A 3-Part Fuel Mixture is the "Solution"

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SY-Will Engineering

- What's the Problem?
- 3-Part Mixture Advantages
  - Initial compositions
  - Future compositions
- Minimal Disadvantages
- What Do We Do Now?

TM

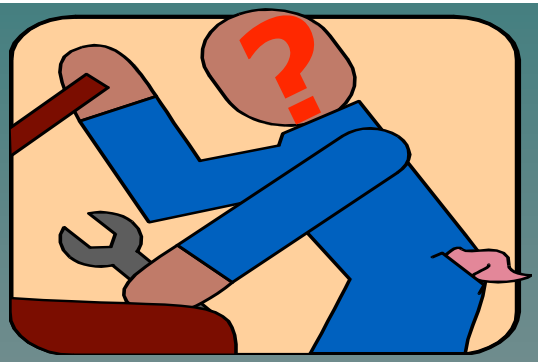
Why Are We So Tied to Crude?

- Crude Oil Is a Mixture of Many Hydrocarbons (HC)
- Some Refined HC's Have High Energy Densities & Easily Stored on Vehicles
- Gasoline Fuels for Spark Ignition (SI) Engines Have Been Low in Cost
- Harmful Emissions Have Been Reduced, but Not Eliminated

----------> Current Emissions

- Emission Control Types/Examples
  - Exhaust gas/three-way catalytic converters (TWC)
  - Evaporation/activated carbon canisters
  - Spills or leaks/double wall tanks
- **But,** Some Exhaust Gas Emission Controls Decrease Fuel Economy
  - Increasing fuel cost
  - Increasing CO_2 emissions

So, What's the Problem for Ammonia Fuels?



- Technical Development & Cost Reductions are Needed, but **BIGGEST** Problems are Societal!
  - Turf wars, e.g., auto vs. fuel industry, greens vs. economic growth, and 1st vs. 3rd world nations
  - Who pays for huge vehicle and fueling infrastructure changes that are needed?
  - Uncertain public acceptance of strong odors, pressurized fuel tank safety, need to address global warming, costs, etc.

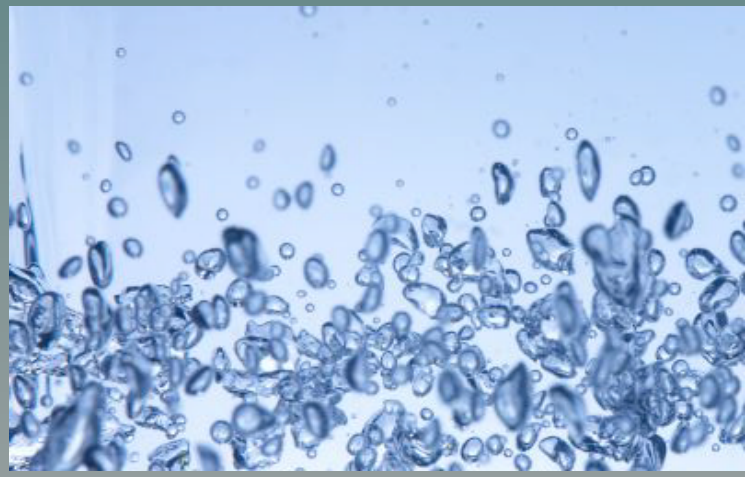
THE 3 PART "SOLUTION"

- Take Small HC to NH_3 Transitional Steps, and for Each Step:
  1) Minimize Societal Impacts
  2) Make It Cost Effective
  3) Increase Performance and Reduce Emissions
  4) Make Future Steps Easier

Initial "Solution"

- **Dissolve ~0.1 to 0.4% NH_3** in 90-10 Gasohol Mixtures for **Existing** & **New** SI Vehicles
- **Add** Selective Catalytic Reduction (**SCR**) System to New SI Vehicles that:
  - **Strips** NH_3-enhanced vapor stream from the 3-part mixture and injects stream portion into SCR system
  - **Adjusts** to leaner air/fuel ratio (A/F)
  - **Combusts** other stream portion

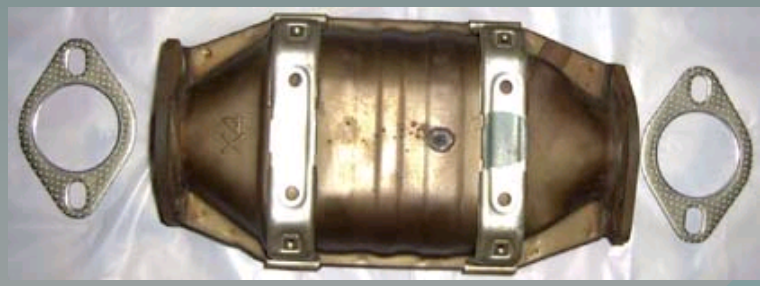
Dissolving Ammonia in Gasohol



- Can Be as Simple as Bubbling NH_3 Through Ethanol or 90-10 Gasohol Mixtures
- Accomplished at Terminals Similar to Current Ethanol Additions
- SY-Will Has Proprietary Ammonia Solubility and Mixing Data with Gasoline and Ethanol

Selective Catalytic Reduction of Combustion Exhaust Gas NOx

- Long History of Use on Stationary Engines
  - Using NH_3 or ammonia precursor, e.g., urea
  - $4NH_3+4NO+O_2 \rightarrow 4N_2+6H_2O$
    $2NH_3+NO+NO_2 \rightarrow 2N_2+3H_2O$
  - More efficient combustion



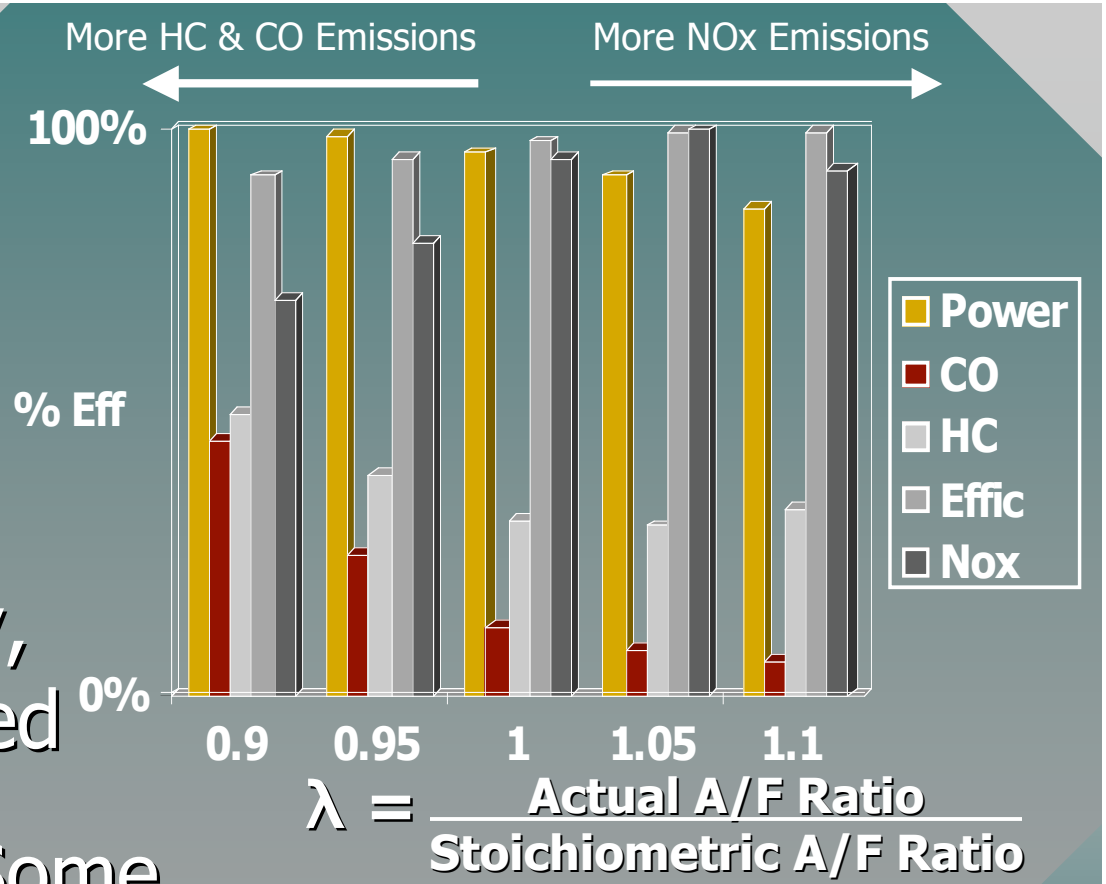
- Used on Diesel Vehicles with Separate Urea Tanks
- Has Been Used on SI Vehicles, but
  - 3-way catalyst (TWC) is now standard
  - Added NH_3/reductant tanks create societal problems

Stripping Reductant Process

- Can Be as Simple as Withdrawing Vapors from Fuel Tank
  - Ammonia, Ethanol, and light HCs Are concentrated in mixture vapor space
  - Can increase withdrawn NH_3% if needed
  - Vacuum vapor transfer minimizes odor & spill risks

- Stripping Reductants from HC Fuels: Demonstrated
- Injecting Reductant Vapor Stream into SCR: More Efficient Than Injecting Liquid Urea Mixture

Higher A/F Ratio



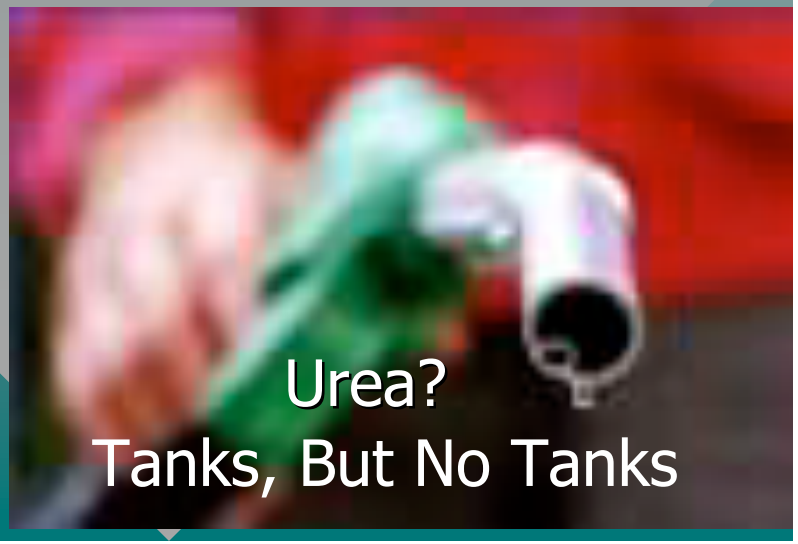
- Better Fuel Economy, but More NOx Emitted
- TWC Still Removes Some NOx if Only a Small A/F Increase
- Reductant Vapor Stream & Combined TWC-SCR System Makes Up for Lower NOx Removal by TWC

Initial Step Advantages

- **Avoids** Many **Social Problems**
  - Uses existing fuel system for existing **and** new cars
  - No disabling engine if no reductant
- Initial 3-Part Mixture is **Safer** than NH_3 or Gasoline
  - NH_3 is **soluble** in ethanol, avoiding pressurized tanks
  - Strong **odor gives early warning** of small leaks/spills & ammonia vapors are **difficult to ignite**
  - Similar gasoline additive is **already in use**

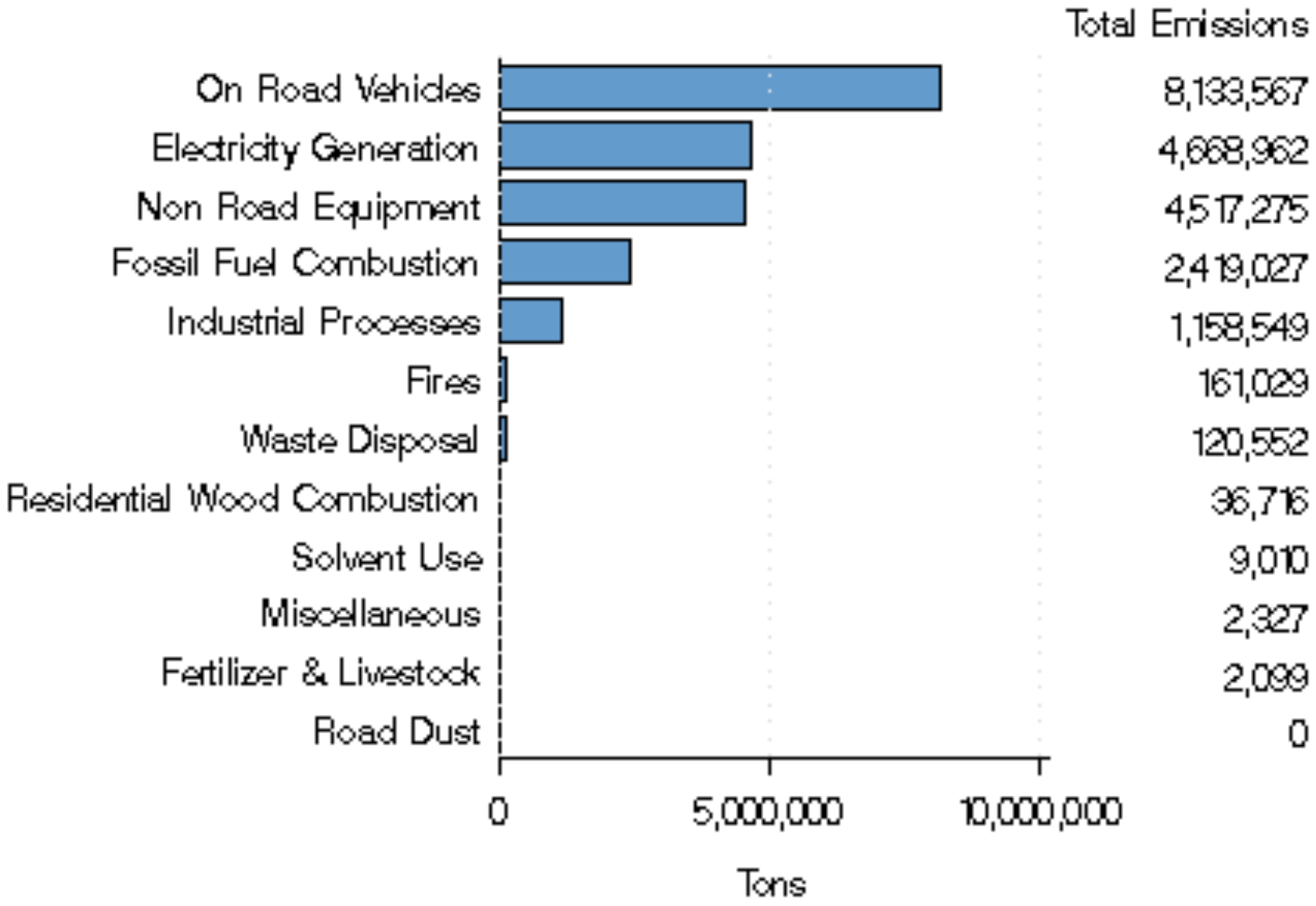
More Advantages of Initial Steps

- **Increased Fuel Economy/Reduced Fuel Costs**
  - Increased A/F ratio avoids incomplete combustion of fuel & raises combustion temperature & pressure
  - NH_3 lowers $/BTU and may replace detergent additive
- **Reduced Capital and Other Operating Costs**
  - Avoids separate urea dispensing facilities & vehicle tanks
  - May avoid added SCR catalyst
  - Avoids separate urea purchases
  - Avoids urea/water vaporization, draining, & heating costs



National Nitrogen Oxides Emissions by Source Sector

in 2002



More Advantages of Initial Steps

- TWC-SCR & Reductant **Reduces NOx Emissions**
  - If A/F ratio is enriched for heavy loads, reductant stream can be combusted or used to further reduce NOx
- **Evaporative Emissions Controlled**
  - Reductant stream mostly vacuum transferred
  - Carbon canisters also control NH_3 emissions
- **Reduces Other Major Emissions**
  - Combusting at lean A/F ratios reduces engine-out CO & HC

Advantages with Ammonia ↗ %

- Even **Better Fuel Economy & Performance**
  - Leaner A/F Ratio
  - Higher compression ratios with lower cost, high octane fuel
- Even **Lower Costs** with more ammonia used as fuel
  - Replace alternators with NH_3 fuel cells & efficient hybrids, e.g., with NH_3 batteries
  - Lower NH_3 $/BTU than gasoline or ethanol
  - Less foreign oil plus energy security
  - May avoid need for TWC

More Advantages with Ammonia

- More **Emission Reduction**
  - Leaner A/F ratio further reduces CO & HC
  - More NH_3 combustion → less CO_2
  - Less NOx emissions & pressurized tanks reduce evaporative emissions
- **Stimulate Green** Sources of Ammonia
  - Nuclear or renewable power for H_2O electrolysis
  - Biogas, sewage, agricultural & animal waste

Minimal Disadvantages

- Very **Low Initial Costs**
  - Amount of ammonia similar to detergent additive
  - Little or no added cost for similar SCR diesel vehicles
- Very **Low Initial Infrastructure Impacts**
  - Use with existing fuel dispensers & vehicles
- **Step Increased** NH_3 Content
  - Allows time for renewable sources
  - Allows time for incremental auto/oil industry impacts

TIME TO STEP-UP?

What Do We Do NOW?

We Have a Winner!

- ***Sell*** **Cost-Effectiveness** of Initial Steps, i.e., Make'em an Offer They Can't Refuse
  - Improves fuel economy & better economies on the way
  - No urea-water purchases & lower BTU/lb cost
  - Lower cost higher octane fuels
  - May eliminate separate detergent additives
  - No dramatic increases in demand for ammonia as fuel, unlike ethanol fuel derived from corn

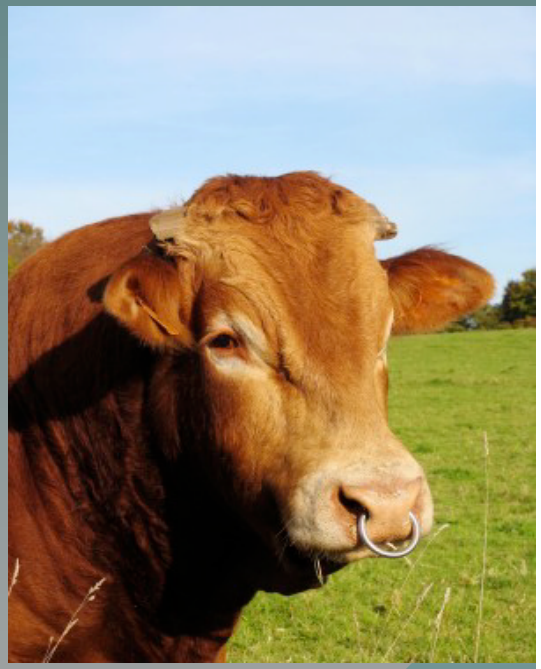
What Do We Do NOW?

Does Dis-Solve Fuel Problems?

- ***Sell*** **Safety** of NH_3
  - Odorant, similar to natural gas mercaptans
  - Lighter than air & difficult to ignite
- ***Sell*** Ammonia as **Renewable Energy**
  - For example, Vemork hydroelectric production of NH_3
  - "Cellulosic ammonia [e.g., from corn stalks] may be more viable than cellulosic ethanol."
  - From animal and human waste - the original source of agricultural ammonia as a fertilizer

What Do We Do NOW?

- ***Sell*** **as Organic**, e.g., per US Dept. of Health & Human Services:
  - NH_3 is "**throughout the environment** in air, water, soil, animals, and plants."
  - NH_3 is "taken up by plants, bacteria, and animals . . . [and] does not build up in the food chain, but serves as **a nutrient for plants and bacteria**."
  - "**No health effects** have been found in humans exposed to typical environmental concentrations . . . There is **no evidence that ammonia causes cancer**."



That Ain't No BS!

What Do We Do Now?

Some hydrocarbon species formed from the combustion of blended gasoline

Methane	Propylene
Formaldehyde	1,3-Butadiene
Ethane	1-Butyne
Ethylene	2-Butyne
Acetaldehyde	1-Butene
Acetylene	2-Butene (*cis* and *trans*)
Propadiene	2-Methylpropene
Propyne	

- ***Sell*** **Gasoline Hazards**
  - Toxic exhaust & evaporative gases
  - Greenhouse gases
  - 1 of every 4 fires involve a motor vehicle & causes 7X more deaths than non-residential structural fires
- ***Sell*** Ammonia is **Already in Your Car** Exhaust
  - A typical car with a catalytic converter emits 0.28 ounces of ammonia/100 miles

Is our ammonia slip showing?

What Do We Do Now?

- ***Sell*** **Green**
  - Less carbon monoxide, NOx, & hydrocarbons in exhaust gases
  - Less evaporation, spills, & leaks
  - Less carbon dioxide
  - Less gasoline additive combustion products
  - More H_2O emissions
  - Oxygen consumed in engine combustion is replaced by electrolysis of water into hydrogen and oxygen

When Opportunity NOx, Will You Take the First Step?

Thanks for your attention
& **sales letters**!

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