



Improving Heavy Fuel Oil Usage by Homogenization

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Due to improvements in the refining processes over the past 25 years, additional lighter distillate products are now produced from each barrel of crude oil. Thus, the residual oil (refinery waste) used for producing heavy fuel oil has undergone a dramatic change in quality, as well as quantity.

Today's heavy fuel oil contains a greater concentration of impurities including higher levels of asphaltenes, along with changes to other fuel properties such as density and viscosity. Also observed is an increased tendency toward incompatibility from overblending residual oil with distillate "cutter stock", resulting in excessive fuel sludge production. The fuel sludge created is primarily asphaltenes, which represent burnable hydrocarbons, and are normally removed by centrifugal purifiers and filters, for disposal at a high cost.

Through the use of fuel homogenization, fuel sludge reduction and improved combustion can be achieved, resulting in cost savings to the power plant operators. Fuel homogenization can also have a positive impact for reducing exhaust emissions and help achieve NO_x reduction.

Introduction

A sharp increase in the price of residual fuel has focused attention on scrutiny of purchasing and improving fuel-handling practices. With prices remaining at high levels, fuel buyers continue to shop for the best price, often sacrificing quality. But even when heavy fuel oil prices are at much lower levels, satisfactory quality is often not available.

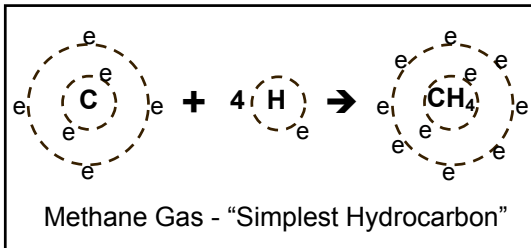
As a result of "take what you can get" fuel quality, an increasing percentage of heavy fuel supplied ends up as sludge, creating new problems and associated cost for its disposal.

Consider a diesel engine burning 40 tons per day of heavy fuel oil and producing one percent of fuel sludge. With today's high fuel prices and even higher disposal cost, the financial loss is in excess of US\$30,000 annually. Increase the sludge production for less efficient fuel handling systems, and the financial picture becomes even bleaker for these wasted hydrocarbons.

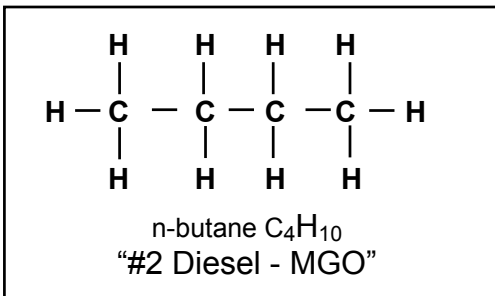
To better utilize today's heavy fuel oil and reduce wasted energy and disposal costs, fuel homogenization has been reintroduced as a cost-effective means to address today's fuel handling and combustion problems.

Chemistry of Hydrocarbons

Four hydrogen and one carbon atom naturally combine on a molecular level to produce a very stable fuel – Methane or “Natural gas” (CH_4). This fuel will vaporize and mix very well with oxygen, producing high-energy release (42,000Kcal/kg) when combusted and not leave any residue or ash deposits.

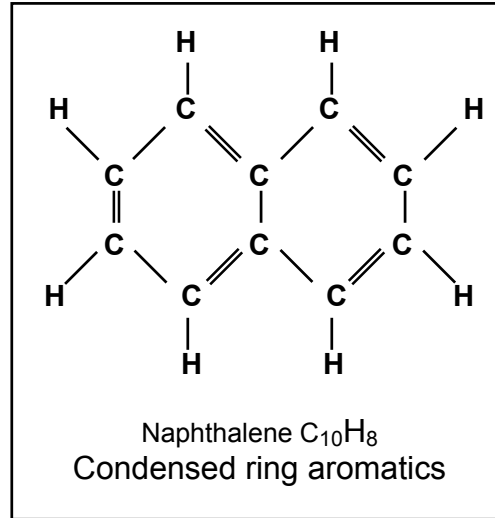


However, the crude oil used to produce commercial hydrocarbon fuels does not contain the 4:1 ratio of hydrogen-to-carbon necessary to refine all of it into methane gas. This allows impurities such as vanadium, sulphur, sodium and trace metals to combine both physically and chemically with the carbon atoms, which are not “saturated” with hydrogen.

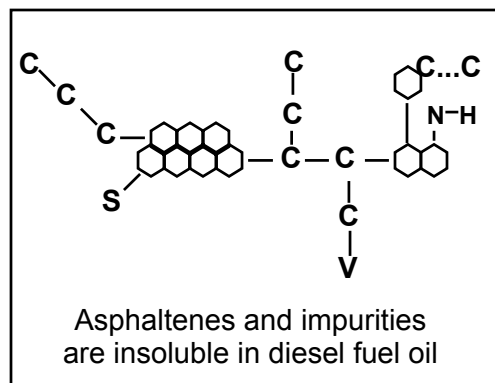


During the refining process, the lighter gases and distillate fuels are extracted from the crude oil. They contain higher hydrogen-to-carbon ratios, produce high-energy output and subsequently are sold at higher prices. What remains

after refining is the residual oil - rich in carbon and poor in hydrogen.



The impurities found naturally in the crude oil, physically and chemically combined with the carbon atoms, will also remain in the residual oil – the waste from the refinery. Attempts to remove them would be very expensive in comparison to the value of the residual oil; therefore, they remain in the refinery waste.

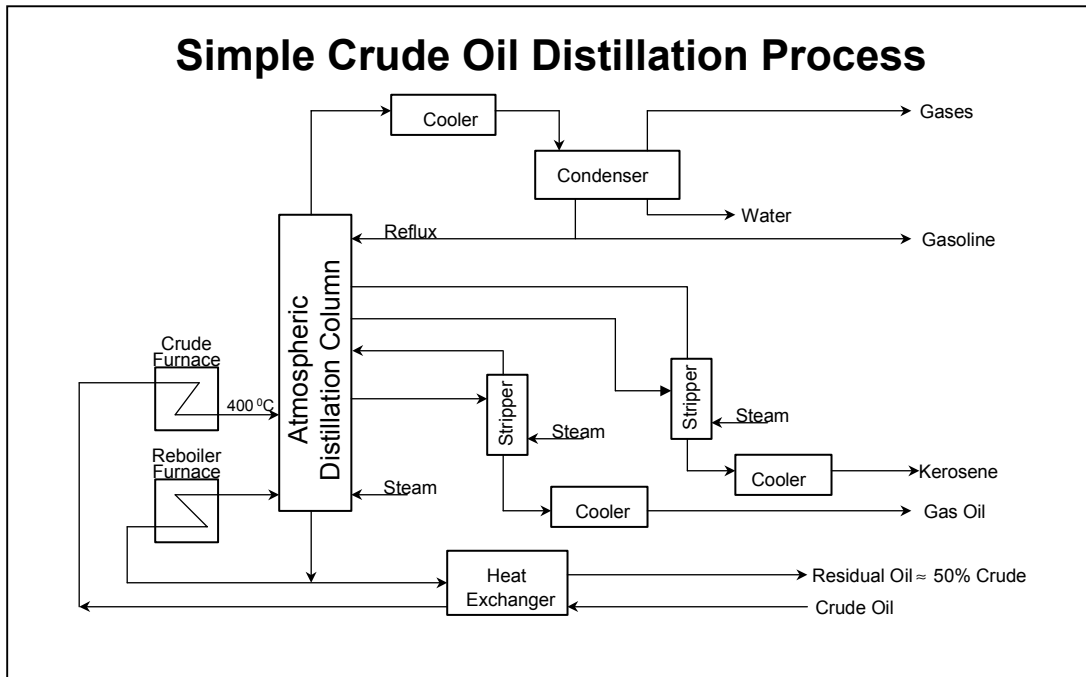


The dense carbon particles, known as asphaltene, are the cause of fuel sludge and incomplete combustion.

Fuel Problems – The Legacy of Modern Refining

Running diesel engines with “straight run” residual fuels, as was done in the 1960’s, was a relatively straightforward task. The fuel was received, stored, then purified and burned – normally without incident. Fuel related problems were rarely encountered. The “straight run” fuel of that day was of reasonable quality and well within the capabilities of the diesel engine or boiler to use.

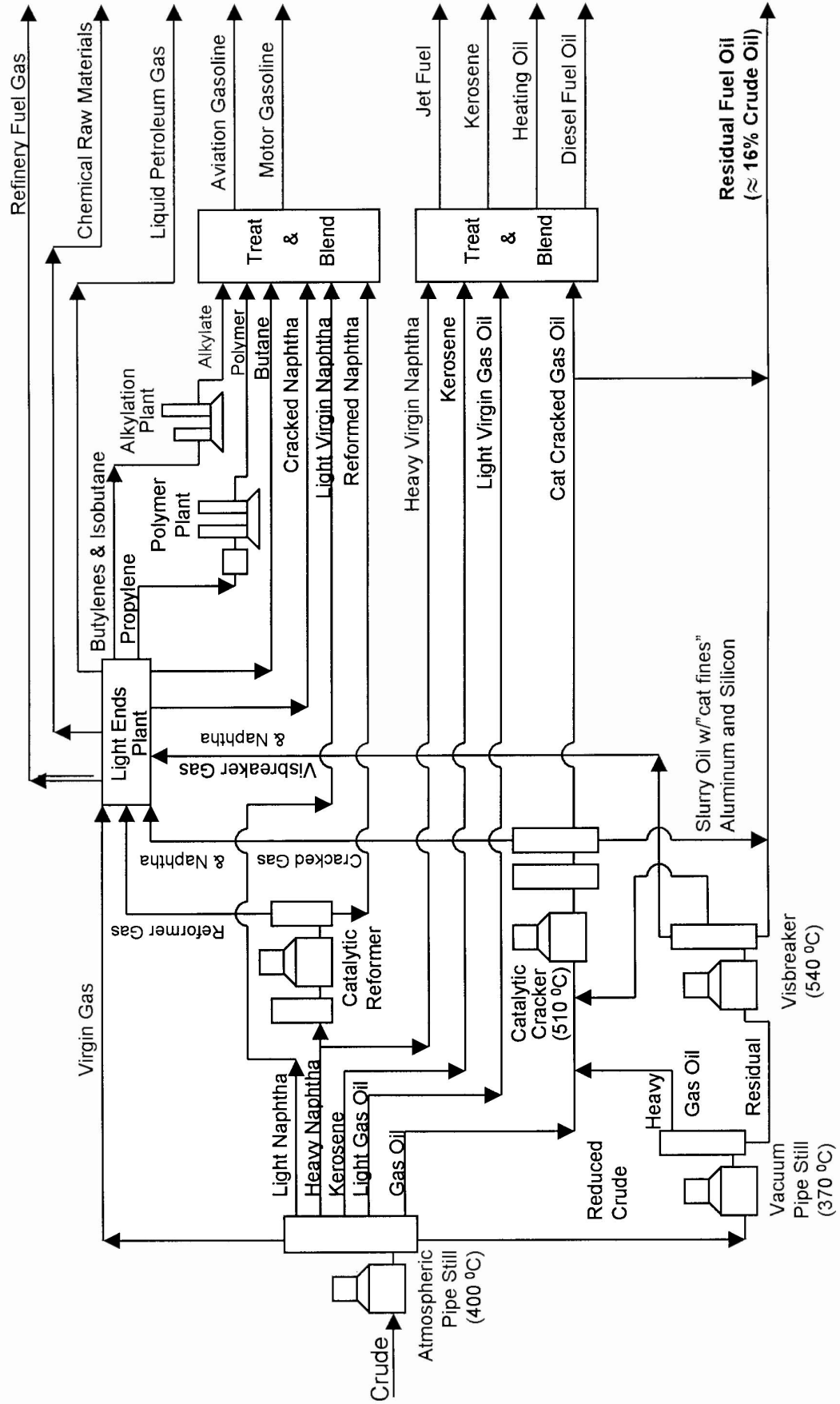
Unfortunately, due to the additional refining processes and the proliferation of these processes throughout refineries worldwide, the use of heavy fuel oil today has become a more technically challenging process. As the quality of residual fuel worsens, and more diesel engines use poorer quality fuel oil, so do the number of fuel handling and combustion problems increase.



The residual fuel oil that remained after atmospheric distillation equaled approximately 50 percent of the original barrel of crude oil that entered the refinery. These “straight run” residual fuels still contained sufficiently high levels of hydrogen to provide good combustion, along with lower concentrations of asphaltens and impurities, due to their dilution in the higher volume of oil.

Keeping pace with worldwide demand for gas, gas oil and middle distillates, the additional refining processes of vacuum distillation, visbreaking and catalytic cracking enable the refiner to “squeeze” more light end products from each barrel of crude oil. Today’s residual fuel oil equals approximately 16 percent of the pre-refined crude oil, and contains more concentrated levels of impurities.

Modern Crude Oil Distillation Processes



Effects of Modern Refining

The yield of residual fuel oil, per barrel of crude oil, has been reduced by more than 40 percent in the past twenty-five years. This has resulted in:

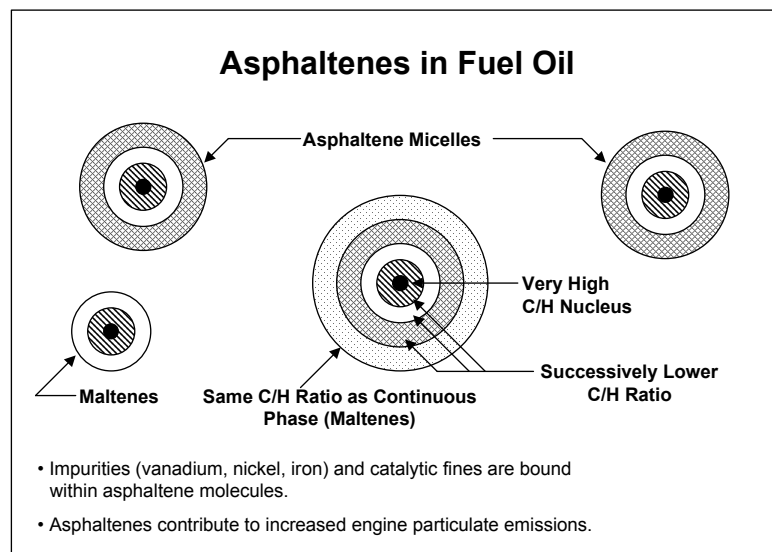
- Lower hydrogen content of the fuel.
- Increased concentration of sulphur, vanadium, sodium and trace metals found naturally in the crude oil.
- Increased density making water and impurities difficult to remove.
- Lower ignition quality resulting in increased ignition delay.
- Higher level of asphaltenes.
- Tendency toward incompatibility problems, resulting in precipitation of asphaltenes as fuel sludge.

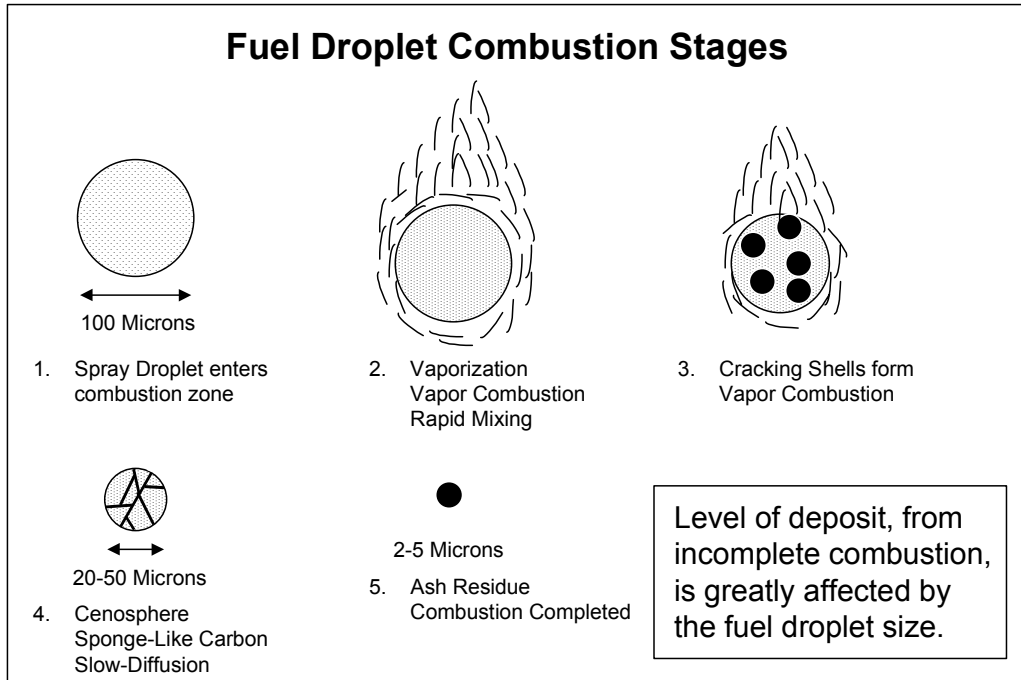
Collectively, improvements in the refining processes have reduced the quality of heavy fuel oil. This contributes to a wide range of fuel handling and performance problems, as well as the creation of undesirable combustion byproducts.

Sludge Build-up: Double the Waste

Fuel sludge is produced by the precipitation of suspended asphaltenes from the fuel. This occurs due to the high carbon content in heavy marine fuels, which is triggered by incompatibility caused by blending residual fuels with distillate fuel “cutter stocks” or two different fuels in the same tank. As the fuels are blended, the paraffinic fuel reduces the carbon/hydrogen ratio of the maltenes, and the asphaltenes become mutually attracted.

Excessive sludge builds up in storage tanks and is carried through the transfer system, where it can overload the purifier. The sludge is comprised primarily of asphaltenes as large as 120 microns, which cannot be burned in their present physical state. Additionally, when the sludge is removed by the purification system and disposed of as waste for a fee, the fuel is effectively paid for twice without any energy benefit to the engine or boiler operator.





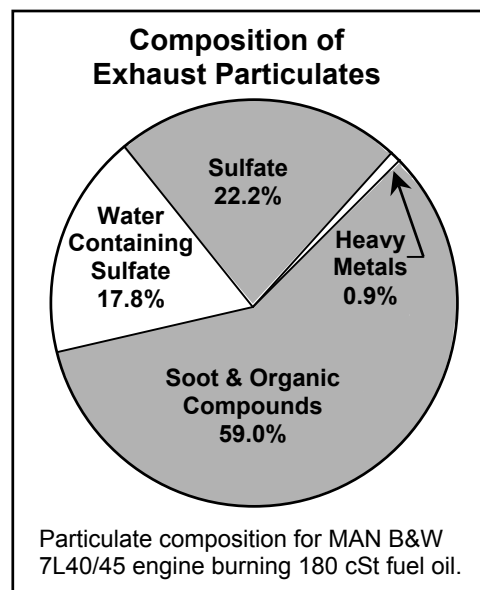
Incomplete combustion

Under ideal condition and through design improvements by diesel engine manufacturers, all hydrocarbon molecules in the injected fuel droplets will vaporize, mix with oxygen and burn completely. This is all expected to occur within a fraction of a second, leaving no residue or unwelcome byproducts. Fuels with high levels of asphaltenes and rich in carbon, however, are more difficult to burn.

Unevenly mixed in the fuel, asphaltenes create a non-homogenous fuel mixture. They contribute to viscometer fouling and “hunting”, causing inaccurate injection viscosity and a non-uniform spray pattern. In addition, large size fuel particles will not completely vaporize, leading to incomplete combustion

Incomplete combustion also produces high levels of particulates in the exhaust

gas, primarily unburned hydrocarbons, which contain varying levels of ash – vanadium, sodium and other trace metals. Deposits in the engine exhaust trunk and on turbocharger nozzle rings and rotor blades restrict exhaust gas flow and can lead to vibration and turbocharger damage.



Fuel Homogenization

To counteract the problems associated with today's heavy fuel oil, especially asphaltenes and fuel sludge, improved engine performance resulting from fuel homogenization has been reintroduced.

Fuel homogenization was initially introduced for boilers and diesel engines when fuel prices suddenly rose in the 1970's. Some operators installed fuel blenders, which included simple homogenization, for the purpose of onsite fuel blending of heavy fuel oil with distillate fuel oil. In doing so, operators were able to slightly reduce fuel costs, especially for the fuel burned in auxiliary engines. However, the high fuel prices and short supply eventually disappeared, and so did the need for onsite heavy fuel oil blending and homogenization.

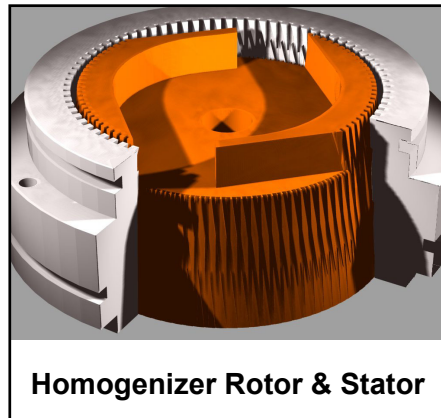
Renewed interest in heavy fuel oil homogenization has a different purpose in today's power generating industry. Although fuel prices have again risen during the past few years, fuel homogenization is now primarily focused on engine performance and reducing waste disposal costs.

Anatomy of the Homogenizer

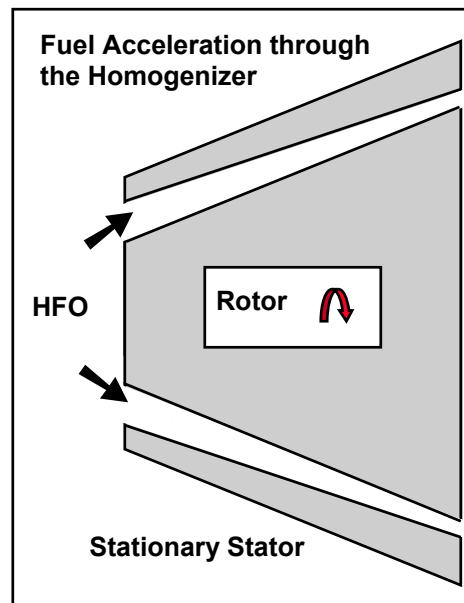
Today's performance-effective fuel homogenizer is essentially a milling machine that physically grinds the fuel as it is pumped through the unit.

Modern homogenizers often consist of a stationary stator housing with a motor-driven rotor, which is concentrically mounted inside the stator. The mating

surfaces of the rotor and stator have special channeled grinding surfaces.



The rotor and stator are often conical in shape, having a slightly different taper with respect to each other. This narrows the gap clearance between the rotor and stator where the fuel passes through, and is designed to accelerate the fuel as it passes through the unit.



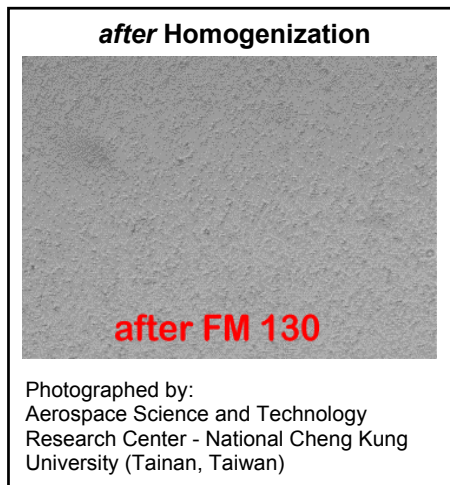
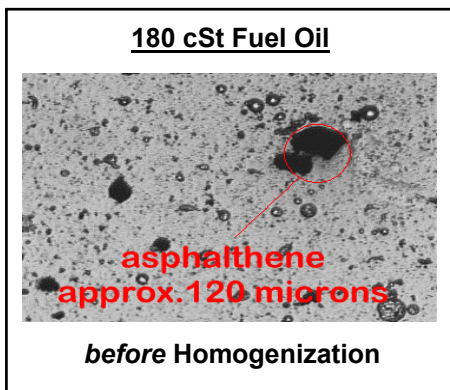
Although its appearance is similar to a pump, the homogenizer has no pumping capability. Therefore, flow through the unit must be provided by a pump installed in the system.

Cutting Asphaltenes Down to Size

During operation, at a speed of 1500 to 2000 rpm, the fuel passing through the homogenizer is exposed to hydro-dynamic power:

- Shearing and frictional forces
- Acceleration power
- High frequency ultrasonic waves

In combination, these forces act together to shear the asphaltene particles down to 3 to 5 microns. Smaller particle size allows the asphaltenes to be evenly blended with the heavy fuel oil, reducing sludge formation and associated waste disposal costs and yielding more burnable fuel.



Better Combustion Performance

Effectively homogenizing the heavy fuel oil improves in-line viscometer operation, reducing fouling by large carbon particles and “hunting” of the system. This will result in improved fuel injection, with finer fuel droplets and increased surface area. This allows better vaporization of the fuel, leading to improved and more complete combustion.

As combustion is improved and becomes more complete, the cenosphere – the leftover unburned core of the fuel droplet that cracks into coke – is much smaller. Thus, piston ring groove, exhaust trunk and turbocharger deposits are significantly reduced, along with associated maintenance costs and the potential for dangerous exhaust trunk fires.

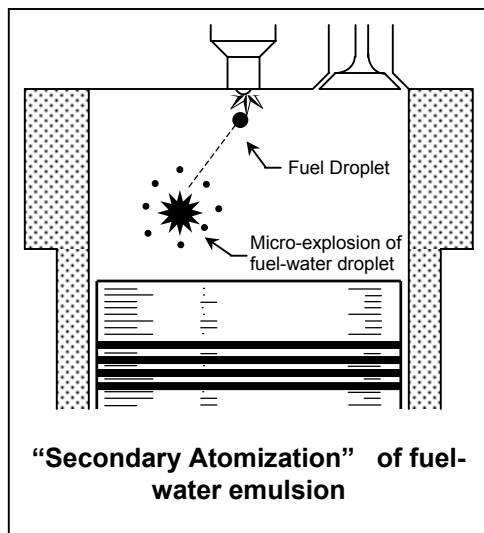
Reduced NOx Emissions

To achieve improved combustion, while reducing noxious exhaust emissions, smoke and NOx, some engine manufacturers have incorporated homogenization to produce fuel-water emulsification, as a component of their engine control package.

In the process, heated fresh water is introduced into the fuel handling system after fuel purification, creating a water-in-fuel emulsion. Injected into the engine cylinders, the mixture consists of water droplets coated with fuel. As the water at the center of the droplets flashes due to high temperature, creating a “secondary atomization”, the fuel coating the water explodes into smaller droplets.

This “secondary atomization” will,

- Increase the surface area of the injected fuel, improving the rate of vaporization,
- Absorption of heat by the vaporization of water will reduce peak combustion temperatures, and
- The resulting lower local ignition temperature and the reduction in partial pressure of oxygen present will reduce the formation of NO_x.



Multiple Applications

Multiple homogenizers are currently being installed onboard ships and in power stations, to address multiple fuel handling and combustion applications.

Sludge reduction – fitted for storage tank circulation or in the fuel transfer line, with reports of up to 2.5 percent more fuel available for the engine.

Improved combustion – fitted in the fuel line, commonly between the supply and circulating pumps. Claims of low engine wear rates, reduced smoke and reduced turbocharger maintenance.

Improved sludge burning – fitted in the waste oil system, with reports of improved blending of fuel sludge and waste oils with diesel fuel oil, for burning in incinerators and auxiliary boilers.

Conclusion

Residual fuel oil, the waste from the refinery, contains less energy and more impurities than 25 years ago. The quality of residual fuel oil may not continue to worsen any further, but no methods of improving it by the refiners can be seen on the horizon. So, engine and boiler operators need new tools to combat today’s poor quality fuels.

From both an economic and ecological point of view, fuel homogenization provides power plant operators a new opportunity to effectively burn today’s poor quality fuel oil, improving their financial picture by reducing fuel wastage, while simultaneously reducing harmful exhaust emissions, exhaust deposits and sludge disposal.

References:

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- (2) T. Lee, “The Performance of Mar-Tec Marine’s FUEL MILL™ Homogenizer”, Technical Report (1999)
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