)
3. Example of benefits

**EEDI / IMO (MEPC) regulation**

EEDI : Energy Efficiency Design Index

\[
EEDI = \frac{\text{CO}_2 \text{ emission [g/h]}}{\text{Capacity [ton]} \times \text{Speed [mile/h]}}
\]

**Regulation**

- For New Ship
  - 2013~2015: 10%
  - 2015~2020: 15 or 20%
  - 2020~2025: 30%

**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

- **18,000TEU class C/V EEDI estimation**

![Graph showing improved 3(g/ton-mile) by WHRS application](image)

- **Improved 3(g/ton-mile) by WHRS application**

<table>
<thead>
<tr>
<th>Reference Line</th>
<th>Phase1</th>
<th>Phase2</th>
<th>Phase3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full DWT</td>
<td>260,000</td>
<td>210,000</td>
<td>196,000</td>
</tr>
<tr>
<td>EEDI [g/ton·mile]</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>60,000</td>
<td>110,000</td>
<td>160,000</td>
<td></td>
</tr>
</tbody>
</table>

**O: 10G95ME-C9.5**

**Δ: 10G95ME-C9.5 with MERS STG**

- **50% Less**
- **53% Less**
### 3. Example of benefits

#### STG output

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

<table>
<thead>
<tr>
<th>Ambient Condition</th>
<th>ISO</th>
</tr>
</thead>
<tbody>
<tr>
<td>M/E Load (%)</td>
<td>100</td>
</tr>
<tr>
<td>Output from P/T (kW)</td>
<td>1,472</td>
</tr>
<tr>
<td>Output from S/T (kW)</td>
<td>2,021</td>
</tr>
<tr>
<td>Gen. Output (kW)</td>
<td>3,492</td>
</tr>
</tbody>
</table>

![Graph showing the relationship between Main Engine Load (%) and Gen. Output (kW) for S/T and S/T + P/T.](image)
3. Example of benefits

**Saving fuel cost**

Summary:
HFO price: 400 US$
Annual Operation Time: 7,000hrs (21 knots(75% load))

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

- **Reducing emission gas**

  Main engine: 10G95ME-C9.5 (SMCR: 59,000 kW x 78.4 r/min), Tier2
  - Vessel speed: 21kt (about 75% SMCR)
  - Annual operating time: 7,000 Hr

<table>
<thead>
<tr>
<th></th>
<th>CO₂ (mil. ton/year)</th>
<th>NOₓ (ton/year)</th>
<th>SOₓ (ton/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>without WHRS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with WHRS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>without WHRS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with WHRS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Vessel speed: 21kt (about 75% SMCR)
- Annual operating time: 7,000 Hr
4. Small STG for 250K Bulk Carrier

STG arrangement & Shaft Motor in Engine Room

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

**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))
5. Solution for slow steaming operation

- **(1) Part load optimization design concept**

  ☑ Part load optimization design concept

<table>
<thead>
<tr>
<th>EGE Exh. Gas line configuration</th>
<th>(a) Conventional des.</th>
<th>(b) Part load optimum des.</th>
</tr>
</thead>
<tbody>
<tr>
<td>* EGE : Exh. Gas Economizer</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>EGE design point</td>
<td>ISO 90%</td>
<td>ISO 75%</td>
</tr>
<tr>
<td>Heat transfer area</td>
<td>100%</td>
<td>79%</td>
</tr>
<tr>
<td>Installation space</td>
<td>100%</td>
<td>80%</td>
</tr>
<tr>
<td>Weight</td>
<td>100%</td>
<td>85%</td>
</tr>
<tr>
<td>Exh. gas velocity (at same M/E load)</td>
<td>100%</td>
<td>133% ✓ Soot blowing at lower M/E load</td>
</tr>
<tr>
<td>EGE start point</td>
<td>M/E load 30%</td>
<td>M/E load 22%</td>
</tr>
</tbody>
</table>

*EGE : Exh. Gas Economizer

- Bypass at higher than 75% load
  - (Very similar steam generation at 75% and lower load)

- Soot blowing at lower M/E load
5. Solution for slow steaming operation

(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

![Graph showing performance comparison](image)

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

(1) Part load optimization design concept

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

<table>
<thead>
<tr>
<th>M/E type [SMCR x rev.]</th>
<th>10G95ME-C9.5 [59,000 kW x 78.4 r/min]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a) Conventional design</td>
</tr>
<tr>
<td>Fuel consumption without WHRS</td>
<td>48,350 ton</td>
</tr>
<tr>
<td>Fuel consumption with WHRS</td>
<td>45,850 ton</td>
</tr>
<tr>
<td>Saving fuel consumption</td>
<td>2,500 ton</td>
</tr>
<tr>
<td>Saving operating cost</td>
<td>1,074,960 US$</td>
</tr>
</tbody>
</table>
5. Solution for slow steaming operation

(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

From L.P. Steam Line by M/E EGE LP Section

To Ship Service (3bar)
To F.O. Heating (6bar)
To Funnel

A/B Feed Water Pump
Aux. Boiler
G/E EGE Circ. pump
G/E EGE
Generator Engine
Generator Engine
5. Solution for slow steaming operation

- (3) Increase of steam generation

- Increase of steam generation in low load operation
MOVE THE WORLD FORWARD