Ambient Temperature Operation and Matching

MAN B&W Two-stroke Engines

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MAN Diesel & Turbo

Content

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Introduction

All diesel engines that are used as prime movers on ships are exposed to the varying local climatic conditions that prevail throughout the world.

In some areas, the ambient sea and air temperatures can, occasionally, be extremely high. Likewise in arctic areas, the temperatures can be very low. Under both extreme temperature conditions some engine design precautions might be necessary to enable the engine to operate in unrestricted service.

This paper will outline operation possibilities with a standard matched engine in any extreme temperature environment and describe the possibilities for special matching of engines for more permanent operation under such conditions.

Standard ambient temperature matched engine

Standard unrestricted service demands

For a standard main engine, the engine layout is based on the ambient reference conditions of the International Standard Organization (ISO):

ISO 3046-1:2002(E) and ISO 15550:2002(E): ISO ambient reference conditions

Barometric pressure:	1,000 mbar
Turbocharger air intake temperature:	25ºC
Charge air coolant temperature:	25ºC
Relative air humidity:	30%

With this layout basis, the engine must be able to operate in unrestricted service, i.e. up to 100% Specified Maximum Continuous Rating (SMCR), within the typical ambient temperature range that the ship is exposed to, operating from tropical to low winter ambient conditions.

According to the International Association of Classification Societies (IACS) rule M28, the upper requirement, normally referred to as tropical ambient reference conditions, is as follows:

IACS M28 (1978): Tropical ambient reference conditions

Barometric pressure:	1,000 mbar
Air temperature:	45ºC
Seawater temperature:	32ºC
Relative air humidity:	60%

The above tropical ambient relative humidity of 60% at 45ºC is theoretically the absolute limit at which it is possible for humans to survive. The corresponding wet bulb temperature is 36.8ºC.

MAN Diesel has never measured levels above 50% at 45ºC, and humidity levels above standard tropical ambient conditions will never occur.

When applying the central cooling water system which, today, is more commonly used than the seawater system, the corresponding central cooling water/scavenge air coolant temperature is 4ºC higher than the seawater temperature, i.e. equal to 36ºC.

The winter ambient reference conditions used as standard for MAN B&W two-stroke engines are as follows:

Winter ambient reference conditions

Barometric pressure:	1,000 mbar
Turbocharger air intake temperature:	10ºC
Cooling water temperature: (minimum for lub. oil cooler)	10ºC
Relative air humidity:	60%

Shipyards often specify a constant (maximum) central cooling water temperature of 36°C, not only for tropical ambient conditions, but also for winter ambient conditions. The purpose is to reduce the seawater pump flow rate when possible, and thereby to reduce the electric power consumption, and/or to reduce the water condensation in the air coolers.

However, when operating with 36°C cooling water instead of for example 10°C (to the scavenge air cooler), the

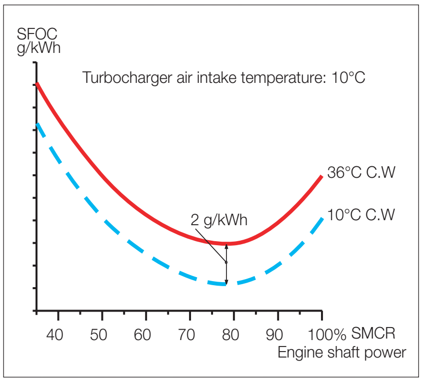

Fig. 1: Influence on SFOC of the cooling water (scavenge air coolant) temperature

specific fuel oil consumption (SFOC) will increase by approx. 2 g/kWh, see Fig. 1. Any obtained gain in reduced electric power consumption, therefore, will be more than lost in additional fuel costs of the main engine.

The above ISO, tropical and winter ambient reference conditions are used by MAN Diesel for ships, and MAN B&W two-stroke engines comply with the above rules. MAN B&W engines matched according to the above rules are able to operate continuously up to 100% SMCR in the air temperature range between about -10 and 45ºC.

Often the engine room temperature is mistaken for being equal to the turbocharger air intake temperature. However, since the air ventilation duct outlets for a normal air intake system are placed near the turbochargers, the air inlet temperature to the turbochargers will be very close to the ambient outside air temperature. Under normal air temperature conditions, the air inlet temperature to the turbocharger is only 1-3°C higher than the ambient outside air temperature.

The classification society rules often specify an engine room air temperature of 0-55ºC as the basis for the design of the engine room components. The 55ºC is the temperature used when approving engine room components. This, however, must not be mistaken for the above air intake temperature of 45ºC specified when related to the capacity or effect of the machinery.

In recent years, owners/shipyards have sometimes required unrestricted service on special maximum ambient temperatures higher than the tropical ambient temperatures specified by IACS M28. In such cases, the main engine has to be special high temperature matched, as described later in this paper.

Furthermore, operation in arctic areas with extremely low air temperatures has also sometimes been required by owners/shipyards, and the measures to be taken are also described later in this paper.

Operating at high seawater temperature with standard matched engine

An increase of the seawater temperature and, thereby, the scavenge air temperature has a negative impact on the heat load conditions in the combustion chamber. Therefore, all MAN B&W two-stroke engines for marine applications have an alarm set point of 55°C for the scavenge air temperature for protection of the engine, as described later.

For a standard ambient temperature matched engine operating at an increased seawater temperature existing in some inland, gulf, bay and harbour areas, the maximum power output of the engine should be reduced to an engine load resulting in a scavenge air temperature below the level of the scavenge air temperature alarm.

Nevertheless, the engine's obtainable load level will in all cases be much higher than required to ensure a safe manoeuvrability (4-6 knots) of the ship even at an extreme seawater temperature of for example 42°C.

When sailing in, for example, the harbour area during manoeuvring, the engine load will normally be relatively low (15-30% SMCR), and the corresponding scavenge air temperature will then only be slightly higher than the scavenge air coolant temperature. Therefore, a seawater temperature as high as for example 42°C in harbour areas is not considered a problem for the main engine, and a special temperature matching is not needed under these operating conditions

In general, when sailing in areas with a high seawater temperature, it is possible to operate the standard ambient temperature matched main engine at any load as long as the scavenge air temperature alarm limit is not reached. If the alarm is activated, the engine load has to be reduced.

Non-standard ambient temperature matched engine

If unrestricted loads are desired in a temperature range different from the standard, different matching possibilities are available.

Engine matching for non-standard air temperature conditions

Usually, higher or lower turbocharger air intake temperatures may result in lower or higher scavenge air pressures, respectively, and vice versa.

An increase of, for example, 5°C of the tropical air temperature from standard 45°C to special 50°C will result in a too low scavenge air pressure at 50°C.

Fig. 2: Principles for standard and special high (or low) ambient air temperature matched engines

However, the pressure reduction can be compensated for by specifying a correspondingly higher (turbocharger) scavenge air pressure at ISO ambient reference conditions. This involves that the engine, instead of being matched for the ISO-based design air temperature of 25ºC, has to be matched for the 25 + 5 = 30ºC turbocharger air intake temperature.

The original ISO-based heat load conditions will then almost be obtained for this higher design air temperature. The principles for standard and special high ambient air temperature matched engines are shown in Fig. 2.

At the other end of the air temperature range, the increase of 5ºC of the design air intake temperature will involve a too high scavenge air pressure when operating at -10ºC. Operation below -10 + 5 = -5ºC will then only be possible when installing a variable exhaust gas bypass valve system for low air temperatures, as described later.

Fig. 2 may in a similar way also be used to explain a special low temperature matched engine. For example, if the standard tropical air temperature needed is reduced by 10ºC, from 45ºC to 35ºC, the engine matching design air temperature can be reduced to 25 -10 = 15ºC.

This involves that the exhaust gas temperature will increase by about 16ºC compared with a standard ISO temperature matched engine, whereas the SFOC will increase.

Engine matching for high tropical seawater temperature conditions

For long time operation in an area with high tropical seawater temperatures, the following should be observed.

An increase in the seawater temperature and, thereby, of the scavenge air coolant temperature will involve a similar increase in the scavenge air temperature, which has a negative impact on the combustion chamber temperatures.

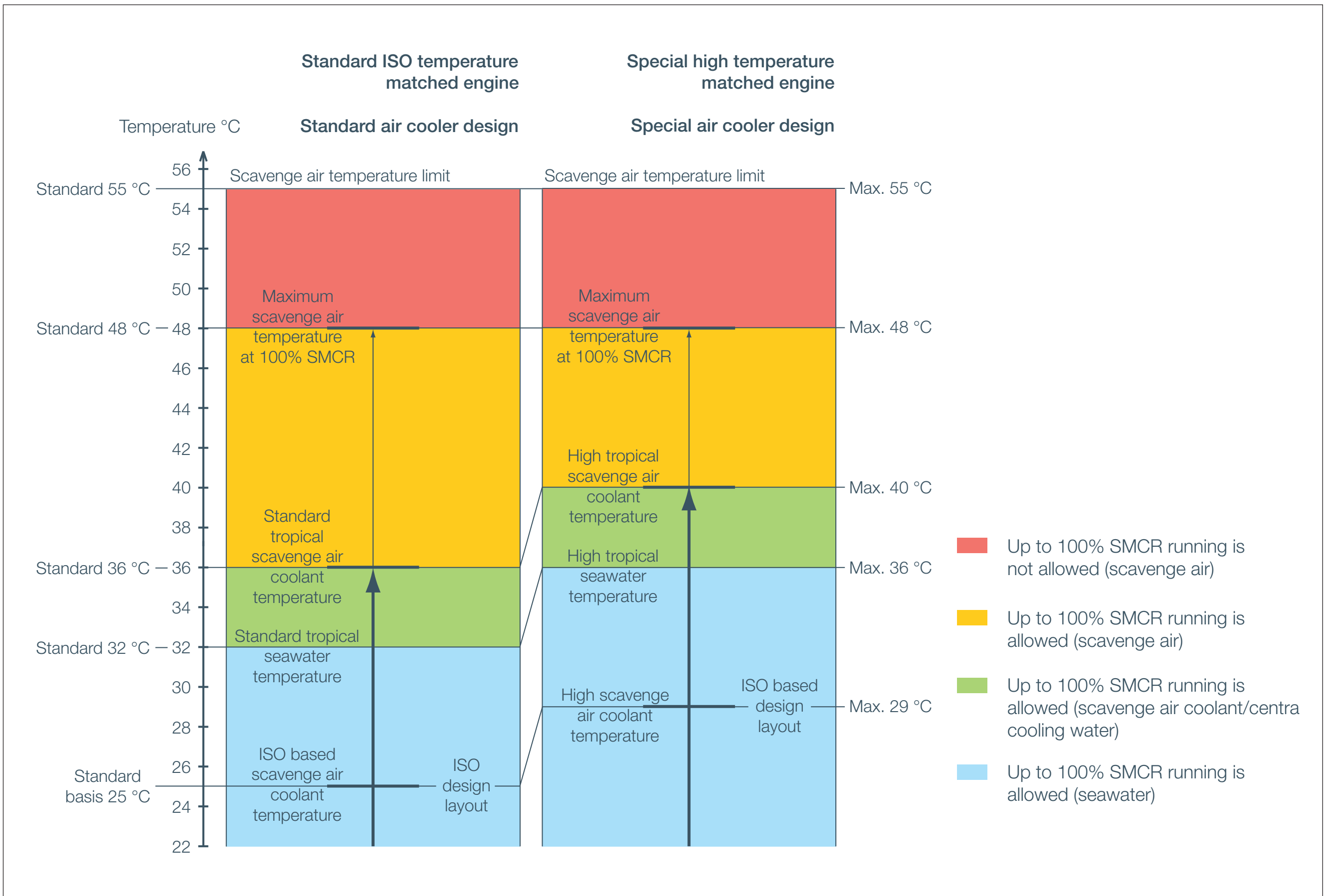

Fig. 3: Principles for layout of scavenge air cooler for standard and special high scavenge air coolant temperature (illustrated for a central cooling water system)

Therefore, for all marine applications, an alarm set point of 55ºC for the scavenge air temperature is applied for protection of the engine.

The standard marine scavenge air cooler is specified with a maximum 12ºC temperature difference between the cooling water inlet and the scavenge air outlet at 100% SMCR, which gives a maximum scavenge air temperature of 36 + 12 = 48ºC for the scavenge air cooler layout and, accordingly, a margin of 7ºC to the scavenge air temperature alarm limit of 55ºC.

A temperature difference of 8ºC is considered to be the lowest possible temperature difference to be used for a realistic specification of a scavenge air cooler. Accordingly, the 48 - 8 = 40ºC is the maximum acceptable scavenge air coolant temperature for a central cooling water system, see the principles for layout of the scavenge air cooler in Fig. 3.

The demand for an increased tropical scavenge air coolant (central cooling water) temperature of up to 40ºC, therefore, can be compensated for by a reduced design temperature difference of the scavenge air cooler. This can be obtained by means of an increased water flow and/or a bigger scavenge air cooler.

Design recommendations for operation at extremely low air temperature

When a standard ambient temperature matched main engine on a ship occasionally operates under arctic conditions with low turbocharger air intake temperatures, the density of the air will be too high. As a result, the scavenge air pressure, the compression pressure and the maximum firing pressure will be too high.

In order to prevent such excessive pressures under low ambient air temperature conditions, the turbocharger air inlet temperature should be kept as high as possible (by heating, if possible).

Furthermore, the scavenge air coolant (cooling water) temperature should be kept as low as possible and/or the engine power in service should be reduced.

However, for an inlet air temperature below approx. -10ºC, some engine design precautions have to be taken.

Main precautions for extreme low air temperature operation

With a load-dependent exhaust gas bypass system (standard MAN Diesel recommendation for extreme low air temperature operation), as shown in Fig. 4, part of the exhaust gas bypasses the turbocharger turbine, giving less energy to the compressor, thus reducing the air supply and scavenge air pressure to the engine.

For the electronically controlled ME engine (ME/ME-C/ME-B), the load-dependent bypass control can be incorporated in the Engine Control System (ECS) as an add-on.

Engine load, fuel index and scavenge air pressure signals are already available for the ME software and, therefore, additional measuring devices are not needed for ME engines.

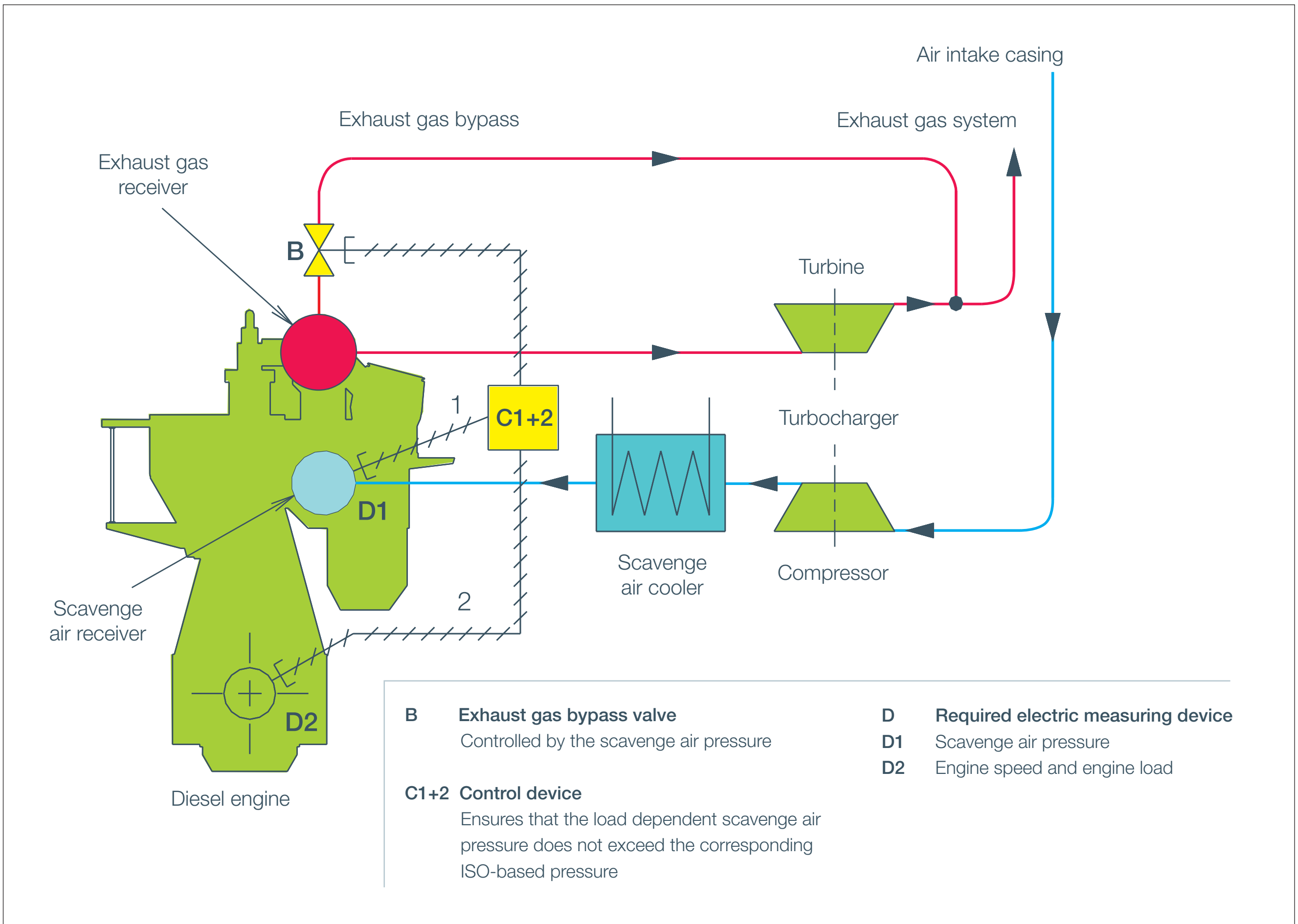

Fig. 4: Standard load-dependent low ambient air temperature exhaust gas bypass system

In general, a turbocharger with a normal layout can be used in connection with an exhaust gas bypass. However, in a few cases a turbocharger modification may be needed.

The exhaust gas bypass system ensures that when the engine is running at part load at low ambient air temperatures, the load-dependent scavenge air pressure is close to the corresponding pressure on the scavenge air pressure curve which is valid for ISO ambient conditions. When the scavenge air pressure exceeds the read-in ISO-based scavenge air pressure curve, the bypass valve will variably open and, irrespective of the ambient conditions, will ensure that the engine is not overloaded. At the same time, it will keep the exhaust gas temperature relatively high.

The latest generations of turbochargers with variable flow, e.g. the VTA (Variable Turbine Area) system from MAN Diesel, can replace the variable bypass and ensure, the same scavenge air pressure control.

Other low temperature precautions

Low ambient air temperature and low seawater temperature conditions come together. The cooling water inlet temperature to the lube oil cooler should not be lower than 10°C, as otherwise the viscosity of the oil in the cooler will be too high, and the heat transfer inadequate. This means that some of the cooling water should be recirculated to keep up the temperature.

Furthermore, to keep the lube oil viscosity low enough to ensure proper suction conditions in the lube oil pump, it may be advisable to install heating coils near the suction pipe in the lube oil bottom tank.

The following additional modifications of the standard design practice should be considered as well:

- Larger electric heaters for the cylinder lubricators or other cylinder oil ancillary equipment
- Cylinder oil pipes to be further heat traced/insulated
- Upgraded steam tracing of fuel oil pipes
- Increased preheater capacity for jacket water during standstill
- Different grades of lubricating oil for turbochargers
- Space heaters for electric motors
- Sea chests must be arranged so that blocking with ice is avoided.

Ships with ice class notation

For ships with the Finnish-Swedish ice class notation 1C, 1B, 1A and even 1A super or similar, all MAN B&W two-stroke diesel engines meet the ice class demands, i.e. there will be no changes to the main engines.

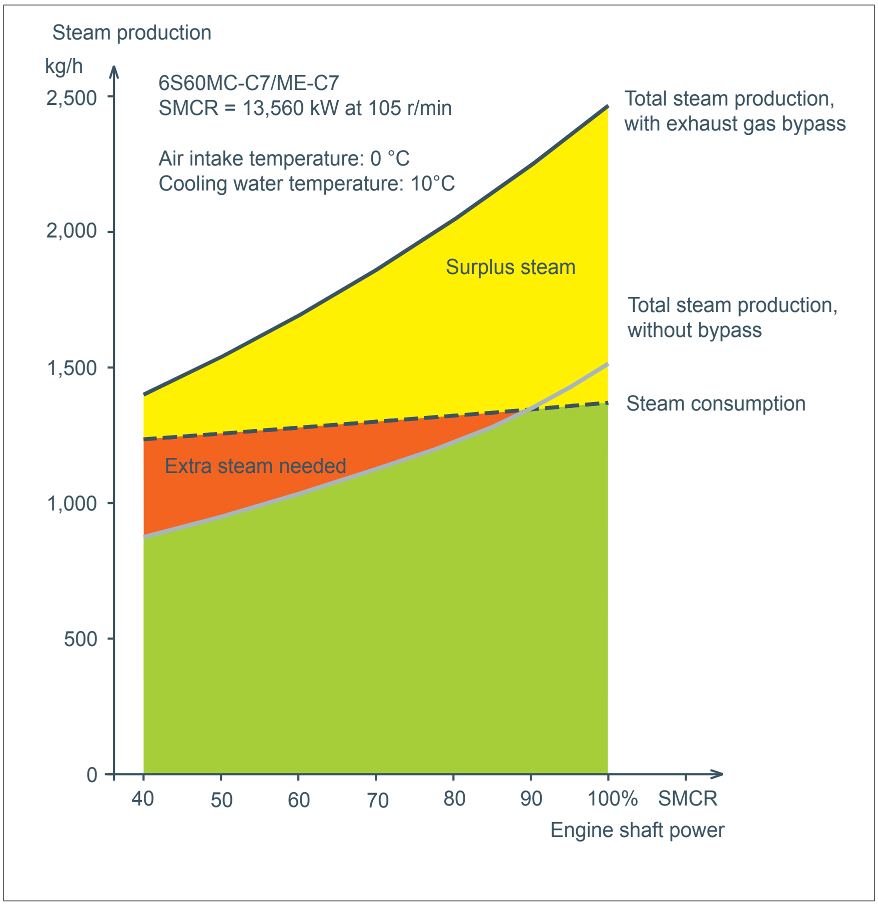

Fig. 5: Expected steam production by exhaust gas boiler at winter ambient conditions (0 °C air) for main engine 6S60MC-C7/ME-C7 with/without a load-dependent low air temperature exhaust gas bypass system

However, if the ship is with ice class notation 1A super and the main engine has to be reversed for going astern (Fixed Pitch Propeller), the starting air compressors must be able to charge the starting air receivers within half an hour, instead of one hour, i.e. the compressors must be the double in size compared to normal.

For other special ice class notations, the engines need to be checked individually.

The exhaust gas bypass system to be applied is independent of the ice classes, and only depends on how low the specified ambient air temperature is expected to be. However, if the ship is specified with a high ice class like 1A super, it is advisable to make preparations for, or install, an exhaust gas bypass system.

Increased steam production in wintertime

During normal operation at low ambient temperatures, the exhaust gas temperature after the turbochargers will decrease by about 1.6ºC for each 1.0ºC reduction of the intake air temperature. The load-dependent exhaust gas bypass system will ensure that the exhaust gas temperature after the turbochargers will fall by only about 0.3ºC per 1.0ºC drop in the intake air temperature, thus enabling the exhaust gas boiler to produce more steam under cold ambient temperature conditions.

Irrespective of whether a bypass system is installed or not, the exhaust gas boiler steam production at ISO ambient conditions (25ºC air and 25ºC C.W.) or higher ambient temperature conditions, will be the same, whereas in wintertime the steam production may be relatively increased, as the scavenge air pressure is controlled by the bypass valve.

As an example, Fig. 5 shows the influence of the load-dependent exhaust gas bypass system on the steam production when the engine is operated in wintertime, with an ambient air temperature of 0ºC and a scavenge air cooling water temperature of 10ºC.

The calculations have been made for a 6S60MC-C7/ME-C7 engine equipped with a high-efficiency turbocharger, i.e. having an exhaust gas temperature of 245ºC at SMCR and ISO ambient conditions.

Fig. 5 shows that in wintertime, it is questionable whether an engine without a bypass will meet the ship's steam demand for heating purposes (indicated for bulk carrier or tanker), whereas with a load-dependent exhaust gas bypass system, the engine can meet the steam demand.

Closing remarks

Diesel engines installed on ocean-going ships are exposed to different climatic temperature conditions because of the ship's trading pattern. Because the temperature variations on the sea surface are relatively limited, the engines will normally be able to operate worldwide in unrestricted service without any precautions being taken.

Even if the ship has to sail in very cold areas, the MAN B&W two-stroke engines can, as this paper illustrates, also operate under such conditions without any problems as long as some low temperature precautions are taken.

The use of the standard load-dependent low ambient air temperature exhaust gas bypass system may – as an additional benefit – also improve the exhaust gas heat utilisation when running at low ambient air temperatures.

Furthermore, at the other end of the temperature scale, if the ship should need to sail in unrestricted service in areas with very high ambient air temperatures, higher than 45°C, this will also be possible provided a high temperature matching of the engine is applied. Even when sailing should be needed at very high seawater temperatures, this will be possible provided a specially designed scavenge air cooler is installed on the diesel engine.

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