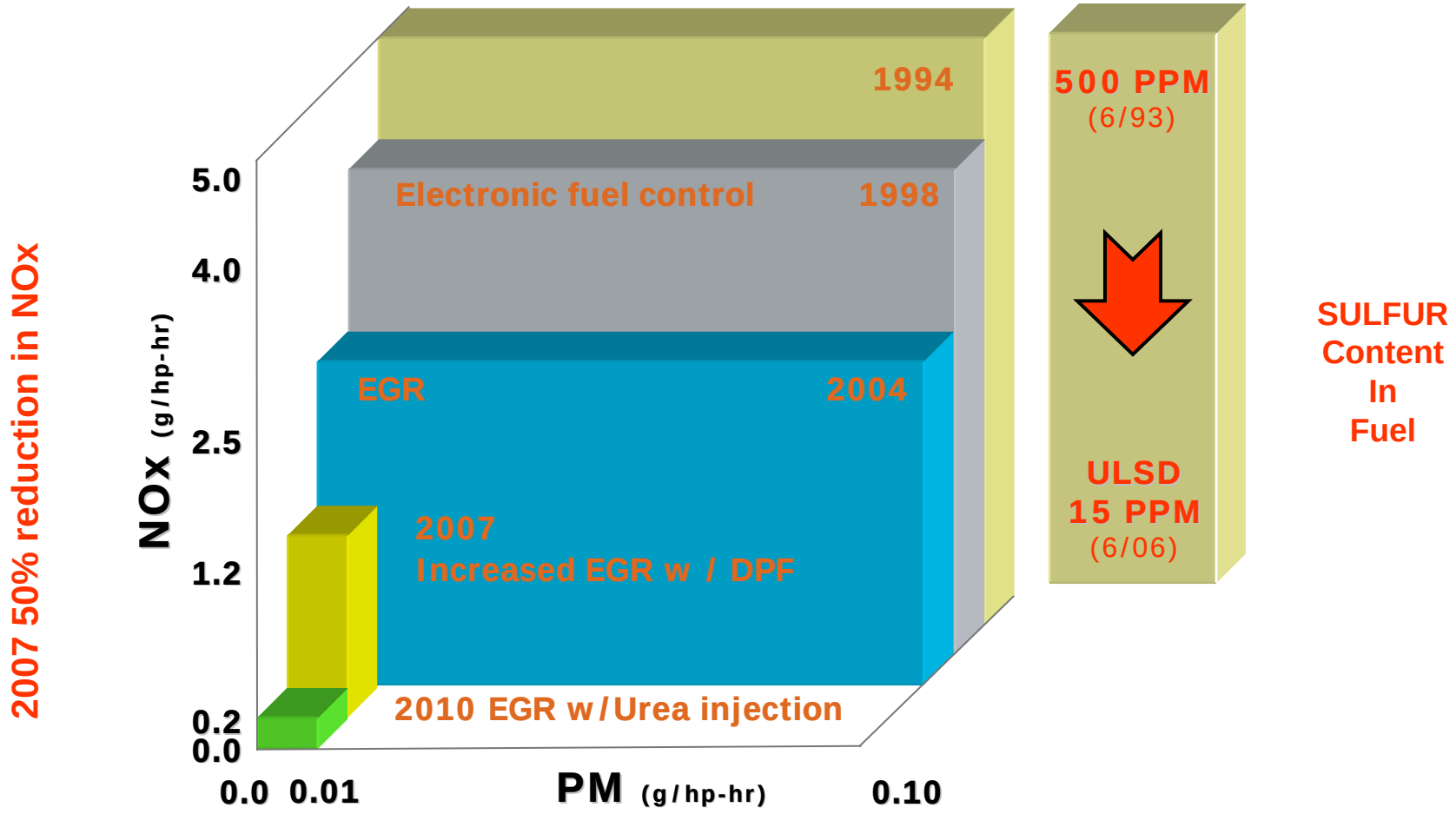
INTERNATIONAL

2010 Diesel Engine

Emissions Requirements & Technology

Independent
Armored Car
Operators Association, Inc.
2008 Annual Convention
Monday, June 23, 2008

2007 EPA Emissions Standards



2007 90% reduction in Particulate matter

Emissions Technology

Hardware Strategies

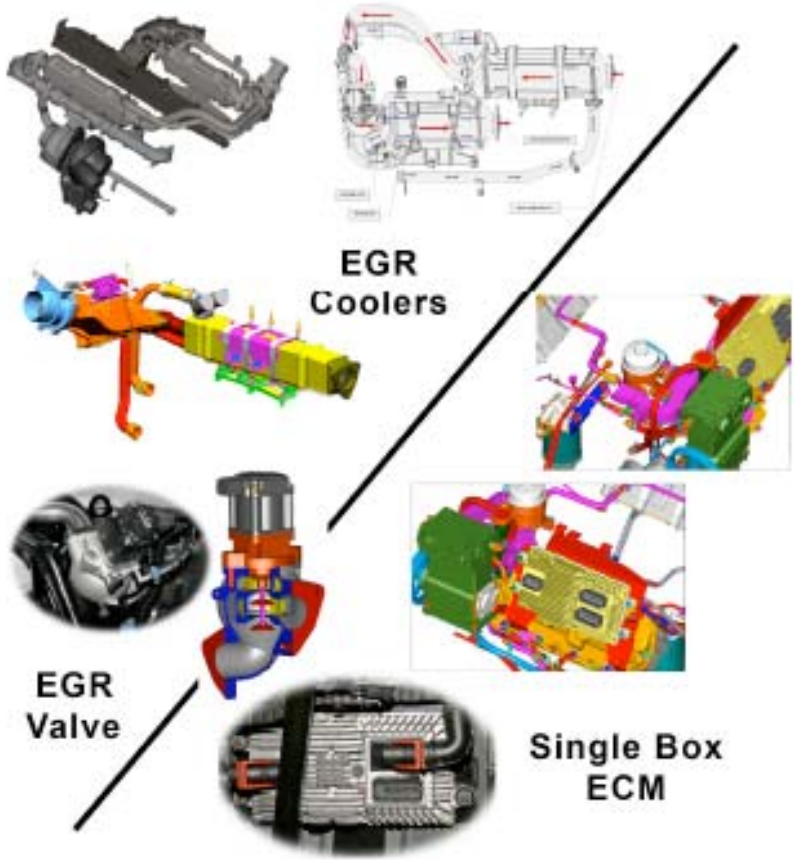
VG Turbo –

CAC –

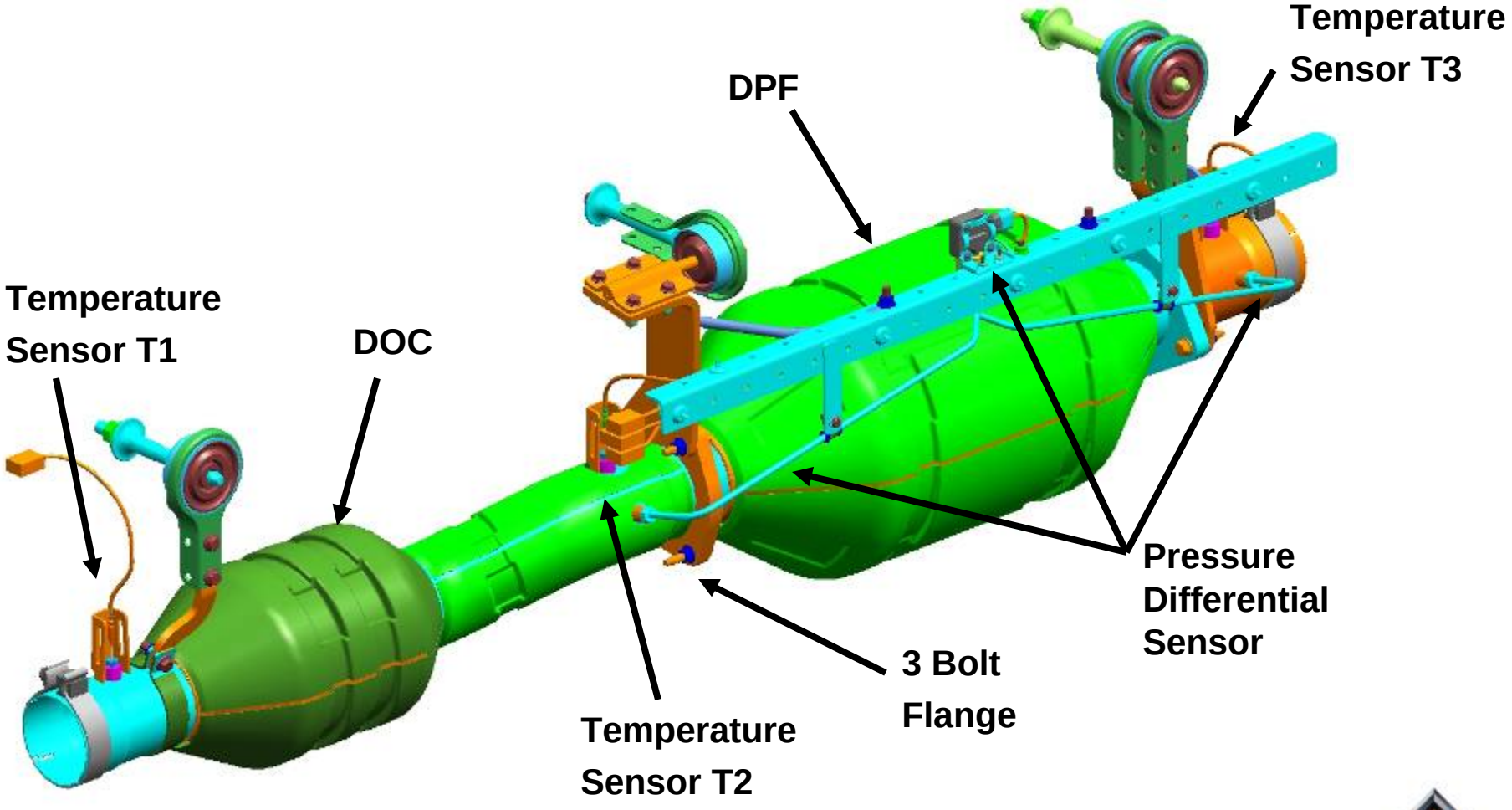
EGR –

DOC –

DPF –



International Exhaust Configurations



Challenge for 2010

Particulate matter challenge met in 2007

- No technology change required

NOx emissions – 83% reduction

- 2007 rule allows certification of engines below 2.5 g, but half of engines must be measured against 0.20 g standard
  - **De facto 2007 NOx limit of 1.2 g/bhp*hr**
- Full implementation of NOx rule for 2010 at 0.20 g/bhp*hr
- Banking and trading of credits still allowed, but engines must be certified at or below 0.5 g

Technology change required to meet the NOx standard

After-Treatment Approaches

- NOx Catalysts
- Selective Catalytic Reduction
- NOx Adsorbers
- Combination Aftertreatment Systems

Common Goal:

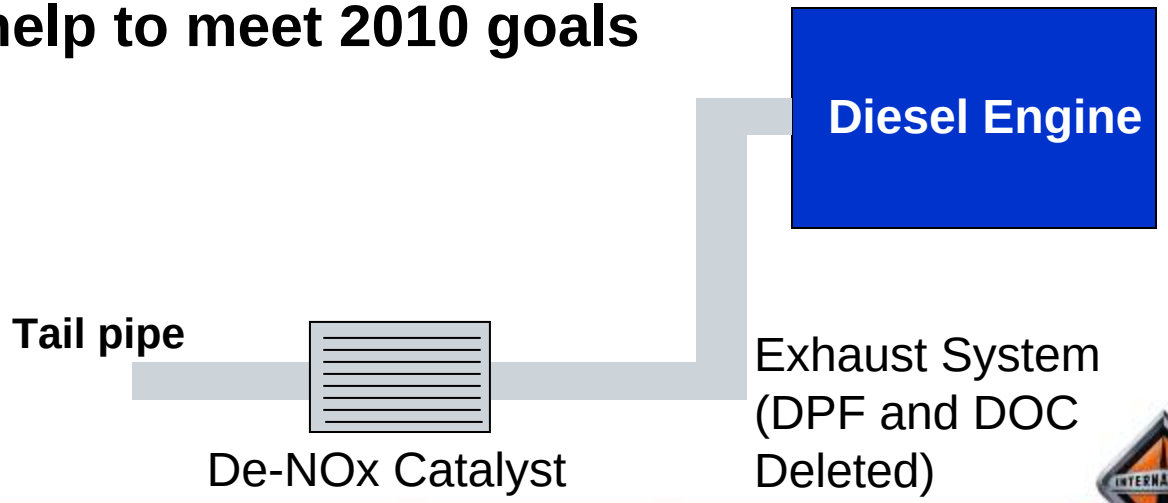
Separate the N from the O

$$NO_X \longrightarrow N_2$$

Passive NOx Catalysts

Passive NOx Catalysts which require no urea or fuel injection do exist, but their effectiveness is not high enough for them to be a stand alone solution for 2010.

- **Simple pass-through device**
- **NOx reduction 20% or less**
- **Need additional help to meet 2010 goals**



Selective Catalytic Reduction

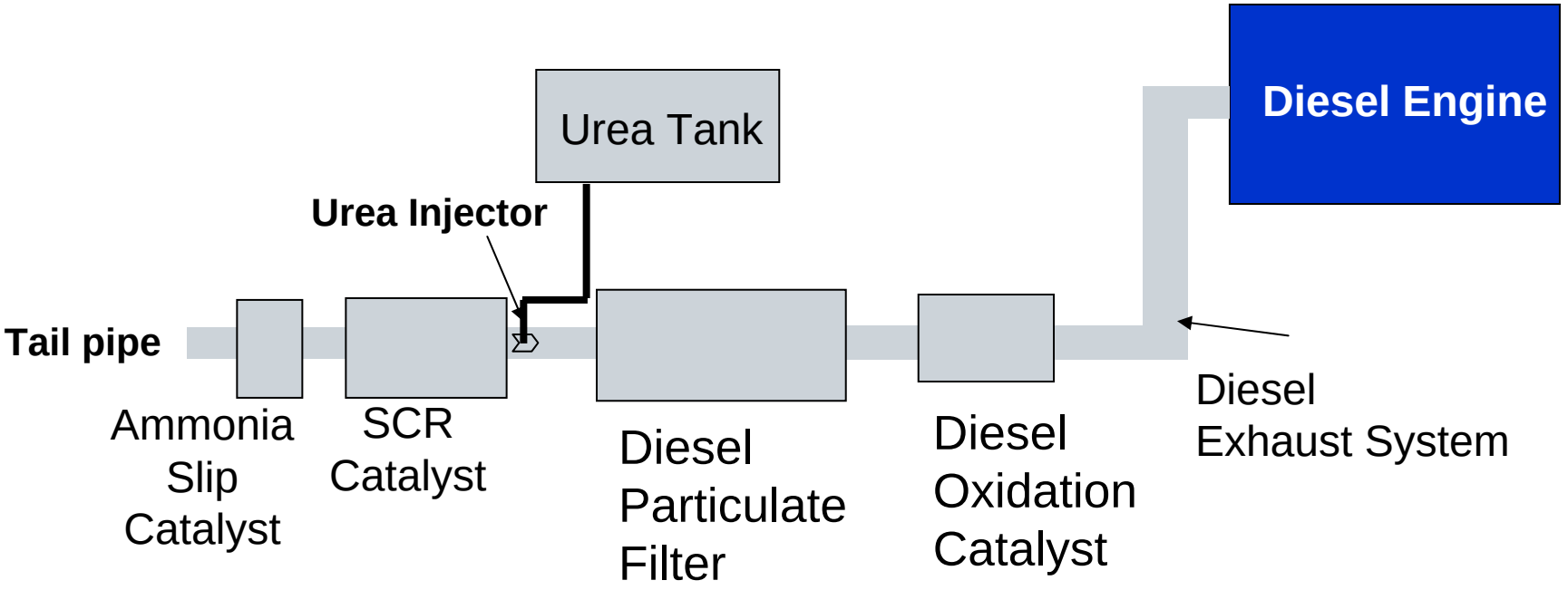
SCR is probably the simplest NOx reduction technique

$$NH_3 + NO_x \longrightarrow N_2 + H_20$$

Ammonia reacts with NO and NO_2 in presence of a catalyst forming N_2 gas and water

Selective Catalytic Reduction

SCR system on a vehicle



Selective Catalytic Reduction

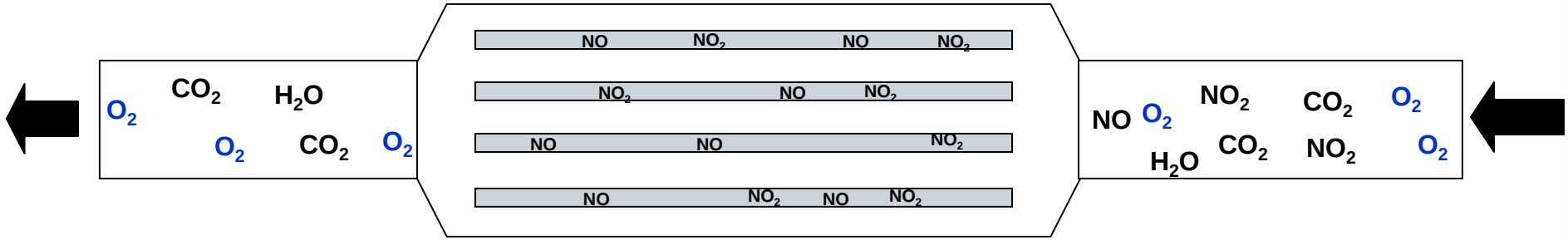
Issues with SCR

- When Urea tank runs dry, vehicle is in violation of the EPA ruling and must be shut down
- Engines will require Urea in the amount of 1.5 percent of total fuel volume per gm of NOx reduction
- Space for tanks and catalysts on short wheel base vehicles and specialty truck bodies
- Urea solutions freeze at +12 °F and evaporate at +112 °F
- Logistics of Urea supply for on-road consumption
- SCR catalysts are sensitive to contamination

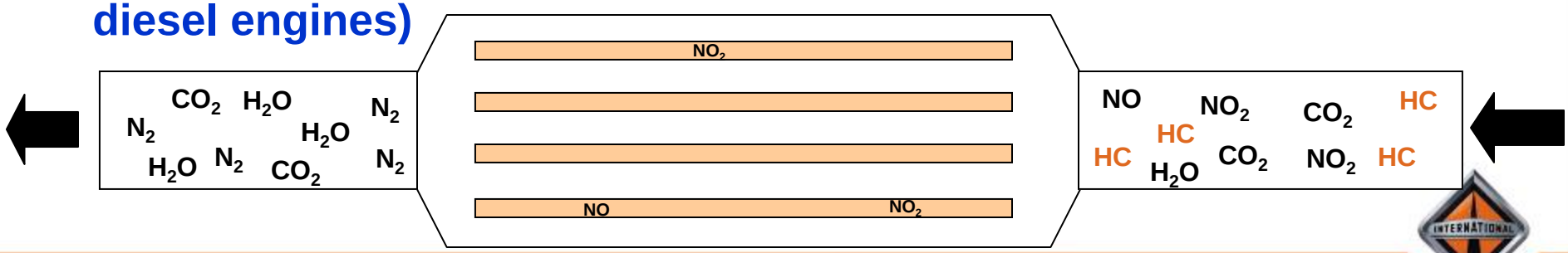
NOx Adsorbers

A NOx adsorber (sometimes called a NOx trap) is a device which captures NOx on the surface of a catalyst and periodically regenerates – conceptually similar to DPF

The NOx is captured during normal lean Air-Fuel Ratio conditions

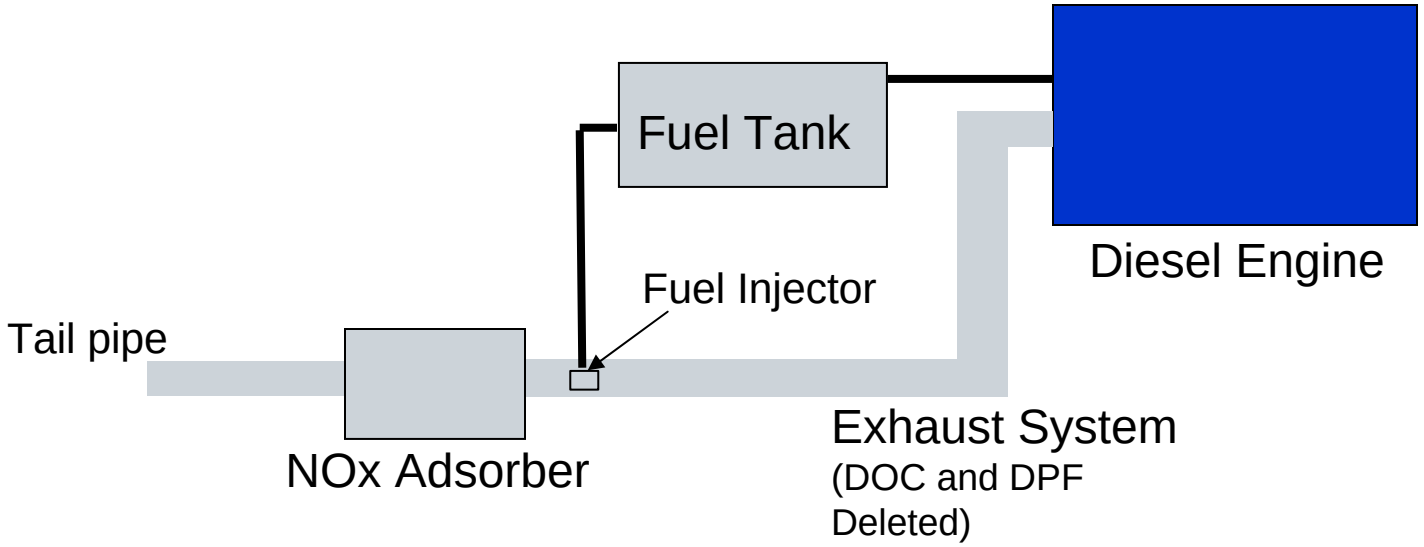


NOx is regenerated during rich A/F conditions (abnormal for diesel engines)



NOx Adsorbers

NOx Adsorber system on a vehicle



NOx Adsorbers

Pros

- **No extra fluid tanks required or any of the other issues associated with SCR systems**
- **Weight and space savings compared with SCR**

Cons

- **Frequent regeneration required**
- **More complicated to control than SCR systems**
- **Fuel consumed in regeneration**

Hybrid Aftertreatment Approaches

SCR catalysts that use diesel fuel as reductant instead of urea

These are only effective in limited temperature ranges, so they are matched with a NOx adsorber to provide a complete solution

- **Pros**
  - **Advantages of SCR without the need for urea storage**
- **Cons**
  - **More expensive overall exhaust system**
  - **Packaging of multiple aftertreatment stages**

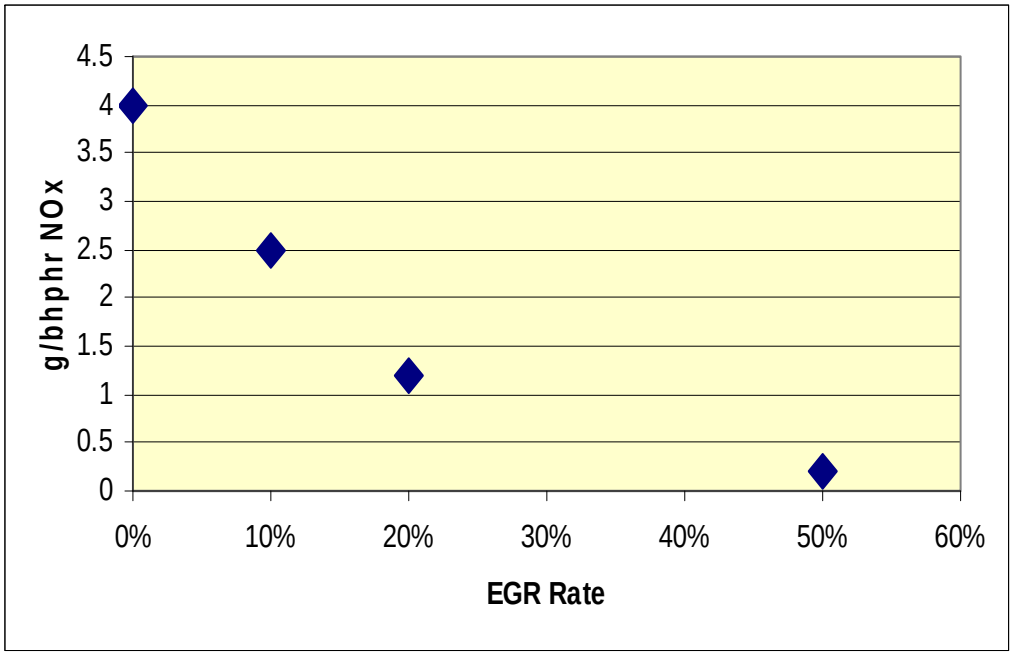
On-Engine Approaches to 2010 NOx Control

- **EGR Rates**
- **Turbocharging Strategies**
- **Fuel Injection Strategies**
- **Homogenous Charge Compression Ignition**

EGR Rates

At high enough rates of Exhaust Gas Recirculation it is possible to meet the 2010 NOx requirements

- Precise engine controls required
- Difficult to achieve at high load conditions
- High particulate matter generation

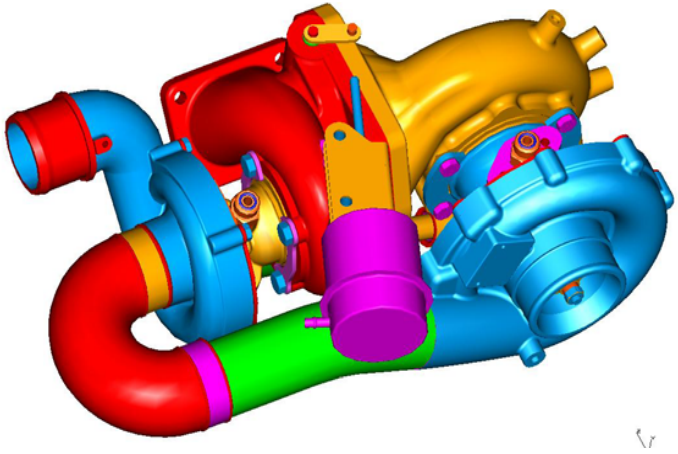


EGR rate strategy will vary

- Reduced EGR
  - Requires more aftertreatment and urea or fuel dosing
- Increased EGR
  - Less need for urea or fuel dosing

Turbocharging Strategies

- Trend towards 2-stage turbocharging will continue
- More controls (wastegates, VGT, by-pass)
- Supercharging in conjunction with turbos
- Alternate uses for turbine energy (compounding)



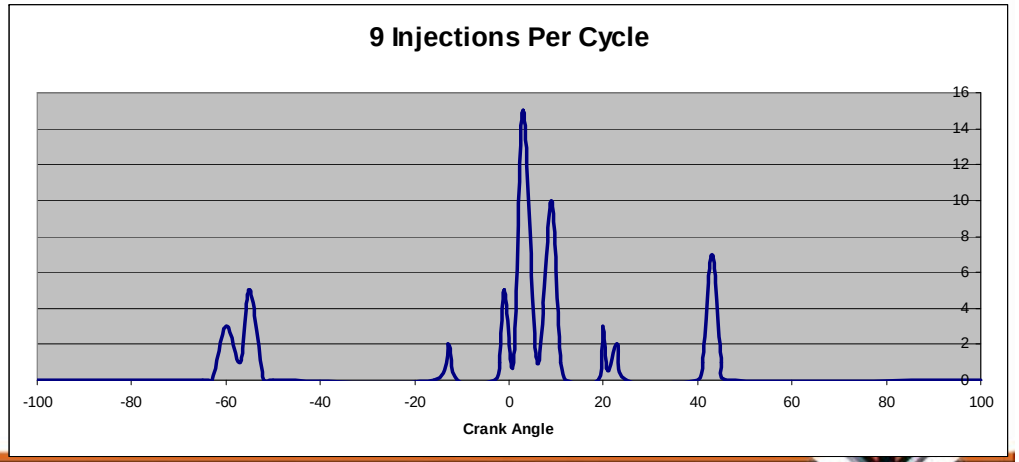
- Turbo strategies may largely depend on engine-out vs. aftertreatment NOx emissions strategies

Fuel Injection Strategies

9 shot capable fuel systems

To better control combustion and engine out emissions, fuel system suppliers are working on injection systems that are capable of 9 shots per cycle

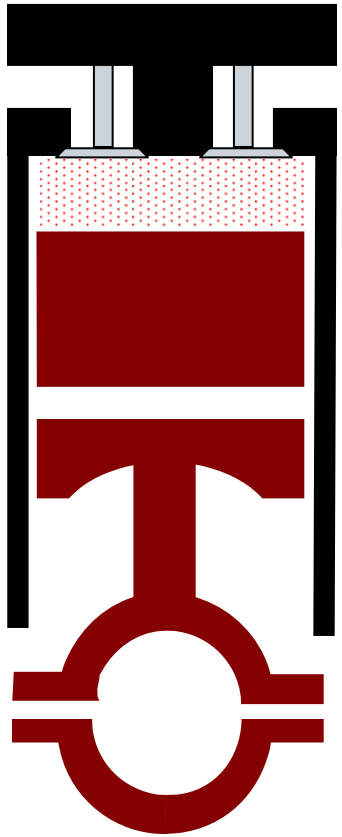
- **3 shots prior to main injection**
  - **NOx control**
  - **Noise reduction**
- **3 shots to replace the current one main injection event**
  - **Precise control of combustion**
- **3 shots post main injection**
  - **Particulate matter clean up**
  - **Post dosing**



Homogenous Charge Compression Ignition

HCCI – the Holy Grail of Diesel combustion

- Well mixed (homogenous) air and fuel charge
- Compression Ignition delayed until the piston is at the top of its stroke.
- Diesel efficiency
- Gasoline emissions levels

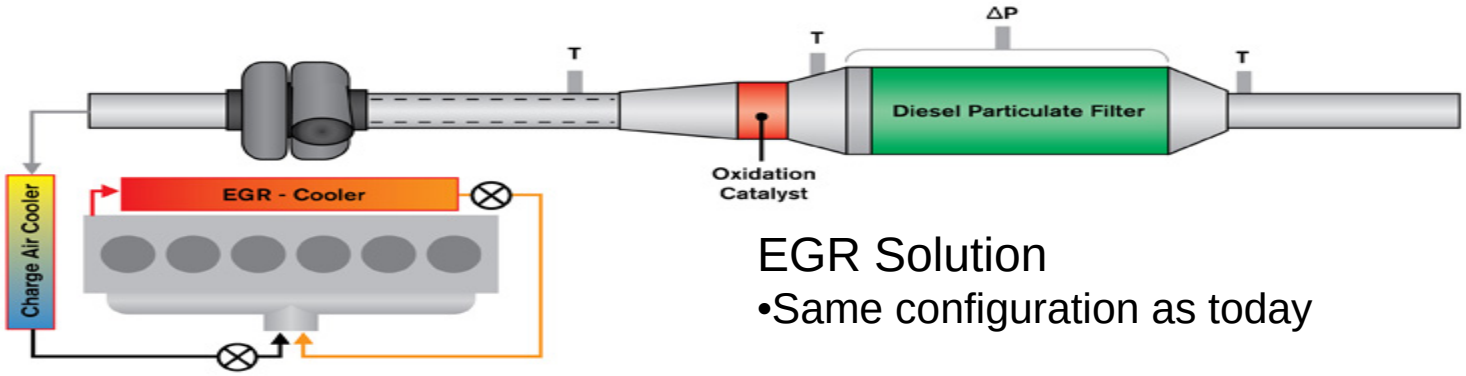


Theoretically this is achievable and could result in Diesel engines that meet the 2010 standard without need for aftertreatment devices

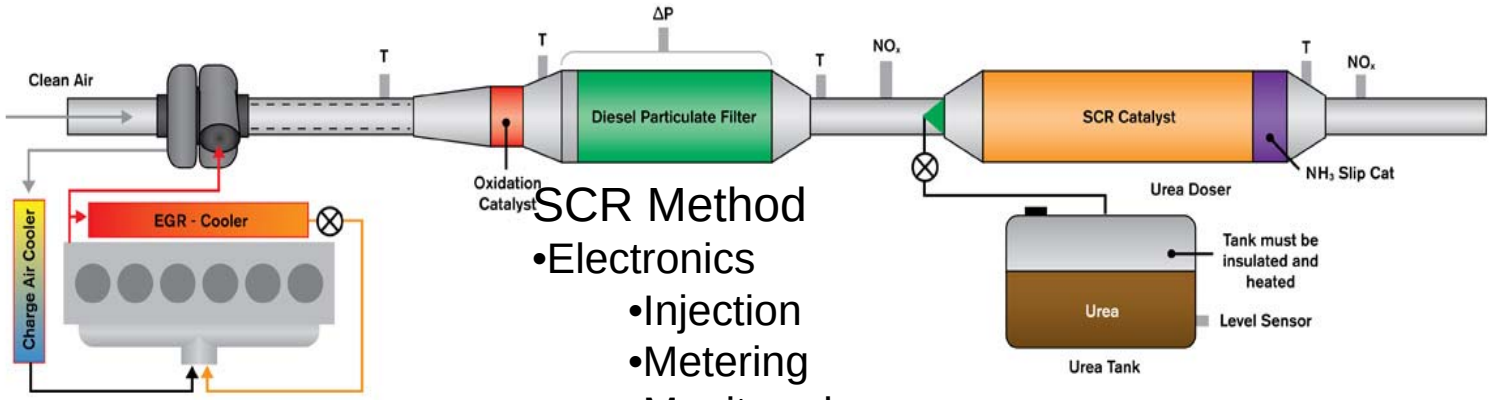
2010 Technology Summary

- **Big challenge to meet NOx standard (83% reduction)**
  - No change for particulates, but DPFs will stay
- **NOx aftertreatment strategies**
  - De-NOx Catalysts
  - Selective Catalytic Reduction (Urea injection)
  - NOx Adsorbers
  - Hybrid SCR/Adsorber Technologies
- **On-Engine approaches**
  - EGR systems
  - Turbo and supercharging
  - Fuel systems
  - Homogenous Charge Compression Ignition

2010 Emissions Methods



EGR Solution
- Same configuration as today



SCR Method
- Electronics
  - Injection
  - Metering
  - Monitored
- Urea tank
  - Heated/cooled
  - Monitored

Ammonia Slip Catalyst
- Monitored


ups

THANK YOU!!

Questions?