

Representative Studies Demonstrating Safety and Efficacy of TFA Products and Technology

In general, all TFA products must pass two types of tests. Are they safe? (safe for the environment; safe for fuels and combustion equipment; and are they also compliant and safe for use with other modern emission reduction technology systems) Are they effective?*

The schedule below notes representative studies that demonstrate TFA products' safety and efficacy. We have organized these data in two groups ... Trials and Dyno Testing Results (generally prove efficacy), and Third Party Standard Tests and Certifications (generally prove safety).

* we further highlight that TFA products have undergone continuous improvement; current generation of products provide greater benefits than earlier products

Trials and Dyno Testing Results

1996 – 2005 Gas Turbines, So. Korea

- 12, 104 MW turbines at major power plant
- 4, 104 MW turbines at major refinery power plant
- 3, 42 MW turbines at major electronics plant
- 1, 150 MW turbine at major power plant

Significant reduction in particulate matter (PM) was measured. “Before” and “after” PM results were documented, where gas turbines operated on low-sulfur residual fuels. Average PM measurements without catalyst (“before”) were $>160 \text{ mg/M}^3$ (whereas the Korean Government requirement for PM was $<40 \text{ mg/M}^3$). *PM measured with catalyst (“after”) were in the 12.4 to 14.4 range, in compliance with the Korean Government requirements.* Use of the catalyst brought down PM well below the required 40 mg/M^3 threshold (it is noteworthy that since PM is also correlated with unreacted fuel, a reduction in PM indicates a reduction in wasted fuel ... or an improvement in the thermodynamic efficiency of combustion of the gas turbines).

2002 Automotive Research Association of India (ARAI)

ARAI Road Tests on passenger car with small diesel engine

- 16% reduction in fuel consumption during city trials
- 18% reduction in fuel consumption during highway trials

Third Party Standard Tests and Certifications

ASTM D975 at major US third party lab

- no physico-chemical changes in ultra-low sulfur Diesel

ASTM D665a at major US third party lab

- no rust formation in ultra-low sulfur Diesel

ASTM D6079 (HFRR lubricity) at major US third party lab

- products meet required lubricity standards for ultra-low sulfur diesel

Metals by ICP, ASTM D1976k at major US third party lab

- Where applicable (most TFA products are totally metal free), treated distillate and residual fuels have metal concentration of 1.4 ppm or less

Bomb Calorimeter IP Protocol at major third party classification society

- significant combustion improvements on heavy fuel oil via measured changes in ignition characteristics

Prior chemistries registered with the US EPA agency as totally safe fuel-borne combustion catalysts, for on road fuels

Wärtsilä Letter of No Objection for Two-Stroke and Four-Stroke engines (for safe use on Wärtsilä engines)

General Electric Energy Letter of Approval for liquid-fuel fired Gas Turbines

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Trials and Dyno Testing Results

2005 US-based independent railroad company results

- 12% fuel savings on GP-7 1,500 hp locomotive

2007 US-based independent railroad company results

- 6.6% fuel savings on GP-9 1,500 hp locomotive

2007 – 2012 Wide range of successful marine results

- 10% fuel savings; 9%+ NOx reduction and 34%+ CO reduction on major European cruise ferry with 10,800 bhp Wärtsilä main engines
- 10-13.4% fuel savings; 20%+ NOx reduction on major European ferry, general cargo, anchor handling, oil & gas and supply vessels with MaK, Wärtsilä and MAN engines, ranging from 1,350 to 8,940 bhp

2011 – 2012 Texas based logistics company

- 10%+ fuel savings on Class 8 trucks
- Cummins engines with ~400 hp and ~1,500 ft-lb torque
- Trials performed over long duration to ensure credible and repeatable results

2012 South Texas based major port government entity

- 9%+ fuel savings
- Class 8 trucks
- Cummins engines
- Trials performed over long duration to ensure credible and repeatable results

2012 SAE J1321 Type II Protocol (3rd party fuel efficiency test)

- ~7% fuel savings
- 7%+ efficiency improvement

2012 Major City in Louisiana Municipal Bus Fleet, Louisiana

- ~7% fuel savings
- Trials performed over long duration to ensure credible and repeatable results
- Measured 75%+ reduction in emissions of PM

2013 Major tanker company, US

- ~50k dwt tanker vessel
- MAN B&W slow-speed 2-stroke main engine operating on HFO
- 11%+ specific fuel consumption reduction; 10%+ net ash reduction; 20%+ NOx reduction; ~80% CO reduction

2009 – 2014 Independent trucking company, Texas

- 8%+ fuel savings
- Cummins engine
- “Longitudinal Trials” that followed same tractor over a multi-year period
- Significant engine exhaust spaces cleaning properties noted

2014 Major international (national) shipping company

- Large container vessel (4k+ TEU)
- Wärtsilä low-speed 2-stroke main engine operating on HFO
- 10% specific fuel consumption reduction; 20% NOx reduction; 75% PM reduction

2015 Major US shipping company

- Large container vessel (2.6k+ TEU)
- MAN B&W low-speed 2-stroke main engine operating on HFO
- 10% fuel savings; 20% NOx reduction; 60% CO reduction; 90% PM reduction; 15% increase in combustion period

2016 International oil and gas “major”

- 5% fuel economy measured on dynamometer testing
- Light distillate diesel fuel used for dyno test

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Trials and Dyno Testing Results

2017 Major US shipping company

- Large container vessel (2,6k+ TEU)
- Sulzer low-speed 2-stroke main engine operating on HFO, LSFO and MGO
- 9% fuel savings; 80%+ PM reduction; 8%+ reduction in ash and heavy metal emissions; major reduction in NO, NO₂ and CO

2017 Major power generation authority in Middle East

Trials conducted on grid scale gas turbine with significant reductions in emissions and improvement in fuel efficiency

2017 International oil & gas “major”

Trials conducted for major international pharmaceutical company multiple fire tube boilers operating on industrial fuel oil (with 20,000 ppm sulfur) under the supervision of O&G “major”

- 8% reduction of fuel oil measured for equivalent power output
- 80%+ PM reduction; 30% NO_x and 30% CO reduction
- significant de-carbonization of boiler smoke tube stacks

2018 Major US shipping company

- Large container vessel (2,8k+ TEU)
- Sulzer low-speed 2-stroke main engine operating on MGO, HFO and LSFO (10,000 ppm sulfur)
- 8% fuel consumption reduction on MGO; increased power under high-rpm operations; significant PM reduction

2018 Major international (national) shipping company, Middle E.

- Ultra large tanker vessel (3+ million dwt)
- MAN B&W low-speed 2-stroke main engine operating on HFO and MGO
- 7%+ specific fuel consumption reduction on HFO; significant PM reduction

2018 Multiple successful international small diesel engine trials

- engines operating on light distillate diesel
- standalone power generation units
- 10%+ fuel savings; estimated 20-30% smoke and PM reduction