

Smart and Futuristic Vessels- Alternate Propulsion System for LNG Carriers

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Abstract: As the maritime industry marches through an era of stringent environmental regulations and increasing fuel costs, shipping companies and organizations are spending considerable amount of resources to search for viable alternative propulsion systems which would not only help in successfully powering the ships. In an effort to do so, the DFE (Dual Fuel Engine) in conjunction with an electric propulsion motor, to obtain higher plant efficiency and the DRL (Diesel engine with Re-Liquefaction Plant) ship fitted with 2 cycle, low speed engine, for propulsion have been introduced. The first DFE ship was built in a French shipyard and a number of these vessels are in service, while a number of the LNG carriers with DFE and DRL plants are now being built in Korea.

Although existing steam turbine plants have good operational reliability, maintainability, and operability proven by past performance, they are far behind the new plants in plant efficiency, which is an urgent issue. To address this issue, two agencies in Japan, namely Mitsubishi Heavy Industries, Ltd. (MHI) & Kawasaki Heavy Industries(KHI)have developed the UST (Ultra-Steam Turbine) which claims 15% higher efficiency than a conventional steam turbine plant and almost same as new Diesel engine.

Ship pollution affects the health of communities in coastal and inland regions around the world, so various attempts have been made to regulate pollution from ships. This paper attempts to bring out some of the features of the UST plant which introduces developments to achieve marine propulsion plants

with improved thermal efficiency together with reduced emissions, to ensure that new UST ships contribute as low as possible to the global pollution.

Keywords: Thermal Shield, Reheat cycle, Specific Fuel Consumption, Plant Cost.

1. Introduction

Until a decade ago, steam turbines were used for almost all LNG carriers for the propulsion plant because of their various advantages. Another reason is that the steam turbine plant could safely treat boil-off gas (BOG) generated from the cargo tank and could also use heavy oil as fuel when BOG is not available. The steam is generally obtained through boilers with burners, which can consume a variety of fuels including natural gas. However, the development of the low speed diesel engine with its ability to run on both residual fuel and gas with a higher thermal efficiency overtook the conventional steam turbine plant in LNG carriers.



FIGURE 1. UST plant

1.1 Characteristics of Marine Steam turbine:

Marine Steam Turbine Propulsion Systems have the following characteristics which made them a popular choice prior to advent of the 2 cycle slow speed diesel engine:

- Ability to convert large quantity of enthalpy in steam to mechanical work.
- Produce steady torque under steady steam flow.
- Develop high output beyond range of diesel engines.

- Very reliable for long voyages.
- Advantage of burning boil off gas (BOG) in the boiler and dumping surplus steam in condenser.

When selecting propulsion machinery, life cycle costs need to be considered, namely: initial costs (price of the plant, installation costs, etc.), variable costs (fuel, maintenance, and crew) & potential costs (derived from the reliability and availability expected).

In general, when evaluating a propulsion system for a merchant ship the operating costs (fuel costs, crew and maintenance required) are the primary consideration, while the initial costs are a secondary consideration.

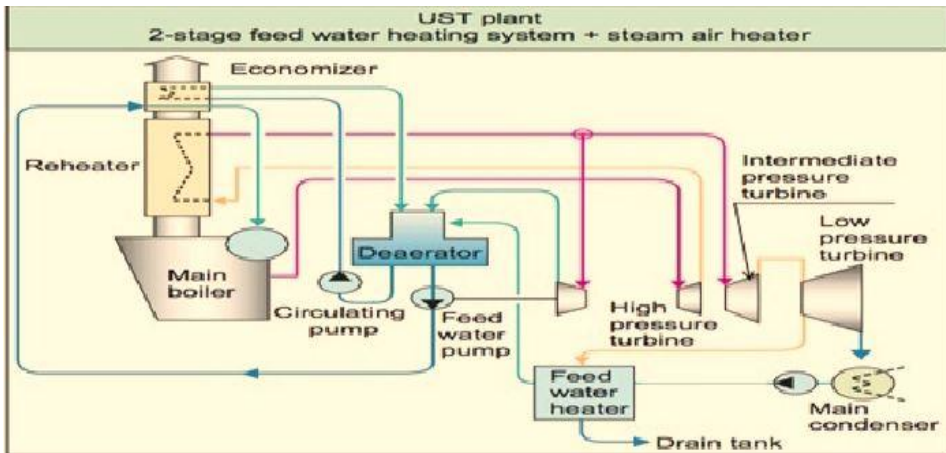


FIGURE2: Schematic Layout of UST plant

2. MAIN WORK

2.1 UST Plant configuration:

The UST plant is a 2-stage feed water heating system based on the reheat cycle, ensuring a simple configuration with improved efficiency, operability, and maintainability. A comparison with the conventional plant is shown.

TABLE 1: Comparison of conventional steam turbine plant and UST plant

		CST(Conventional plant)	UST
Boiler	Steam	6Mpa X515°C	HP:10MpaX600°C
Conditions			

Steam Flow	BLR=>HPT=>LPT	BLR=>HPT=>REHTR=>IPT=>LPT
Flange standard	ANSI 900LB	ANSI 2500LB

BLR: boiler, HPT: high pressure turbine, LPT: low pressure turbine, REHTR: reheater, IPT: intermediate pressure turbine

2.2. Components of UST Plant

2.2.1 UST Turbine:

The UST turbine developed by MHI is a high performance turbine based on the latest technology and which has a good track record on land based plants. It consists of High&Intermediate Pressure Turbines, a Low Pressure Turbine, a Main Condenser and a Reduction Gear unit.

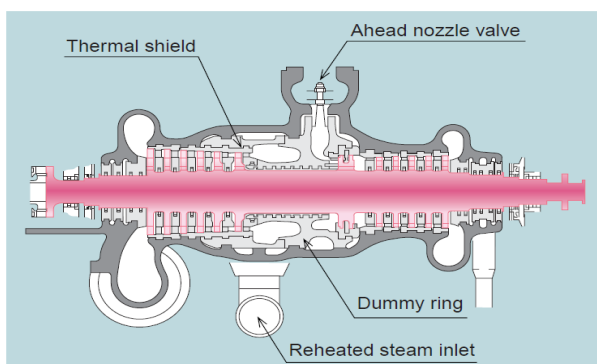


FIGURE 3: Cross-section of UST high/intermediate pressure turbine

The HPT & IPT are located in a single casing and on a single shaft provided with a heat shield. The superheated steam at 100 bar & 600⁰C, enters the HPT. The exhaust from the HPT at about 20 bar & 350⁰C returns to the boiler reheater to be reheated to 600⁰C before being led to the IPT. Steam exhausted from the IPT is led to the LPT, which also contains a reversing stage for astern operation. Both the HPT/IPT as well as the LPT drive the propeller through a common reduction gearbox. Steam bled from the LPT is used to improve plant efficiency by heating the feed water.

2.3. Reheat Boiler:

Generally, main boiler for marine propulsion system requires:

- High reliability and redundancy.

- Compact and light weight.
- Easy maintenance and operation due to simple system.

Consequently, the Reheater tubes must avoid failure due excessive tube metal temperatures. Even if tube failure occurs as worst case, continuous operation of the ship is desired.

For a marine reheat boiler, there are three different types, mainly:

- Dual Furnace Type.
- Gas By-pass Type.
- Individual Type.

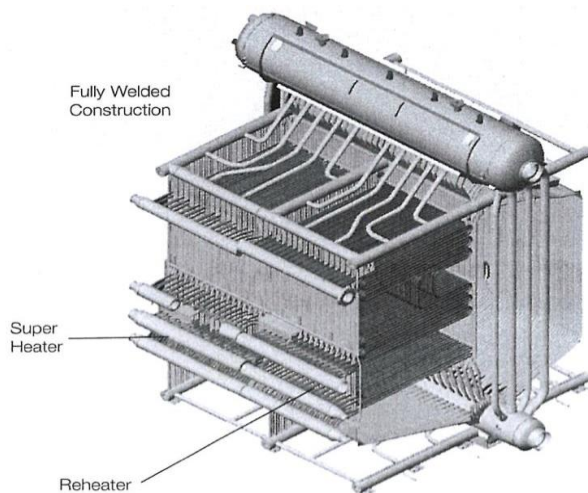


FIGURE 4: Overview of Reheat Boiler

Separated Reheater in the Dual Furnace type is selected for UST.

In this type of boiler, Reheater and reheat furnace are located at the outlet of combustion gas where the gas temperature is low. So, continuous operation can be done only with Reheat Burner stopped in the case of no steam flow or extremely low steam flow conditions.

Reheater is designed to achieve specified steam temperature by using Reheat Burner which is located at the bottom of Reheat furnace. There is the case of no steam flow or extremely low flow condition in frequent load changes or astern / loading / stand-by of the ship which is the major difference with On-

shore plant. In this situation, there is possibility of overheating of Reheater tubes due to excessive tube metal temperature due to reduction of heat transferred to steam.

To solve the above problems, Reheater and Reheat furnace are located at the outlet of combustion gas where the gas temperature is low. Hence, Reheater Tubes are not exposed high temperature combustion gas when the Reheat Burner is stopped. In addition, combustion gas at Reheater inlet during Reheat Burner operation will be high.

2.3.1 Construction of Super heater:

For improvement of plant efficiency in UST, high pressure and temperature for main steam is applied compared with conventional steam turbine plant. Accordingly, increasing of heating surface area for the Superheater and improvement of thermal resistance are required. For increasing of heating surface area, together with control of superheater temperatures, the division of the Superheater in 2 parts – with steam flow in primary & secondary sections in series, with a controlled attemperators in between, which was a feature in the conventional LNG Boiler, has been retained.

As for improvement of the thermal resistance of Superheater tubes, secondary Superheater which is a higher steam temperature compared with that of primary Superheater, is located downstream of the primary superheater & thus not exposed to furnace radiation directly.

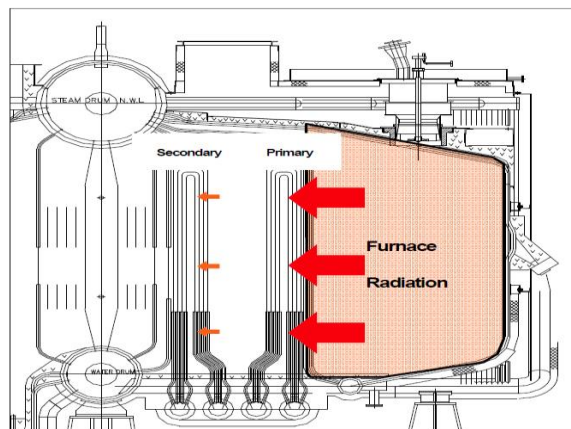


FIGURE 5: Conceptual Image of furnace radiation

Furthermore, combustion gas temperature will be reduced due to heat absorption of primary Superheater. Therefore, metal temperature of Superheater tubes can be kept similar with that of conventional main boiler even if steam temperature is higher than conventional.

To achieve corrosion resistance at superheater, stainless steel with high chrome content rate is adopted for the material for higher metal temperature section.

2.4. The Newest Technologies Used to Improve the Internal Efficiency of the UST Turbine

2.4.1 Thermal shield:

While HP and IP turbines are located in the same single casing, we should remember that the operation mode of the UST turbine is different from land use turbine. That is, the UST turbine requires both start and stop operations within one voyage and the HP/IP turbine casing in particular is subjected to repeated thermal loads.

The severe difference between HP turbine inlet steam temperature and LP turbine inlet steam temperature may cause uneven deformation of the casing and consequent steam leakage from the horizontal flange of HP/ IP casing. For that purpose, a thermal shield structure has been applied, which has been proven in MHI land-use turbines.

2.4.2. Implementation of ISB(Integrated Shroud blade) with Multi-seal Blade:

- Optimization of the angle of the nozzle at high pressure stages.
- Development of the last stages Curtis (Control) with a much higher efficiency for UST steam conditions.
- Implementation of 3-D stationary blades in LR reaction stages.
- Implementation of blades with small non stationary-losses.

- Optimization of a guide for exhaust flow (LR / T).

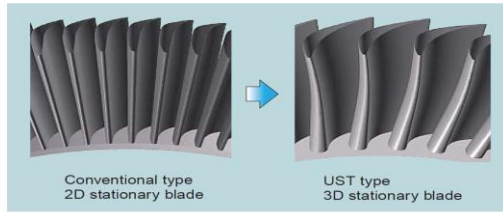


FIGURE 7: 3D stationary blade (low pressure turbine reaction stage)

2.5. Influence on environment

2.5.1 Comparison of exhaust gas components during navigation:

Under normal sea going conditions in gas burning mode, SO_x is not emitted at all from the propulsion plant. Content of carbon dioxide for steam turbine plant is lower than other plant because of the source of exhaust gas coming from the main boiler. Fuel consumption for UST plant will be reduced compared with conventional steam turbine plant due to high plant efficiency. Therefore, further reduction in exhaust gas constituents can be expected.

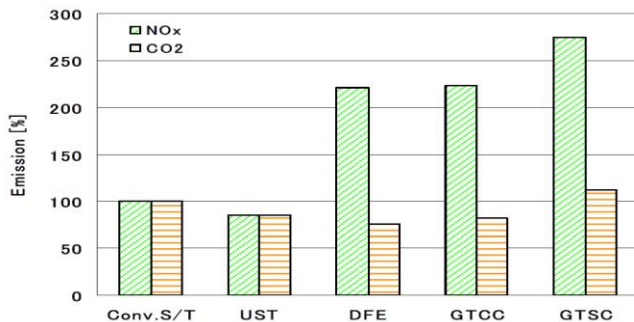
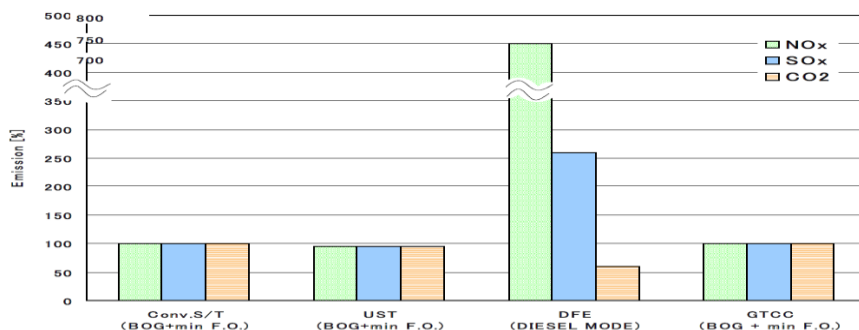


FIGURE 9: The exhaust gas emission during normal operation of different plants

2.5.2. Comparison of exhaust gas components during port operation:

During loading and unloading, steam turbine plants (CST and UST) have



dual fuel burning modes. However, a DFE plant is restricted to diesel mode only, because gas mode cannot be used in low load conditions. Therefore the NO_x and SO_x emissions from a DFE plant are higher than other plants.

FIGURE 10: Emission during port operation in different plants

The majority of emission regulations for current environmental measures are targeted at coastal zones and port areas including those of Europe and the US west coast. The introduction of stricter regulation is expected in the near future especially concerning exhaust gas components during loading and unloading. In this regard, the UST plant is the most outstanding compared with other plants.

3. Conclusion

This paper has introduced the UST plant which can achieve an efficiency equivalent to that of other diesel propulsion engines.

- Its major characteristics are summarized as follows:
- Improved conditions of steam to UST turbine, Implementation of reheat cycle and Improved internal efficiency of turbine, which contributes to the claimed 15% increase in efficiency.
- The specific fuel consumption of UST plant is 250 g/KWh compared to 285.5 g/KWh of conventional plant.
- High reliability and safety: the same high reliability and safety as available in conventional turbine plants.
- Low maintenance costs: similar low maintenance costs to conventional turbine plants.
- Environmentally friendly: about 15% decrease in emissions (NO_x, SO_x, CO₂).
- Flexibility of fuel selection: flexible burning of any fuel combination, heavy fuel oil or gas.
- Extremely long plant life: operational for more than 40 years.
- The UST plant could safely burn boil-off gas (BOG) generated from the cargo tank in the boiler and dump it in the condenser, when the loaded tanker is standing by to unload cargo, thus avoiding need to install a reliquification plant to conserve the BOG.

Finally, it is very likely that the UST plant developed through the efforts of 2

independent agencies in Japan, i.e. MHI &KHI, will be successful in competing with the slow speed dual fuel Diesel Engine in the near future. We would like to express our sincere appreciation to all parties concerned for the wide-ranging guidance and cooperation extended to us.

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