History of Regulation and Technologies
Government Regulations
+
Customer Needs

Product Design
What Drives Emissions Regulation?

- Public opinion – green mindset
  - Climate change
  - Environmental concerns
**EPA Diesel Emissions Legislation**

### NOx / NOx+HC

- 1988: 10.7 g/HP-hr
- 1990: 6.0 g/HP-hr
- 2000: 5.0 g/HP-hr
- 2005: 4.0 g/HP-hr
- 2010: 2.5 g/HP-hr
- 2015: 1.2 g/HP-hr
- 2020: 0.2 g/HP-hr

*Phase-In Average*

### Particulate Matter

- 1988: 0.6 g/HP-hr
- 1990: 0.25 g/HP-hr
- 2000: 0.1 g/HP-hr
- Urban Bus: 0.05 g/HP-hr
- 2015: 0.01 g/HP-hr
- 2020: 0.0 g/HP-hr

*Near Zero Emissions*
Evolution of Technology

- **1990**: Aftercooling
- **2000**: Electronic Fuel Systems
- **2010**: Diesel Particulate Filter
- **2020**: Selective Catalytic Reduction (SCR)
- **NOx, PM**
- **CO₂**
Innovation Through Technology Integration

Combustion & Fuel Systems

Transmission Integration

Air Handling & EGR

Aftertreatment

Electronic Controls

Energy Recovery
Examples of Customer Benefits

- More horsepower from the same package
- Increased reliability
- Better engine control (fire pump governing)
- Enhanced diagnostics (diagnostic codes)
- Operational information (trip information)
Upcoming Regulation
Upcoming Regulation

- EPA 2017 regulations are finalized
  - Greenhouse Gas (GHG) reduces CO2
    - Further fuel economy improvements
  - On Board Diagnostic (OBD) ensures clean operation
    - Assists technicians in troubleshooting
    - Improved reliability

- EPA 2020 regulations are being drafted (GHG)
  - 2014 Framework established
  - 2015-2016 Comment period
  - 2016 Rule finalized
The Future
Energy Conversion

- Friction
- Accessories
- Gas Exchange

- Cooling System
- Exhaust
- Useable Power
Potential Technologies to Enable Greater Efficiency

**Combustion & Air Handling**
- Piston bowl size and shape
- Injector specification
- Calibration optimization
- Turbocharger efficiency
- Aftertreatment optimization

**Heat Recovery**
- EGR, exhaust, recuperation
- Turbine expander
- Low GWP refrigerant

**Parasitic Reductions**
- Cooling and fuel pump power
- Shaft seal
- Variable flow lube pump
- Low viscosity lubricant
- Geartrain
- Cylinder kit friction

**Other trends**
- Rear Engine PTO
- Lightweighting
- Space saving technology
- Telematics/Data Analysis
- Electrification
Customer Needs + Government Regulations

Product Design
Questions?