SulNOxECO™

REPORT:

The SulNOxEco™ HFO Emulsion report

Prepared by Jimmy Redman Jnr, Scientific Officer of SulNOx Research & Development

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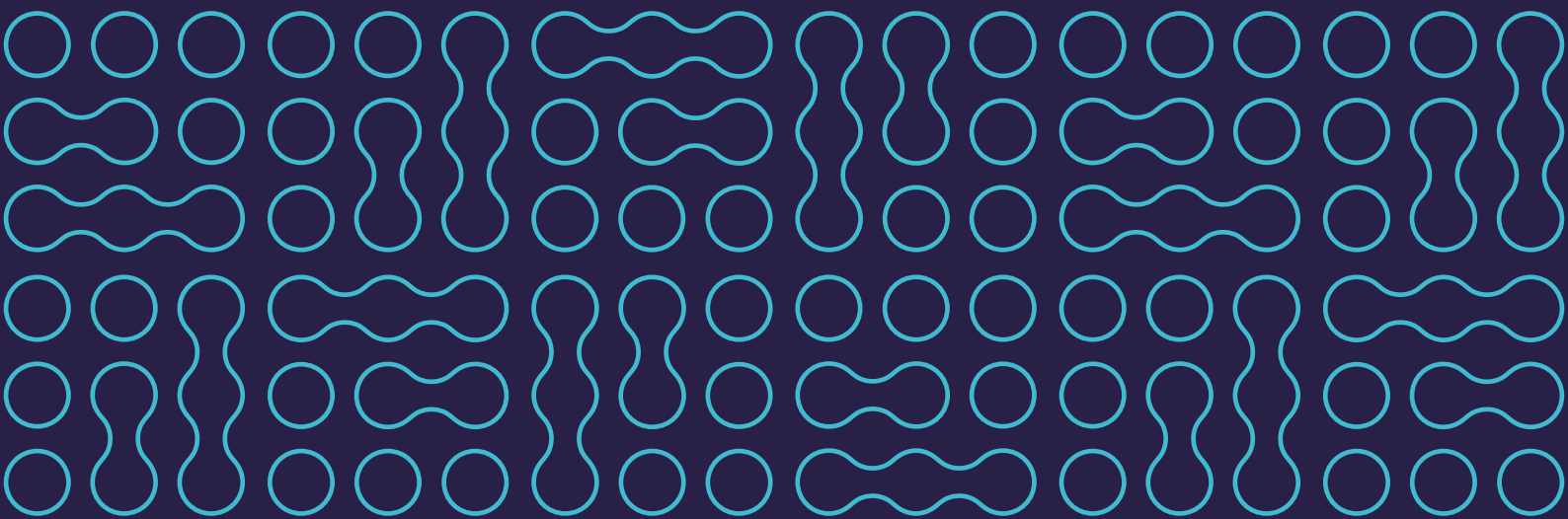

This report has been prepared by Jimmy Redman Jnr the Scientific Officer of SulNOx Research & Development and is the culmination of many thousands of hours of reading of the available academic papers from all corners of the globe and a lifetime formulating Fuel Emulsions.

What is the purpose of this report for users of Heavy Fuel Oil throughout our world?

To the scientists, chemists and engineering community it brings together many or all of the vital documents that have been written on Fuel Emulsions and Sulnox R&D has summarised what can be expected from SulNOxEco™ HFO Emulsion in our own words. All the answers to any further questions can be found in the Referenced works and we would encourage all of the world's experts to read these important papers in full as all the answers are there.

Having understood the science behind the SulNOxEco™ HFO product Appendices 1&2 show the "third party" trials and tests that have been undertaken to show that our formulation works in the real world.

Our message to the world's Heavy Fuel Oil users is clear - this proprietary product will be a vital part in reducing toxic emissions substantially and all users will actually save money in doing so.

For the non scientists amongst our audience, we at SulNOx Fuel Fusions plc offer you a guide to what this scientifically proven product can and will do.

The benefits of SulNOxEco™ HFO Emulsion in laymen's terms:

1. Major users of HFO have to heat it to well over 100C, to make it flow to the burners or engines and the costs of this process are staggering. We are told that between 12-20% of the HFO consumed is used in this process.

2. The toxic waste emissions from this extra HFO burning is substantial on a global scale.

3. In the SciMed/Sulnox/Hielscher trials and tests on The SulNOxEco™ HFO Emulsion, they showed that the product only needs to be heated to between 70-90C. One does not need to be an expert to see the enormous benefits that this will create. Less heating means less HFO used, which will save operators substantial sums of money and less HFO used will dramatically reduce toxic emissions.

4. The SGS Certificate tells us that using SulNOxEco™ HFO Emulsion reduces smoke & soot (particulate matter), NOx gases, sulphurous emissions and the acidity in the ash is almost eliminated. So if one uses 12-20% less HFO and what is burnt is dramatically less toxic, even the most non academic evaluation has to conclude that the use of this product must dramatically reduce "net emissions" and this is a huge step forward in the fight against global warming.

5. For at least 100 years' companies have been trying to mix water and fuel and most have failed. The Hielscher report shows, beyond doubt, that SulNOxEco™ HFO is stable at 30% water and will not break down. Put quite simply, this is of enormous global significance.

Conclusion

To the business world, our message is simple -

If you use SulNOxEco™ HFO Emulsion you will have to buy less fuel and that will offer you major financial savings.

If you burn less fuel you will reduce toxic emissions and The SulNOxEco™ HFO Emulsion that you do burn will be much less polluting than traditional HFO.

If we can offer SulNOxEco™ HFO Emulsion at around the same price as traditional HFO that would be truly exciting.

Stephen Bamford (Chairman & CEO)
On behalf of the SulNOx Fuel Fusions Plc. Board of Directors

Practical expectations and understanding the effects of using ultrasonically emulsified and stabilized fuel oil in burners

This report has been prepared by Jimmy Redman Jnr the Scientific Officer of SulNOx Research & Development.

Pre-Combustion Expectations

- **High quality, stable, homogenous emulsion**
  - Štimac et al. [1], describe how the effects provoked by ultrasonic cavitation cause chemical and structural changes of liquids under treatment, creating homogenous stable emulsions.
  - Hielscher Report, describes the creation of stable emulsions using ultrasonic cavitation.
- **Fine, evenly spaced water droplets in the emulsion with clustering prevented**
  - Štimac et al. [1], describe creating fine, high quality emulsions.
  - Gollahalli et al. [2], describe how the addition of external surfactant makes the water droplet size more uniform and prevents their clustering.
  - Sheng et al. [3], note that the emulsion needs to be fine and even.
- **No separation of water**
  - Štimac et al. [1], describe how under the influence of ultrasound it is possible to perform emulsification and homogenization of immiscible liquids in such a way that even after long time periods eventual component separation could be avoided.
  - Gollahalli et al. [2], describe emulsions of No.4 and No.6 oil prepared without external surfactant remaining stable for periods of several weeks.
- **Less sludge in storage tanks**
  - Poullikkas [4], describes the elimination of deposits in tanks.
- **Elimination of waste fuel heavy fraction sediments**
  - Štimac et al. [1], describe the use of waste fuel (heavy fractions) that has sedimented at the bottom of fuel tanks.
- **Clean fuel oil pipe and pump system**
  - Poullikkas [4], describes the cleaning and avoidance of deposits of sludge in the HFO system.
- **Reduced maintenance**
  - Poullikkas [4], describes the reduction in time for boiler maintenance, and the improvement in boiler maintenance working conditions. Deposits are soft and friable, non-corrosive and can be easily removed.
- **Ability to use lower grade heavy fuel oil**
  - Poullikkas [4], describes the potential to handle lower grade HFO with high content in asphaltenes, vanadium and sodium by additive.

- **Reduced Asphaltenes**
  - Mohapatra et al. [5], describe how sonication treatment results in the disintegration and solubilization of asphaltene flocs.
- **Reduced viscosity**
  - Poullikkas [4], Describes using additives to fluidize HFO, facilitating the flow along the pipes to the burner and eliminating filter blockages. This leads to increased e□ciency and reduction in maintenance.
  - Mohapatra et al. [5], describe how sonication treatment and the reduction of asphaltenes results in decrease in viscosity and shear stress.
- **Increased Calorimetric Value**
  - Štimac et al. [1], describe how the aim of ultrasonic emulsification is fuel fragmentation into small particles, mixed with water droplets, which easily evaporates explosively in the heat and tear apart heavy fuel oil clusters. The “consequence” of such effect is much better combustion with increase in calorimetric value.

Expectations During Combustion

- **Longer spray penetration**
  - Zhou [6], observed a higher velocity and longer spray penetration during the beginning of injection for emulsion. Penetration increased with water content.
- **Wider spray angle**
  - Zhou [6], observed a wider spray angle for emulsified fuel and its edge is blurred. The shape of the spray head is like a mushroom.
- **Micro-explosions**
  - Tarlet et al. [7], describe that the sudden and dramatic vaporizing of water leads to the disintegration of the whole emulsion droplet, cited as 0.2 ms. The unique and total disintegration of the emulsion droplet is generally observed with water droplets dispersed finely and uniformly enough inside the emulsion. Among combusting sprays, this disintegration into smaller and faster droplets of pure heavy fuel oil is called the secondary atomization.
  - Shinjo et al. [8], describe the interaction between multiple fuel emulsion droplets increasing the degree of breakup.
- **Finer atomization**
  - Zhou [6], observed that for emulsified fuel, after the spray breaks up, its head is less dense and more air is combined with the spray.
  - Tarlet et al. [7], describe how in comparison with a combusting spray of pure heavy fuel oil, an example of subsequent decrease in the Sauter Mean Diameter is 50%, enabling a larger interface area between air and fuel.
  - Sheng et al. [3], observed that the higher water percentage helps the injector to get finer fuel droplets and give the spray more initial momentum to improve the air fuel mixing process.

- **Better spray droplet size** distribution
  - Zhou [6], observed that as water content increases, the number of middle sized droplets increases, so the droplet size diameter in emulsified fuel is “more” homogenous.
- **Brighter flame**
  - Gollahalli et al. [2], describe flames turning brighter with emulsification with water.
  - Fu [9], describes a cleaner , shorter, bushier, brighter flame when changing to emulsified fuel.
- **Wider flame**
  - Sheng et al. [3], observed that the angle and the area of the emulsion flame are larger than for the pure fuel, the edge of the emulsion flame is unclear and irregular. This phenomenon can be regarded as the macro effect of the micro-explosion.
- **Flame base lifted from spray nozzle**
  - Zhou [6], describes long ignition delay leading to an increase of fuel/air mixture amount ready for combustion which further results in an increased heat release ratio at the beginning, of the combustion which is useful for shortening the combustion period.
  - Tuttle et al. [10], describe the lifting of the flame base away from the burner nozzle due to ignition delay.
- **Reduced combustion temperature**
  - Štimac et al. [1], describe how the evaporation of emulsified water reduces the combustion temperature.
- **Good temperature distribution**
  - Poullikkas [4], describes the use of additives in fuel oil to prevent conversion of SO2 produced by combustion of sulphur, into SO3. Such elimination means elimination of the sulphuric acid from the cold parts of heating plants. In this way, appreciable lowering of the dew point is achieved, allowing greater utilisation of the heat, since the fumes can leave the air heater at lower temperatures without causing LT corrosion.
- **Improved heat transfer**
  - Fu [9], describes improves heat transfer due to cleaner boiler heat transfer surfaces.
- **Improved combustion**
  - Štimac et al. [1], describe how the evaporation of emulsified water and ensures better “contact” of the fuel droplets with oxygen, which enhances the combustion.
  - Gollahalli et al. [2], describe how the emulsification of fuel, and the addition of surfactant, both improve the combustion efficiency.
  - Poullikkas [4], describes improved combustion by additive.
  - Zhou [6], describes that for emulsified fuel the increase in friction force between fuel and gas causes an increase in turbulence strength at the surface of the spray, results in more gas being involved in the fuel spray. This makes the head of the spray wider and less dense than that of pure fuel. These phenomena are favorable in the formation of fuel/air mixture and improves engine combustion processes.

- Siva Balan et al. [11], describe that the combustion of emulsion droplets is accompanied by micro-explosion which is not common to the combustion of pure fuel droplets. The micro-explosion of the primary droplet is followed by secondary atomization, producing a number of secondary droplets of a fine size that can evaporate very quickly. The violent disintegration produces the momentum to disperse the fine secondary droplets into a large physical volume and consequently enhances the fuel–air mixture in the combustion field. This result in improvement of the combustion efficiency and helps suppress the formation of soot and unburned hydrocarbons.

- **More complete burn of fuel**
  - Zhou [6], describes micro-explosions of fuel drops leading to much finer atomization and very thorough mixing of air and fuel. This allows complete combustion with much less air and a reduction in soot production.

- **Better thermal efficiency**
  - Poullikkas [4], describes better thermal efficiency.
  - Kutty et al. [12], describe the use of less excess air improving boiler efficiency.

- **Less demand for excess air**
  - Gollahalli et al. [2], describe that in practical application, all studies agree that excess air needed for combustion can be decreased by emulsification of residual fuels.
  - Poullikkas [4], describes reduction of forced draught fan, and induced draught fan power.
  - Kutty et al. [12], describe reduced levels of excess air significantly reducing SO3 generation and subsequently reduced corrosion.

- **Reduce fuel costs**
  - Štimac et al. [1], describe how the ultrasonic homogenization of water into heavy fuel oil emulsions enable better quality of combustion, increase of calorimetric value of prepared emulsion and reduce fuel costs.
  - Poullikkas [4], describes a gain in fuel consumption by reduction of exit gas temperature, due to a better combustion, less deposits on high temperature zone, reduction in steam requirements of steam air heater and reduction of forced draught fan and induced draught fan power because of reduced boiler gas side resistance.

Expectations Post Combustion

- **Less Fireside and high temperature and low temperature corrosion**
  - Poullikkas [4], describes the potential for high temperature corrosion and tube wastage is virtually eliminated, and a reduction in corrosion and blockage in the low temperature zone of air filters and fans.
  - Kutty et al. [12], describe the use of additives to reduce fireside corrosion in the high temperature zone of boilers and superheaters, as well as the low temperature zone of air heaters and economizers.

- **Improved fireside cleanliness**
  - Gollahalli et al. [2], describe increased fireside cleanliness in practice when the heavy fuels are emulsified with water.
- **Lower exit gas temperature**
  - Poullikkas [4], describes reduced exit gas temperature.
- **Improved characteristics of exhaust gas**
  - Štimac et al. [1], describe how the ultrasonic homogenization of water into heavy fuel oil emulsions enable better quality of combustion and improve characteristics of exhaust gasses.
- **Less soot**
  - Štimac et al. [1], describe describe how the ultrasonic homogenization of water into heavy fuel oil emulsions enable better quality of combustion with reduced soot.
  - Gollahalli et al. [2], describe that emulsification of No4 and No6 oils with water decreases soot liberation markedly.
  - Poullikkas [4], describes reduced blockage of air filters and fans.
  - Zhou [6], describes that good fuel atomization, better air/fuel mixing and reduction in large droplets result in a better fuel combustion process, hence a reduction in soot formation.
- **Less high and low temperature deposits**
  - Fu [9], describes cleaner boiler heat transfer surfaces.
- **Less fouling**
  - Kutty et al. [12], describe the use of additives to reduce tube fouling.
- **Reduced frequency of boiler washing**
  - Poulikkas [4], describes an improvement in boiler cleaning requirements.
- **Less SOx**
  - Poullikkas [4], describes a reduction in SO3 and consequently, acid smut emission.
  - Kutty et al. [12], describe lower levels of excess air leading to significant decrease in SO3 generation.
- **Increased boiler availability**
  - Poullikkas [4], describes improvement in boiler availability, boiler cleaning requirements, improvement in boiler maintenance conditions, and a reduction in time for boiler maintenance, eg. annual overhaul time for furnace inspection, cleaning etc.
- **Less NOx**
  - Štimac et al. [1], describe how the ultrasonic homogenization of water into heavy fuel oil emulsions enable better quality of combustion and reduced NOx.
  - Gollahalli et al. [2], describe how the emulsification of fuel, and the addition of surfactant, both reduce NOx.
  - Poullikkas [4], describes reduction of NOx emissions by additive.
  - Zhou [6], describes that lowered combustion temperature produces a significant reduction in NOx.

Literature:

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