



Every Alternative.

ISL G Technology Overview

May 2009

ISL G - Three Key Emission Technologies

- Cooled Exhaust Gas Recirculation (CEGR)

Cummins

- Stoichiometric Combustion

Cummins Westport

- Three Way Catalyst (TWC)

**Cummins
Emission Solutions**

Evolution of Natural Gas Engine Technology

- **Stoichiometric combustion** is the ideal combustion process during which fuel and oxygen are burned completely
 - Ideal air/fuel ratio - chemically correct mixing of fuel and air
 - Consumes all fuel & air without excess of either in exhaust
 - Three way catalysts (TWC) are highly effective at NOx reduction, but only if there is no oxygen in exhaust stream
 - Technology used in light duty market for over 20 years
- Previous CWI engines (e.g. C Gas Plus) use **Lean Burn combustion**, where the air content is higher than the stoichiometric ratio
 - Lean burn enables better efficiency, power density and durability than conventional stoichiometric combustion
 - Excess air leads to reduced exhaust temperatures
 - Cannot use TWC
- **Stoichiometric combustion with cooled EGR** combines & improves the best attributes of both Stoichiometric & Lean Burn combustion
 - Cooled EGR reduces exhaust temperature better than lean burn engines
 - Better efficiency and power density compared to Lean and Stoichiometric technologies

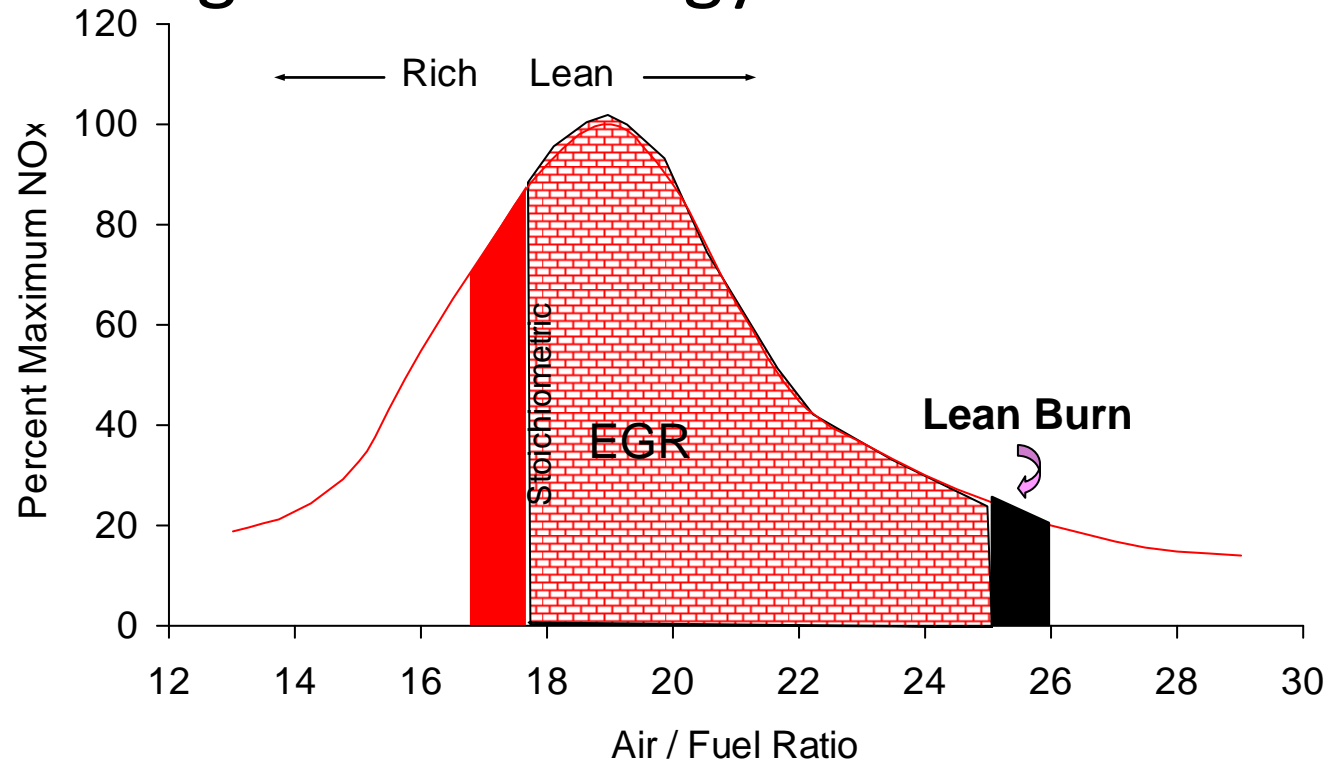
Natural Gas Engine Technology Evolution

1. Stoichiometric

- Light duty gasoline engines
- Low NOx with TWC
- Limited power density, efficiency, durability

2. Lean Burn

- Proven reliability/durability in heavy duty applications
- Lean combustion reduces in cylinder temperatures
- NOx control is in-cylinder
- Capable of EPA07 emissions



3. Stoichiometric with Cooled EGR

- Combines & improves the best attributes of Stoichiometric & Lean Burn combustion
 - EGR in place of air in Lean Burn reduces combustion temperature
 - TWC for NOx control - Sub-EPA10 emissions with passive aftertreatment
 - Improved power density & efficiency

Three Way Catalyst

- TWC reduces three harmful emissions: NO_x , CO, HC
- End products are: N_2 , CO_2 , H_2O
- Packaged as a replacement muffler
- Simple, passive, maintenance-free
- Consistent performance across all duty cycles

Catalyst Inlet

NO_x

CO

HC



Catalyst Outlet

N_2

CO_2

H_2O

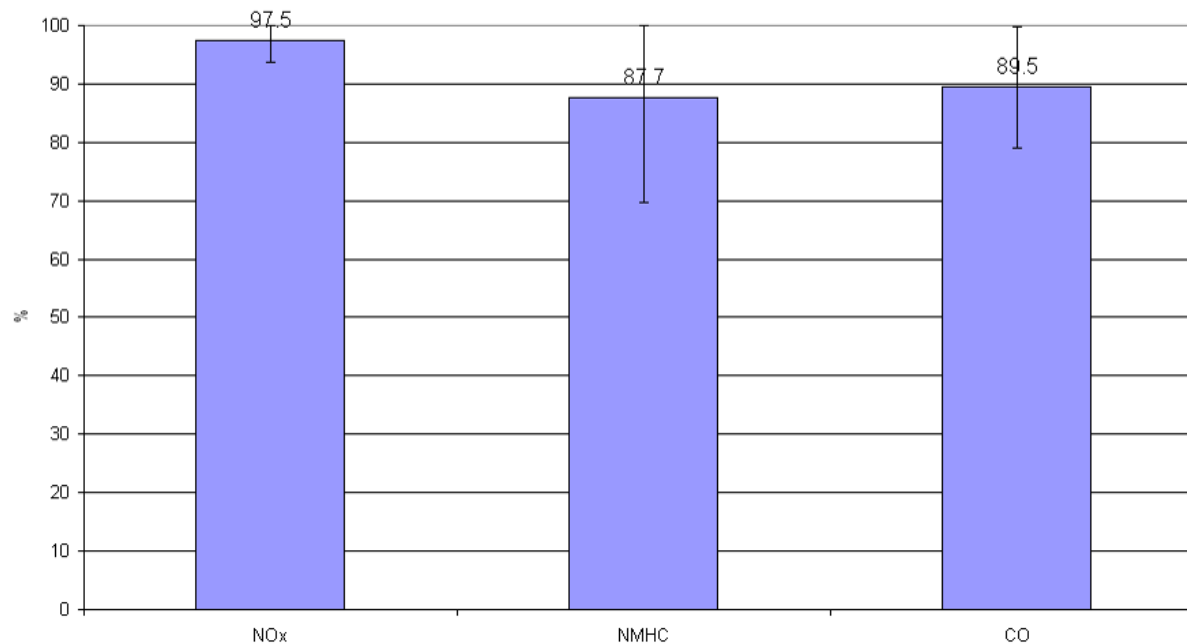


ISL G TWC - similar package size to current mufflers

Catalyst Effectiveness

- Achieved high effectiveness of emissions reductions

Typical 3 Way Catalyst Conversion Efficiency



Benefits of Stoichiometric EGR Combustion

- Increased power density
 - Torque curves are virtually the same as diesel
 - Diesel-like transient response/performance
 - More torque at idle

- Increased thermal efficiency
 - 5% fuel economy improvement vs. lean-burn natural gas engines
 - Lower methane emissions (GHG benefit)

- Decreased emissions
 - Beats 2010 emission standards today
 - Simple, passive, maintenance-free aftertreatment

ISL G and ISL Diesel

What is the Same?

- Cummins Base Warranty
- Extended Warranty Option
 - Available
- 500 hour Maintenance Interval
- Parts and Service
 - Available from global Cummins Distributor Network
- Factory Engineered
- Manufactured at Cummins Rocky Mount Engine Plant, North Carolina, USA
- 320, 300, 280, 260 and 250 HP ratings
- Major Engine Components
 - Block, crankshaft, main bearing, piston rods, EGR
 - Over 80% parts commonality
- Compatible with Cummins Diagnostic tools
 - Insite
 - QuickServe Online



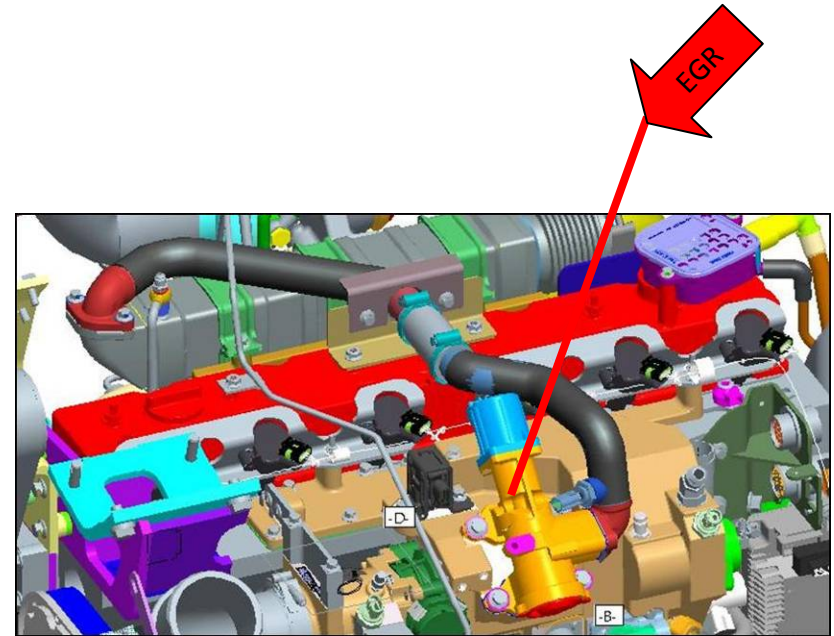
ISL G and ISL Diesel

What is Different?

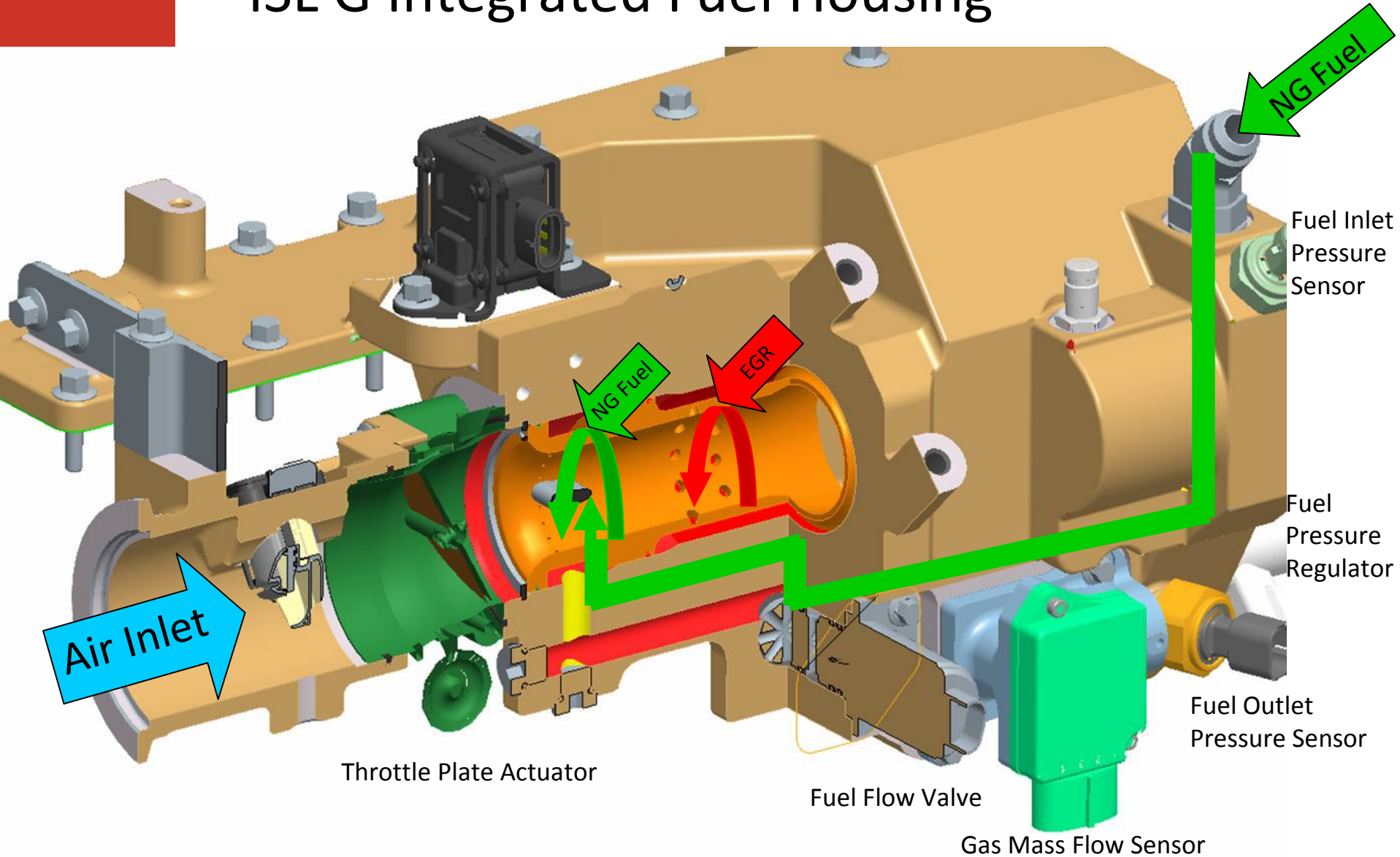
- Cylinder Head
 - 4 valve (diesel) vs. 2 valve
- Ignition
 - Compression (diesel) vs. spark ignition
- Fuel System
 - Common rail injection (diesel) vs. manifold injection
- Aftertreatment
 - Particulate Filter + Selective Catalytic reduction (diesel) vs. maintenance free TWC
- Noise
 - Natural gas engines are up to 10dB quieter at idle
- Emission Certification
 - ISL G is the only 2010 compliant HD engine available today
- Fuel Cost
 - Natural gas total fuel costs (including station) are less than diesel
- Fuel Economy
 - Diesel engines typically obtain better fuel economy
- Initial Costs
 - Natural gas trucks typically cost more than diesel trucks

ISL G Exhaust Gas Recirculation (EGR)

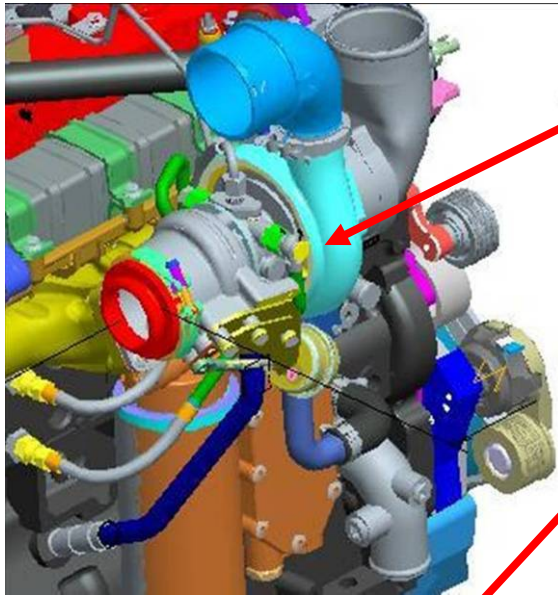
- Cooled exhaust gases flow via crossover tube to EGR valve
- EGR valve controls EGR flow & is mounted on the fuel housing
- EGR in place of excess air creates Lean Burn-like combustion conditions, with oxygen-free exhaust
- Oxygen-free exhaust enables a three way catalyst



ISL G Integrated Fuel Housing



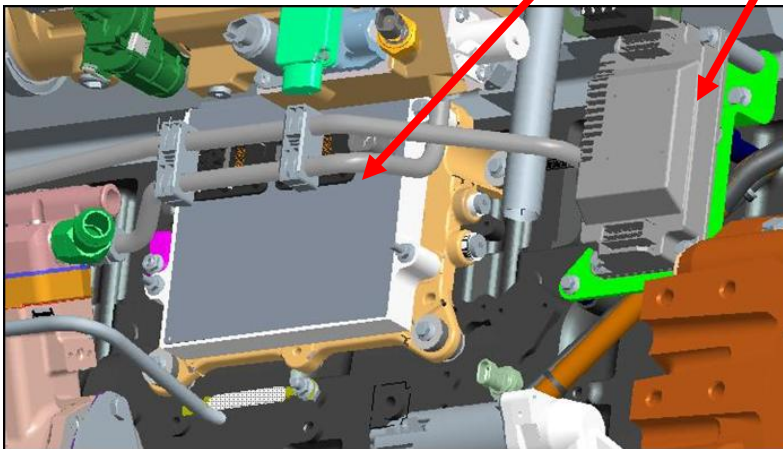
ISL G Turbocharger and Controller



- Turbocharger
 - Wastegate actuator incorporated with “Boost Control Valve”
 - Optimal transient response over a wide range of operating points

- Electronic Control Module (ECM)
 - CM2180A
 - Compatible with Cummins Diagnostic Tools

- Ignition Control Module (ICM)
 - Controls Start of Ignition Event
 - Aluminum case with gasket & lid to seal out moisture
 - Allows for Misfire Detection & Ignition Voltage Detection



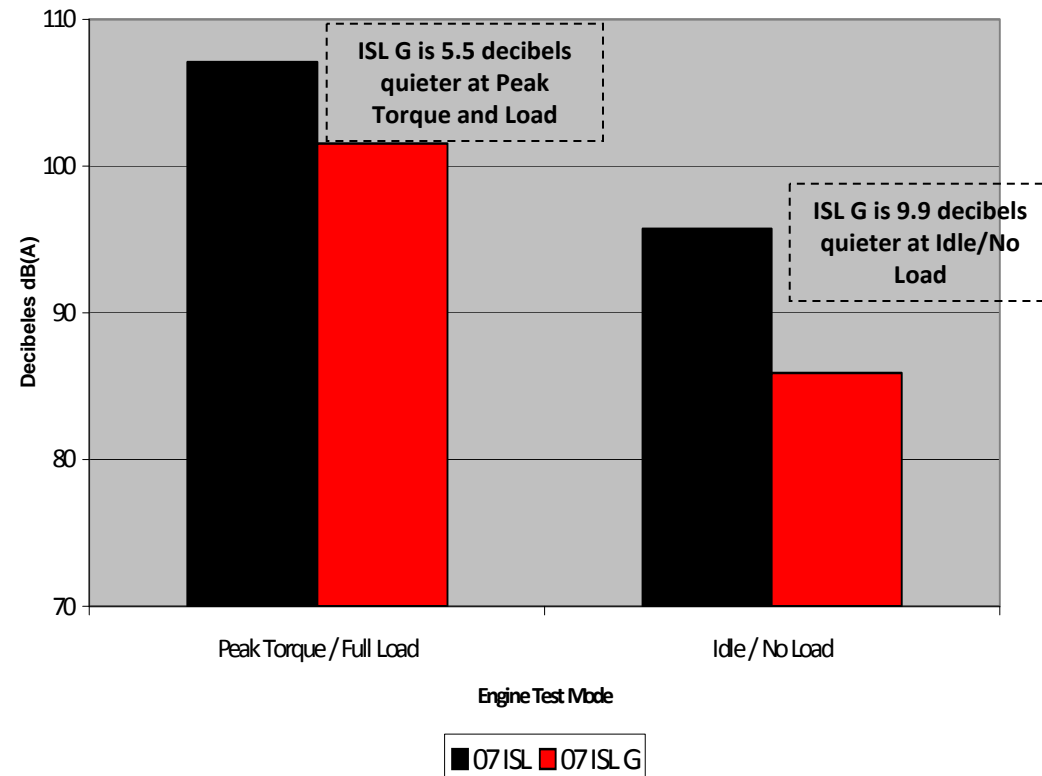
Reduced Noise

Communities notice the natural gas noise advantage.

ONE Diesel engine idling is louder than **TEN** natural gas engines idling together



Noise Comparison



Fuel

- Natural gas fuel must meet ISL G fuel specs per AEB 79.05
- Minimum Methane Number (MN) is 75
- Natural Gas fuel for the ISL G can be stored on the vehicle in either liquid (LNG) or compressed (CNG) form.
- ISL G requires fuel to be regulated to max 150 psi, min 70 psi
- Cummins Westport approves the use of up to 100% biomethane that meets published natural gas fuel specifications per Cummins Application Engineering Bulletins (AEB 79.01, AEB 79.02, and AEB 79.05)



Biomethane Profile: Hilarides Dairy - Lindsay, California

- Hilarides Dairy uses manure produced by 10,000 cows to generate 226,000 cubic feet of biomethane daily — enough to reduce the Central Valley farm's diesel fuel consumption by 650 gallons a day
- Two 18 wheel tractor trailers powered by ISL G 320 operating on compressed biomethane
- Project financed with a \$600,000 grant from the California Air Resources Board Alternative Fuel Incentive Program.



Hilarides Dairy Biomethane Project, California

Natural Gas Applications

TRUCK



SPECIALTY



BUS



REFUSE



ISL G Ratings

ENGINE MODEL	ADVERTISED HP(KW) @ RPM	PEAK TORQUE LB-FT @ RPM	GOVERNED SPEED
ISL G 320	320 (239) @ 2000	1000 (1356) @ 1300	2200 RPM
ISL G 300	300 (224) @ 2100	860 (1166) @ 1300	2200 RPM
ISL G 280	280 (209) @ 2000	900 (1220) @ 1300	2200 RPM
ISL G 260	260 (194) @ 2200	660 (895) @ 1300	2200 RPM
ISL G 250	250 (186) @ 2200	730 (990) @ 1300	2200 RPM

Warranty - Every Coverage

- *Base Warranty for Bus/Shuttle, School Bus and Truck are the same as diesel*
- *Extended Coverage options are available for Truck and Bus Customers*
 - *5 yr 200,000 mile or 300,000 mile - Transit*
 - *4 yr / 5 yr 150,000 mile Vocational -Truck*
 - *4yr / 5 yr 150,000 mile Turbocharger -Truck*
 - *6 yr, 300,000 mile Major Component – All applications*
- *All warranty programs administered per Cummins Standard Policies*

