Cummins Westport, Inc.

Engine Overview

March 2015
Cummins Westport Inc. (CWI)
A Cummins JV Company

- CWI was established in 2001 as a 50/50 joint venture company between Cummins Inc and Westport Innovations.
  - Cummins Inc. - world’s largest independent manufacturer of commercial diesel and natural gas engines.
  - Westport Innovations Inc. - world leader in gaseous fuel engine technology
- CWI offers 8.9 and 12 liter spark ignited alternative fuel automotive engines.
- Engines are manufactured by Cummins in Rocky Mount, North Carolina, and Jamestown, New York.
- Local parts and service support through Cummins Distributor network.
Cummins Westport

Heavy Duty Engines Designed Specifically for Alternative Fuels

- Based on Reliable Cummins Engine Platforms
- Common parts and design provide heavy duty performance
- Engineered and Optimized Specifically for Alternative Fuel
- Continued improvement in reliability and cost of ownership
- Service, Parts and Training Support through the Cummins Distributor network
2014/16 Cummins Westport Products.

**ISB6.7G**
6.7 Litre
Spark Ignited
SEGR
Three Way Catalyst

**ISL G**
8.9 Litre
Spark Ignited
SEGR
Three Way Catalyst
Up to 60,000 miles/year
66,000 lb. GVW

**ISX12 G**
11.9 Litre
Spark Ignited
SEGR
Three Way Catalyst
Up to 80,000 lb. GVW

2016
Natural Gas Engines: Features

- ISX12 G: 12 Liters, 80,000 lb GVW
- ISL G: 9 Liters, 66,000 lb GVW
- Use 100% Natural Gas
  - Stored as CNG, LNG
- Spark Ignited, In-line 6 cylinder
- Wastegate Turbocharger
- Charge-Air Cooled (CAC)
- Stoichiometric EGR Combustion
- Three Way Catalyst Aftertreatment
  - Maintenance Free
- Base Warranty: 2 yr/250,000 miles
- Extended Coverage Available
2015 Engines Aftertreatment Comparison

2015 Diesel

- Heated Urea Tank
- Urea Tank
- SCR Catalyst
- Particulate Filter
- Urea Dosing Control Unit
- ECM
- Three Way Catalyst
- ISL G
- ISX12 G
Natural Gas Engine Introduction

- **Target Markets**
  - Regional haul truck / tractor
  - Vocational
  - Refuse

- **Platform & Technology**
  - Cummins 11.9 litre ISX12 diesel is base engine
  - Utilizing spark-ignition with cooled EGR & three way catalyst (TWC)
    - Same combustion technology as ISL G
Natural Gas Engine

Key Product Attributes

- 4 cycle, spark ignited, in-line 6 cylinder, turbocharged, CAC
- Displacement – 11.9 litres (726.2 cu in)
- Peak rating: 400 hp, 1450 lb-ft
- 2013 EPA/CARB certified
- Meets 2014 EPA GHG requirements
- Dedicated 100% natural gas engine
  - Will operate on CNG or LNG
- Three Way Catalyst after-treatment
- Engine braking
- Manual/Automatic Transmission capable
  - AMT Available Now.
Design Architecture

- Wastegate Turbo
- 4 Valve Cylinder Head
- Engine Control Module
- Ignition Control Module
- Fuel Module
- EGR Valve
- Coil on Plug Ignition

Cummins Westport March 2014
## Differences
### ISX12 diesel and ISX12 G natural gas

<table>
<thead>
<tr>
<th></th>
<th>ISX12</th>
<th>ISX12 G</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horsepower</strong></td>
<td>310-425 HP</td>
<td>320-400 HP</td>
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<tr>
<td></td>
<td>231-317 kW</td>
<td>239-298 kW</td>
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<tr>
<td><strong>Peak Torque</strong></td>
<td>1150-1650 lb-ft</td>
<td>1150-1450 lb-ft</td>
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<td></td>
<td>1559-2237 N-m</td>
<td>1559-1966 N-m</td>
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<tr>
<td><strong>Torque at Idle</strong></td>
<td>800 lb-ft</td>
<td>700 lb-ft</td>
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<tr>
<td></td>
<td>1085 N-m</td>
<td>949 N-m</td>
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<td><strong>Aftertreatment</strong></td>
<td>DPF + SCR</td>
<td>Three Way Catalyst</td>
</tr>
<tr>
<td><strong>Engine Brake</strong></td>
<td>Optional 380 HP @ 2100 RPM</td>
<td>Optional 240 HP @ 2100 RPM</td>
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<tr>
<td><strong>Performance</strong></td>
<td></td>
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</table>
ISX12 G Features

- Coil on Plug Ignition
- Three Way Catalyst
- ISX12 G Coil and Extension
- ISX12 G Spark Plug
- Fuel Flexibility (CNG, LNG)
ISX12 G Cylinder Head, Coil, Spark Plug

Cylinder head cross section

Coil

Coil Extension

Spark Plug

Flexible coil extension for serviceability

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### ISX12 G Maintenance Intervals - Revised Aug 2014

**Note:**
50 mph (80 kph) Average Speed

<table>
<thead>
<tr>
<th>Maintenance Item</th>
<th>Hours</th>
<th>Miles</th>
<th>Kilometers</th>
<th>Months</th>
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<tr>
<td>Spin-on Fuel Filter</td>
<td>Daily Check</td>
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<td>Oil &amp; Filter*</td>
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<td>Coolant Filter*</td>
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<tr>
<td>Spin-on Fuel Filter*</td>
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<td>50,000</td>
<td>80,000</td>
<td>9</td>
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<tr>
<td>Spark Plugs*</td>
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<td>75,000</td>
<td>120,000</td>
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<tr>
<td>Overhead Adjustment*</td>
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<td>75,000</td>
<td>120,000</td>
<td>12</td>
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<tr>
<td>Engine Brake (Adjust)</td>
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<td>480,000</td>
<td>24</td>
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<tr>
<td>Standard Coolant</td>
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<td>300,000</td>
<td>480,000</td>
<td>24</td>
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<tr>
<td>Air Cleaner/Element</td>
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</table>

- Default interval is the hours stated. Interval is whichever comes first – hours, miles or time.
- Use CES20074 engine oil
- Refer to Owners Manual or QSOL for complete details on Maintenance Intervals.

* Assuming normal line haul duty cycle based on 50 mph average speed. Maintenance Intervals must be reduced for slower average speed applications.
Cold Weather Operation

- Cold weather requirements for Cummins diesel and natural gas engines are the same
  - Guidelines are published in ISX12 G CM2180 owners manual and operation and maintenance manuals
  - Important to pay particular attention to protecting natural gas engines from freezing intake temperatures by using winter fronts and/or warm underhood air
- AEB 174.04 Provides further guidelines for Cold Weather Engine operation for All Automotive and Industrial Engines.
- Also refer to Customer Service Bulletin 4332709 – Operation of Natural Gas Engines in Cold Climates.
2014 Gearing Recommendations

ISX12G

320-400 HP

Linehaul: Up to 80,000 lbs GCVW
- Balance
- Fuel Economy

Vocational: Up to 80,000 lbs GCVW
- Balance
- Fuel Economy

RPM

September, 2013

Cummins Westport March 2014
Powerspec 5.4

- Software Application
  - Gearing calculator
  - Electronic features- settings and descriptions
  - Customized engine ‘specs’
  - “Easy Spec” available for fleets
  - Collects valuable trip information
  - Reporting feature

For more information or to download PowerSpec, visit:

http://www.powerspec.cummins.com
Fuel Systems

- Cummins Westport natural gas engines fuel requirements enable the use of both CNG or LNG.
- Customers may choose CNG or LNG depending on duty cycle, application, and/or fuel availability.
- Natural gas fuel (CNG or LNG) must meet fuel quality requirements per AEB 79.05 (CES14624)
- Regardless of how the fuel is stored on the vehicle, the at engine fuel inlet pressure at rated conditions requirement is the same
  - ISL G - minimum 70 psi, maximum 150 psi
  - ISX12 G – minimum 60 psi, maximum 150 psi
Fuel Quality

- Natural gas fuel must not contain water, dust, sand, dirt, oils or any other substance detrimental to the operation of the engine.

- For CWI ISL G and ISX12 G engines Cummins Engineering Standard (CES) 14624 applies.
  - For these engines the methane number based on the SAE922359 must be **75 or higher**, and the Lower Heating Value must equal or exceed 37448.6 kJ/kg (**16100 BTU/lbm**)
  - Four constituents that must also meet requirements

| CES 14608 and CES 14624 Maximum Allowable Hydrogen, Hydrogen Sulfide, Sulfur, and Siloxanes |
|---------------------------------------------|-----------------------------------------------|----------------------|
| **Constituents**                            | **Requirements**                              | **Test Method**       |
| Hydrogen (H₂)                               | 0.03 percent volume maximum                   | ASTM D2650           |
| Hydrogen Sulfide (H₂S)                      | 0.0006 percent volume maximum                 | ASTM D4084           |
| Siloxanes                                   | 0.0003 percent volume maximum                 | Environmental Protection Agency (EPA) TO-14, 15 GC/ELCD, GC/AED, GC/MS |
| Sulfur (S)                                  | 0.001 percent weight maximum                  | Title 17 CCR Section 94112 Method 16         |
On Line Fuel Quality Calculator

http://www.cumminswestport.com/fuel-quality-calculator
Fuel System Flow - Engine

1. Fuel inlet from remote mounted gas filter
2. Low-pressure regulator
3. Fuel inlet pressure sensor
4. Fuel shutoff valve
5. Fuel transfer tube
6. Fuel outlet pressure/temperature sensor
7. Gas mass flow sensor
8. Fuel control valve
9. Air inlet
10. Throttle actuator
11. Air/fuel mixer
12. Exhaust gas to exhaust gas recirculation (EGR) valve
13. EGR valve
Fuel System Flow – Total System Diagram

Vehicle OEM

High Pressure Fuel Filter

Cummins

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OEM Supplied Fuel System Components
(Both CNG and LNG Systems)

- Mounted on the vehicle
- Primary fuel shut off valve opens in key on position
- Regulates fuel storage pressure to engine pressure (60-150 psi)
- Fuel heater supplied with warm engine coolant to prevent freezing
- Fuel pre-filter(s) mounted near engine has a daily drain requirement
Compressed Natural Gas Filling

- During CNG refueling, gas heats up (expands) as it compresses in the tanks
- Two CNG refueling strategies exist:
  1. Time fill
     - Tanks can be slowly filled to 3,600 psi to allow heat to dissipate during refueling.
     - Full fill (i.e. 3,600 psi @ 70F ambient temperature) is possible with time fill stations.
  2. Fast fill
     - End up with 3,600 psi at some elevated temperature in the tanks. As gas cools to ambient temperature, pressure of gas decreases - no loss of gas. End result is less than 3600 psi fill
     - Results vary by station, but 15-20% under fill is not uncommon for temperature-compensated fast fill stations

- Usable fuel pressure limited to approx 400+ psi tank pressure (10%)
  - Avoid low pressure faults at engine

- Recommended net vs. gross fuel capacity assumptions:
  - Time fill CNG: Net capacity 10% lower
  - Fast fill CNG: Net capacity 25-30% lower

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CNG Fuel System – Off Engine

- Normal North American fill cycle will exert pressures up to 4500 psi under some ambient conditions.
- CNG system container valves, PRD’s, regulators and other system components should be rated for 3600 psi service pressure/4500 psi working pressure.
- Unlike traditional temperature activated PRD’s (Pressure Relief Device), new rupture disc PRDs may vent gas if working pressure is exceeded.

Source: CVEF Safety Alert Improper Use of Underrated European CNG Valves and Rupture Disc PRDs on US Vehicles
http://www.cleanvehicle.org/index.shtml
# Two Types of LNG Systems

<table>
<thead>
<tr>
<th>Tank Pressure System</th>
<th>LNG Pump System</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Relies on vapor pressure in the tank to push fuel to the engine</td>
<td>▪ Utilizes Westport “iCE Pack” Pump Technology to keep tank pressures low (and LNG cold) and provide consistent fuel pressure to match engine requirements</td>
</tr>
<tr>
<td>▪ Fuel delivered from LNG station must be “warm” or saturated to maintain adequate tank pressure *</td>
<td>▪ Compatible with unsaturated (Cold) and saturated (Warm) LNG.</td>
</tr>
<tr>
<td>▪ Has a tank pressure management system to reduce excess tank pressure as fuel is used, this minimizes need for venting unless the vehicle is stored for long periods.</td>
<td>▪ Increases fuel storage time to up to 10 days,</td>
</tr>
<tr>
<td>▪ Hold time is maximized if tank pressure is set low and tank relief pressure is high.</td>
<td>▪ Provides for faster fill times, and eliminates the need to equalize truck tank pressures with the fuel station.</td>
</tr>
</tbody>
</table>

* New system
Typical LNG System Pressures

- **Economizer**
- **Heat Exchanger**
- **Solenoid**
- **Overpressure Regulator**
- **Engine Filter**

Pressures:
- **Vapor**
  - 85-230 PSI
  - 80-230 PSI
  - 75-150 PSI
  - 70-150 PSI

- **Liquid**
  - 100-230 PSI
Fuel Filter (Spin-on Type) - Drain

- Shut off the engine. Use your hand to open the drain valve. Turn the valve **counterclockwise** approximately 1-1/2 to 2 turns until draining occurs.
- Drain the oil from the fuel filter.
- When closing the drain valve, do **not** over tighten the valve. Over tightening can damage the threads. Turn the valve **clockwise** to close the drain valve.

- **no more than one ounce of oil in the fuel filter.**
Fuel Filter Draining Oil
Fuel Filter (Spin-on Type) - Change

- Before removing the filter, **turn off the fuel supply** at the vehicle's main fuel shutoff valve.
- Start the engine and allow it to run at idle. **Allow the engine to run until it dies.**
- Remove the fuel filter and clean the gasket surface of the fuel filter head.
- Lubricate the seal with clean gas engine lubricating oil.
Fuel Filter (Spin-on Type) - Change

- Install the fuel filter on the fuel filter head. Turn the filter until the gasket contacts the filter head surface.
- Tighten the fuel filter, by hand, an additional ½ to ¾ of a turn after the gasket contacts the fuel filter head surface.
- Turn on the vehicle's main fuel shutoff valve.
- Use a gas detector, Part Number 3823984, or soap solution to check for leaks.
- If leaks are found, close the valve, turn the key to the OFF position, and repair leaks immediately.
Use 15W-40 Natural Gas Engine Oil

- Cummins Westport natural gas engines require special engine oil that is available from major oil suppliers.
- Careful attention must be paid to engine oil specifications because natural gas engine oil has different properties than diesel engine oil. A sulfated ash limit of 0.6 percent has been placed on all engine lubricating oil recommended for use in Cummins Westport engines.
- Higher ash oils can cause valve and/or piston damage and lead to excessive oil consumption and degradation of the catalyst.

Do not use diesel engine oil in a natural gas engine. If diesel engine oil is used, valve torching, piston scuffing, and reduction in spark plug life will occur.
CES20074 Gas Engine Only (GEO) engine oil is available from most major oil companies.

Specs

Recommended for Cummins B&amp;C, Detroit Diesel, John Deere and Caterpillar dedicated natural gas engines for vehicular applications. It is a Cummins 20074 approved engine oil.
Intended Use Guidelines

AEB 140.26
Published April 2013

<table>
<thead>
<tr>
<th>Intended Use</th>
<th>Minimum Startability (%)</th>
<th>ISLG GVW (lbs)</th>
<th>ISLG GCW (lbs)</th>
<th>ISX12 G GVW (lbs)</th>
<th>ISX12 G GCW (lbs)</th>
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</thead>
<tbody>
<tr>
<td><strong>Tractor configurations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Line haul</td>
<td>20</td>
<td>66000</td>
<td>66000</td>
<td>80000</td>
<td>80000</td>
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<td>Local pickup &amp; delivery</td>
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<td>66000</td>
<td>66000</td>
<td>80000</td>
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<td>Regional haul</td>
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<td>Mining service</td>
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<td>Utility/Dump Truck</td>
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<td>Wrecker service</td>
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Note: No waivers or exceptions will be granted for operation outside these guidelines. Customers should be advised that applications outside these boundaries will result in some negative consequences or degraded performance and/or reduced engine life.
ISLG and ISX12 G Warranty Coverage

• Base Warranty for ISL G and ISX12 G Engines are similar to Cummins diesel engines

• Extended Coverage options are available for ISX 12 G Truck

  • 3 to 5 yr. 100,000 to 500,000 mile - Protection Plan 1 - Truck
  • 3 to 5 yr. 100,000 to 500,000 mile – Protection Plan 2 – Truck
  • 5 yr. 500,000, 6 yr. 600,000, 7 yr. 700,000 mile Major Component

• All Extended Coverage warranty programs posted on Cummins CIRCUIT
Learn more @ cumminswestport.com

Featuring the Natural Gas Academy videos covering:

• What is Natural Gas?
• Natural Gas Engines
• Natural Gas Fuel Systems
• How to Fuel a Vehicle
• ISL G Engine Walk-Around
• ISX12 G Engine Walk-Around
• ISX12 G Driver Familiarization
• Natural Gas Engine Maintenance
• Upgrading Your Facility for NGVs