Creating Affordable Clean Power SM

May 4, 2004

Brief History

• Clean Air Partners Founded	1991
• 1st Dual-Fuel™ Conversion	1994
• 1st Caterpillar Prototype	1996
• License with Caterpillar	1996
• 1st CARB HD LEV engine	1997
• First 1,000 Dual-Fuel Units	2001
• 1st Round of Venture Capital	2001

Recent Achievements

- 2,000 Heavy-Duty Dual-Fuel™ units in service
- Acquisition of HIS, manufacturer of catalytic emissions reduction systems
- First two powergen orders – 1.6 MW
- Clean Air Partners demonstrates ultra-low Dual-Fuel emissions (NO_x levels of 0.5 g/bhp-h and PM of 0.004 g/bhp-h)
- **Clean Air Partners Certifies to Euro 4**
- UK JV, CAP-HARDSTAFF – Foden Dual-Fuel™ trucks for the UK market
- **Formation of Clean Air Power Ltd. – Leyland, UK**

Facilities

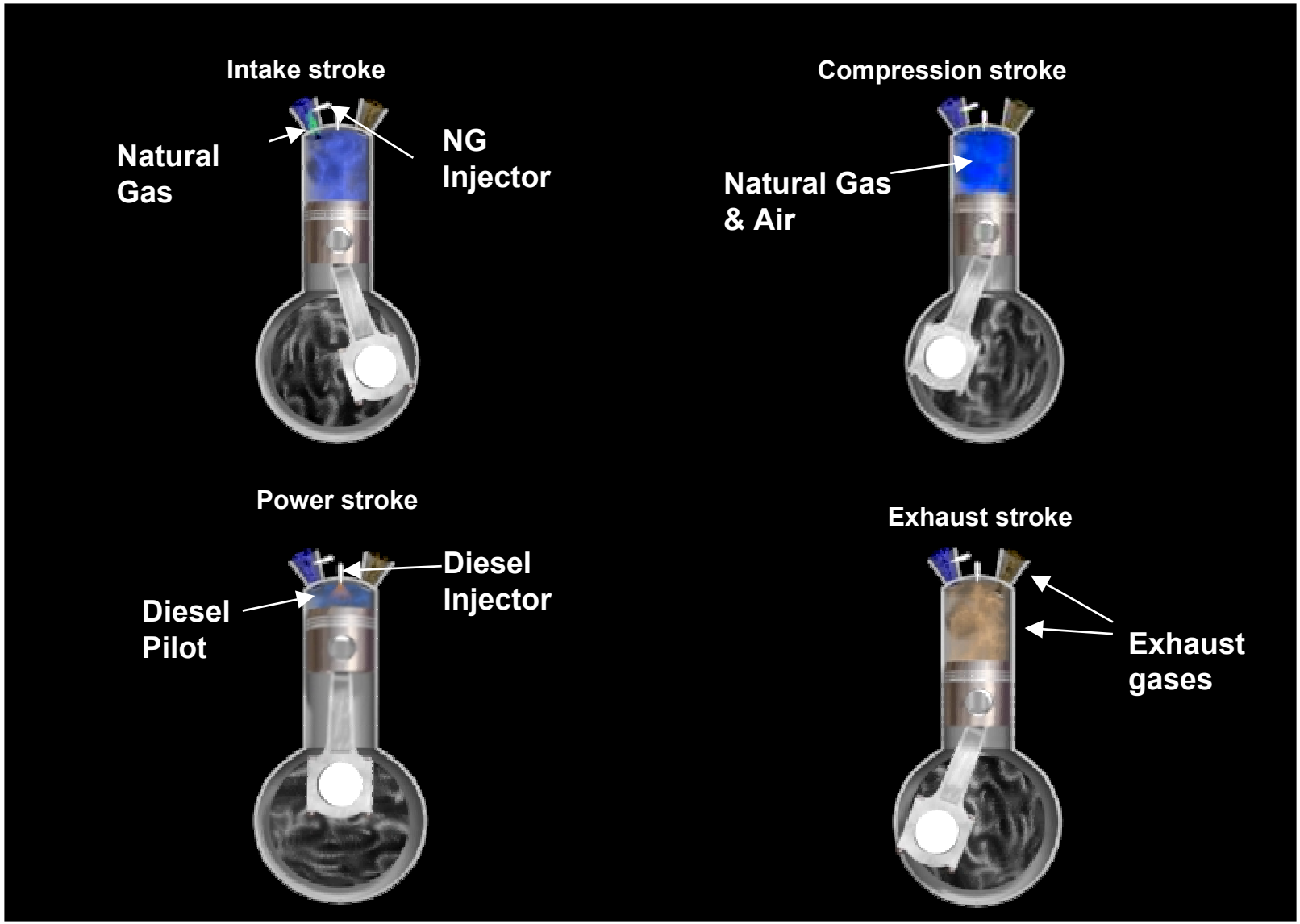
- **SAN DIEGO** Headquarters
  Product Develop
  Operations
- **HOUSTON** Catalysts
  Components
- **Leyland, UK** Dual-Fuel Conversions

What is Dual-Fuel™?

- Natural Gas with Diesel Pilot Ignition
- Fumigated w/ Mechanical Diesel
- Electronic Gas w/Mechanical Diesel
- Electronic control of Gas & Diesel

Electronic Control . . . best performance

Dual-Fuel in Action



How the Dual-Fuel™ Engine Works

- Electronically controlled, multi-point, port-injected
- Pilot ignition from the standard diesel fuel system
- Natural gas injectors and sensors combined with custom intake manifold

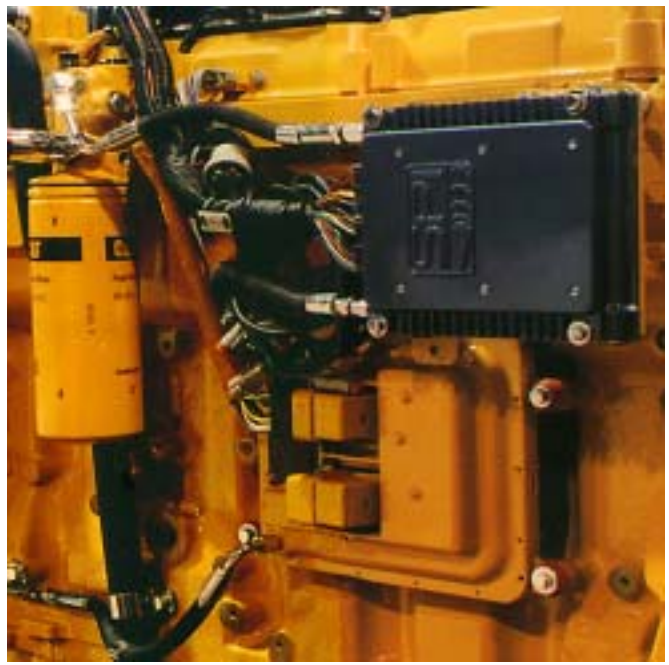
No internal modifications

NG Injector

How the Dual-Fuel™ Engine Works

- Diesel ECM and the **Dual-Fuel ECU** interface for:
  - **Optimizing** combustion, performance & emissions
  - Data storage & retrieval
- Control code provided by OEM
- The ECU and ECM coordinate fuel delivery
- Gas and Diesel injectors controlled individually

Electronics are fully integrated



Only HD Euro IV Gas Engine

Emissions Values (gms /KW hr.)	Diesel	Euro IV	Current Dual-Fuel
NOx	5.54	3.5	3.18
CO	1.1	1.5	0.061
Particulates	0.06	.03	0.013
NMHC	0.07	0.55	0.23
Methane	NA	1.1	0.88

21% Reduction of GHGs, 29% - CO2!

Dual-Fuel Advantages

- **Reduced emissions** over base diesel
- **EURO IV** Certified
- **Fuel costs** are lower
- **Diesel Fall-back**
- **Drivability** is similar to diesel
- **Diesel efficiency**
- Extended **engine life**
- Less **fuel storage** required than dedicated
- Enhanced **resale value**

Dual-Fuel™ - Future Emission Improvements

ACERT Platform

- Variable Valve Actuation
- Extended light load gas operation
- Improved NOx control
- Improved Knock control
- Higher efficiency
- Series Turbochargers
- Improved diesel injection control
- Higher gas substitution
- Comes from CAT w/ PM trap

CLEAN AIR POWER

MicroPilot®

- Replaces the standard diesel fuel system MicroPilot Injectors for greatly improved natural gas substitution.
  - Advantages
    - Much higher gas substitution 95 – 99%
    - Better spray distribution in the cylinder for ignition.
    - Less NOx and PM from pilot combustion.
    - Seven years of system development know-how
  - Challenges
    - Eliminates diesel-only limp home
    - OEM availability re-enters the equation

Dual-Fuel Applications: Mid-Range








Dual-Fuel Applications : Vocational

Dual-Fuel Applications : Heavy-Duty

Road Train - Australia

Foden Alpha

US Tractor

Creating Affordable Clean Power SM

November 8, 2003