Attachment 1: Description of Emission Reduction Measure Form

Please fill out one form for each emission reduction measure. See instructions in Attachment 2.

Title: Urea/ammonia injection into vehicle exhaust gases

Type of Measure (check all that apply):

- [x] Direct Regulation
- [ ] Market-Based Compliance
- [ ] Monetary Incentive
- [ ] Non-Monetary Incentive
- [ ] Voluntary
- [x] Alternative Compliance Mechanism
- [ ] Other Describe:

Responsible Agency: ARB

Sector:

- [x] Transportation
- [ ] Electricity Generation
- [ ] Other Industrial
- [ ] Refineries
- [ ] Agriculture
- [ ] Cement
- [ ] Sequestration
- [ ] Other Describe:

2020 Baseline Emissions Assumed (MMT CO2E): 167.7 (using ARB's 2004 data)

Percent Reduction in 2020: 1.7 (CO2 diesel) + 6.7 (CO2 gasoline) = 8.4 MMT CO2

Cost-Effectiveness ($/metric ton CO2E) in 2020: TBD

Description: By injecting urea (as an ammonia carrier) into engine exhaust gases to reduce NOx (commercially accomplished in Europe for diesel engine vehicles), gasoline engine vehicles can use leaner, more efficient fuel/air ratios (F/A) since current F/A is limited by catalyst removal of NOx without excess oxygen. Combustion at lean F/A (plus urea injection) will allow catalytic converters to reduce other criteria pollutants and significantly increase fuel economy, reducing CO2 emissions.

Alternatively, small amounts of ammonia can be added to gasoline-ethanol blends to create a new fuel mixture with ethanol acting as a co-solvent for ammonia and gasoline. Some of the ammonia is directly stripped off the mixture before combustion in new vehicle engines with some of the stripped ammonia injected into the exhaust gases as a NOx reductant. Stripping some ammonia (and possibly ethanol which is also a NOx reductant) from a new fuel mixture removes the need for a separate urea supply and distribution infrastructure. This approach further reduces CO2 since combustion of some of the ammonia (NH3) generates power but does not generate CO2. Moreover, a similar concept can also be applied to diesel fuel & engines having the further benefits of meeting year 2010 EPA and ARB NOx reduction requirements for heavy duty diesels without the need for separate urea infrastructure plus the ability to incorporate partial homogeneous charge compression ignition (HCCI) technology (using premixed ammonia and air) to further reduce emissions and improve fuel economy.

Based on the stoichiometric amounts needed to react with NOx and commercial NOx reducing applications, the amounts of ammonia needed is small, e.g., less than about 1% ammonia dissolved in the new fuel mixture. Safe handliing of this small amount of dissolved ammonia has been shown by common household glass cleaners (having as much as 10% dissolved ammonia) and mixtures using commercially available ethanol as a solvent.

Although initial development of proprietary hydrocarbon fuel-ethanol-ammonia mixtures (plus additives and/or other co-solvents) has aleady been accomplished by SY-Will Engineering, further R&D effort is needed to optimize fuel mixture compositions, assess auto/oil industry impacts/costs, and quantify fuel economy/emission benefits and costs.

Emission Reduction Calculations and Assumptions: Ammonia (NH_3) has no carbon to generate CO_2. NOx reductions of up to 80% have been achieved, allowing lean combustion in gasoline engines. Lean combustion data supports an assumed fuel economy improvement of 5% for gasoline engines. HCCI (diesel) engine test data support up to about 25% CO_2 reductions for HCCI (diesel) engines plus up to about 80% reductions in NOx when using higher concentrations of ammonia and ethanol.

Cost-Effectiveness Calculation and Assumptions: TBD, but initial estimates suggest the dissolved ammonia approach is a least costly alternative based on urea experience in Europe, current costs of ammonia and urea, and the small amounts of ammonia needed to react with exhaust gas NOx. Ammonia can also be derived from renewable sources

Implementation Barriers and Ways to Overcome Them: Further R&D is needed.

Potential Impact on Criteria and Toxic Pollutants: Reductions in nearly all criteria pollutants is expected, especially NOx. Since ethanol is already a component in many gasoline/e-diesel mixtures and ammonia is already a component in vehicle exhaust gases, no new exhaust pollutants would be present. And controls of the injected ammonia into the exhaust to prevent excessive ammonia being injected (more than what is needed to react with NOx) are commercially available, e.g., commercially available NOx sensors. Moreover, existing evaporative emission controls for gasoline-powered vehicles also controls ammonia evaporative emissions.

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