Dual Fuel – a growing characteristic of the British truck market

What is dual fuel, who supplies dual fuel systems and what are the benefits?

With dual fuel demand a growing business in the UK and other European countries, we take a closer look at the practicalities and challenges faced by the suppliers such as **Hardstaff** and **Clean Air Power** of fitting such a system into regional distribution trucks and tractor units.

Dual Fuel Systems

With around 20 out of 100 tractive units already running on compressed natural gas (CNG), famous British baker, Warburtons, makes no secret of having a penchant for this fuel. But recently the company has changed direction a little, by taking delivery of six **Mercedes-Benz** Axor tractive units with dual-fuel (diesel and CNG) conversions by **Hardstaff Group**. This is indicative of growing demand from UK truck operators for such dual-fuel conversions, and not only from Hardstaff.

Many operators take a similar view to that of Warburtons group transport manager, Mark Sutcliffe, who says: "We're committed to gas for environmental reasons – it's a clean fuel that helps us to reduce our emissions and so meet our own carbon management and corporate social responsibility targets. But the trucks also have to make financial sense for our business, and a dependable warranty is a key part of that equation. Reliable performance is obviously crucial too and while Mercedes-Benz is a relatively new brand to Warburtons, having worked with the manufacturer in the past I am confident the vehicles will perform well in our operation."

Hardstaff's conversion of the Axor's straight-six, 400hp engine automatically feeds gas into the cylinders on demand, at a constantly variable ratio. This translates into a sizeable reduction in emissions of carbon dioxide, carbon monoxide, nitrogen oxides and particulates. There is no noticeable difference in power delivery or in the driving experience, Hardstaff claims; and so should a vehicle run out of gas before its tanks can be topped up, it will run equally well on pure diesel.

Interception of the engine's ECU

"We don't have to interfere with the vehicle manufacturer's ECU," says Hardstaff managing director, Trevor Fletcher, describing his company's OIGI HDXI system. "No manufacturer wants you to go into the CAN-bus system, so we don't. But we can still control the volume and timing of diesel injection." Fletcher describes this as "mugging" the electrical signal that goes to the diesel injectors. "That gives us the information and we prevent it getting to the injectors," he says. Hardstaff's own ECU then splits the signal to reduce the volume of fuel to allow for the injection of the gas, but cleverly bounces the original signal back to the engine's ECU so that the vehicle's other functions are not upset by the reduction in fuel demanded. "This means the automated gearbox continues to behave normally, rather than shifting up because it has been told that less fuel is needed," explains Fletcher.

The electronics responsible for this are contained in a box called an "emulator," developed in partnership with Loughborough University. The system is a closed loop, with a lambda oxygen sensor in the exhaust to gauge combustion efficiency and adjust the diesel/gas balance. "If vehicle systems such as electronic stability programme (ESP) kick in to adjust power, our system automatically drops out within five milliseconds until it is safe to resume," points out Fletcher.

Hardstaff's approach with this system offers the key commercial advantage of being applicable to any electronically-controlled diesel engine with minimal customisation. There is no need to map the system for each engine, which takes considerable development effort. Multipoint injection involves a pair of injectors mounted as close as possible to each cylinder's inlet port on the manifold.

Clean Air Power Ltd of Leyland, UK, another big supplier of dual-fuel conversions, has its own US-designed gas injectors and solenoid gas valves, which it calls Genesis. This dual fuel system uses six electronically-controlled gas injectors clustered together in a piece of ducting at the entrance of the

Trying something different: Mercedes-Benz Axor tractor retro-fitted with Clean Air Power's Genesis dual-fuel (diesel/LNG) system.

Clean Air Power and Volvo Partnership Agreements

Clean Air and Volvo Powertrain

It was just under one year ago that Clean Air Power Ltd (Clean Air) of Leyland, UK and Volvo Powertrain, a subsidiary of Stockholm, Sweden-based **AB Volvo**, signed its latest supply and development agreement relating to Clean Air's dual fuel combustion technology for heavy-duty vehicles to allow diesel engines to operate on a combination of diesel and natural gas. It was agreed the agreement would be for a period of five years initially - this agreement followed three years of close cooperation of a product development partnership, it also superseded the Letter of Intent signed in January 2009.

The agreement permits Clean Air's OEM product to be marketed and supported by **Volvo Truck Corporation**. The engines can use natural- or bio-gas as the main fuel and can also operate on only diesel; an important feature as gas distribution systems, says Clean Air, face many years of development. The testing in commercial operation began in 2010, initially in, UK, Sweden and Thailand.

Clean Air and Volvo Bus Corporation

It was at the same time, July 2010, that Volvo's bus division, **Volvo Bus Corporation**, also signed a development agreement with Clean Air Power regarding dual fuel.

Volvo Bus and Clean Air Power will jointly develop the installation of Dual-Fuel kits provided by Clean Air Power on existing bus engines to make it possible for buses from Volvo to run on Dual-Fuel in the future. The development programme was valued at GBP160,000.

In a further development, in January this year, Clean Air announced that it would deliver 11, Dual-Fuel systems to Volvo Bus Corporation, worth an estimated EUR225,000. The Dual-Fuel systems were to be fitted by Clean Air directly onto engines of the 11 buses on the Volvo production line.

These buses are expected to be in service in Sweden by July 2011 and once in service, the vehicles will be the first Volvo buses to operate on both biogas and diesel as part of a Swedish government backed project. Using diesel technology increases environmental efficiency, Clean Air claims by up to 30-40% compared with current gas-only operated buses.

The resulting positive environmental impact, this project is receiving considerable support from the Swedish government, which is contributing almost SEK24m (GBP2.25m) of funding towards the project through the Swedish Energy Agency.

Clean Air's most recent development with Volvo Bus Corporation now involves discussions regarding the joint development of Dual Fuel engines for the next generation of Volvo buses and bus chassis.

air inlet manifold, giving single-point gas injection. Clean Air Power's electronic control unit (ECU) manages volume and timing of gas injection as well as regulating air to the manifold by controlling the turbocharger by-pass valve. Thus the system controls the gas/air mixture being drawn into the cylinders on the intake stroke.

Volvo Truck and Clean Air Power working together to offer dual fuel (diesel / natural gas) trucks

"We do not have access to the engine management software," explains Rob Oaten, chief engineer for engine management systems. "But we are connected to the CAN-bus so we have digital control of the volume of diesel going in, even though we can't control when it is going in." This limits gas substitution rate to an average of about 50% with Genesis, compared with percentages in the high 80s from Caterpillar dual-fuel engines running in Australia, it is claimed. The engine is solely diesel fuelled until coolant temperature is up to about 60 degrees Celsius, which normally takes about five minutes. The gas substitution rate is between 50% and 60% at full-load, rising to 70-80% at medium load and dropping to zero at idle and very light loads, when the minimum amount of diesel required to keep the engine running is enough on its own.

The exhaust system is modified to include a methane oxidation catalyst to take out any un-burnt methane. Methane is generally regarded as having over 20 times more global warming potential than CO_2.

Economics of dual fuel

Dual fuel system costs vary with type of gas tank (LNG or CNG) and with the number needed to give the vehicle the required range between refills. Clean Air Power reckons GBP22,000 (USD35,000) is a typical average cost. The usual payback period is 18-22 months, Clean Air claims, but this can be as little as 14 months in certain applications, it claims. Hardstaff suggests the overall fuel costs of a dual-fuel truck would be lower by around 25% than that of a diesel only powered truck, suggesting a typical payback period of around two years.

Payback periods reflect fuel costs. The missing factor is the cost of a private gas supply infrastructure (CNG or LNG) or the cost of travelling to one of the few public-access gas-supply sites.

G-volution Ltd of Newport, Gwent, another dual fuel system supplier, which was formed as recently as 2008 and whose system has been confined to MAN so far, can still boast quite a heritage in the commercial vehicle alternative fuels business.

Sales director Simon Pickess is a former managing director of The Leasing Group, the company spawned long ago by British Gas to focus on gas-fuelled trucks. And the technology employed by G-volution comes from Zeonardo, a related Bath, UK-based company where the engineers include Colin Gray, who gained practical experience aplenty of gas-fuelled trucks while working for Greenpower Technologies. Though the working principle of the G-volution seems, on the face of it, to be broadly similar to that of the Hardstaff OIGI HDXI system, G-volution Ltd claims that "nobody else can properly control the mix of more than one fuel in the way we can."

G-volution Dual Fuel: Limited to MAN engine conversions so far

Liquefied petroleum gas (LPG): Second fuel of choice for G-volution, but others can be added

It is emphasised that the system is designed to operate with a combination of fuels and is by no means confined to liquefied petroleum gas, which just happens to be the second fuel used with diesel on the trucks converted by G-volution so far.

Dual-fuel to tri-fuel?

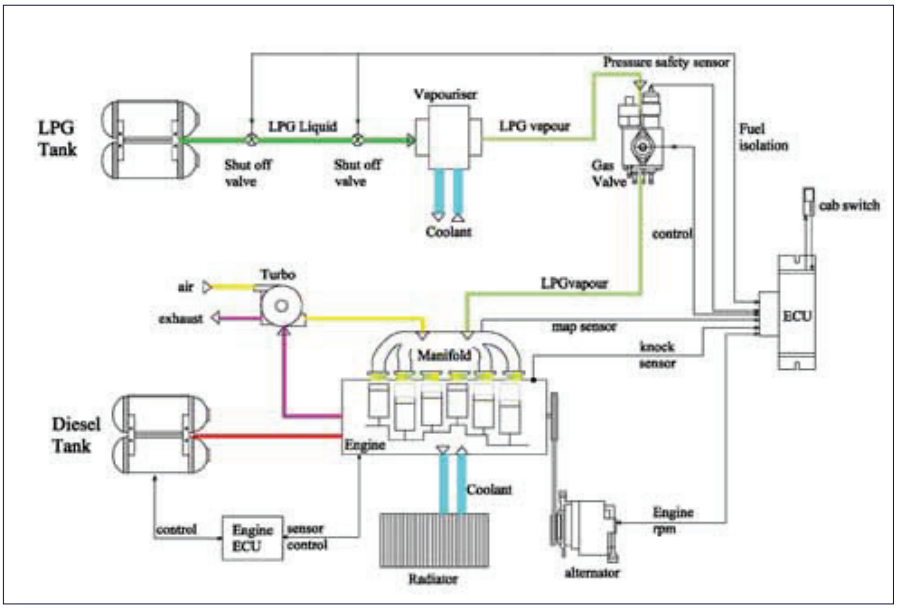
Indeed this dual-fuel system could turn into a tri-fuel system. "The system is unique because it operates by translating the original fuel-control signals from the engine-management system to derive new control signals for both fuel types," says G-volution's Simon Pickess. "When in dual-fuel mode the amount of primary fuelling is reduced to compensate for the addition of the secondary fuel. This occurs in real time and is synchronised with the operation of the engine. The Optimiser provides an emulation facility so that the engine-management system is completely unaffected and continues to operate normally. Because the the original engine-management system continues to control the engine in dual-fuel mode, the original power, torque and ignition-timing maps are maintained. The engine therefore continues to operate entirely within the manufacturer's original specification. These principles of operation of the Optimiser are protected by UK patents, with international patents pending.

"The Optimiser does not rely on the original engine-management system to compensate for the addition of the second fuel to achieve net fuel-cost savings. This method is proven to be inefficient as it only works when the engine is under 'speed-control' operation and therefore generally results in over-powering and increased exhaust emissions at all other times.

"The Optimiser continuously adjusts the relative ratios of the two fuels when operating in dual-fuel mode, in real time, according to engine operating conditions. This ensures optimal operation at all times, rather than just under best-case conditions. The Optimiser is the only retrofit dual-fuel system that can do this, producing superior net fuel cost savings, which are virtually unaffected by changes in operational conditions, drive-cycle, load or driver behaviour."

GSPK Multifuel Technology is a Knaresborough, UK-based supplier of dual-fuel (diesel and LPG) conversions for trucks.

Blue-chip names on the firm's customer list include Aldi, the supermarket chain, which now runs around 90 dual-fuel tractive units. Another loyal customer is Fowler Welch, one of the UK's biggest temperature-controlled distribution specialists.



Dual-Fuel system schematic

Some original GSPK systems have been transferred from old to new trucks in the Fowler Welch fleet.

In-house engineering

GSPK's background is in the design and manufacture of electronic systems, giving it the expertise not only to develop its own dual-fuel system but also to manufacture much of it as well. Only LPG tanks and vaporiser units (to convert LPG from liquid to gas) are bought-in. Even the bit at the sharp end, the gas valve directing vapour into the inlet manifold downstream of the turbocharger, is GSPK's own.

GSPK technical director Andrew Lees says: "If you go down the route of sequential injection you've got to be extremely sure that your injection pulse is timed correctly and quick enough or you will definitely create rich cylinders."

Simplicity of engine modification is a GSPK selling point (a single point in the manifold is easy to plug) making it easy to transfer the dual-fuel kit to a second vehicle and restore the original one to diesel-only fuel.

The success or failure of any dual-fuel system hinges largely on the electronic control system governing the mix. Truck manufacturers refuse to sanction any direct interference with their own electronic control units (ECU) and CAN-bus (controller area network) systems, so how does GSPK get around this? "Effectively, we sit on top of the manufacturer's management system," explains Lees. "We monitor rpm and turbo boost pressure. We have a map that says this is the appropriate amount of gas for this engine at this rpm and this boost level. We also have a signal clip on the injectors so that we can ascertain when they stop injecting, such as in over-run, and cut off our system instantly."

The basic shapes of the GSPK system's control maps are the results of dynamometer testing.

Every installation is calibrated individually with diesel and LPG meters and a data-logger to record exact volumes of each fuel used at several set points on a test run. The calibration software translates fuel use into pounds and pence, so GSPK engineers can tell at a glance where the system is saving money during the run, where it is not, and calculate overall savings.

Usually the GSPK mix is 35-40% LPG by volume overall on average. This encompasses a start on pure diesel, running with around 50% LPG on light loads and feathering the gas percentage right down as engine load and power output increase.

Care is taken to avoid exceeding standard peak torque and peak power. A knock-sensor is added to prevent excess gas injection causing uncontrolled detonation and the risk of serious engine damage.

The sensor is calibrated to the individual truck during system commissioning by recording noise frequencies when the engine is running on diesel. These frequencies are then used to program thresholds into the GSPK software. Should the thresholds be exceeded, gas injection is automatically wound back in 20% steps every 10 milliseconds. Any knock lasting more than half a second would cause the gas to be shut off completely.

Working within an engine's normal peak ratings limits overall substitution rate to a maximum of 45%. Even with the lightest of applications, that leaves lots of opportunity to open the LPG valve. Edging up the typical substitution rate should be made possible, GSPK believes, by a switch from motorised gas valves to faster-reacting electronic injectors.

Sources of 'clean gas'

Dual-fuel vehicles using natural gas are turning to the opportunity to use biomethane generated from waste digesters as a way of bolstering their green credentials. It is claimed that LPG matches that because it too is a by-product, generated during oil extraction and refining. So LPG extends finite oil resources. Spark-ignition engines running on LPG usually have practically-zero particulate emissions from their tailpipes, so a dual-fuel conversion should offer a worthwhile reduction too. LPG engines also have extremely low NOX (oxides of nitrogen) emissions.

A typical GSPK system costs around £7,000, including installation. LPG has only two-thirds the energy content of diesel on a per litre basis, so the total quantity of LPG plus diesel is greater than when running on diesel alone. So assuming a 37% of the total is LPG, a typical GSPK percentage, instead of consuming 100 litres on pure diesel, the truck would need a total of 115 litres to derive the same total amount of energy: this would comprise 71 litres of diesel and 44 litres of LPG. GSPK claims typical monetary savings of 12-15 per cent.