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Reducing NOx Emissions of Cargo Handling Equipment (CHE) With Humid Air Systems

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Sun-light driven chemical reactions in the lower part of the troposphere (a height of 10 km from the ground) cause ground-level ozone and other photochemical oxidants. The reactions primarily involve volatile organic compounds (VOC) and nitrogen oxides (NOx). Ozone negatively impacts the human respiratory tract, increasing the incidence of asthmatic attacks and even contributing to the development of lung cancer. It damages crops by reducing yields, thus causing major economic losses for those working in agriculture and beyond. Whether ozone is generated locally or regionally and transported over long distances, reducing NOx reduces ground-level ozone leading to increased positive economic and health impacts.

In this research, we have developed a new humid air system (HAS) to generate steam from distilled water, using engine exhaust heat and applied it to a CNG-powered cargo handling equipment, for reducing its NOx emissions and thus reducing a variety of potentially harmful effects on humans and the environment.

Study Methods

The HAS includes a tubular coiled heat exchanger, placed at the outlet of the engine exhaust, a tank of distilled water, a pump that transfers the distilled water through a solenoid valve into the heat exchanger coil to generate steam from the exhaust heat, and delivery of the steam into the intake mixing box that increases the humidity level of the air intake. The authors have performed an iterative process to identify the appropriate design and dimensions of the tubular coiled system to minimize exhaust

blockage. A humidity sensor in the mixing box monitors and maintains the humidity level at near saturation. A feedback control system adjusts the solenoid valve opening per the humidity level in the mixing box. Researchers applied the HAS, tested it on a CNG stationary engine, and field-tested it on an LPG-powered forklift.

NOx reduction with Humid Air System (HAS) has the potential to significantly reduce emissions of CNG, LPG, and diesel-powered engines for improved air quality and health.

Findings

Table 1 shows the results of the field tests of the HAS with the Clark forklift model GM 3.0 LPG. It reveals nearly a 70% reduction in NOx emission with 90% relative humidity at the intake air. The ppm NOx reduction per percent humidity was 2.2. Overall results including results from the stationary engine tests indicate that between 2–3 ppm NOx reduction could be obtained per 1% increase in humidity in the intake air. These results indicate the significant potential of HAS for reducing the NOx emissions of LPG- and CNG-powered cargo handling equipment at the ports.

Table 1. Filed Test Results with Forklift

Forklift Test (67 HP Max)	Baseline	HAS
Power (HP)	30.8	30.8
Humidity level (%)	55.2	90
Ambient humidity (%)	55.2	55.2
Ambient temperature (°F)	69.8	69.8
Stack temperature (°F)	616	274
Air flow rate (cfm)	63	63
NOX (ppm)	117	40
CO (ppm)	58	68
Mass dry air (g/min)	2140	2140
Mass humidity (g/min)	0.	22
Mass fuel (g/min)	203	203
Humidity–Fuel mass ratio (%)	0.	10.8
Ratio of NOx to baseline	1.0	0.34
Ratio of CO to baseline	1.0	1.17
ΔNOx(ppm)/Δ%Humidity	N/A	2.2

Policy/practice recommendations

This research shows a promising simple and efficient technology for reducing NOx emissions of CNG-LNG-and diesel-powered engines. It could be incorporated in new as well as existing vehicles for significant improvement in air quality. Large-scale implementation of the HAS reduces the carbon footprint of the transportation industry as well as cargo handling and transportation equipment at US ports. These improvements could create meaningful changes in environmental and human health in the long term.

About the Authors

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To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/project/1859.

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