

Program Overview: Hydrogen Enriched Compressed Natural Gas

ABOUT WESTPORT INNOVATIONS INC.

Westport Innovations Inc. (Westport) is the leading developer of environmental technologies that enable engines to operate on clean-burning fuels such as natural gas, hydrogen, and hydrogen-enriched compressed natural gas (HCNG). Westport has alliances with leading automotive manufacturers that enable our technologies to be applied to their engines. Westport also has an ownership interest in Clean Energy Fuels Corp., the largest provider of natural gas for transportation in North America. Westport's fiscal year end is March 31.

ABOUT CUMMINS WESTPORT INC.

Cummins Westport Inc. (CWI), Westport's 50:50 joint venture with Cummins Inc., markets the world's widest range of low-emissions alternative fuel engines for commercial transportation applications. Cummins Westport's mid-range 5.9- to 8.9-litre engines are used globally in transit and shuttle buses, medium-duty trucks, and refuse haulers. Cummins Westport is also developing new generations of these engines for international markets and future emissions standards. Cummins Westport's fiscal year end is December 31.

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A SunLine Transit Agency "SunBus" with Cummins Westport 5.9-litre B Gas Plus engine, refuelling with HCNG from an HCNG dispenser.

WHAT IS HCNG?

Hydrogen enriched compressed natural gas (HCNG) is hydrogen blended with compressed natural gas. Adding hydrogen to natural gas improves combustion, by allowing engines to operate with higher air/fuel ratios, improved performance, and significant reductions in emissions. Over the last two decades, a number of light- and medium-duty vehicles have been tested with various HCNG blends (hydrogen up to 50% by volume) in various parts of the world.

ENVIRONMENTAL BENEFITS

HCNG upgraded bus versus a pure natural gas bus

A steady-state heavy-duty test cycle showed that Westport's HCNG engine upgrade reduced nitrogen oxides (NOx) and non methane hydrocarbon (nmHC) emissions by 50%, carbon dioxide emissions by 7%, and additional carbon monoxide (CO) and methane (CH₄) emissions reductions, compared to a pure natural gas engine operation. This was achieved while retaining the performance and efficiency of the engine.

HCNG upgraded bus versus the newest diesel engine bus

The HCNG engine upgrade produced 65% less NOx, 80% less particulate matter (PM), and about 10 tonnes per year less greenhouse gases (GHG), when compared to a bus featuring the newest diesel engine certified to 2002 emissions levels as established by the U.S. Environmental Protection Agency.

ENGINE CALIBRATION AND FIELD TRIALS

In 2003, Westport and Cummins Westport, Westport's joint-venture with Cummins Inc., began a 38,624 km (24,000 mile) road test, in partnership with SunLine Transit Agency of Palm Springs, California. Westport and Cummins Westport calibrated two 230-hp Cummins Westport B Gas Plus engines to operate on HCNG in regular revenue-generating service alongside two control buses with B Gas Plus engines operating on natural gas. Field trial testing was completed successfully during the spring of 2004. Funding was provided by the U.S. Department of Energy's National Renewable Energy Laboratory and South Coast Air Quality Management District.

Advancing the shift of global commercial transportation to natural gas and hydrogen.

Field trials confirmed the steady-state test cell tests results:

- 50% reduction in nitrogen oxides (NOx);
- Engine performance (power and torque of natural gas engines) was unaltered;
- 38,624 km (24,000 mile) field trial in regular service was completed successfully by each HCNG bus.;
- No HCNG related troubles were experienced; and
- Driver feedback was very positive.

The HCNG buses continue to operate in Sunline Transit's regular service, and as of July 2005, both HCNG buses had logged over 105,000 kilometres combined.

NEXT STEPS

- Westport will be upgrading the 8.3-litre C Gas Plus engine to HCNG for a hydrogen bus demonstration project in Greater Vancouver and British Columbia's Lower Mainland as part of British Columbia's Hydrogen Highway™ initiative. Demonstration, calibration, and associated engineering development are under way. The project will utilize recycled waste hydrogen from a local electrochemical plant. The project is funded by Canadian federal government (Sustainable Development Technology Canada, Industry Canada - h2EA program, Natural Resources Canada - CTFA).
- Westport is also working with China's Tsinghua University to co-research and demonstrate technologies using HCNG in the public bus fleets of Beijing and other Chinese cities.
- Westport is considering an upgrade to Cummins Westport's newest engine, the 8.9-litre, 320-hp L Gas Plus, which offers a best-in-class power-to-weight ratio with enough power and torque for heavy duty refuse trucks, municipal works trucks, medium duty trucks, and transit bus applications.
- Westport is also considering an HCNG version of its next generation spark ignited compressed natural gas (SI CNG) engine technology that would be capable of meeting the 2010 U.S. federal heavy-duty emissions standard (0.2g/bhp-hr NOx).

HCNG FUTURE POTENTIAL

HCNG offers the opportunity to use hydrogen as a transportation fuel that is both cost effective (compared to fuel cell vehicles) and environmentally beneficial.

To use HCNG in modern, electronically controlled engines, offers immediate economic and environmental benefits over already clean natural gas engines, currently the most viable commercial environmental solution available today.

HCNG can serve as a catalyst in the development of the hydrogen infrastructure needed for future vehicles powered by pure hydrogen and fuel cells.

Based on the results of this project, it appears that substantial NOx reductions could be achieved compared to both regular natural gas and diesel operations. Opportunities may also exist for improved efficiency and lowered GHG emissions.

With our growing expertise with HCNG technology, Westport is well positioned to rapidly engineer and bring to market commercial HCNG engines.

FAST FACTS

Westport's HCNG Upgrade Uses:

- **20% hydrogen (by volume)**
- **80% natural gas (by volume)**

Westport's HCNG Upgrade Produces:

- **65% less NOx***
- **80% less PM***
- **10 tonnes / year less GHG***
- **maintains original torque rating and fuel energy efficiency**

Hydrogen Requirements (B Gas Plus):

- **4kg/day for 200 miles/day**
- **1.25kg of hydrogen/100km travelled**

WESTPORT'S HYDROGEN PROGRAMS:

- injectors for BMW and Ford Hydrogen Internal Combustion Engine (H2ICE)

HCNG is applicable to Cummins Westport's entire natural gas engine product line:

B Gas Int'l	B Gas Plus	C Gas Plus	L Gas Plus
5.9L	5.9L	8.3L	8.9L
150-230hp	195-230hp	250-280hp	320hp
375-500lb-ft	420-500lb-ft	660-850lb-ft	1,000lb-ft

* compared to today's diesel engines.

**For further technical details, refer to
SAE Paper # 2004-01-2956 entitled
"Hydrogen Blended Natural Gas Operation of a Heavy-Duty
Turbo-Charged Lean-Burn Spark Ignition Engine"**