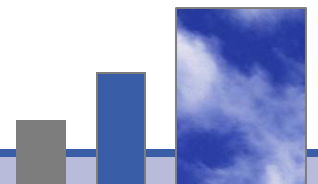


Diesel Emissions & Emission Reduction Strategies

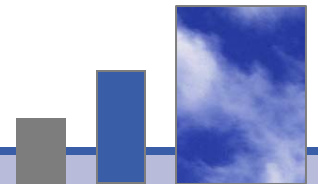
Puget Sound Seaport
Diesel Solutions Workshop
November 15, 2005

Tim Taylor
Cleaire Advanced Emission Controls®



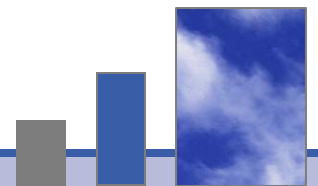
The Diesel Engine

- Ignites fuel without spark – instead uses the heat of compression to exceed the ignition temperature of a fuel
- Capable of using a wide variety of fuels
 - Diesel, Kerosene, Jet Fuel, Residual Oils
- Is the workhorse of the heavy-duty transportation industry
 - Current designs expected to last 1 – 1.5 million miles if properly maintained
 - Fuel efficient, low-maintenance, dependable
- Flexible, dependable, durable, efficient, cost-effective



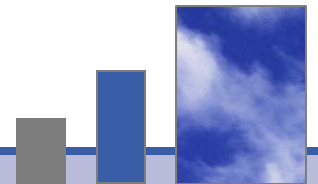
Combustion

- For combustion to occur all three parts of the triangle MUST be present



Combustion

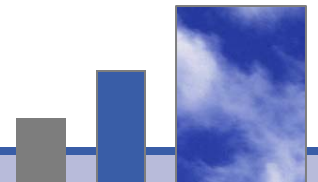
- Textbook combustion has only two exhaust by-products
 - CO_2 and H_2O
- Unfortunately, life is not like a textbook
 - Diesel is not pure carbon and hydrogen:
 - sulfur, nitrogen
 - Air is not pure oxygen
 - nitrogen
- Engine combustion happens at high temperature and high pressure
 - A perfect environment to form many chemical compounds



Diesel Emissions

Health Impact High to Low

- Particulate Matter (PM)
 - A product of incomplete combustion
 - Diesel PM is a Toxic Air Contaminant (TAC) and is the largest single carcinogen in ambient air (MATES II)
- Oxides of Nitrogen ($\text{NO} + \text{NO}_2 = \text{NO}_x$)
 - NO_x is a product of high temperature combustion: the higher the peak combustion temperature the more NO_x formed
 - Direct exposure to NO_2 is harmful
 - NO_x contributes to ozone formation & direct exposure to ozone is harmful
- Diesel engines also emit
 - Volatile Organic Compounds (VOC) which can be TACs and can also lead to ozone formation
 - Carbon Monoxide which is a poison
 - Sulfur dioxide (SO_2) which can form sulfuric acid

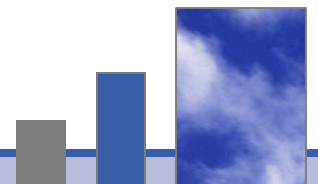


Emission Reduction Strategies

- Reducing PM
 - Improve combustion efficiency
 - Easiest thing to do...increase peak combustion temperature
- Reducing NOx
 - Reduce peak combustion temperature
- Reduce PM, VOC & CO
 - Precious metal catalyst
 - Precious metals can be poisoned by sulfur and diesel fuel has sulfur

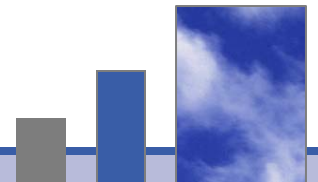
Engineering
Challenge!!!

Engineering
Challenge!!!



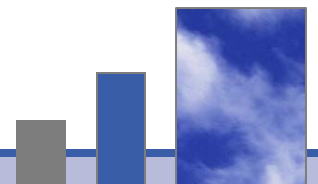
Emission Reduction Strategies

- Engine design changes
 - Combustion chamber designs to maximize air/fuel mixture and minimize local hot spots
 - Air handling (e.g. turbocharging, valve timing)
 - Cooled Exhaust Gas Recirculation (EGR)
 - Injection timing (retard/advance, rate shaping)
- Exhaust after-treatment
 - PM
 - 25% Control – Diesel Oxidation Catalyst
 - 50% Control – Partial Filter (Wire Mesh Filter)
 - 85%+ Control – Diesel Particulate Filter (DPF)
 - NO_x
 - 25% Control - Lean NO_x Catalyst
 - 40% Control – Retrofit EGR
 - 70%+ Control – Selective Catalyst Reduction (SCR)
 - VOC & CO
 - 40% Control – Lightly coated catalysts (DOC)
 - 90% Control – Heavier catalyst coatings (DPF)



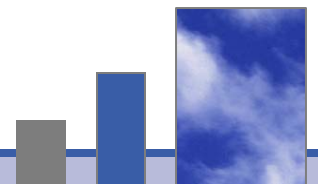
Fuels

- Additives
 - Precious and non-precious metals (platinum, cerium)
 - NO_x: 5% - 10%
 - PM: 10% - 40%
- Low sulfur diesel
 - NO_x: 0%
 - PM: 10%
- Water emulsions
 - NO_x: 15%
 - PM: 50%
- Alternative Fuels
 - Natural gas
 - Biodiesel
 - Propane
 - Ethanol



What does all this mean?

- **THERE IS NO SUCH THING AS A CLEAN FUEL**
- It takes a system approach to control pollution
 - A 2005 diesel engine retrofitted with a DPF and Lean NOx controls can be LOWER in PM and nearly equal in NOx emissions to a 2005 natural gas engine
 - By 2010, new diesel engines and new natural gas engines will have the same near-zero emission levels
- Competing desires impact our ability to control pollution
 - Fuel economy
 - Reducing one pollutant can raise another creating a trade off
 - Drivability
 - Power and performance
 - Dependability, durability, life-cycle cost



Cleaire Contacts

- Tim Taylor, Director – Strategic Market Development
 - (916) 296-7049
 - Tim.Taylor@cleaire.com
- Tom Swenson, Director – Sales & Verification
 - (916) 689-0248
 - Tom.Swenson@cleaire.com
- Brad Edgar, Vice-President & CTO
 - (510) 347-6160
 - Brad.Edgar@cleaire.com
- www.cleaire.com

