

Research Brief



Investigation into the use of bio-diesel fuel on Britain's railways

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Overview

In 2006 RSSB and the Association of Train Operating Companies (ATOC) started an investigation into the use of bio-diesel on GB railways. Over the next decade, the rail industry has an opportunity to improve its environmental performance and its public profile as a sustainable mode of transport. By moving to greener fuels, rail can improve its position, relative to other transport sectors. Additionally, changes in legislation could potentially mandate changes to the diesel fuel used on Britain's railway. The use of sulphur-free diesel has already been investigated in RSSB research project T536 *Investigation into the use of sulphur free diesel on railway vehicles*. Other potential fuels are on the horizon and are being investigated by other transport sectors. Over the next few years road diesel will change to incorporate 5% bio-diesel (sourced from sustainable crops) and there is discussion about higher blends. There may be benefits to the rail industry and to the environment if rail were to follow suit. This research has therefore examined the use of bio-diesel in order to establish the advantages and disadvantages associated with its use.

Initially a desktop study clarified the sustainability of bio-fuel production and the effects on engine performance/emissions of increasing bio-diesel blending with conventional diesel fuel. The views of the engine manufacturers themselves were also captured. The general advantages, disadvantages of, and concerns about, the use of bio-diesel were summarised.

This was followed by the test-bed evaluations of a selection of typical engines with reasonable life expectancy. The effects on the engine's performance and exhaust emissions was tested using increasing bio-diesel blending with diesel fuel, in steps from 5% bio-diesel to 100% bio-diesel. These demonstrated the variations between the engines tested and the results between different blends of bio-fuel. The test-bed trials successfully demonstrated the practical limits of bio-diesel blend that could be applied for subsequent service trials and fleet operation. The Diesel Metering Group (DMG) conclusion from the tests was that

B20 blend represents an acceptable compromise between adverse performance effects and emissions benefits.

The third stage of the research was to trial the use of bio-diesel on trains in service. A variety of operators and diesel engine types were used to act as an actual comparison of bio-diesel use in service.

From the research project results, the DMG has concluded that B20 (a 20% blend of biofuel mixed with 80% ultra-low sulphur diesel) is sensibly the highest blend that could be universally accepted without significant expenditure to retune some engines. The use of B20 bio-diesel does not appear to cause any significant engine wear, but the fuel consumption performance is significantly worse. From test-bed and in-service trials a justifiable estimate would be to assume an average 10% increase in fuel use, although this figure appears to vary widely depending on the engine type and state of the engine tuning.

Aims

On behalf of the Bio-Diesel Working Group (now the DMG, a sub-group of the Vehicle/Train Energy System Interface Committee), the research aimed to provide information for the industry about the engineering, financial, and sustainability implications of using bio-fuel in the diesel engines of railway locomotives and diesel multiple units of GB trains.

Findings

Desk-top review

The desk-top study clarified the sustainability of biofuel production, the likely effects on engine performance and emissions of increasing bio-diesel blending with conventional diesel fuel, and sought the views of the engine manufacturers themselves. The general advantages and disadvantages of, and concerns associated with, the use of bio-diesel were summarised.

This study concluded that although bio-diesel introduction may not be imminent, there was a strong argument for some initial engine testing and inspections to better understand the future implications for the industry. It recommended that an industry focus group be established to coordinate such work and feedback ongoing developments to the industry.

The study was produced during the second half of 2006 and whilst land use issues are referenced within it, it is reasonable to note that land use and 'food versus fuel' debates have gained greater

prominence subsequently and are not dealt with as part of this research.

Test-bed trials

The results of the test-bed trials varied between the engines tested and between different blends of biofuel. Generally when using bio-fuel: the fuel consumption increased; the nitrogen oxides (NO_x) levels tended to increase; the total hydrocarbon (THC) emissions tended to decrease; carbon monoxide (CO) and carbon dioxide (CO₂) emissions were less consistent throughout but tended to be lower than for diesel; the particulate matter and exhaust smoke decreased.

The test-bed trials successfully demonstrated the practical limits of bio-diesel blend that could be applied for subsequent service trials and fleet operation. The QSK19 engine was unable to be operated beyond B20 (20% bio-diesel) blend ratio, because of the resultant loss of power. This was interpreted by the electronic controller as a turbocharger failure, which caused a de-rating of the engine. Other engines were able to run on pure bio-diesel (B100). The blend limits vary depending on engine type and from a performance standpoint will largely be defined by an 'acceptable' balance of power loss and fuel consumption increase. However, the DMG agreed a reasonable conclusion from the tests was that B20 blend represents an acceptable compromise between adverse performance effects and emissions benefits.

In-service trials

The third stage of the research was to trial the use of B20 bio-diesel on service trains.

The South West Trains (SWT) service trial reported no problems as a result of using B20 bio-diesel. Fuel consumption increase on the First Great Western (FGW) trial was greater than had been expected based on the test-bed work for this engine type. Whilst this presumably reflects the state of tune, load factor, etc, of individual engines, the precise reasons for this would need to be investigated in some detail before definitive reasons could be stated. The service trial experience of the Virgin Cross Country (VCC) mirrored the findings of SWT and FGW trials in that the fuel consumption increased but there was no significant engine problem experienced as a result of the trial.

The following summarise the key findings from the in-service trials:

- Service trials with a 20% bio-diesel fuel blend (B20) with ULSD have been successfully completed with no problems attributable to operating on bio-diesel reported during the trials.
- An increase in fuel consumption was experienced.
- There were no adverse indications or characteristics considered to be directly attributable to operating on B20 fuel. This included oil analysis, supported by boroscope and fuel injection inspections carried out on the SWT trial engines.

The use of bio-diesel in the trial of two locomotives by English, Welsh and Scottish Railway (EWS - now DB Schenker Rail (UK)) was not directly comparable because of the use of 100% bio-diesel and the way in which the locomotive engine management system compensates for the power loss, enabling the full engine output to be maintained. However, in broad terms, this trial mirrored the general finding that fuel usage increased without detriment to engine condition.

Deliverables

The research has been undertaken for RSSB by Interfleet and mi Technology. A number of reports have been produced and can be made available to RSSB members to support their own operations as appropriate. They are:

- 1 *An Examination of Bio-diesel Fuel and the Implications of its Potential Use on UK Railways* dated 15 November 2006. **Desk Top Study.**
- 2 *Evaluation of Engine Operation on Bio-diesel Fuel*, dated 30 May 2008. **Test Bed evaluation.**
- 3 *Bio-diesel Service Trials: Monitoring Guidelines for South West Trains* dated 11 January 2008. **In Service Trials.**
- 4 *Bio-diesel Service Trials: Monitoring Guidelines for First Great Western*, dated 29 July 2008. **In Service Trials.**
- 5 *Bio-diesel Service Trials on South West Trains & First Great Western*, dated 27 April 2010. **In Service Trials.**
- 6 *Test Report: to test the effects on gaseous and particulate emissions using ULSD and Bio-diesel on a Cummins NTA855R3 rail engine*, dated 4 September 2007 **Test bed report.**
- 7 *Test Report: to test the effects on gaseous and particulate emissions using ULSD and Bio-diesel on a Cummins*

QSK19 rail engine, dated 4 September 2007 **Test bed report.**

- 8 *Test Report: to test the effect on gaseous and particulate emissions and radiated noise assessment using ULSD and Bio-diesel on MTU6R183 TD rail engine, dated 22 April 2008* **Test bed report.**
- 9 *Test Report: to test the effects on gaseous and particulate emissions using ULSD and Bio-diesel on a Perkins 2006TWH rail engine, dated 5 September 2007* **Test bed report.**
- 10 *Class 67 Bio-diesel trials for EWS, ATOC and the RSSB ESG-R-V095 (02), dated 2 October 2007* **Independently funded trials (not part of the scope of this research project).**

Method

The research was completed in three phases; a desk-top based review, test-bed trials and in-service trials. This process followed that developed for the earlier trials of sulphur free diesel (SFD) as used in the RSSB research project T536.

Desk-top review

A desk-top review was carried out to identify the potential advantages and disadvantages of using bio-fuels. The study reviewed the population of diesel engines used in the GB railway fleet and identified several engines as examples for further study based on their common use, longevity and representation of their type.

Test bed trials

The second stage of the research then carried out test bed trials on the representative engines chosen:

- Cummins NTA855R3 DMU engine (ex-Class 159)
- Cummins QSK19 DMU engine (ex-Class 221)
- Perkins 2006TW-H DMU engine (ex-Class 165)
- MTU 6R183 DMU engine (as used in Class 168/170/171)
- EMD 12N710-G3B freight locomotive engine (Class 67)

The engines were tested under laboratory conditions on a range of blends of bio-diesel, from 5% bio-diesel (B5) in steps up to 100% bio-diesel (B100). All engines were monitored for fuel consumption, nitrogen oxide emissions, hydrocarbon emissions, carbon monoxide emissions, carbon dioxide and oxygen emissions, particulate matter emissions and exhaust smoke.

In-service trials

The third stage of the research was to trial the use of B20 bio-diesel on service trains.

Two of the three train operators who had previously undertaken the SFD trials were willing to participate in the service evaluation of bio-diesel. The two train operators were SWT using a Class 159 train from Salisbury and FGW using Class 165/166 trains from Reading.

For completeness, the DMG agreed to include other known trials that were also conducted and financed independently of this research project. These were the VCC and EWS trials. Their inclusion here was considered beneficial to the industry by increasing the number of tests completed and enhancing the overall knowledge gained.

For the VCC and SWT trials, the B20 blend was applied to all engines of a 4 car and 3-car set respectively. For the FGW trial, the centre vehicle of four 3-car trains was filled with bio-diesel and other engines on the same train with standard diesel. The fuel consumption on each engine was monitored so that a direct comparison could be made. The VCC service trial ran from May to November 2007, the SWT service trial from March 2008 to February 2009 and the FGW service trial from December 2008 to October 2009.

The EWS service trial used two Class 67 locomotives running on 100% bio-diesel to haul the Royal train on several occasions. The report for this trial is included under the deliverables.

Next Steps

If further bio-diesel operation was to be considered, either as a trial or a more general introduction, the DMG has recommended that a maximum 20% blend ratio is used, based upon the satisfactory results from these service trials. The impact on the engine fuel consumption should also be investigated in detail at an early stage in order to quantify the increase.

From the research the DMG has concluded that there are two important barriers to bio-diesel use:

- The first barrier is sustainability of the source fuel. This is a political/environmental decision and requires verification of the source of the fuel.
- Secondly the research has shown that, for bio-diesel blends up to B20 the concern is an economic one and not an engineering one.



ATOC and key members of the DMG will continue to promote the findings and results of the research to other industry members including presentations at Sustainability Conferences and Engineering Forums. Already the emerging findings have been used by ATOC in support of discussions with HM Treasury and more specifically by parties involved in franchise bidding as to the trade off between cost of operation and other government targets.

The Department for Transport will soon begin a consultation on the Renewable Transport Fuel Obligation that will look to extend the current requirement for all road vehicle fuel to be supplied with 5% from renewable sources by 2010 to apply to the rail sector. This research will enable the DfT and the rail sector to consider the bio-diesel blend ratio in meeting these expectations going forward. Further, the DMG is recommending a certification scheme to government with tax rebates in order to facilitate the uptake of bio-diesel by train operators.

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