"no" because such monuments are unique and once destroyed cannot be replaced. But whether the term "priceless" can be used or not seems to me to be largely irrelevant. For I think we can "invert" the process of valuation and ask ourselves what we have to do to prevent air pollution damage. Assuming we are not to coat the Acropolis in transparent plastic or continue to move parts of it for protection, that cost will be given by the cost of reducing pollution to levels which will not harm the monuments in question. Simple techniques exist for expressing such a cost in annual terms and we can then ask the question: "since it costs X million collars to protect the Acropolis each year, do we value it at more than X million dollars a year?" If we do, we have an automatic economic rationale for outright protection through abatement schemes. If we find ourselves hesitant, we must then refer to the other benefits such protection would bring - e.g. the health and aesthetic benefits. Those, I suggest, may be directly quantifiable. If they come to Y million dollars, we can rephrase our question as "do we value the Acropolis at more than X-Y million dollars a year?" In this way, as I mentioned at the outset, we have used the framework of cost benefit analysis to guide our thinking. I believe that is valuable in itself. And if anyone finds this all rather like an economist's fairy tale, let he or she ask why it is then that we have not already implemented a vast pollution control programme to protect such monuments. The issue of cost explains why not.

Conclusions

While I understand the suspicion with which many scientists regard economists, I am concerned to indicate that, outrageous and impossible as many of the economist's techniques may seem, they have a strong basis in terms of trying to rationalise, albeit in a limited fashion, the way in which we spend our money. I will be honest and say that my concern is that in years of recession we shall find the environment a "dispensable" item. It is easy to relegate it to the bottom of our list of priorities. It is in this context that I suggest to you that cost-benefit has a role to play in demonstrating that, whatever the methodological and statistical and sometimes philosophical problems involved, there are still very substantial gains to be obtained from air pollution control. If anything, our programmes must be strengthened and not reduced or held stable. I do suggest, however, that we shall find the economic rationale for that control not so much in our traditional areas of concern such as health, but in the other benefits that air pollution control bring.

References

1. Adams, R. and al., **An economic assessment of air pollution damages to select Annual Crops in Southern California**, Journal of Environmental Economics and Management, Volume 9, no 1, March 1982.

2. Chappie, M. and Lave, L., **The health effects of Air Pollution : a Reanalysis**, Journal of Urban Economics, Volume 12, p 345-376, 1982.

3. Chinn, S., **The relation of mortality in England and Wales from 1969-1973 to measurements of air pollution**, Epidemiology and Community Health, 1981.

4. Crocker, T. and al., **Experiments in the Economics of Air Pollution Epidemiology Methods development for Environmental Control Benefits Assessment**, Volume 1, Environmental Protection Agency, Washington DC, 1979.

5. Freeman, A.M., **The benefits of Air and Water Pollution Control : a review and synthesis of recent estimates**, US Council on Environmental Quality, Washington DC, 1979.

6. Lave, L. and Seskin, E., **Air Pollution and human health**, Johns Hopkins University Press, Baltimore, 1977.

6. Schulz, W.D. and al., **The benefits of preserving visibility in the National Parklands of the Southwest, methods development for Environmental Control benefits assessment**, Volume VIII, Environmental Protection Agency, Washington DC, 1981.

EMISSIONS FROM ALCOHOL AND ALCOHOL-BLEND ENGINES

DUTKIEWICZ, R., NATES, R.,

ENERGY RESEARCH INSTITUTE, SOUTH AFRICA

INTRODUCTION

Previous work on emissions from methanol fuelled engines has shown that levels of component emission are either similar to those from gasoline fuelled engines or have significantly reduced emissions. Bechtold and Pullman (1) have shown that the carbon monoxide levels are slightly less at lean mixture conditions but slightly higher at stoichiometric conditions than those of the equivalent gasoline engine. Brinkman (2) has also shown the carbon monoxide levels are similar to those of gasoline engines.

Oxides of nitrogen levels in alcohol engines are significantly lower than those in gasoline engines. The levels found by Brinkman (2) were approximately 40% of those for gasoline engines whilst Bechtold and Pullman (1) quote levels 30% of the gasoline engine.

Unburnt fuel emissions are in general much higher than from gasoline engines but most of this is unburnt methanol. Typically 98% of hydrocarbon emissions are methanol (2).

The only significant emissions which are higher for a gasoline engine are aldehydes. In the case of an ethanol fuelled engine the main emissions are acetaldehyde whilst the methanol fuelled engine produces mainly formaldehyde. Aldehyde levels are typically between 2 and 3 times those of gasoline engines (3).

Since aldehydes are toxic - e.g. formaldehyde has a Threshold Limit value of 2 p.p.m which is one hundredth of that of methanol (220 p.p.m) - it is important to determine the effect of aldehyde emissions on health and its effect on the production of photochemical smog, and also methods must be sought to decrease emission levels.

ALDEHYDE EMISSIONS

It has been shown that the engine compression ratio (CR) has a significant effect on aldehyde levels (3) with aldehyde concentrations decreasing with increasing CR. At a CR of 9,7 Bernhardt found formaldehyde (HCHO) levels of 160 p.p.m compared with 50 p.p.m at a CR of 14.0. However Samaga (5) found that the HCHO concentrations increased with increasing CR.

Massive Ducon Venturi scrubber handling more than 400 000 m³/hr soda ash emission at SAPPI, Springs.

Mikro-Pulsaire filter plant in operation on non-ferrous metal furnace fumes at Denver Metals.

An extraordinary commitment to excellence, that's what.

In over twenty-five years we have achieved an enviable excellence in all skills relating to dust control and from the day our project engineers assess the problem to the day we commission the plant, this commitment to excellence shows.
Even after our commissioning engineers have tuned the plant to optimum performance, we pursue our obligation by servicing and maintaining it if so desired.
Different industrial processes need different dust control systems. Brandt have a long and intimate experience with all types of dry and wet dust collection problems – and have the equipment and technology to undertake each and every dust control challenge with enthusiasm – to meet our client's satisfaction, air pollution control regulations and, above all, our own strict standards of excellence.

For a better environment

Brandt
Engineering (Pty) Ltd.

MEMBER
GAS CLEANING EQUIPMENT SUPPLIERS' ASSOCIATION OF SOUTH AFRICA

Head Office:
P.O. Box 4901, Johannesburg, 2000.
88 Marlborough Road, Springfield, 2197
Tel. 011-683-7310.
Telex: 8-6105 SA

Natal:
P.O. Box 429, Pinetown, 3600.
Tel. 031-71-2227.
Telex: 6-5233 SA

Western Cape:
David Rice & Co. (Pty) Ltd.
P.O. Box 125, Maitland, 7405.
Tel. 021-51-0776.
Telex: 57-26062 SA

Eastern Cape:
D. Davidson Co.
P.O. Box 2619,
North End, 6056.
Tel. 041-4-7532

LINKS 1553 DC

A similar anomalous result is found with the effect of water in methanol on HCHO levels. Hilden and Parks (6) found that the addition of 10% water to methanol had no effect on aldehyde emissions, Bernhardt (3) found that a 5% water in methanol blend reduced aldehydes by 40%, whilst Pischinger (7) found that water increased aldehyde emissions. The increase in aldehydes found by Pischinger was up to 400% at a water content of 10%.

These conflicting results might be explained by considering the three main parameters thought to affect aldehyde emissions, namely compression-ratio, combustion chamber shape, and fuel preparation. There is evidence to show that the aldehyde emission levels are a function of unburnt methanol in the exhaust. Thus anything which improves combustion efficiency will, by decreasing unburnt fuel levels, decrease HCHO levels. Thus mixture preparation would be expected to have a large effect on emissions. The combustion chamber shape, particularly the surface to volume ratio has been shown by Scheffler (4) to affect the amount of quench zone in the engine. It is postulated that the size of the quench zone affects the amount of aldehyde produced.

Various workers (2), (3), (8) have found that a catalytic converter in the engine exhaust system can significantly reduce unburnt methanol and aldehyde levels. With a standard three-way catalytic converter on a Fort Pinto, Baisley and Edwards (8) found a catalyst efficiency for aldehyde emissions of 88%.

EXPERIMENTS

In view of the apparently conflicting results reported by various workers, as outlined above, it was decided to carry out experiments on a number of engines to determine aldehyde levels, and the effect of the various parameters on these levels. Tests were carried out using a variable compression ratio engine - a Ricarde E-6 engine - two passenger vehicle engines and two large engines.

The passenger vehicle engines tested were a Ford Cortina 2 litre engine and a VW Passat engine, both engines having been converted to 100% methanol and being used as part of a fleet experiment. The Ford Cortina engine was tested in a vehicle on a rolling-road dynamometer, whilst the VW Passat engine was tested on a bench dynamometer.

The two large engines were a Mercedes-Benz 355 engine and a Daimler Benz 407 engine, rated at 177 kW and 147kW respectively. Both these engines had been converted from diesel engines to spark-ignition 100% methanol operation.

The aldehyde measurements were carried out using the chromotropic acid method (9). This method measures formaldehyde, rather than total aldehydes, but it is reported that the main aldehyde from methanol fuelled engines is formaldehyde.

The tests were carried out at constant conditions of speed and torque, the air-to-fuel ratio being varied. The variable-compression engine tests were carried out at compression ratios of 8:1, 10:1 and 12:1 and with either 100% methanol or a 90% methanol and 10% water blend (by volume).

Tests on the variable compression ratio Ricardo E-6 engine also included a series using a three-way platinum-rhodium catalytic converter installed 400 mm from the exhaust port. No secondary injection air was used.

RESULTS

The formaldehyde measurements on the two passenger vehicle engines confirmed the results obtained by previous research workers, that the formaldehyde levels were in the range 100 p.p.m to 200 p.p.m compared with a typical gasoline engine emission of around 40 p.p.m. The effect of engine power output is shown in Figures 1 and 2 for the Volkswagen and Ford engines respectively. The Ford tests showed a larger scatter - 30 p.p.m for a 95% confidence band - due to the fact that the tests were carried out on an old Clayton water-brake rolling-road dynamometer which was unable to maintain adequate steady state operating conditions.

Both engines showed a reduction of emission levels with power output. The levels of formaldehyde were between 3 and 5 times the expected values of a gasoline engine at idle conditions. It was not possible to vary the air-to-fuel ratio of these engines.

Tests on the two large engines showed a marked effect of air-to-fuel ratio on formaldehyde emission levels. Figure 3 shows the effect of air-fuel ratio on formaldehyde levels at speeds of 1250, 1300, 1500 and 1650 r.p.m and at maximum torque. From an initial high value (300 - 400 p.p.m) under rich conditions, the level dropped rapidly approaching stoichiometric conditions and continued to drop, though at a slower rate, as the mixture became more lean. A similar picture emerges from the tests on the Daimler-Benz 407 engine. The tests on this engine were more comprehensive than those on the 355 engine and it was possible te draw a map of formaldehyde emission levels against air-fuel ratio and exhaust temperature (Figure 4).

More comprehensive tests could be performed on the Ricardo E-6 engine and the results are shown in Figures 5 to 7. Because of the apparently contradictory results published on the effect of compression ratio on formaldehyde levels a range of tests with variable compression ratio and variable air-fuel ratio were carried out. The results of a range of CR's from 8:1 to 12:1 (Figure 5) show that under rich conditions the formaldehyde level decreases with increasing compression ratio, whilst under lean conditions the correlation is confused. Between air-fuel equivalence ratios of 1.1 to 1.25 the emission levels increase with decreasing CR. Since most multi-cylinder engines run rich the decreasing emission level with increasing CR is possibly the more appropriate practical conclusion.

The effect of a 10% water blend with alcohol at a CR of 10:1 is illustrated in Figure 6. Under all air-fuel ratios the HCHO emission from the 10% water blend is lower than from the 100% methanol fuel - at lean mixtures the reduction is as much as 80%. At higher compression ratios the decrease in HCHO emission is not as great and near stoichiometric conditions and higher compression ratios the water-blend emission can be higher than that from pure methanol. At stoichiometric conditions and a compression ratio of 12:1 the increase of HCHO emission with the water blend fuel was 67% above that for the pure fuel. The results of the water blend tests are summarised in Figure 7.

Tests were carried out on the effect of a platinum-rhodium catalytic converter using the Ricardo E-6 engine at a compression ratio of 12:1, at speeds of 1000 r.p.m and 200 r.p.m and with a variable air-to-fuel ratio. The results of these tests showed that with a warm catalytic converter formaldehyde emissions were reduced to well below the values expected from a gasoline engine. Depending on air-fuel ratio the efficiency of the catalytic converter was between 90% at an air-fuel equivalence ratio of 0,9 and 80% at stoichiometric conditions. Under all conditions the levels were below 15 p.p.m.

DISCUSSION

In view of the number of variables involved in correlation of methanol engine emissions, it is not surprising that apparently contradictory results are obtained by various researchers. Thus the effect of compression ratio (CR) on formaldehyde (HCHO) levels is reported as either HCHO levels decreasing with increasing CR (3) or HCHO levels increasing with CR (5). From Figure 5 it can be seen that under fuel-rich conditions (air-fuel equivalence ratios up to 1,0) emissions decrease significantly with increasing compression ratios. Between air-fuel equivalence ratios of 1.1 to 1.3 the same

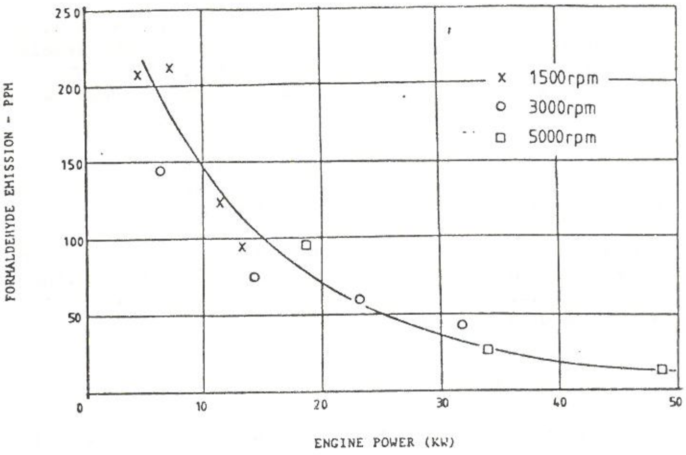
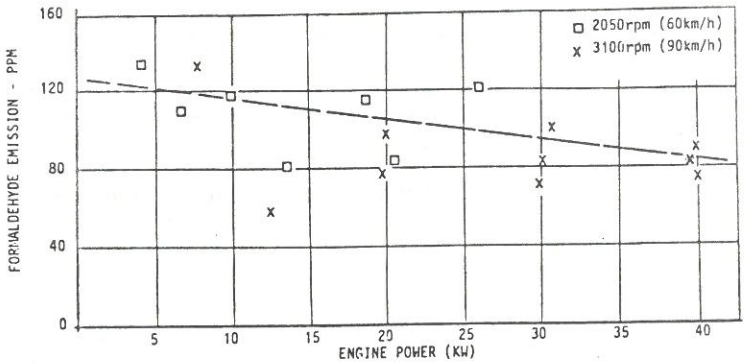


FIGURE 1: V W PASSAT ENGINE - FORMALDEHYDE EMISSION OPERATING ON 100% METHANOL

FIGURE 2: FORD CORTINA 21 - FORMALDEHYDE EMISSION FOR OPERATION ON 100% METHANOL. TESTED ON ROLLING ROAD DYNAMOMETER



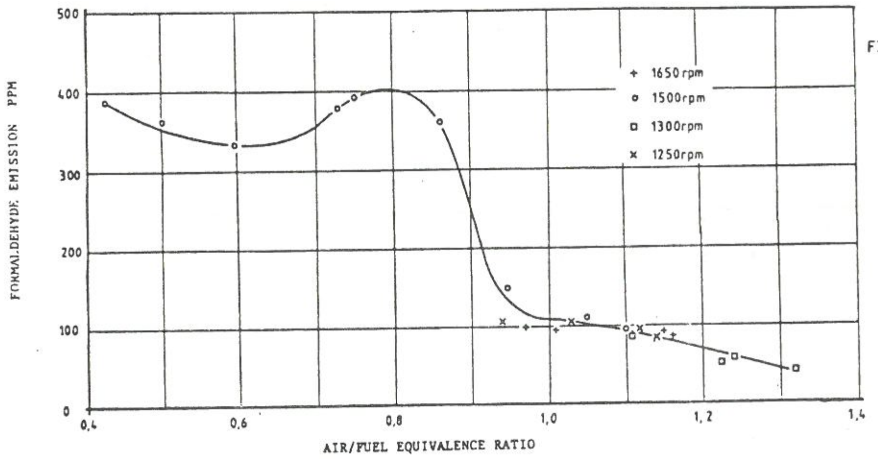


FIGURE 3: FORMALDEHYDE EMISSION FROM A CONVERTED MERCEDES BENZ ENGINE (M 355) OPERATING ON 100% METHANOL

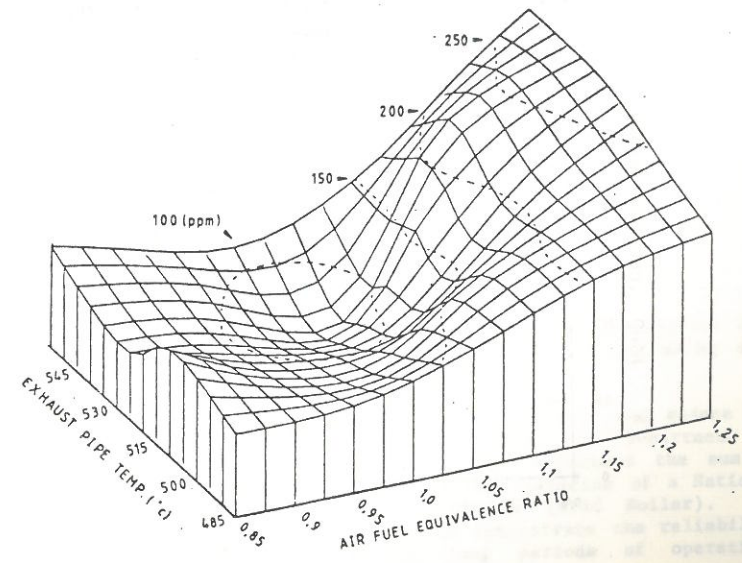


FIGURE 4: DIAMLER BENZ M407 METHANOL ENGINE FORMALDEHYDE EMISSIONS MAP

applies, namely HCHO levels decreasing with increasing CR. However, at other conditions the converse can apply. For instance, at an air-fuel equivalence ratio of 1.05 the HCHO level at a CR of 12:1 is significantly higher than at a CR of 8:1. These particular results apply to variable CR on the Ricardo E-6 engine and the results need not be the same for other engine types.

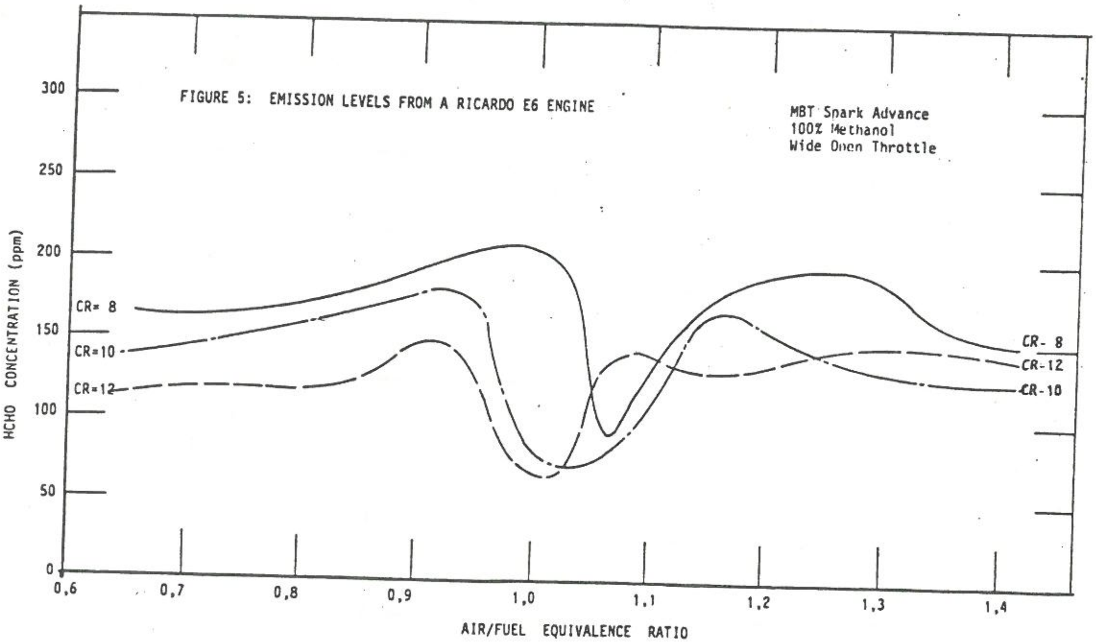
The effect of water addition to methanol is also reported as being beneficial to HCHO levels (3), as being detrimental (7), or had no significant effect (6). Figure 7 shows the various effects of compression ratio and air-fuel ratio on HCHO emissions from the Ricardo E-6 engine. Values below the ordinate of 1.0 show beneficial effects, i.e. a reduction of HCHO levels when 10% water is blended to methanol, whilst values above 1.0 show a deleterious effect. Whilst in the rich or lean conditions there is a significant reduction in HCHO levels due to the addition of water, near stoichiometric conditions the converse applies, the deleterious effect increasing with compression ratio. Thus at a CR of 8:1 the water blend levels are always below the pure methanol levels, at CR of 10:1 there is a narrow band of air-fuel ratios around stoichiometric conditions where water blend HCHO levels are above those for pure methanol, whilst for a CR of 12:1 there is a wide band where HCHO levels are significantly increased by the addition of water.

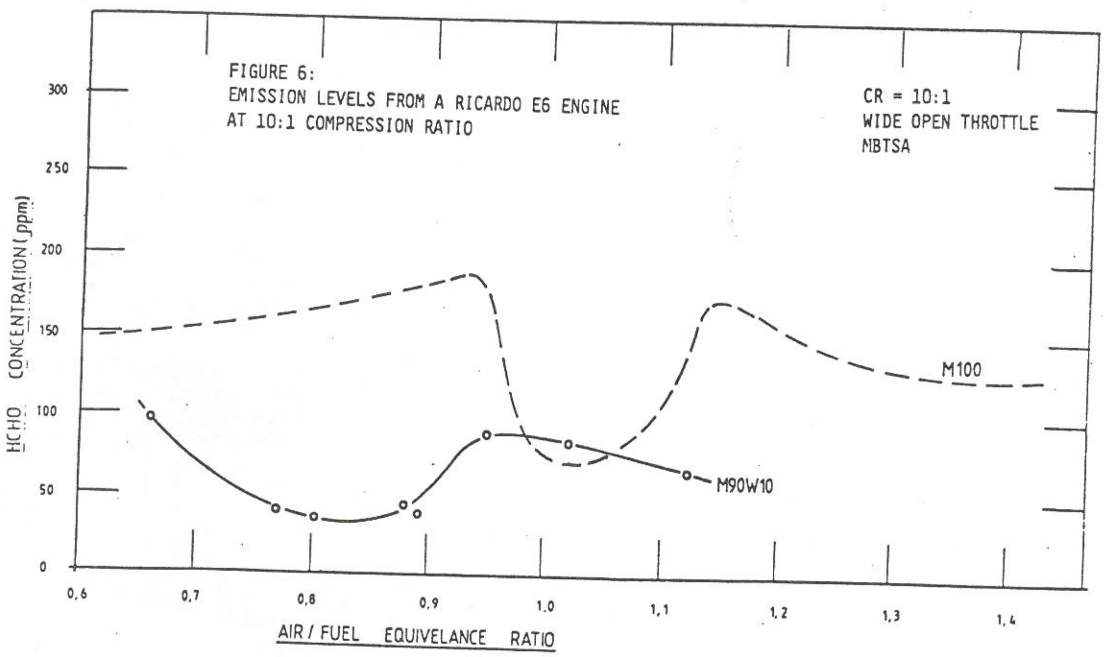
The high levels of formaldehyde produced in methanol engines may be adequately treated by the use of standard automotive catalytic converters.

The work reported here, and by other workers has shown that acceptable levels of HCHO are possible. Further work is required in order to understand more fully the mechanism of formaldehyde formation.

ACKNOWLEDGEMENTS

The research work described was supported financially by the Anglo-Transvaal Company and by the Council for Scientific and Industrial Research. Their support is gratefully acknowledged.





...Driving cycle compari-
...and emissions from an
...lled vehicle, Third
...Alcohol Fuels Techno-
...May 1979. Proceedings

...evaluation of neat
...ng exhaust emissions,
...lity, Warren, Mich.,
...(Research Publ. GMR -

...Engine performance and
...istics of a methanol
...Automotive Fuels Sympo-
...rs Research Laboratory,

...chamber surface area,
...bons, Automotive Engi-
...t, Mich., Jan 1966,

...luation of methanol for
...in a single-cylinder
...nternational Symposium of
...ogy, California, 1979,

...A single-cylinder en-
...uel - Emphasis on organic
...Engineering Congress and
..., Feb 1976, Proceedings.

...Influence of engine para-
...emissions of a methanol
...Otto-cycle engine, Third
...of Alcohol Fuels Techno-
...nia, May 1979, Proceedings

...C.F. Emissions and wear
...alcohol fuelled fleet using
...and three-way catalysts,
...Symposium on Alcohol Techno-
...1980, Proceedings.

...al. Determination of Form-
...res by the chromotropic acid
...nalytical Chemistry, Vol 33,
...21-625.

...tonnes per year. The accumulated duff
...of 2m tonnes and is increasing at a
...per year.

...ize the inferior coals and reduce the
...quality coals, the Department of
...Affairs has allocated the sum of
...construction and operation of a National
...combustion Boiler (NFBC Boiler). Its
...would be to demonstrate the reliability
...over long periods of operation,
...card and duff coal.