

# Wärtsilä R&D is responding to increasing concern about particulate emissions

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**Particulate emissions are assumed to be a contributory factor in causing asthma, allergies, and various other human health problems. In the marine industry, abatement remedy choices are limited due to the quality of the typical fuel used. At the same time, the measurement method currently applied by marine legislators, is not adequate to deal with residual fuels.**

Campaigners have often cited combustion sources, including diesel engines, as being contributory factors to ill health. In making this claim, they point to the increase in hospital admissions for bronchial infection and disease.

Studies have shown that smaller sized particulates show a stronger correlation between ambient concentrations and health symptoms than larger ones. Smaller particulates are considered more likely to penetrate deep into the human lung. The most minute of these particles may even move into the blood stream. The chemical composition of the particulate may significantly contribute to the biological effect. However, the real mechanism causing such adverse health effects remains unknown.

The particulate is made up of randomly agglomerated carbonaceous spherules, which build up into a highly branched three-dimensional structure. Various hydrocarbons, ash and sulphur compounds are all associated within this structure. Due to the complexity of the particulate, it is impossible to give a satisfactory general definition, since the characterization depends, to a large extent, on the measurement method used. It can be defined, for example, in terms of opacity, filter blackening, particle number, size or mass.

Due to increasing concern regarding

particulate emissions, and with tighter emission regulations anticipated, Wärtsilä is devoting a substantial part of its R&D activities to a better understanding of the subject. This work covers formation and size distributions, the influence of engine specification, environmental and biological effects, and other aspects relating to diesel particulate emissions.

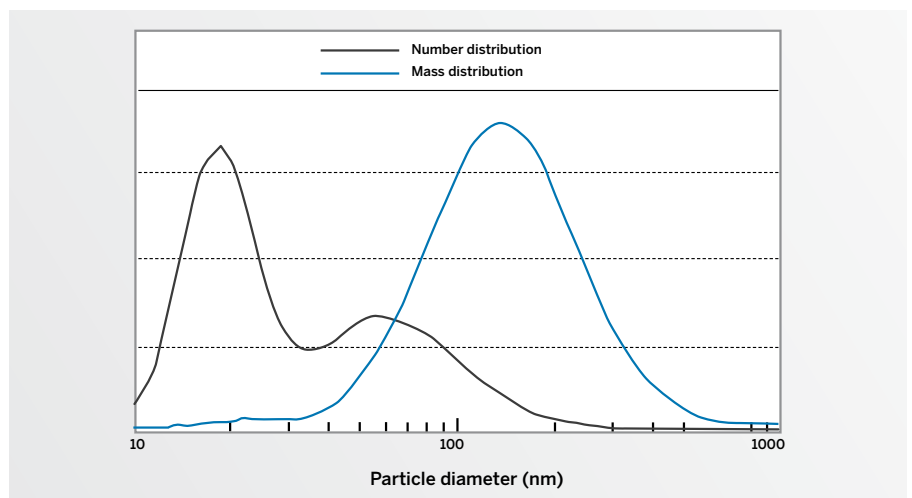
### Wärtsilä study

In a study carried out by Wärtsilä, presented at the International Council on Combustion Engines (CIMAC)

in Vienna, in May 2007, it was found that typically between 50 and 70% of the particulate composition consists of compounds that are related directly to the quality of residual fuel oil, i.e. the sulphur and ash content of the fuel, and cannot be reduced by improved combustion. Consequently, typically only about 30–50% of the particulate composition can be affected – thus even a significant improvement in engine combustion will not necessarily result in any major reduction of particulate emissions.

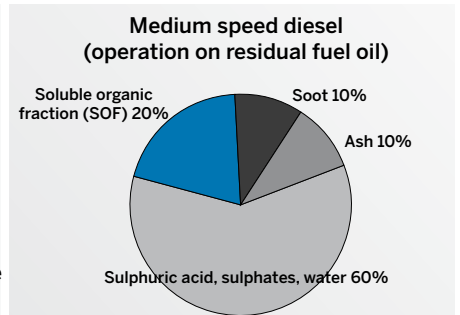
After formation inside the cylinder,

■ Fig. 1 – Example of simplified number and mass size distributions of particulates of diesel exhaust.



■ Fig. 2 – An example of typical exhaust particulate composition at high engine loads when operating on high sulphur residual fuel.

- Sulphuric acid, sulphates and water fraction – a result of sulphurous compounds in the fuel.
- Ash – a result of ash in fuel.
- Soluble Organic Fraction (SOF) and Soot – typically a result of incomplete combustion of fuel and lube oil.



the nanometre-sized primary particles coagulate to form larger particulates to which are attached, as the exhaust gas cools, hydrocarbons and sulphates.

Secondary particulates can be formed outside the engine combustion chamber as a result of the absorption and condensation processes. This means that the particulate composition and size distribution in the engine exhaust duct is completely different to that reaching the human respiratory tract.

**Particulate abatement**

The abatement measures for diesel particulates can be divided into three categories – the improvement of fuel and lube oil quality, improvement of the engine combustion process, and exhaust gas cleaning.

Examples of engine measures for improving combustion include advanced fuel injection properties, such as advanced rate shaping with common rail technology, and improved combustion chamber geometry including swirl and squish.

Traps and oxidation catalysts, used for

exhaust gas cleaning in truck engines, are unsuitable for use with residual fuel-operated big diesel engines, due to the high sulphur and ash content of the fuel.

For engines running on residual fuel, an Electrostatic Precipitator (ESP) is a viable option, but their size makes marine applications impractical. While exhaust gas scrubbers are potential options for the future, no demonstrated working solution for the onboard scrubbing of particulates, exists on the market today. The particulates reducing potential of scrubbers is still, therefore, unclear. However, Wärtsilä is currently evaluating such a technology with the aim of introducing it on the market.

**Common rail technology**

Wärtsilä has, nevertheless, already improved the combustion process of its marine diesel engines. Consequently, by improving the fuel injection properties as implemented in the company’s common rail fuel injection engine technology, particulate formation has been reduced, especially at low engine loads. Fuel rate

shaping, increased fuel injection pressure and advanced injection timing are all used.

Whatever methods are favoured by, or indeed available to the ship owner, particulate measurement systems are an inevitable legislative requirement. But there are various methods approved by various administrative bodies, and most of them have widely differing results. Often the results are not comparable, and the establishment of correlations between results is often impossible because emission regulations are based on different measurement methods. This is due to regulators defining particulates in different ways.

**Measurement challenges**

There are several direct measurement methods (without dilution), used for measuring particulates from all types of land-based stationary industrial sources, including diesel and gas engine power plants; the ISO 9096 method; the US-EPA Methods 17 and 5, and US-EPA Methods 201 and 202.

The ISO 8178 method (with dilution) is the standard applied to most marine emission regulations, although it should not be used together with high sulphur fuel.

According to ISO, the sulphur upper limit for application of this method (ISO 8178) is 0.8%, while according to CIMAC Recommendation (23/2005), the upper limit is 0.05%. The dilution conditions are crucial to the measurement result. Various dilution ratios and strategies, dilution air temperatures, and humidities can be used, and all affect the measurement result substantially. The reproducibility of measurement results with the ISO 8178 standard, when operating on typical marine fuels, is often poor. Furthermore, by an improper choice of the dilution and measurement settings within the permitted requirements of the standard, it is possible to manipulate the measurement results significantly. For achieving repeatable results, and enabling comparison of results with land-based stationary industrial sources, Wärtsilä recommends that direct measurement methods are used. ●

■ Table 1. – Means to reduce particulate emissions.

<b>Reduction of particulate soot fraction</b>
Increased fuel injection pressure and boost pressure
Optimized combustion chamber
<i>Common rail</i> with split injection/ multiple injection
Change to fuel quality with reduced content of aromatics and asphaltenes
<b>Reduction of soluble organic fraction (SOF)</b>
Faster rate of injection pressure decay at end of fuel injection
Reduction of leakages from turbocharger turbine seal, exhaust valve guides and fuel injection nozzles
<b>Reduction of particulate sulphuric acid/water fraction</b>
<i>Reduced fuel sulphur content</i>
Reduced lube oil sulphur content
Reduced lube oil consumption
<b>Reduction of particulate ash fraction</b>
<i>Reduced fuel ash content</i>
Reduced lube oil additives (containing ash components)
<b>Particulate exhaust cleaning</b>
Dry electrostatic precipitator (not applicable in marine installations)
Scrubber technology (particulates reducing potential is still unclear)