EMISSIONS CHARACTERIZATION OF AN AMMONIA-GASOLINE SI ENGINE

By

Shawn Grannell Dennis Assanis

Don Gillespie Stanislav Bohac

University of Michigan

Mechanical Engineering Dept. & Applied Physics Program

Supported by the Fannie and John Hertz Foundation.

Overview

- Engine Out Emissions
- Post Catalyst Emissions
- Oxygen Sensor Characteristics
- Conclusions

Motivation

- Dependence on oil
- Greenhouse gas emissions
- Possible local pollution improvement
- Economics

Equation of Combustion

- $(0.79\ N_2 + 0.21\ O_2) + 0.024b\ C_6H_{11} + 0.28(1\text{-}b)\ NH_3 \Rightarrow (0.93 - 0.14b)\ N_2 + (0.42 - 0.288b)\ H_2O + 0.144b\ CO_2$

But Some Leftovers Products Are Also Made

- Carbon Monoxide (CO) (Toxic, regulated) and Unburned Hydrocarbons (CH_n) (Stinks, carcinogenic, smog former, regulated) from Gasoline
- Unburned Ammonia (NH_3) (Stinks, not anticipated in regulations)
- Nitric Oxide (NO) (Smog former, regulated) and Nitrous Oxide (N_2O) (Greenhouse gas ~300xCO_2)

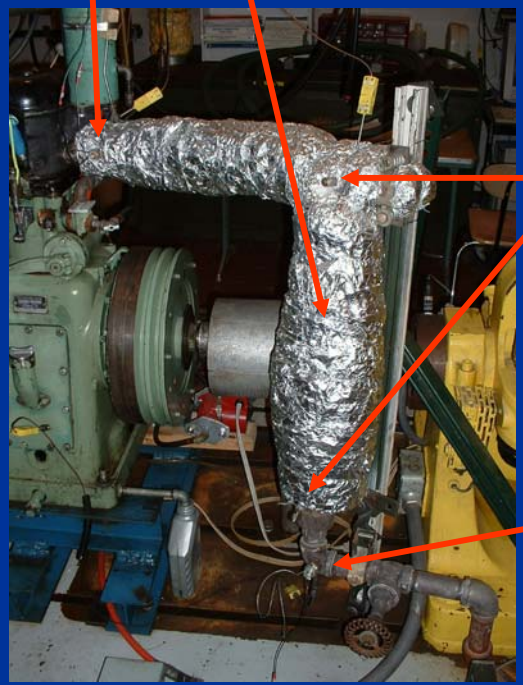
Engine and Emissions Equipment

Engine-Out Oxygen Sensor

Horiba NDIR for HCs (dry)

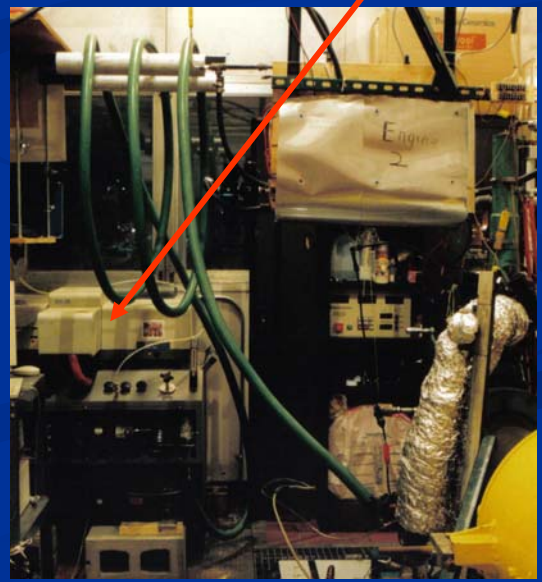
Nicolet FTIR for NO, N_2O, NH_3 and CO (wet)

Catalytic Converter

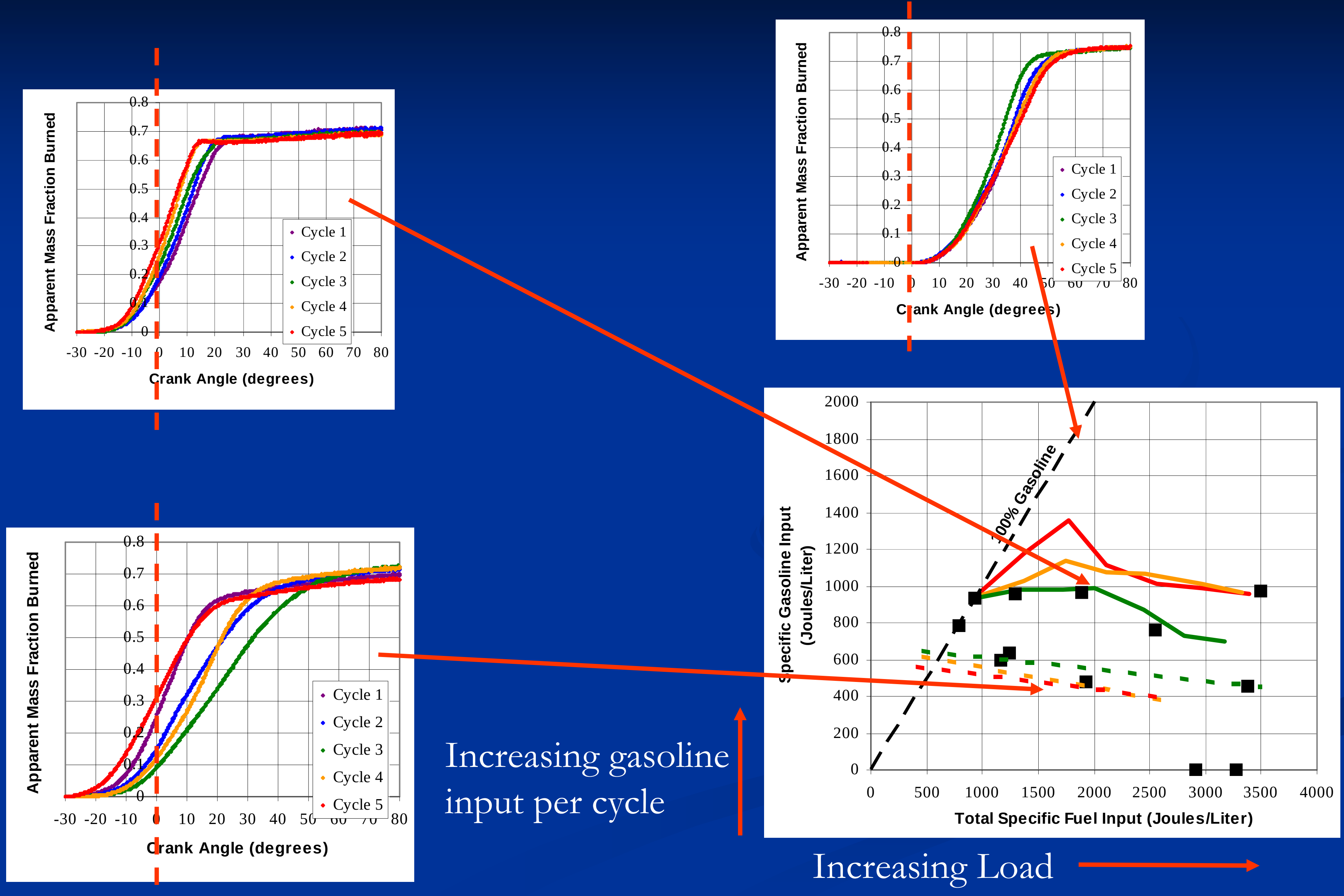


Emissions Ports

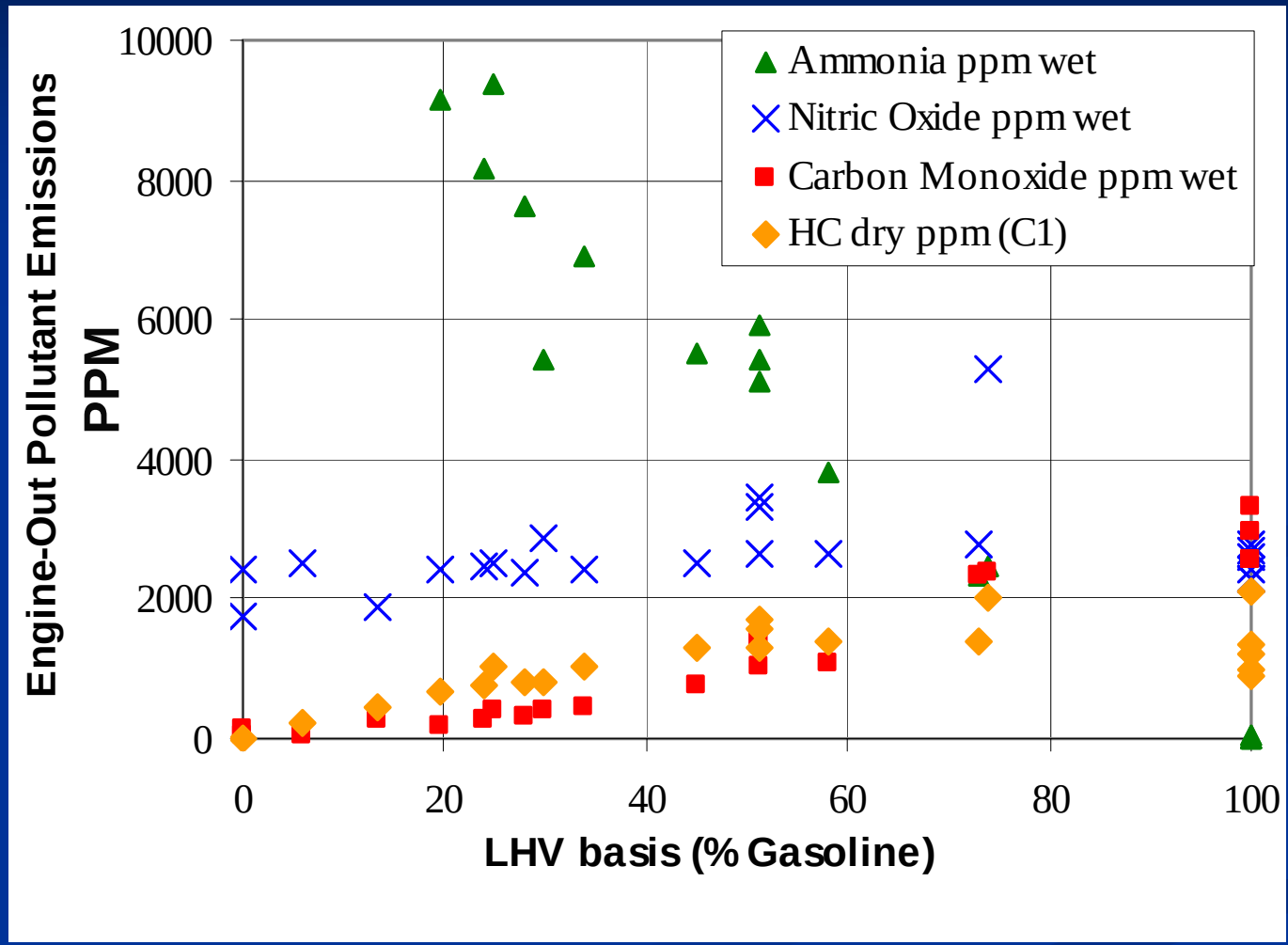
Post-Catalyst Oxygen Sensor



Fuel Map at 10:1 Compression Ratio

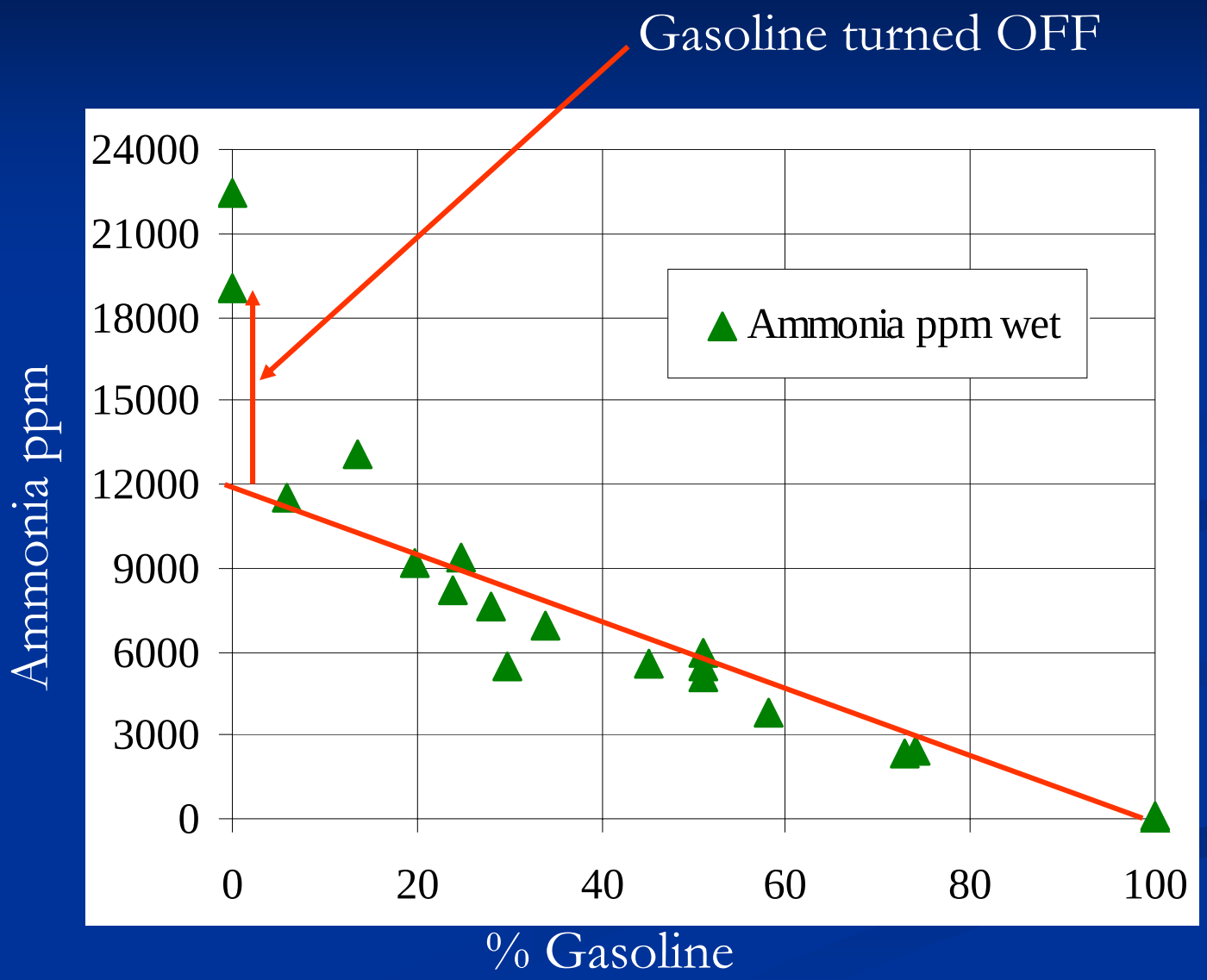


Engine-Out Pollutant Emissions

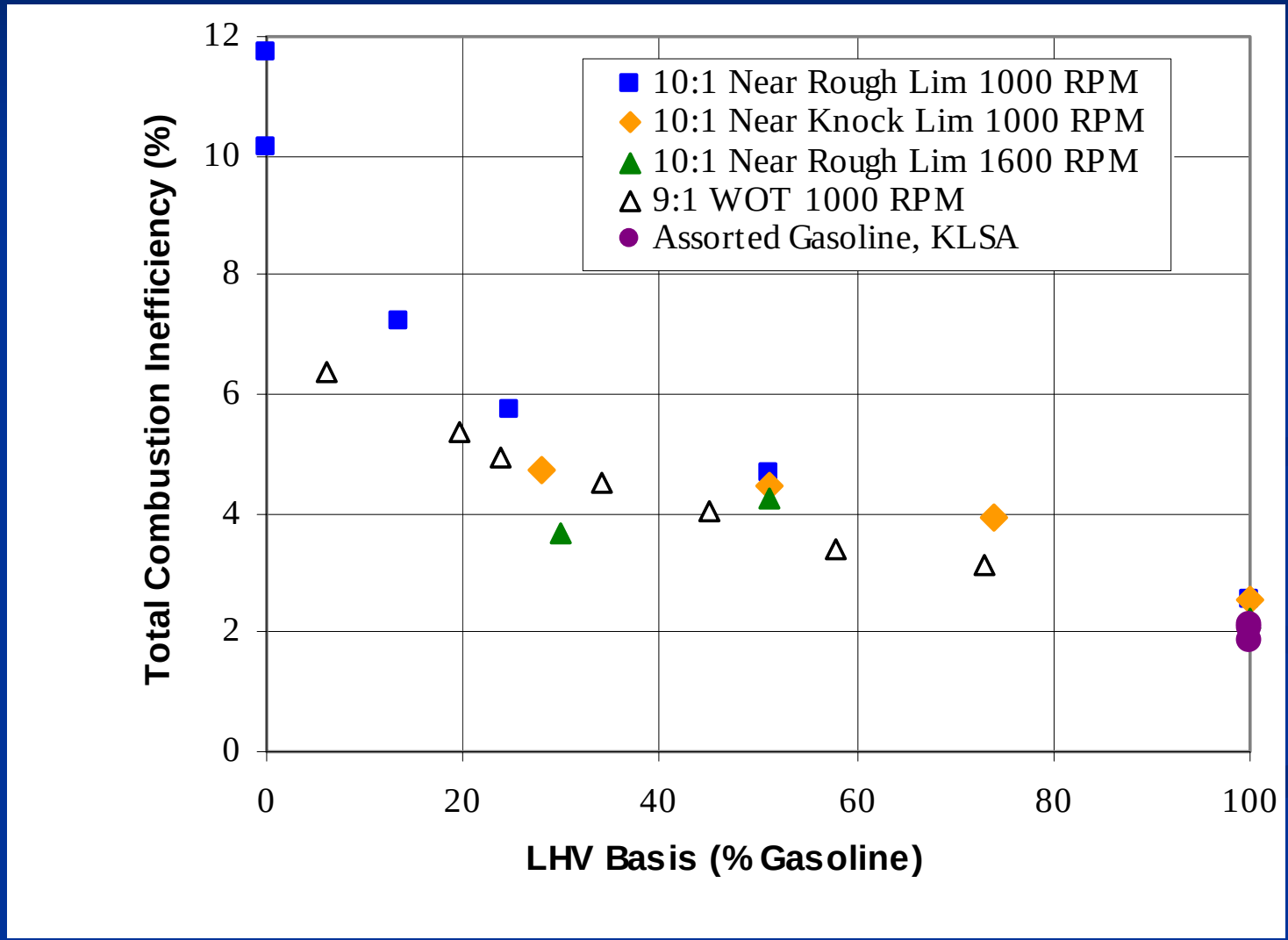


N_2O: 10-40 ppm

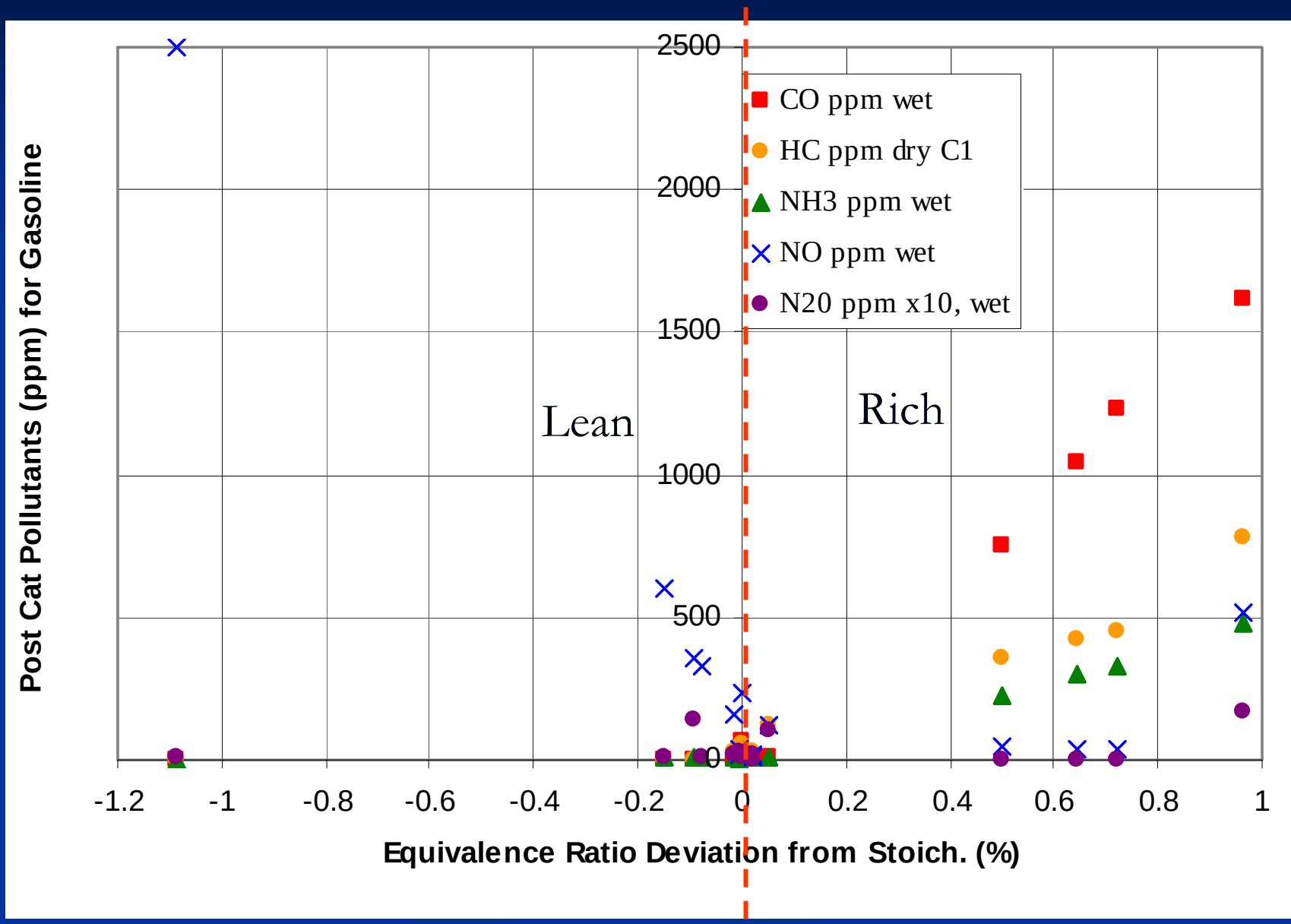
Engine-out Ammonia Emissions



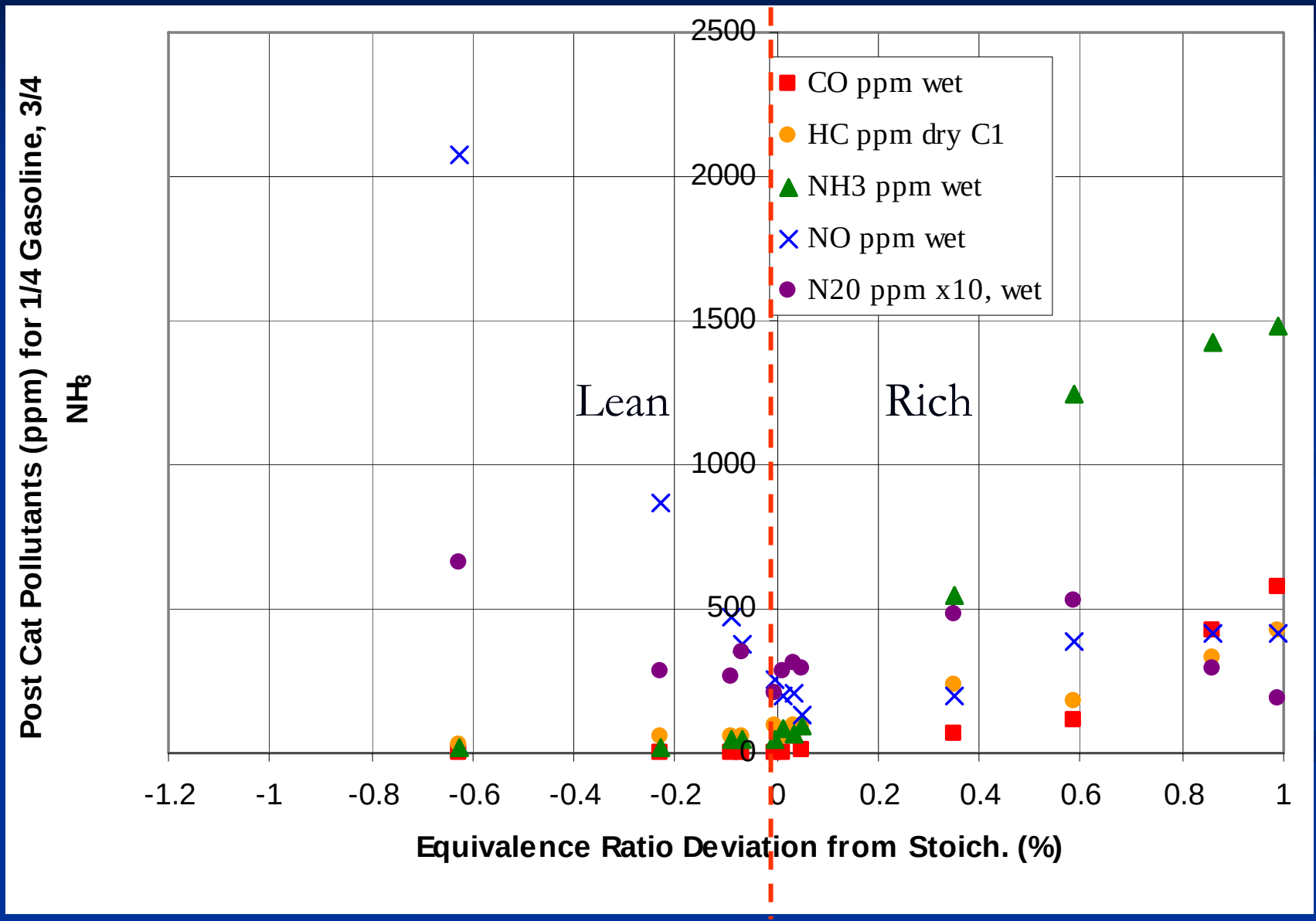
Combustion Inefficiency



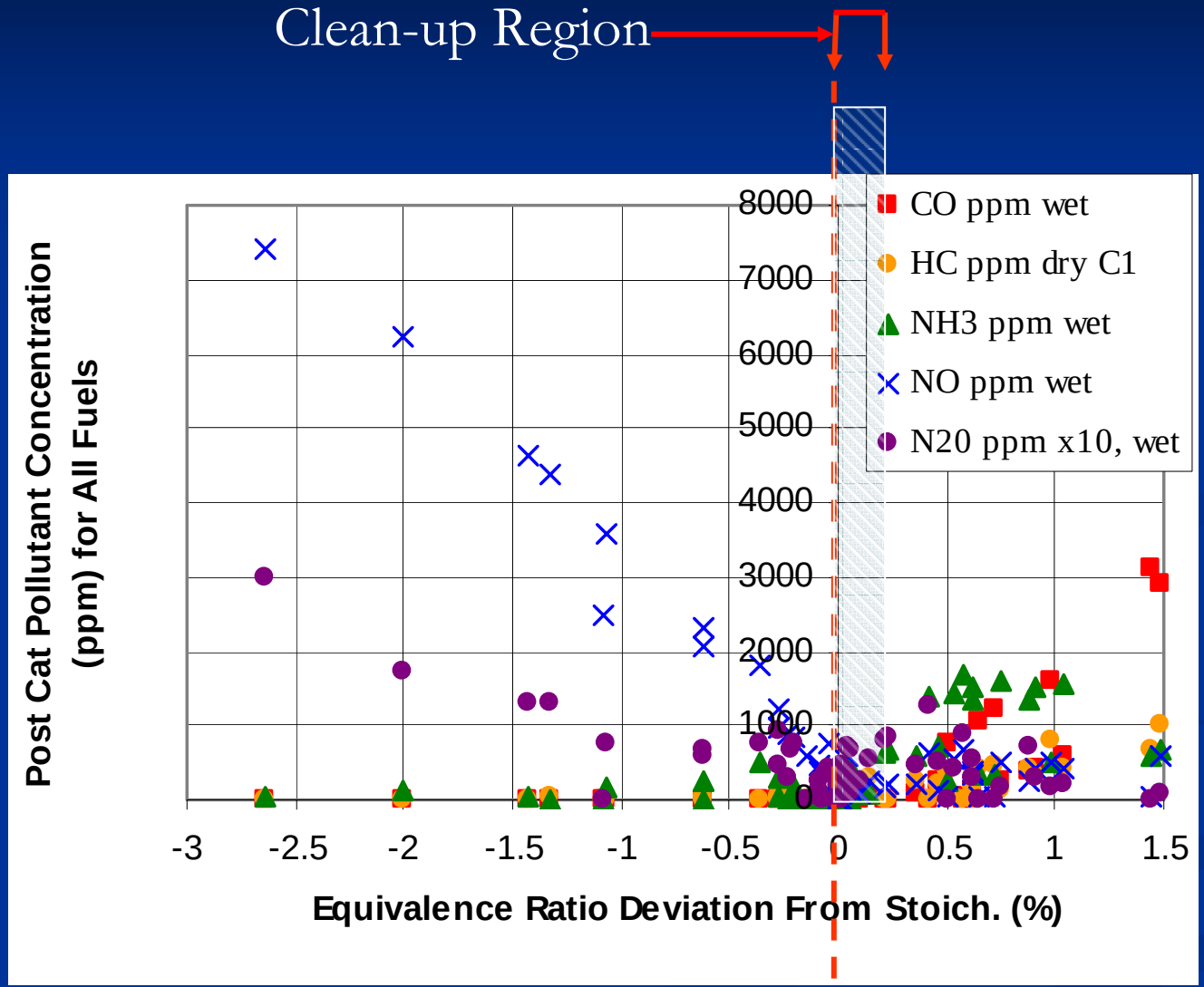
Post Catalyst Emissions, Gasoline Only



Post Catalyst Emissions, ¼ Gas., ¾ NH_3



Post Catalyst Emissions, All Mixtures



Typical Values in Clean-up Region:

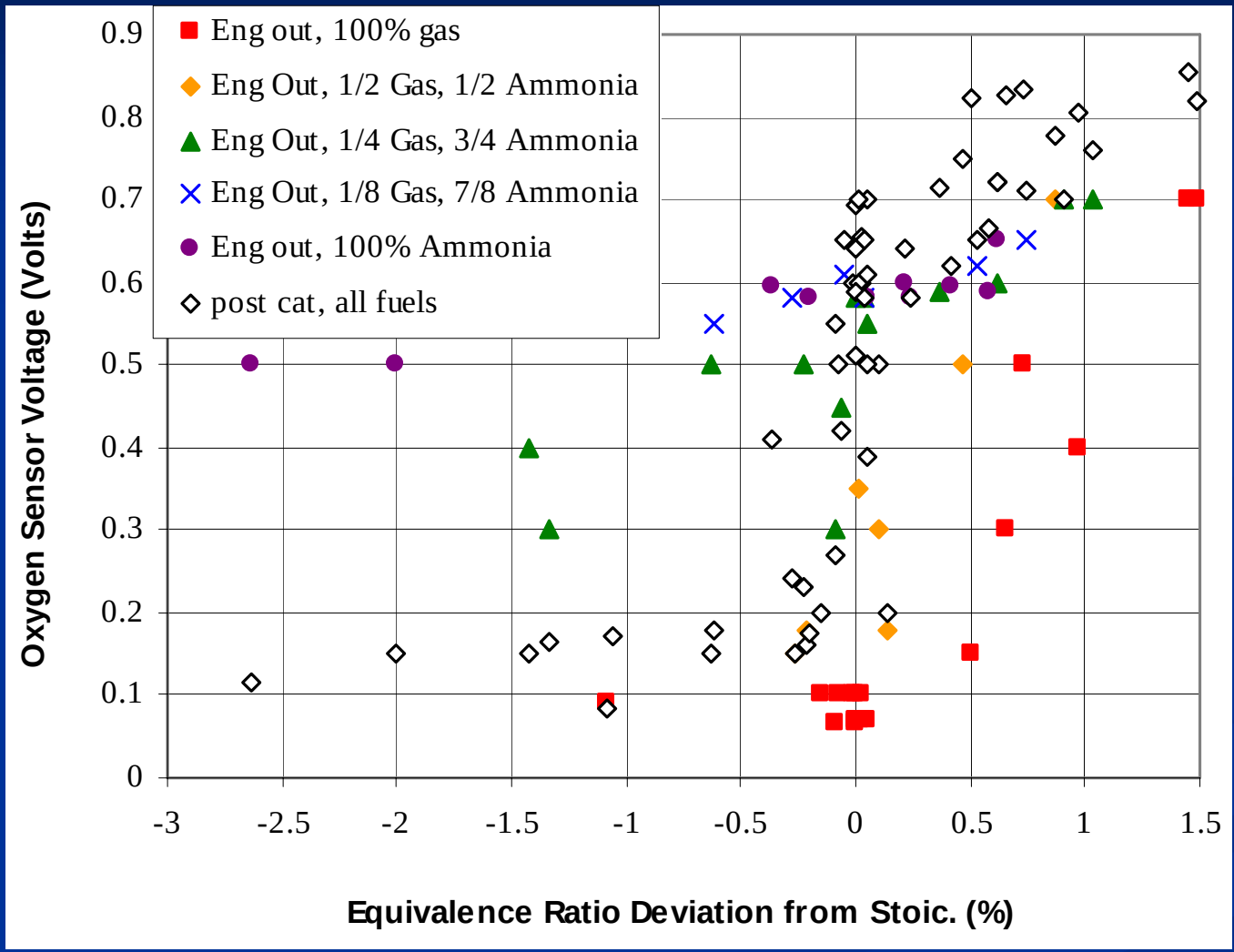
NH_3: 100 ppm

NO: 200 ppm

CO and N_2O: 30 ppm

HCs (C_1): 100 ppm

Oxygen Sensor Characteristics



Stoic Corresponds to Sensor Voltage:

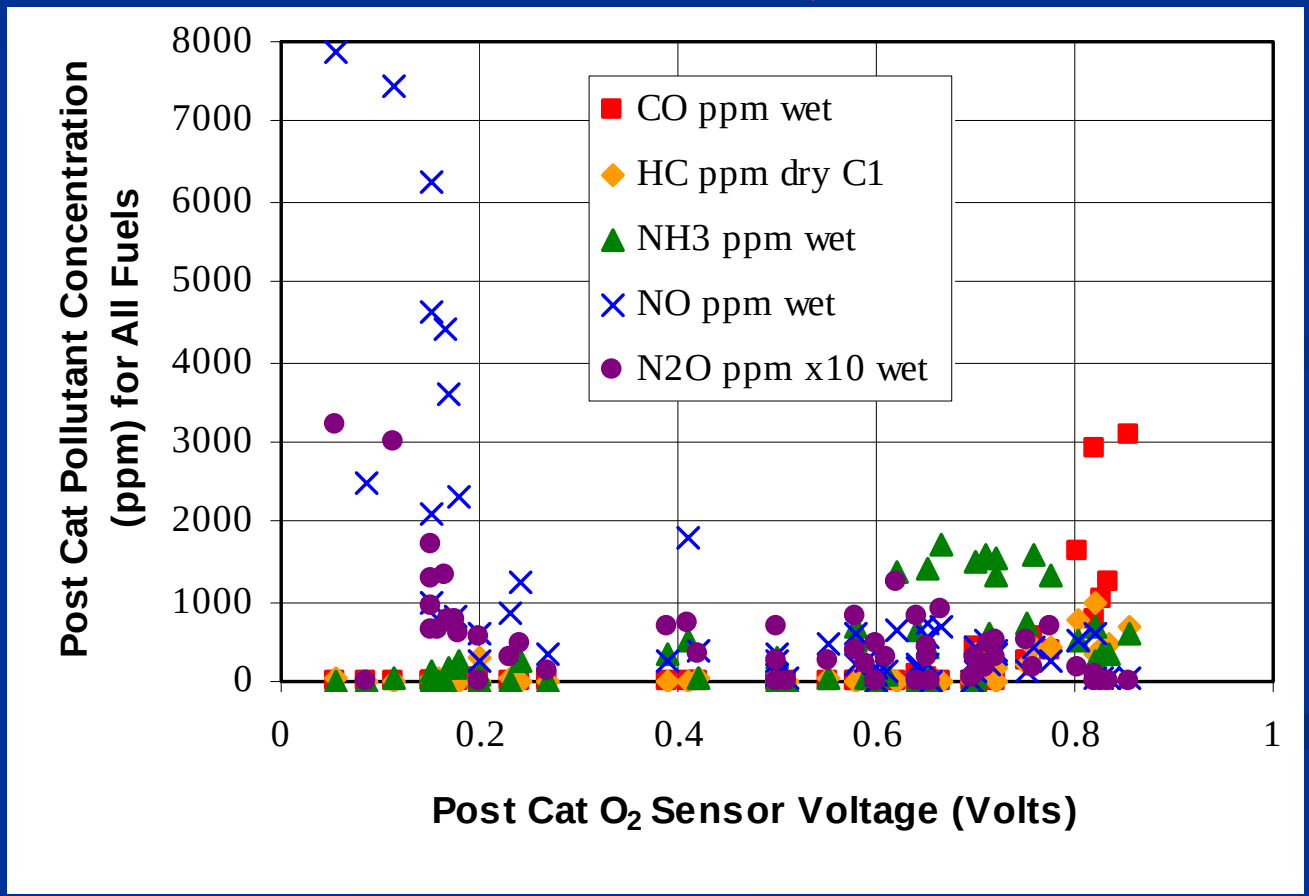
Engine-out Gasoline: 0.1V

Engine-out Ammonia: 0.6V

Post-Cat All Mixtures: 0.25 to 0.55V

Post Catalyst Emissions Correlate with Post Catalyst Oxygen Sensor Voltage.

Clean-up Region



Conclusions

- Engine out emissions of hydrocarbons and carbon monoxide are replaced with ammonia when ammonia is substituted for gasoline.
- Engine out emissions are reasonable when combustion is stable.
- Emissions clean up with a catalyst at stoichiometric, as they also do for gasoline.
- Lean operation must be absolutely avoided with ammonia, otherwise post catalyst emissions of nitric oxide can exceed the engine out value.
- Significant quantities nitrous oxide are also made on the catalyst under lean conditions.
- Standard oxygen sensors and catalytic converters are usable with ammonia.

Future Work

- Production capacity is needed using sustainable means.
- Hundreds of gigawatts are needed. Wind? Nuclear?