Emulsified Fuels: Improved Combustion of Heavy Oils & Emission Control for Sustainable Fuels

Helping to save the planet - one drop at a time

At MEPEC 2011
by
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Outline

- **Biodiesel in Engines**
  - Emission impact of Biodiesel and Biodiesel blends in light of emission norms
  - Emulsified Biodiesel as solution for disadvantages of combusting neat biodiesel

- **Heavy Fuel Oil in Furnaces**
  - Increased heavies content and contamination in tanks or during distribution
  - Traditional approaches for effectively combusting heavier oil
  - Emulsified fuels for improved efficiencies, lower emissions and cleaner operations

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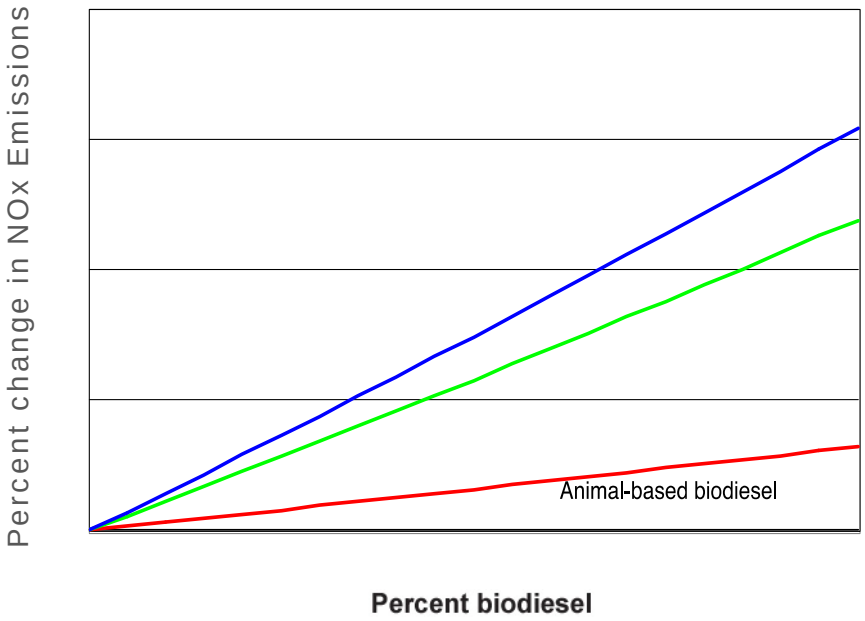
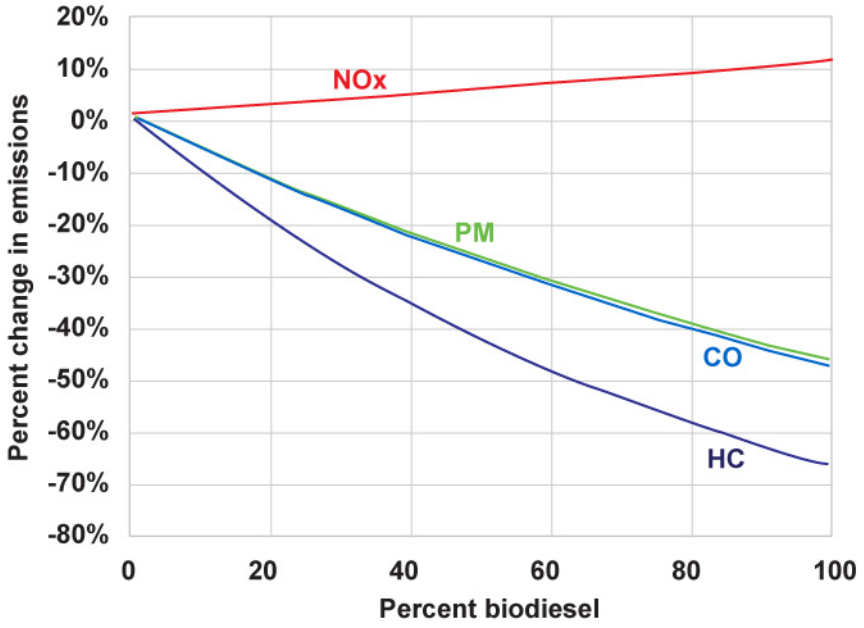
Biodiesel Emissions

- **Biodiesel can be made from a wide variety of bio-fuel feedstock as well as a range of biodiesel-diesel contents depending on its intended use.**





- **There is however the problem of elevated NO_X emissions from biodiesel, exemplified in this EPA graph showing NO_X increasing with the concentration of biofuel.**

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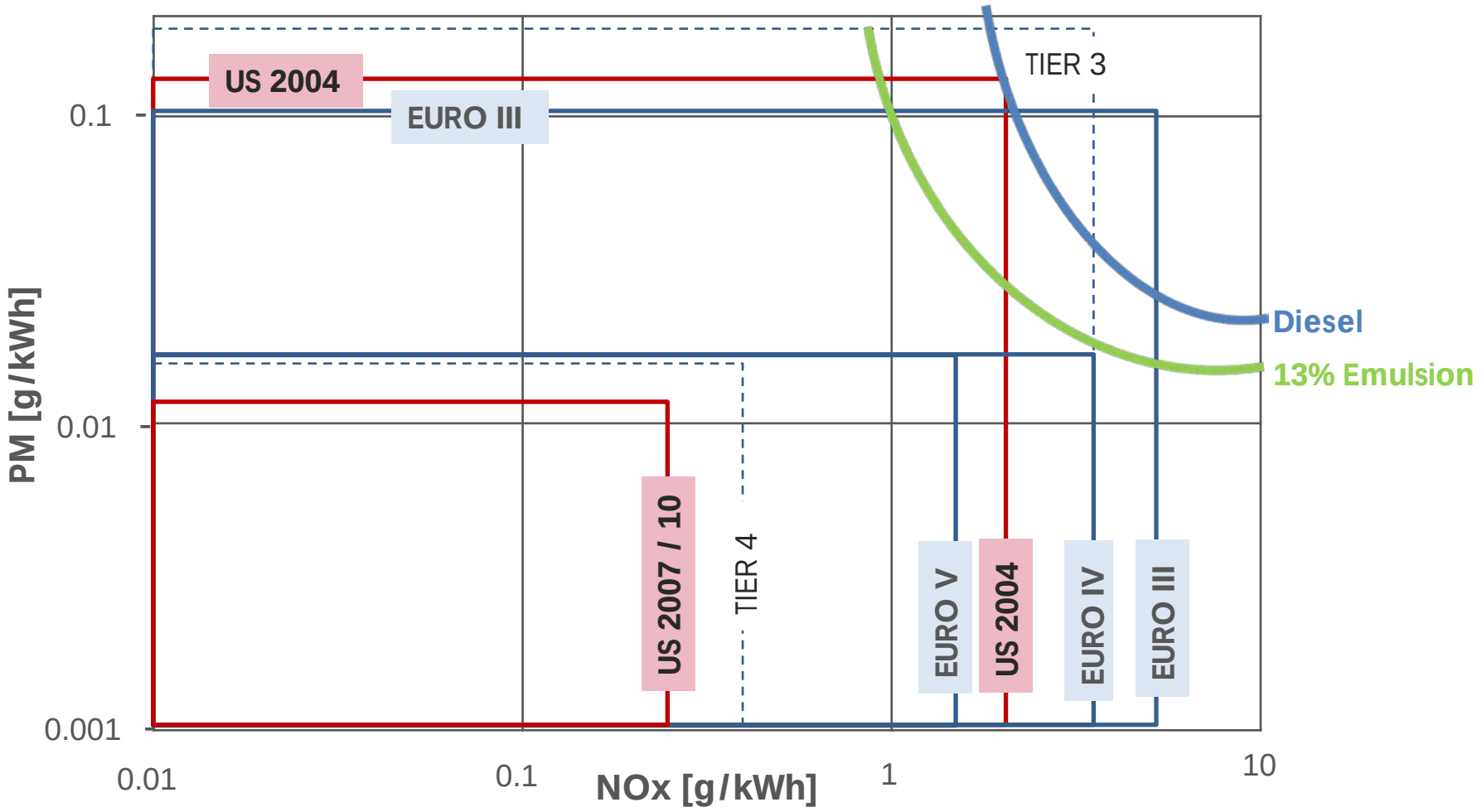
NO_X – PM Trade off and Emissions Standards for HD Engines



Reference: SAE 2003-01-3146. Influence of Water-Diesel Emulsions and EGR on Combustion and Exhaust Emissions of Heavy Duty DI-Diesel Engines equipped with Common-Rail Injection System. Bertola, A; Li, R, Boulouchos, K.

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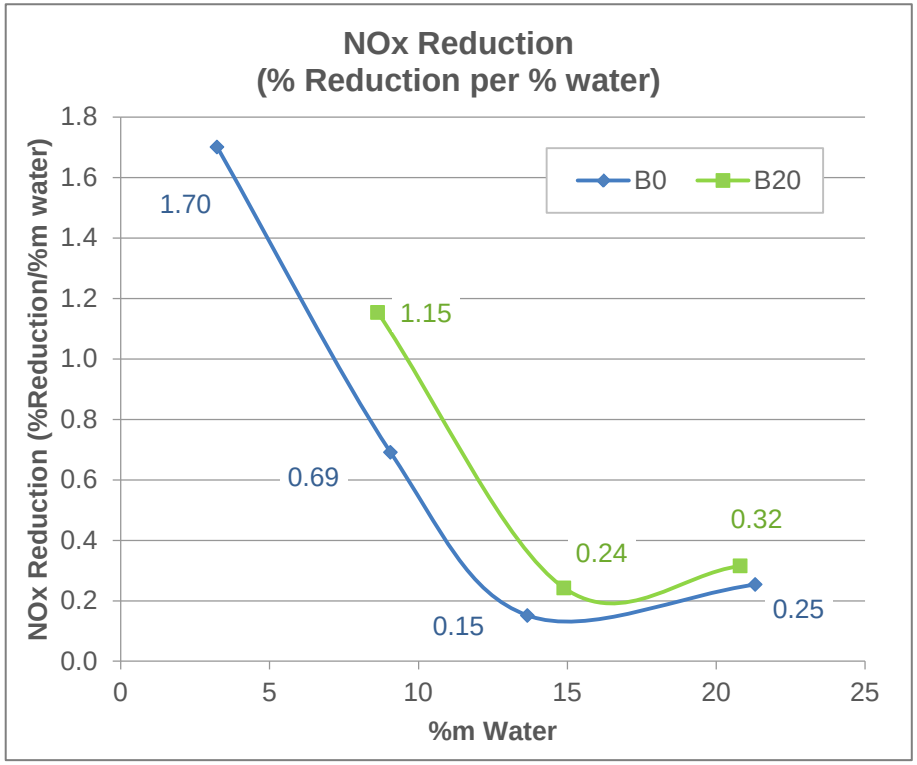
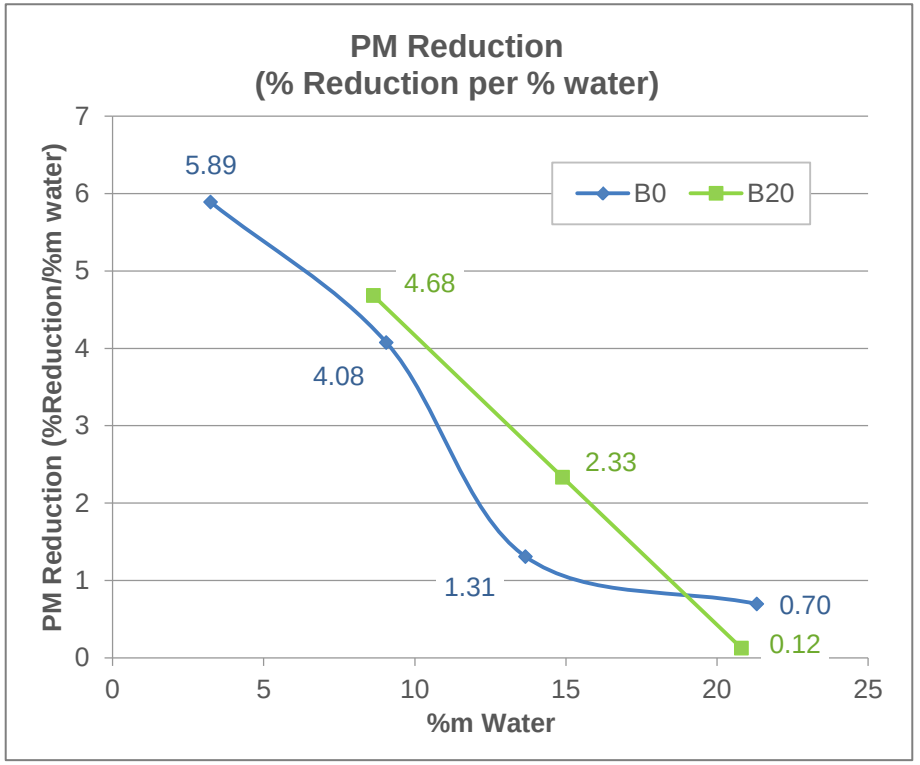
Rate of change in PM and NO_x

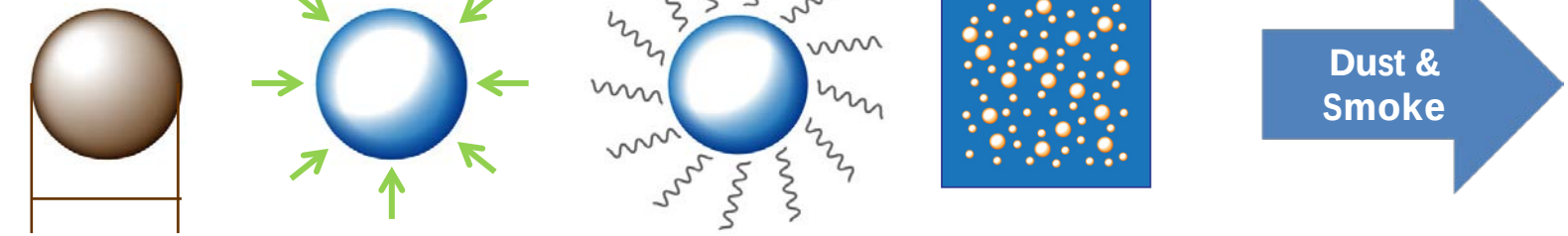
- **The rule of thumb is that for every 1% water NOx is reduced by 1% and PM by 2%. In fact the value of a percent of water is far greater at low water content for both diesel (B0) and B20.**





Efficient Combustion in Furnaces

- **Requires -**
  - Atomization – combustion time
  - Fuel-Air ratio – turbulence and mixing
  - Flame temperature



Dust is generated when oil is vaporized but not combined with oxygen

Small carbon particles which are incompletely combusted, gather up and become smoke, etc.

Heavy Fuel Oil: Quality Standards

	Parameters/Properties	Units	IS-1593 max	FO sample	Recent Trends
i.	CCR (residual carbon)	% mass	4.0 max	16.11	↑
ii.	Asphaltene / tar content	% mass	-	6.8	↑
iii.	Moisture Content	% mass	1 max	0.29	Contamination
iv.	Sediment	% mass	0.25 max	0.03	↑
v.	Viscosity @50 degree	cSt	250 max	204.3	-
vi.	Viscosity @90 degree C	cSt	-	36.6	-
viii.	Sulphur content	% mass	4.5 max	3.5	-
ix.	Density (@ 15 deg C)	g/cc	-	0.9761	↑
x.	Gross Calorific Value	cal/g	-	10820	-

Recent years have seen deteriorating quality of furnace oil

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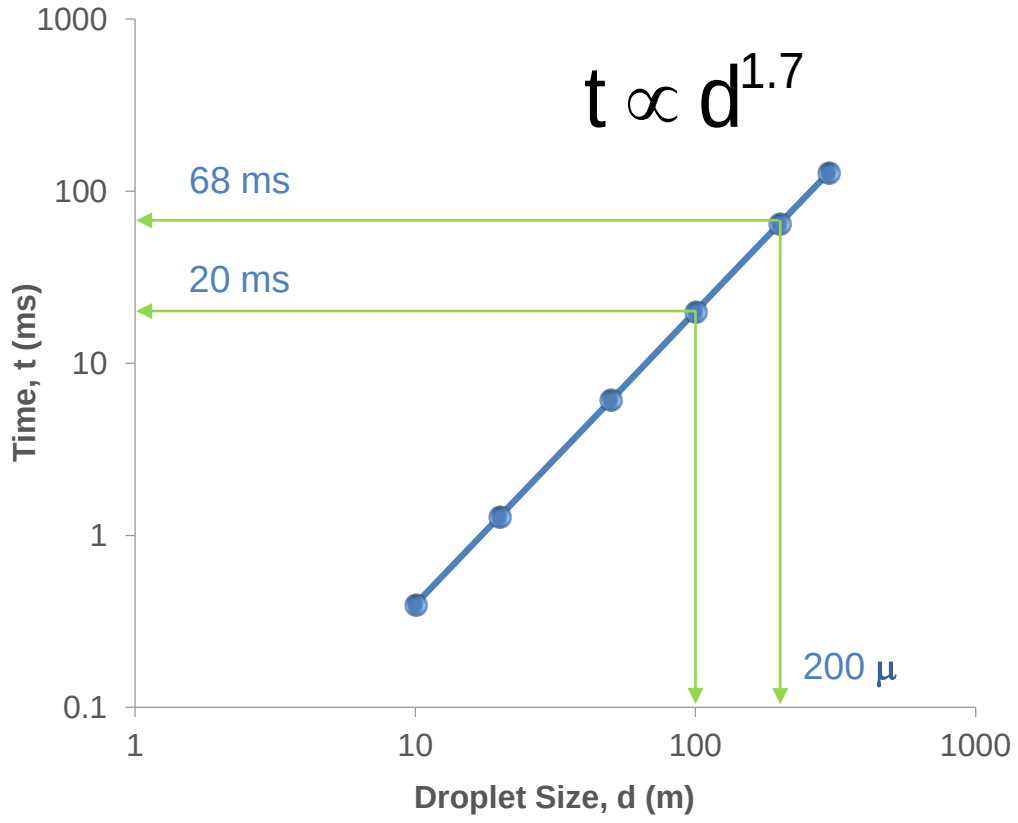
Impact of Heavies

- **Higher viscosity – Affects fuel atomization and hence larger fuel droplets**



INSUFFICIENT TIME & higher un-burnt residues and increased fouling

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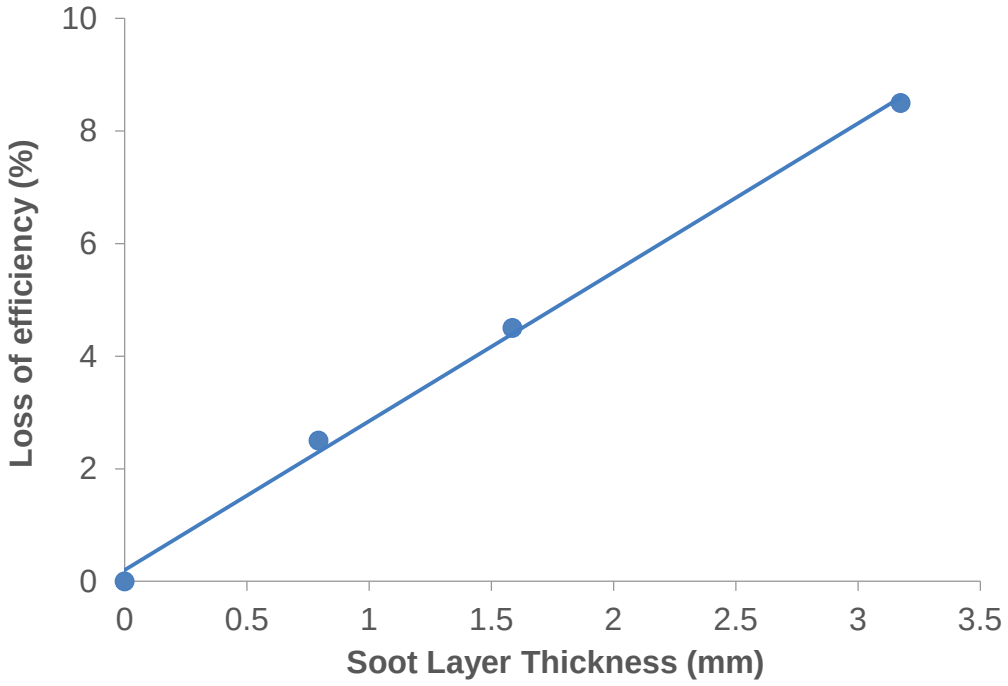
Incomplete Combustion

- Complete combustion needs sufficient Time, Temperature, and Turbulence
- Heavier components such as Asphaltenes, etc. are more viscous and require higher combustion temperature
- Un-burnt carbon and dust accumulate as slag and lead to fouling of boiler furnace and tubes and performance deterioration



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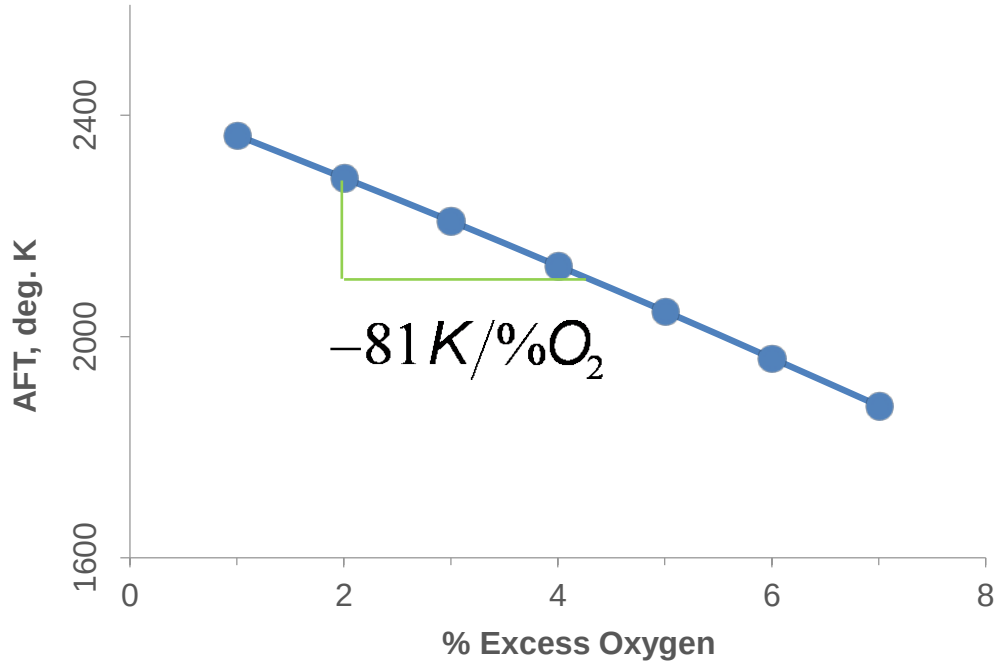
Higher Excess Air

- To avoid incomplete combustion and un-burnt carbon residue, users operate at high excess air for better mixing and TURBLUENCE
- Lower flame temperature and high stack losses impact efficiency



- Water in oil emulsions aid problems arising due to incomplete combustion

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Emulsified Fuels – O/W and W/O

- **Emulsion Fuels are not new. When two immiscible fluids, oil and water are sheared together in the presence of a surfactant additive, a stable emulsion can be produced.**

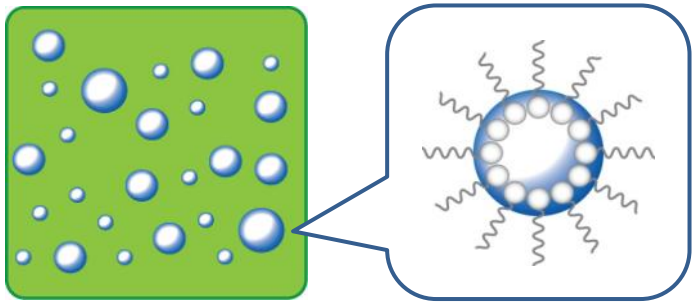
Water

+

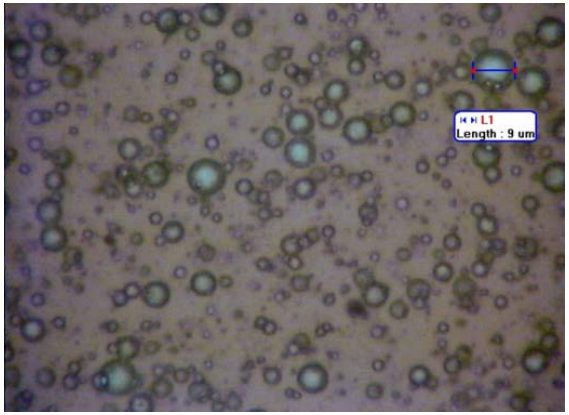
Fuel

Additive
High Shear

You need (1) enough energy and (2) good chemistry.



Water in OIL



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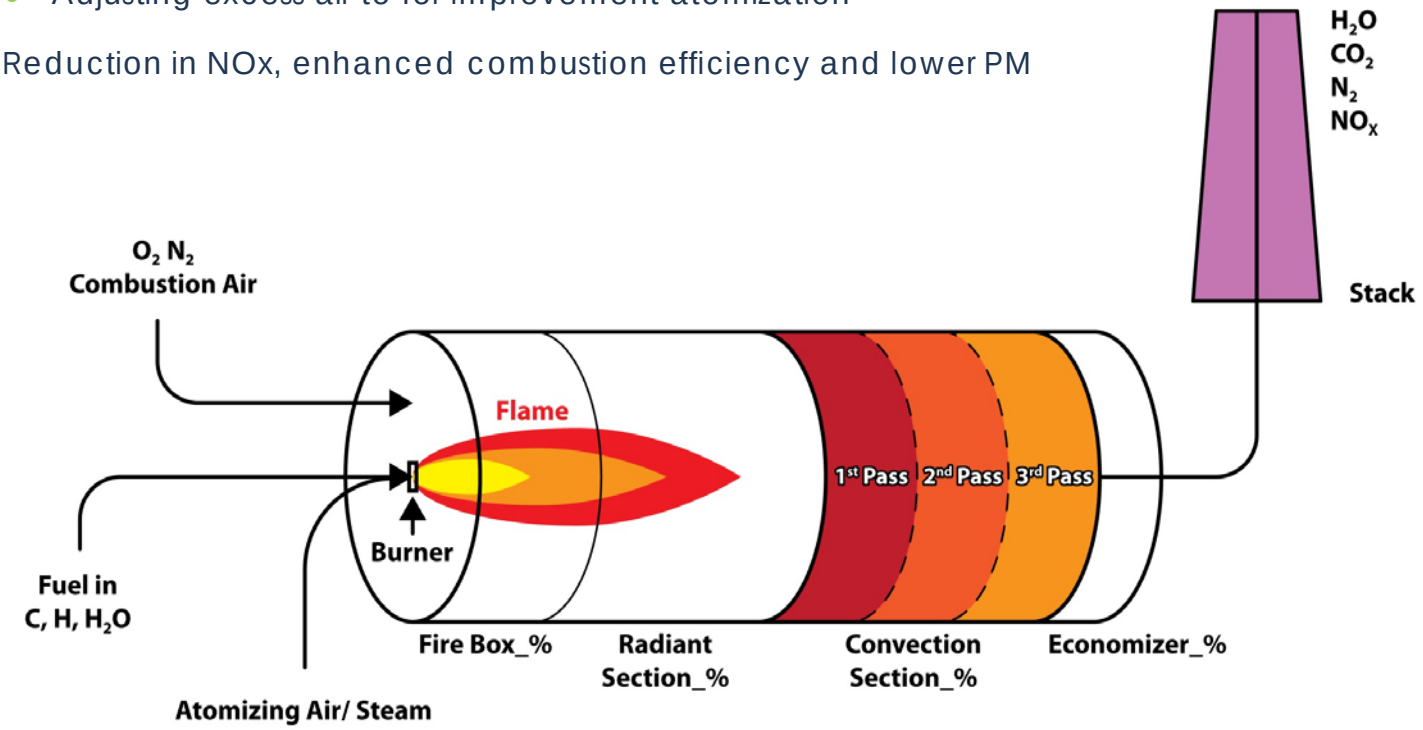
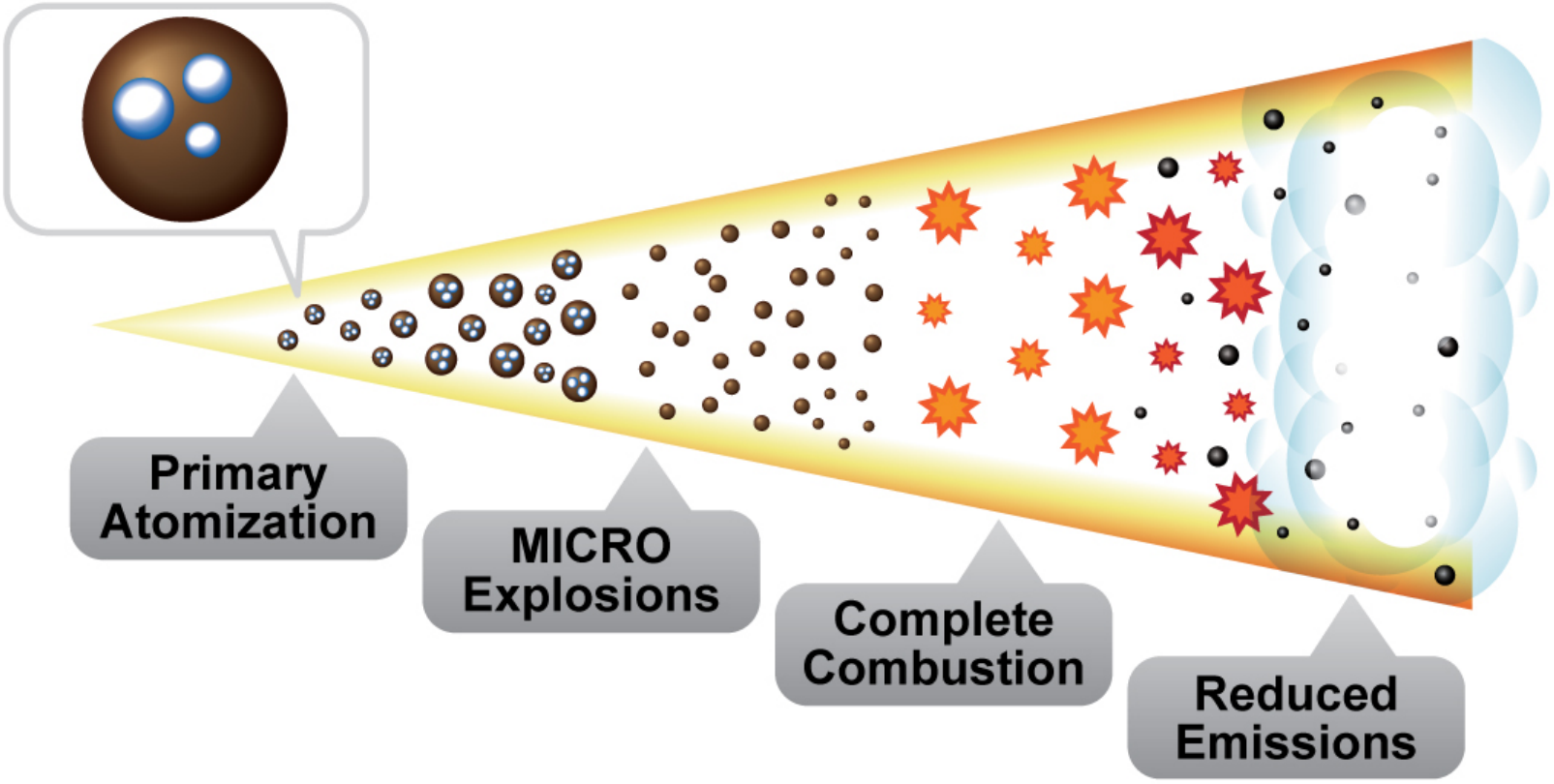
Emulsified Fuel Benefits

- **Modifications to boilers**
  - No modifications are necessary
  - Protocols for “fuel switching” involve:
    - Ensuring storage and recirculation temperatures don’t exceed 100C; and
    - Adjusting excess air to for improvement atomization
  - Reduction in NOx, enhanced combustion efficiency and lower PM



Emulsified Fuel Combustion

- Micron sized droplets of water initiate secondary atomization and fuel is shattered to fine and turbulent mist of smaller droplets in air
- Improved turbulent mixing and virtually eliminates smoke



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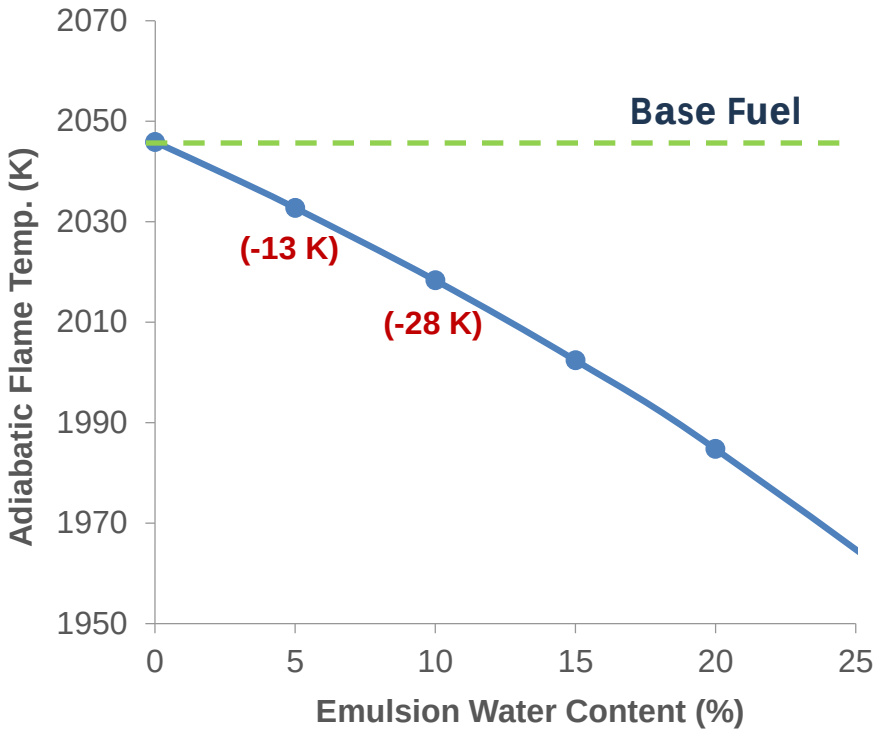
Impact on Flame Temperature

- **At 10% water in oil:**
  - Theoretical flame temperature (AFT) reduced by 0.65 %



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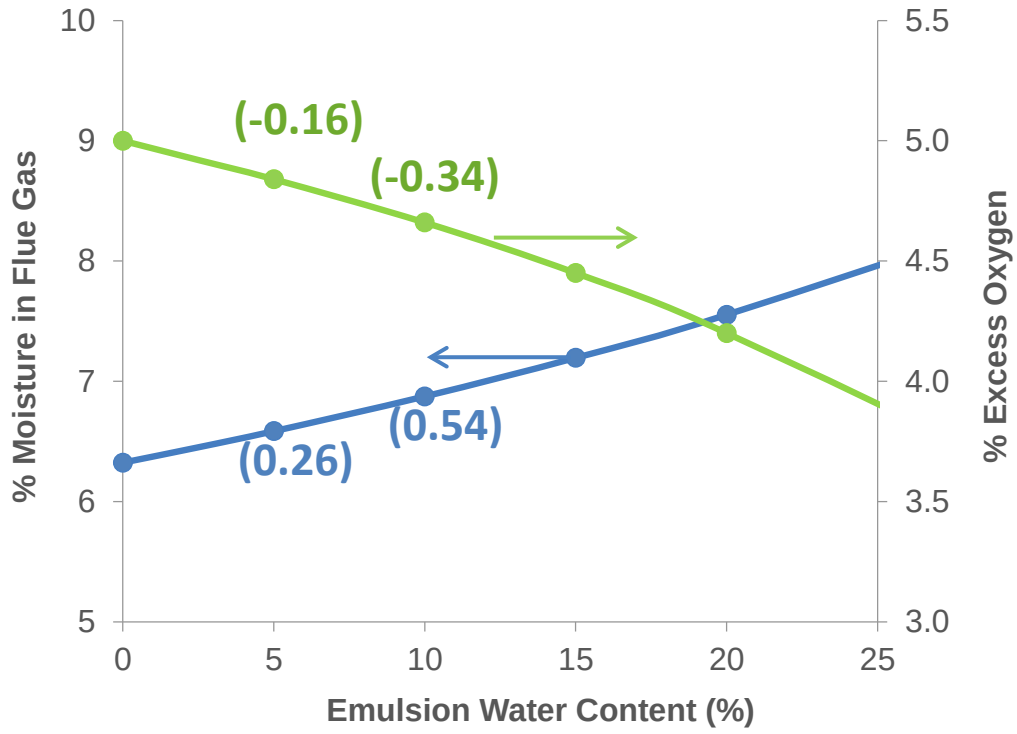
Reduced Combustion Air

- **10% water in oil is commensurate to**
  - Small increase in water content of flue gas stream (by 8.5 %)
- **Low excess air levels are possible with emulsions**
  - Small trimming of excess air (6.8 %) is sufficient to off-set temperature reduction due to water



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Impact on Combustion and Heat Transfer

- **Relative contributions of**
  - added water in fuel and
  - reduced excess air
- **impact following parameters and hence the heat transfer dynamics:**

Parameter	Water Addition	Air Reduction	Combined
Flame T	↓	↑	↑
Flame Emissivity	↑	↑	↑
Radiation Heat	↓	↑	↑
Reynolds No	↑	↓	-
Prandtl No	↓	↑	-
Heat Transfer Coefficient	↑	↓	-
Un-burnt HC	↑	↑	↑
Efficiency	↓	↑	↑

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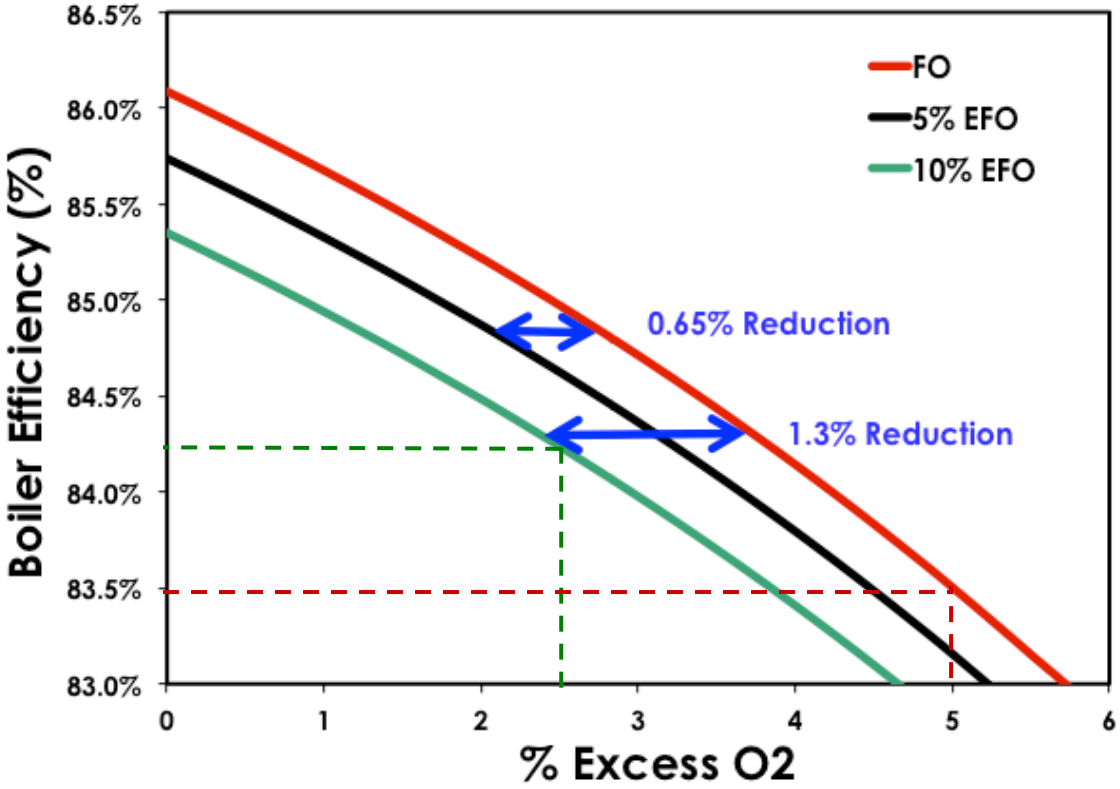
Boiler Efficiency

- While efficiency increases with lesser excess oxygen, For every % water, efficiency is reduced by 0.13%



- Efficiency will increase by switching from base fuel operation at 5% to 2.5% excess oxygen efficiency increases from 83.5% to 84.3%
- With scope for further increase through even lower excess O_2 and improved combustion

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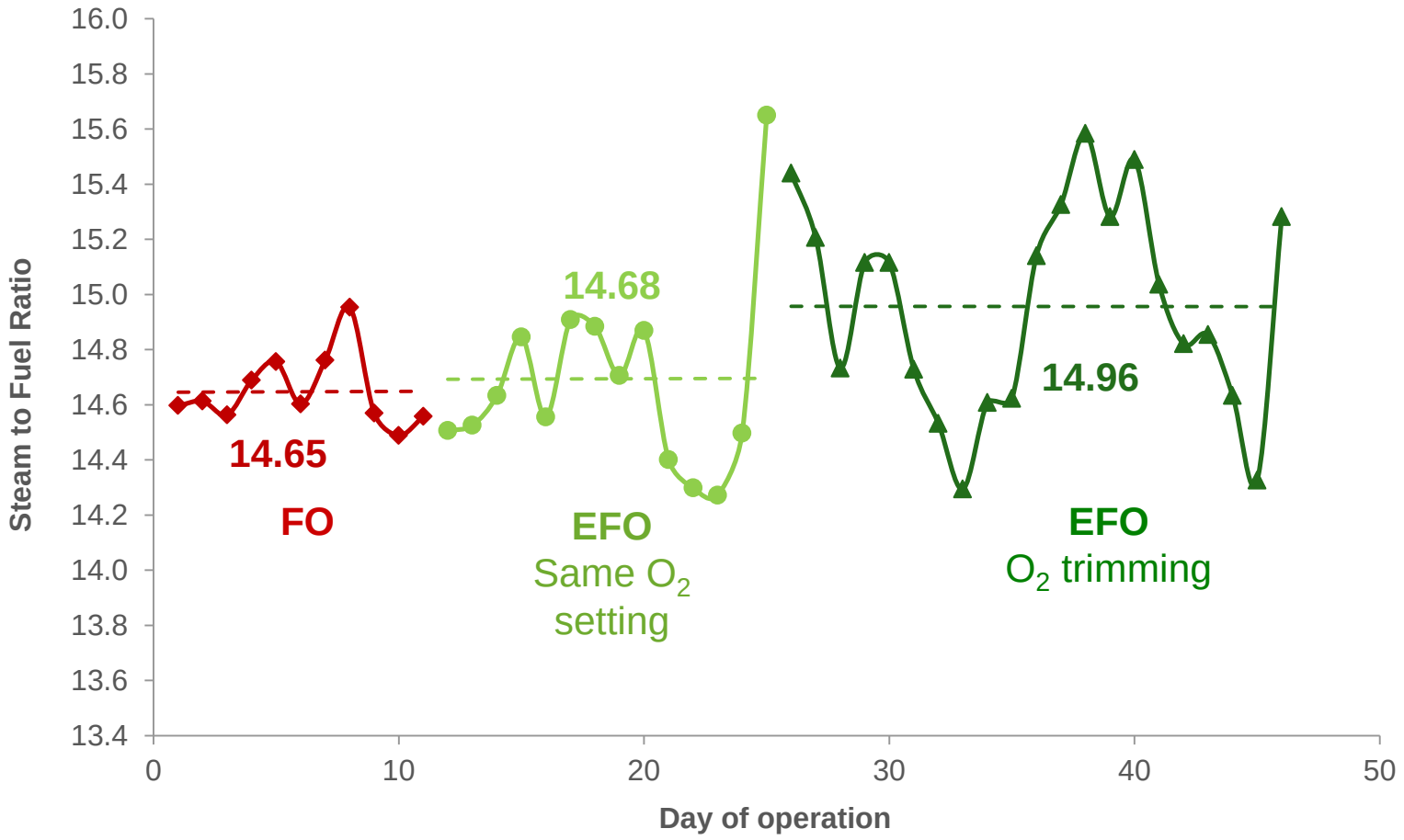
Field Test: Steam to Fuel Ratio

- **Performance of emulsified fuel oil shows improvement over baseline fuel oil**



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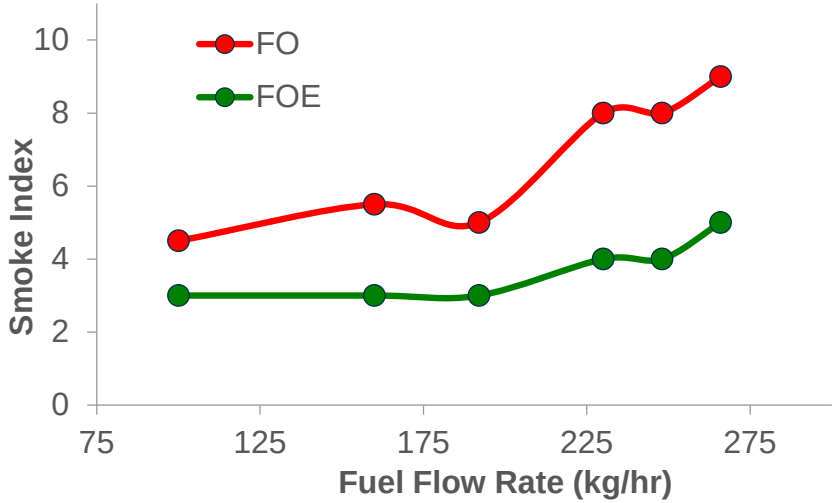
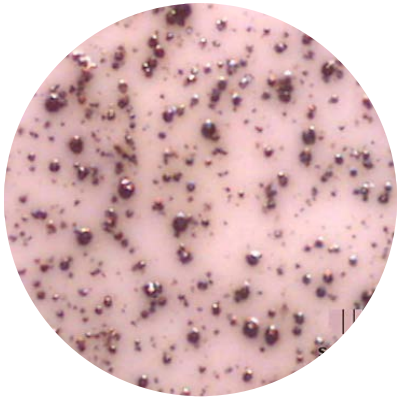
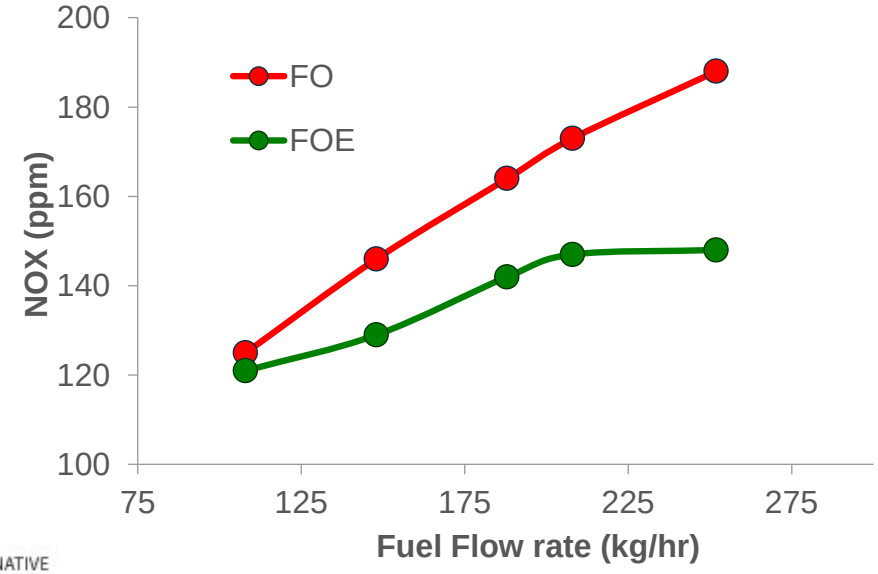
Lower Soot and Reduced Fouling



with #6 FO (60X)





with FOE (60X)

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Summary

	FO	FOE	FOE + Trim
% Improvement		0.2%	2.1%
Predicted		-1.0%	1.0%
Smoke Index	6.0	3.0	3.5
Soot Collection	12 kg / week	-	2.4 kg / week

1 Week FO firing

1 Week FOE firing

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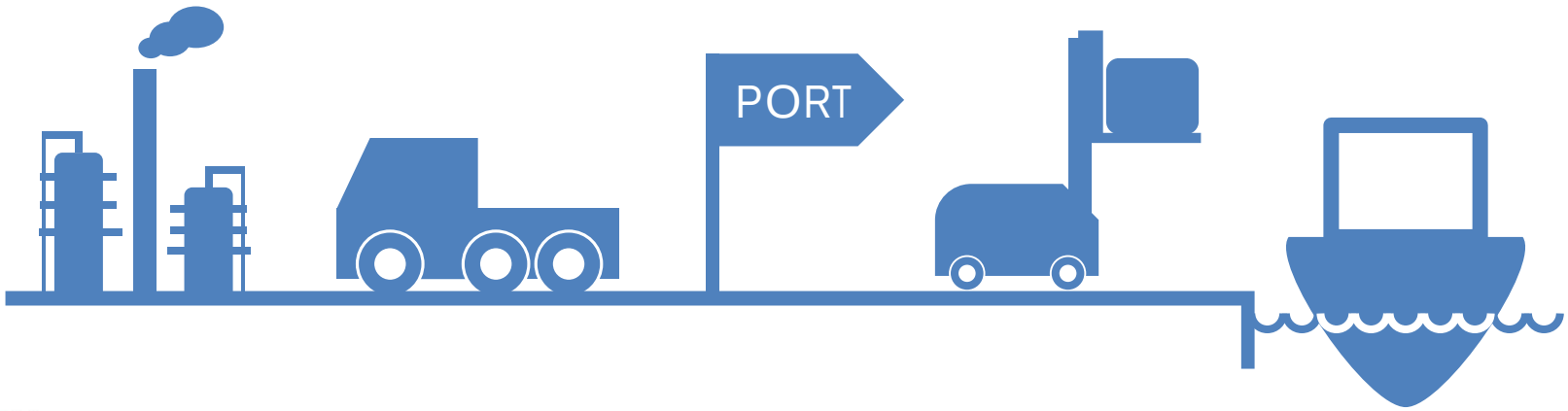
Emulsion Fuels: Summary & Benefits

- **The improved combustion efficiency offered by Emulsion Fuels leads to the following benefits (both in Engines and Boilers):**
  - Fuel economy;
  - Emissions Reductions;
  - Reduced Engine / Boiler maintenance.
- **These benefits have been illustrated:**
  1. Marine power generation
  2. Port Terminals
  3. Industrial Boilers



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