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Biogas in reciprocating engines

This is part of a series of factsheets developed for the JVAP/AGO funded "Bioenergy Atlas of Australia project by Lyndon Zimmermann and Ian Nuberg of the University of Adelaide Faculty of Sciences.

Watch the RIRDC webpage for more information on the Atlas Project.

email <lyndon.zimmermann@adelaide.edu.au>
<ian.nuberg@adelaide.edu.au>

ADELAIDE UNIVERSITY
AUSTRALIA

BIOENERGY ATLAS FOR AUSTRALIA PROJECT

Mr. LYNDON ZIMMERMANN
RESEARCH OFFICER

FACULTY OF SCIENCES, WAITE CAMPUS
PMB1 GLEN OSMOND, SA, 5064
AUSTRALIA
TELEPHONE +61 8 8303 6571
FACSIMILE +61 8 8303 6717
MOBILE 0414 91 4577
lyndon.zimmermann@adelaide.edu.au

Dr IAN NUBERG
CO-PRINCIPAL INVESTIGATOR

FACULTY OF SCIENCES
ADELAIDE UNIVERSITY ROSEWORTHY CAMPUS
ROSEWORTHY SA 5371
AUSTRALIA
TELEPHONE +61 8 8303 7729
FACSIMILE +61 8 8303 7979
ian.nuberg@adelaide.edu.au

Introduction

The objective of this paper is to provide some background on modifications and monitoring which may be required when operating engines on biogas. Most is drawn from information from the Caterpillar Company and focuses particularly on the most common biogas sources: landfill and anaerobic digester.

The engine manufacturer should be consulted when converting to any alternative fuel.

There are various practical reasons for running generator sets on biogas, including:

- reduction in methane emissions from landfill;
- stabilisation of landfill;
- reduction in odours from landfill and waste treatment plants;
- utilisation of methane from digester plants installed to eliminate the dumping of organic material into landfill.
- financial gain;
- green power and carbon credits;

There are a number of issues to be considered in converting reciprocating diesel or spark ignition engines to biogas fuels, including:

- lower calorific value;
- corrosive and solid contaminants in the fuel;
- acidic and solid contaminants in the exhaust;
- tar;
- load transients

Definitions

Blowby	Gases which escape from the engine cylinder into the crankcase.
CFCs	Chlorofluorocarbons
Digester gas	Gas produced by an anaerobic digester, fed on sewage, animal waste of food processing wastes.
H_2S	Hydrogen sulphide
Landfill gas	Gas extracted from landfill
Methane number	A measure of the resistance of a fuel to engine knock.
MSW	Metropolitan solid waste

Producer gas	Gas produced by gasification of a solid fuel, such as woody materials, straw, MSW or coal.
Sour gas	Fuels containing a high concentration of sulphur compounds.

Conversion Issues

Lower calorific value

Lower calorific value requires higher fuel throughput to maintain rated output. This can include modifications to fuel supply systems, engine inlet valves and camshaft dwell.

Engines are often supplied configured for natural gas for initial commissioning, then converted to suit the biogas fuel.

Methane number and compression ratio

The higher the methane number of the fuel gas the higher the anti-knock characteristics and the higher the maximum compression ratio. Determination of methane number is complex. The compression ratio for pure methane can be as high as 15:1, compared with 12:1 for propane.

Corrosive and solid contaminants

A number of approaches are taken to protect the engine against corrosive gases, be they in the fuel or in the combustion products.

Operating with a higher coolant temperature reduces condensation of contaminants. This may require further modifications to cope with the higher operating pressure of elevated temperatures. To maintain a satisfactory oil temperature a separate cooling system, operating at a lower temperature, may be required. Oil temperature has to be maintained relatively high to minimise condensation.

Radiator discharge air is often deflected away from the engine block to reduce crankcase cooling and the potential for condensation.

Care must be taken with exhaust heat recovery equipment to minimise condensation. This is more critical if the engine is subject to frequent starting and stopping.

The crankcase ventilation systems need to be improved and modified to prevent ingestion of fuel gases and combustion products, perhaps through the use of an evacuating crankcase blower. Minimisation of blowby is important.

Some engine components, such as the aftercooler, may need replacing with higher corrosion resistant materials.

The levels of corrosive gases, such as H_2S and CFCs, need to be monitored and possibly controlled to minimise corrosive damage. H_2S combusts to form sulphuric acid, CFCs (from landfill) form hydrochloric acid and hydrofluoric acid.

Corrosive contaminants are often water soluble. Drying the fuel may be necessary to reduce corrosion and condensation problems. This is usually achieved through a refrigerative dryer.

Crystals of silicon may be carried with the fuel gas and coagulate in combustion to form larger and more abrasive particles. Filtration may be needed. Siloxanes are silicon bearing organic compounds common in a wide variety of consumer products. Once broken down in the combustion process the components can recombine to form abrasive silica and silicates. Siloxanes can be reduced by refrigeration of fuel gas or by washing with a solvent. Buildup can be controlled by demineralised water injection downstream of the turbocharger.

Tar[1]

Gasifiers produce tar. The major challenge in gasifier design is in ensuring the maximum amount of tar is converted to gas. Gasifiers with high tar output (typically updraft and fluidised bed

[1] Drawn from Reed (undated)

types) are suitable only for direct combustion, not for fuelling an engine. Tar will agglomerate from a mist into droplets, and eventually form deposits on engine intake valves and other parts. Tar also deposits within electrostatic precipitators, causing arcing.

Downdraft gasifiers produce low tar gas and are the preferred design for engine fuelling.

An oversized gasifier produces excessive tars due to failure to develop adequate operating temperatures.

Exhaust gas catalysts

Landfill and digester gas fuelled engines usually produce emissions which will poison or coat the catalyst.

Oil contamination

A scheduled oil sampling program is required to monitor oil contamination and engine wear.

Load transients

Fuel system design for constant load operation (ie grid connected) is different to transient operation (ie standalone).

According to Reed, updraft and fluidised bed gasifiers have poor response times. Crossdraft gasifiers are the fastest and downdraft gasifiers have fast response times[2].

Hazards

Explosion

All fuel gases are flammable and potentially explosive. Beware of all potential ignition sources, including static sources and mobile telephones.

Carbon Monoxide

Gasifiers produce a high CO fuel. CO displaces oxygen from the blood and is extremely poisonous. Proper procedures need to be followed when working with gasifiers.

Tars

Some tars can be toxic or carcinogenic. Disposal of tars and oils collected from scrubbers must be appropriate. Some designs return the tar to the gasifier for another try at cracking and combustion.

H_2S[3]

The odour threshold is a few parts per billion in air and it smells of bad eggs. However, at higher concentrations - 1-3ppm you may not smell it as H_2S numbs the olfactory nerves and effectively at these concentrations is odourless.

If the H2S is above 3ppm it may cause you health problems. At 10ppm the law limits the exposure to 8 hours per day – and from experience you will feel terrible after this level of exposure. At 15ppm the law limits your exposure to 15 minutes per day.

At a few hundred PPM -H_2S in air you may pass out in less than an hour. At a few thousands of PPM - H_2S in air you may die on contact with the gas as the nerves around the heart and lungs are paralysed.

Asphyxiation

All fuel gases are low in oxygen and asphyxiating. Enter storage vessels with caution.

Pathogens[4]

As Anaerobic Digestion relies on a mixed population of bacteria of largely unknown origin, but often including animal wastes, to carry out the waste treatment process care should be taken to avoid contact with the digester contents and to wash thoroughly after working around the digester (and particularly before eating or drinking). This also helps to minimise the spread odours which

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[2] ibid., p105
[3] http://www.roseworthy.adelaide.edu.au/~pharris/biogas/h2sd.htm
[4] http://www.roseworthy.adelaide.edu.au/~pharris/biogas/safety.html

may accompany the digestion process. The digestion process does reduce the number of pathogenic (disease causing) bacteria, particularly at higher operating temperatures, but the biological nature of the process needs to be kept in mind.

Other engine types

Gas turbines, fuel cells and Stirling Cycle external combustion engines are undergoing rapid development and cost reduction. Biomass integrated systems for microturbines and Stirling Cycle are certainly under development. Steam engines have, of course, been long fired with biomass. These engines are outside the scope of this analysis and little information was to hand.

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