TIER 2 COMPLIANCE STRATEGIES FOR GASOLINE-FUELED SUVs

Regulatory Review and Challenges

Technical Issues

Technical Strategies

A “Typical” System

“Commercial” Strategies

Summary

REGULATORY REVIEW AND CHALLENGES

All Passenger Cars, LD Trucks, and MDPVs to meet identical standards.

Extends the weight class of “passenger vehicles” from 6000# to 10,000# GVWR.
Establishes “useful life” of 120K miles, with 150K option (was 100K for LDVs).
Establishes new more stringent evaporative emission standards.
Establishes additional “Supplemental FTP” test cycles.
Establishes complex “phase-in” schedules.
Establishes emission “bins”.
New OBD challenges.
CAFÉ.

Fed Tier 2 establishes a fleet NOx average, CA LEV II a fleet NMOG average.

Unique fuel specifications, test procedures, approvals, etc.

Regulatory complexity creates a formidable “bookkeeping” task for OEMs.

Five current vehicle emission classifications are recombined into two “fleets”.
Fleet average emission requirements are based on vehicle sales volumes.
Unique “interim” and “final” emission standards apply to each fleet.
Total phase-in period covers six model years (2004-2009).

FUNDAMENTAL TECHNICAL ISSUES

SUVs ARE TYPICALLY BIGGER AND HEAVIER THAN CARS

For a given driving schedule, SUVs require the input of more net work.
The work is derived from burning gasoline.
More net work requires more gasoline.

THE COMBUSTION OF GASOLINE PRODUCES EMISSIONS

The combustion of more gasoline produces more emissions.
Gasoline consists essentially of compounds of H_2 and C (hydrocarbons).
Efficient and complete combustion of Hydrogen yields H_2O (good).
Efficient and complete combustion of Carbon yields CO_2 (not as good).

I.C. ENGINES DO NOT BURN FUEL EFFICIENTLY OR COMPLETELY

Inefficient combustion "wastes" a lot of fuel per unit of work produced.
Incomplete combustion wastes fuel and creates HC(NMOG) and CO emissions.
High combustion temperatures and pressures create NOx (not good).

OFFENDING PRODUCTS OF COMBUSTION MUST BE TRANSFORMED

Compliance will necessarily rely heavily on exhaust gas aftertreatment.
The task is to re-arrange atoms into non-offending compounds.
Catalysts are available to do this with very high stabilized efficiency.
Exhaust gas that escapes efficient aftertreatment must be minimized.

TECHNICAL COMPLIANCE STRATEGIES

REDUCE SUV SIZE and WEIGHT to REDUCE GASOLINE CONSUMPTION

To the extent possible while maintaining SUV customer attributes.

REDUCE FUEL USAGE VIA IMPROVED COMBUSTION EFFICIENCY(?)

Combustion during and immediately following startup is an opportunity area.
Cylinder deactivation systems that conserve fuel will become common.
Customer satisfaction (start/drive characteristics) must be maintained.
Total engine emissions will always greatly exceed the allowable tailpipe levels.
Providing exhaust gas that supports efficient aftertreatment becomes the priority.
Fuel-efficient “lean burn” systems (including Diesels) do not accomplish this.

IMPROVE AFTERTREATMENT SYSTEM EFFICIENCY

Develop and utilize optimized catalyst formulations and configurations.
Only “stoichiometric” systems are capable (today) of meeting Tier 2 requirements.
Accelerated catalyst “lightoff” has become the key enabler.
Optimal control of feedgas stoichiometry improves system cost effectiveness.
Catalyst material costs and availability are potential future issues.

ENABLING ACCELERATED CATALYST LIGHTOFF

ENGINE EXHAUST IS THE PREFERRED SOURCE OF CATALYST HEATING

It's there and it's "free."

INITIAL EXHAUST TEMPERATURE AND MASS FLOW ARE CRITICAL

Initial EGT must be elevated (spark, mixture, valve timing, etc.).
Mass flow must be optimized (heat transfer vs. emissions tradeoff).
Stable engine operation must be maintained.

PRE-CATALYST EXHAUST SYSTEM THERMAL INERTIA IS ALSO CRITICAL

Surface area and mass of exhaust plumbing must be minimized.
This favors catalyst placement as close to the exhaust ports as possible.
Insulation is generally not effective for improving lightoff.

CATALYST CONFIGURATION IS THE THIRD CRITICAL ELEMENT

Substrate thermal inertia and catalyst formulation are important.
Frontal area, cell density, and cell wall thickness determine thermal inertia.
PGM and washcoat selection and unit loading are equally important.
OBD (CatMon) requirements can not be ignored.

ONCE ACTIVITY IS INITIATED, CATALYST EXOTHERM TAKES OVER

Feedgas composition and mass flow determine catalyst heating rate.
Time to peak efficiency will be influenced primarily by feedgas strategies.

TECHNOLOGY SHOPPING LIST

"ENGINE" FEATURES

Multi-Port Injection
Gasoline Direct Injection
Diesel Direct Injection
Dual Overhead Camshaft
Variable Valve Timing
Variable Valve Lift
Exhaust Gas Recirculation
Dual Port Induction
Air Assist Injector
Heated Injector (or Fuel)
Fuel Vaporizer (Grid)
Fuel Vaporizer (DCS)
"Cow Magnets"
Dual Spark Plugs
High Energy Ignition
Exhaust Port Air Injection
Fabricated Exhaust Manifold
Air Gap Exhaust Manifold
Maniverter (Integrated Catalyst)
Natural Gas Vehicle

CONTROL STRATEGIES

Dynamic Crankshaft Fuel Control
Individual Cylinder Fuel Control
Model Based Controls
Natural Vacuum Leak Detection
Ionization Misfire Detection
Cylinder Deactivation
Cold Spark (Retard)
Post-Combustion Injection
Multi-Strike Injection
End-of-Injection Timing Control
Starter-Generator
Heat Battery

AFTERTREATMENT

Close-Coupled Catalyst
Prep Catalyst
HydroCarbon Trap
Lean NOx Catalyst
NOx Trap Catalyst
Electrically Heated Catalyst
Specific Catalytic Reduction
Metallic Catalyst
Oxidation Catalyst
Reduction Catalyst
3-Way Catalyst
Vacuum-Insulated Catalyst
Particulate Filter/Trap

A "TYPICAL(?)" SYSTEM...

"Standard" V8/V10 engine (Pushrod, SOHC, or DOHC; 2V or 4V; iron or Al), or...
More inline engines.
Cylinder deactivation systems.
More sophisticated fuel control algorithms.
Unique crank/start/runup fueling strategy.
Warmup spark retard with intake port flow control valve, and/or VVT.
Lean warmup fueling with roughness control feature, or...
Rich warmup fueling with port air injection.
Electronic EGR (or not, if VVT) and purge controls.
Optimized EGR and purge distribution systems.
Higher energy ignition systems.
Fabricated, possibly dual wall exhaust manifolds in more applications.
Small (<0.5L) close-coupled post-manifold "lightoff" catalysts (2).
Dual wall exhaust pipes.
Toeboard "main" catalysts (2) and/or (in some cases) a single underfloor catalyst.
"Stereo" controlling O2 sensors plus downstream trim/OBD sensors.

“COMMERCIAL” COMPLIANCE STRATEGIES

(Exclusive of intentionally influencing SUV market supply or demand)

COMPLIANCE AT MINIMUM (PIECE) COST

COMPLIANCE AT MINIMUM WORKLOAD

VOLUNTARY OVERCOMPLIANCE - “I’M GREEN”

ALL THE ABOVE (OPTIMUM MIX)

SUMMARY

THE TIER 2 REQUIREMENTS POSE MANY CHALLENGES.

THESE WILL KEEP LIFE INTERESTING FOR MANY EMISSION ENGINEERS.

GASOLINE SULFUR REDUCTION IS A MANDATORY ENABLER.

TIER 2 IS MUCH TOUGHER ON SUVs THAN IT IS ON PASSENGER CARS.

TECHNOLOGY WILL BE DEVELOPED TO MEET EMISSION REQUIREMENTS.

T-2 EMISSIONS MAY EXCLUDE SOME FUEL ECONOMY TECHNOLOGIES.