STUDY OF PERFORMANCE AND PREDICTION OF HEAT RELEACE IN COMPRESSION IGNITION ENGIN WORKING ON ETHYL ALCOHOL AND GAS-OIL SOLUTION

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ABSTRACT

The effect of using solutions of ethanol and gas-oil (duel fuel) to fuel the diesel engine on engine performance and heat release have been studied experimentally. A single cylinder diesel engine type Recardo (E6/US) was used and the ethanol percentage in the solution was varied from 0 to 20 percent. The results showed that, in general, addition of ethanol to gas-oil cause the maximum power output to decrease at medium and high range of speed and it was nearly the same as that of the straight gas –oil at low speed ranges . The specific fuel consumption of the dual is nearly the same as that of straight gas-oil at low and medium ranges of load. But at high ranges of load the specific fuel consumption was increase. In general the addition of ethanol to gas-oil cause the maximum rate of heat release to increase during the first stage of combustion and decrease during the second stage of combustion. Further substitution of gas-oil with ethanol(higher than 20 percent) was limited by knock.

الخلاصة

تم في هذا البحث دراسة تأثير استخدام وقود ثنائي يتكون من محلول الايثانول وزيت الغاز على أداء محرك ديزل و استنتاج الحرارة المتحررة منه ولتحقيق ذلك فقد استخدم محرك ديـزل نـوع ريكـاردو (E6/US) وتراوحت نسبة الايثانول في المحلول من (صفر إلى 20) جزء.

أظهرت النتائج المستحصلة إن إضافة الايثانول إلى زيت الغاز تؤدي إلى تناقص القدرة العظمى الخارجـة من المحرك عند السرع المتوسطة والعالية بشكل عام و تبقى مشابهة لتلك المستحصلة من زيت الغاز لوحده عند السرع القليل.

كما أظهرت النتائج بأن الاستهلاك النوعي للوقود الثنائي يكون مماثلا تقريبا للاستهلاك النوعي لوقود زيت الغاز لوحده عند الأحمال المتوسطة و الخفيفة ولكنه يزداد عند الأحمال العالية.

وقد أظهرت النتائج بشكل عام أن إضافة الايثانول إلى زيت الغاز تؤدي إلى زيادة معدل الحرارة المتحـررة في المرحلة الأولى من الاحتراق و نقصانها في المرحلة الثانية من الاحتراق

لم يمكن إضافة كمية من الايثانول (أكثر من عشرين جزء) لتسببها في إحداث طرق عالي في المحرك.

KEY WORDS
Compression Ignition Engine, Fuels blending, Ethyl Alcohol and Gas-oil Solution.

INTRODUCTION

The characteristic of gasoline and gas-oil as automobile fuels have been extensively investigated. The development of new alternative fuels and systems are required with recent increasing importance of the prevention of automotive emissions and fears of shortage and cost increases of the petroleum fuel. It is possible to improve combustion processes and reduce polluting exhaust emissions of engines by directly mixing additive fuels such as alcohol to base fuel. Alcohols are one of the sources which seem to be among the most promising alternative fuels to replace conventional fuels for automobiles. The use of alcohols in compression ignition engines still regarded as considerable challenge because of their low cetane number, high latent heat of vaporization and long ignition delay. But there is however, interest in diesel application because most frame equipment and machinery are diesel powered and it is useful to reduce the unburned hydrocarbons and NOx emissions (Shropshire, G.J, and Goering, G.E. 1982), and (Bill Likos, and others 1983),

PREVIOUS WORKS

Alcohol, particularly ethanol has been used and promoted as an engine fuel since the early years of the automobile. In fact Otto used alcohol in his first engine (Miller, G. L. et al 1981), In 1909 Strong (Carlos Fontana and Alan Rotz 1982), has presented information on engine design, effect of fuel quality and performance resulting from alcohol fuels engine. (Miller, G. L et al 1981), Claim that reports and detailed researches on the use of alcohols the motor fuel, was conducted in 1920s and 1930s. After that the investigations continued their works and researches about the use of alcohol as a fuel for internal combustion engine. References, arranged in historical order, (Shropshire, G.J. and Goering, G.E. 1982, Tadashi et al 1983, and Joel T. Walker 1984), and others studied effects of blending alcohol fuel into the diesel or gasoline engine on engine performance and emission. A solution of alcohol and diesel fuel is one of the methods of introducing alcohol into diesel engine used by some of the workers in this field. This method is the earliest one, of several methods of blending alcohol to essentially anhydrous ethanol because methanol is not soluble or has very limited solubility in the vast majority of diesel fuel (Eugene Ecklund et al 1985), Ethanol itself has limited solubility in diesel fuel as shown in **Fig.(1)** , and thus ethanol-diesel fuel solutions are restricted to small percentage (typically 20 percent or less (Eugene Ecklund et al 1985 , and Tadashi et al 1983), In general, solubility of alcohol in diesel fuels is extensively affected by the temperature, mixing ratio of the blended fuels, specific gravity of diesel fuel and the water content of the ethanol-diesel fuel blend (Eugene Ecklund et al 1985 , and Tadashi et al 1983), **Fig. (1)** shows that the blended fuel is soluble above the curve, and it is dispersive under the curve, around the mixing ratio of 50 percent volume. The soluble limit temperature is highest, showing that dissolving of the two fuels is most difficult at this ratio. This temperature is called the critical solution temperature (Tadashi et al 1983), Another factor affects the solubility of alcohol in diesel fuel is that the alcohols more polar and refuse to blend well with diesel fuels. The fact, that diesel fuel contains only a small amount of aromatics is not helping much, so a solubilizer has to be used to ensure a stable mixture (Kurt Weidmann and Holger Menrad 1985), To improve the solubility of ethanol in diesel fuel, certain additives were used. The additions of higher alcohols such as propanol increase the solubility of ethanol in diesel fuel (Eugene Ecklund et al 1985 and Kurt Weidmann and Holger Menrad 1985), (Tadashi et al 1983), examined ten different additives, their results indicated that the critical solution temperature decreased in proportion to the amount of additives for all types. Also Tadashi found that dodecanol and cetanol, which are higher than alcohol, are most effective to improve the solubility and that gasoline can be an adequate and economical surface active agent for ethanol blend in practical use. An advantage of ethanol-diesel fuel solution is that it requires relatively few major components changes for their use. Small adjustment to injection timing and fuel volume delivery may be necessary to restore full power. The adjustment depends on the ethanol concentration and the combustion effect of the ethanol. The physical properties of the diesel fuel are changed when alcohol is added in solution. The addition of ethanol in solution with diesel fuel cause the cetane number rating to drop and the viscosity to change (Kurt Weidmann and Holger Menrad 1985), The resulting engine performance and emission by use this method of blending alcohol and diesel fuel (solution) by some workers showed that the power output tend to be close to that produced from the original diesel fuel as it was found by Wrage and Goering 1980 who used a solution of 10 percent ethanol and 90 percent diesel fuel called it diesohol. Most investigators studying alcohol introducing into the diesel engine have found that the break thermal efficiency increased in some conditions and decreases under others, or close to that of the base diesel fuel. Typically, the efficiency increases at high engine loads and the decreases at the low engine loads (Shropshire, G.J. and Goering, G.E. 1982, Eugene Ecklund et al 1985, Goering, G.E. and Wood, D.R. 1982 and Marci Cruz et al 1982), Bill Likos et al 1983 found that the stable emulsions (a method of blending alcohol with diesel fuel nearly close to solution method), resulting in overall improvement in brake thermal efficiency. (Falltti et al 1984), used the emulsion method, while Saeed and Henien 1989 used the solution method both found that the ignition delay becomes longer as alcohol addition increased. In general, alcohol blending with diesel fuel cause an increase in unburnt hydrocarbons (HC) and carbon monoxide (CO) emission and reduction in nitrogen oxides (NOx). Also it was found that the smoke reduces due to soot-free combustion of ethanol (Goering, G.E. and Wood, D.R. 1982, Joel T. Walker 1984 and Likos, W.E. 1985), But in the emulsion and solution methods used by (Bill Likos et al 1983, Falltti et al 1984), and (Kurt Weidmann and Holger Menrad 1985), it was found that alcohol-diesel fuel emulsion or solutions cause a slight increase in NOx emission and they ascribed this to increased ignition delay and greater rates of pressure rise causing higher peak cylinder pressure which in turn cause higher peak combustion temperature leads to cause NOx formation.

APPARATUS EXPERIMENTAL PROCEDURE

Apparatus

The Engine used in our experiments was a single cylinder, variable compression ratio Recardo (E6/US). It was overhead poppet valve, four strokes and mounted on a common bedplate with an electric dynamometer. The engine was adaptable to run as either spark ignition engine or as a compression ignition engine. **Fig. (2)** shows a cross section of the engine. Alteration to ignition timing or injection timing can be made while the engine is running. The engine is provided with an American Bosch Pump, type APE IB using a cam from 6/1, and 6 mm plunger. The injector used has a body of CAV manufacture type BKB 3555153 RM , Fitted with a 4 mm spring which adjusted to give an opening pressure of 150 bar . The engine was connected with calibrated electronic indication equipment consists of water cooled transducer type AVL 8QP, piezo channel, synchronizer selector unit, degree marker shaper channel, and oscilloscope. **Fig. (3)** shows the complete circuit connection of all electronic equipment used.

Preparation of The Duel Fuel Used

The conventional diesel fuel (gas-oil) and the added fuel ethanol were mixed using the solution method of blending alcohol with diesel fuel.

First we tried to produce a solutions or emulsion from ethanol (96.5 % pure) and gas-oil using different percentage of ethanol and gas-oil as well as a catalyst like cyclo-alkan (C_5H_{10}), toluene (C_7H_8) and benzene (C_6H_6). A solution could not be produced at all, but an emulsion of 5 percent ethanol 5 percent (C_5H_{10}) 90 percent gas-oil was produced but after a short time the ethanol was separated upside the beaker , due to water content. Another attempt with different proportions of ethanol, gas-oil and catalyst to produce more stable emulsion, were tried and we get some success with these attempts, but they were not practical to use because of separation. None of these emulsions stayed for long time without separation. So it was decided then to replace the (96.5 % pure) ethanol with (99.98 % pure) ethanol which was easily dissolved in gas-oil with proportions ranging from 5 to 20 percent ethanol to produce a solution of ethanol and gas-oil.

Data recodering

Firstly all the measuring equipment were prepared and calibrated then the highest useful compression ratio and the best injection timing were determined, After that the data recoded for two main groups of experiments.

1- Constant speed tests.

2- Variable speed tests.

The constant speed tests were performed for four chosen speeds ranging from 900 to 1800 (r.p.m) and 8 loads for each speed were applied, and the variable speed tests were achieved by changing the speed of the engine between 900 and 1800 (r.p.m.) with constant load of 1.83 (kW). These tests were performed for each type of fuel used and for each case a photograph of the pressure-crank angle curve was taken through the oscilloscope screen **Fig. (4)** shows some of these photographs. Beside that the data which necessary for performing engine performance calculations were recorded.

EXPERIMENTAL RESULTS AND DISCUSSION

The engine performance and heat release prediction when the engine fueled with solutions of gas-oil and ethanol will be discussed and compared with the results obtained when the engine fueled with straight gas-oil. The results for the highest useful compression ratio and the best injection timing are:

Engine Performance

The results showed that the higher ethanol addition leading to a lower maximum power output relative to gas-oil as it indicated in **Fig. (5).** In fact the reasons of this reduction is the reduced energy content of ethanol and the drop in the temperature of the cylinder contents caused by ethanol due to its high heat of evaporation which leads to incomplete combustion and prolong the ignition delay. For the same reasons, the brake thermal efficiency of the dual fuel was found less than that of straight gas-oil at low loads but with load increasing the brake thermal efficiency begins to improved as it indicated in **Fig. (6).** this improvement is due to temperature rise resulting in more efficient combustion. **Fig. (7)** showed that the brake specific fuel consumption for the dual fuel is higher compared to that of the straight gas-oil for all ranges of the loads. The reason is that the calorific value of ethanol is less than that of gas-oil so we found that the specific fuel consumption increase with increasing the percentage of ethanol. Another reason expected is due to long ignition delay resulted from reduced temperature of combustion which reduces the power output and then leads to consume more quantity of fuel to resume the same power.

Engine Heat Release

The rate of heat release was obtained by analyzing the engine pressure data curves which were obtained from the screen of the oscilloscope. All the curves of the rate of heat release have a negative value at its early part resulting from the absorption of the heat required to rise the temperature of the injected fuel and to evaporate it. Also it is noticed that the general characteristic of these curves are nearly similar in all test conditions. **Figs. (8), (9), and (10)** showed that the first peak of heat release for the dual fuel is higher than that of the straight gas-oil , and it accurse with a small delay, while in the second stage, the rate of heat release from the dual is less than that of the straight gas-oil. This behavior is due to the effect of ethanol in increasing the delay period which in turn cause more quantity of fuel to accumulate resulting in increase the burning rate at the first stage of combustion (2 to 6 degree) with a small delay and cause the combustion to occur near the expansion stroke, resulting in lower efficient combustion than that of the straight gas-oil in the second stage of combustion (about 40 degree). The third stage of combustion (about 40 degree) was found nearly the same for all types of fuel used.

CONCLUSIONS

Solution of different percentage of ethanol and gas-oil was used as alternative fuels to fuel a single cylinder, diesel engine and has been investigated their effect on engine performance and engine heat release. The following conclusions were drawn:

1- Ethanol can be used as a diesel fuel supplement in percentage ranging from 0 to 20 percent.
2- Generally, ethanol addition to gas-oil cause the maximum power output to decrease at medium and high speed ranges and has little effect at low speed ranges.
3- The brake thermal efficiency of 15 percent ethanol solution was found nearly close to that of the straight gas-oil at medium load range. Other percentage of ethanol in the solution was found slightly less.
4- Ethanol addition to gas-oil leads to slight increase in brake specific fuel consumption for all the load ranges.
5- In general, addition of ethanol to gas-oil leads to increase the maximum rate of heat release during the first stage of combustion and decrease during the second stage of combustion.
6- Addition of more than 20 percent ethanol creates engine knock.

REFERENCES

Shorpshire, G.J. and Goering, G.E (1982), Ethanol Injection into Diesel Engine, Trans. of ASAE Vol. 25 pp. 570-575.

Bill Likos and others (1983), Performance and Emission of Ethanol and Ethanol-Diesel Blends in Direct-Injection and Prechamber Diesel Engines, Trans of S.A.E. paper No. 821039.

Miller, G.L. and others (1981), Engine Performance Using Butanol Fuel Blend, Trans. of ASAE Vol. 24 pp 538-540.

Carlos Fontana and Alan Rotz, C. 1982 "Economic of Ethanol Fuel for Corp Production", Trans of ASAE Vol. 25 pp.840-844.

Eugene Ecklund, E. and others (1985), State of the Art Report on the use of Alcohol in Diesel Engine, Trans. Of S.A.E. paper No. 840113.

Tadashi Murgama and others (1983), A Method to Improve the Solubility and Combustion Characteristics of Alcohol-Diesel Fuel Blends, Trans. Of S.A.E., paper No. 82113.

Walker, J.T. (1984), Diesel Tractor Engine Performance as Affected by Ethanol Fumigation, Trans. of ASAE, Vol. 27 pp. 49-53.

Kurt Weidmann and Holger Menrad (1985), Fleet Test Performance and Emission of Diesel Engine Using Different Alcohol-Diesel Fuel Blends, Trans. of S.A.E. paper No. 841331.

Wrage, K.E. and Goering (1980), Technical Feasibility of Diesohol, Trans. of ASAE, Vol. 23 pp. 1338-1343.

Goering, G.E. and Wood, D.R. (1982), Over fueling a Diesel Engine with Carbureted Ethanol, Trans. of ASAE vol. 25 pp. 576-580.

Marcio Cruz, J. and others (1982), Dual Fueling Turbocharged Diesels with Ethanol, Trans. of ASAE vol. 25, pp. 1163-1168.

Fallti and others (1984), Energy Release Rates from Hybrid Fuels, Trans. of ASAE Vol.27, pp. 322-325.

Saeed, M.N. and Henien (1989), Combustion Phenomena of Alcohol in C. I. Engine, Trans. of JSME, Vol. 111, pp. 439-444.

Likos, W.E. (1985), The Effect of Alcohol Fueling on Diesel Engine Durability, Trans. of S.A.E. paper No. 841384.

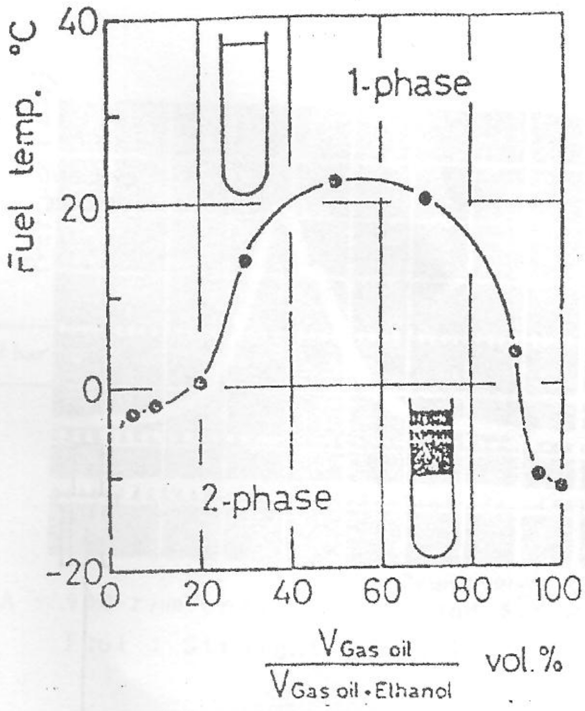


Fig. (1) The solubility of ethanol -gas oil blended fuel.

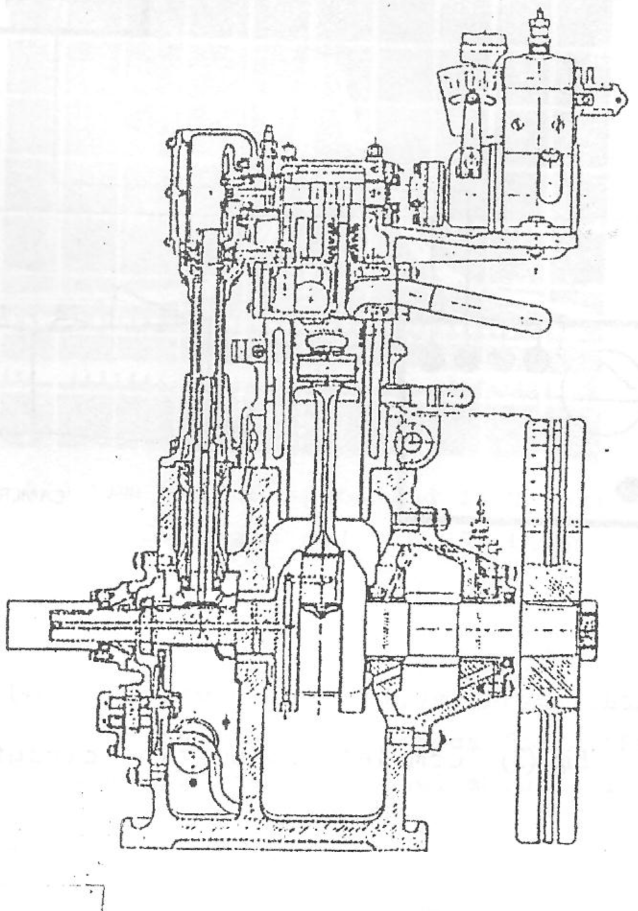


Fig. (2) Cross section of the engine used .

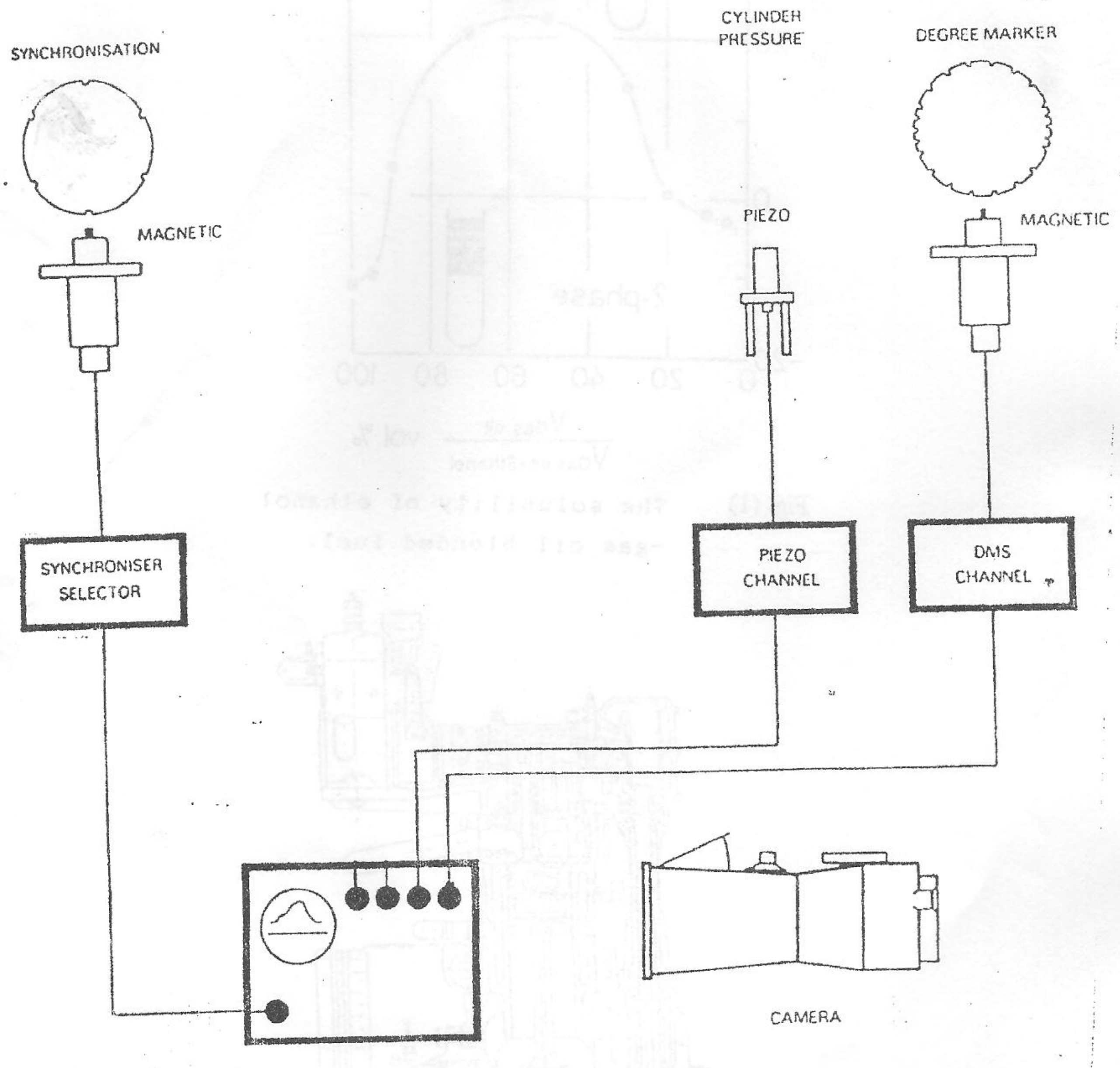
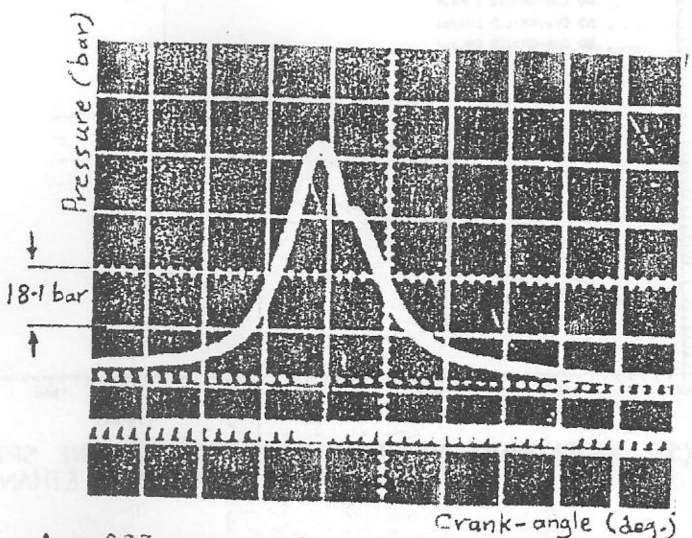
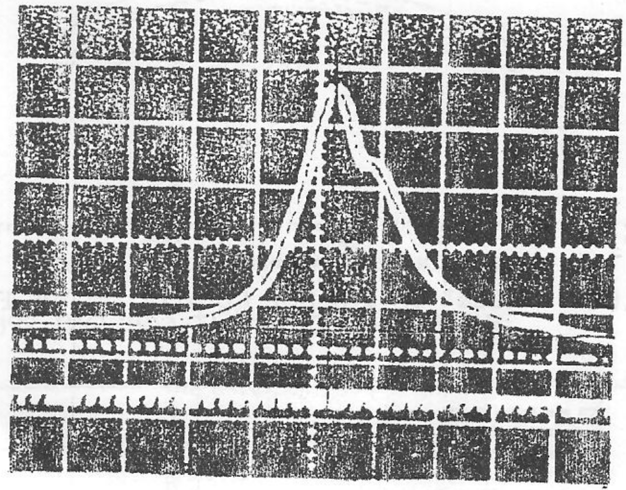


Fig. (3) complete connection circut.



A – 900 rpm engine speed and 5.5 N load
Fuel : Straight gas oil .



B – 900 rpm engine speed and 32 N load
Fuel : 0.95 gas oil + 0.05 ethanol.

Fig. (4) Pressure – crank angle curves obtained from oscilloscope screen for different speeds, loads and fuel solutions .

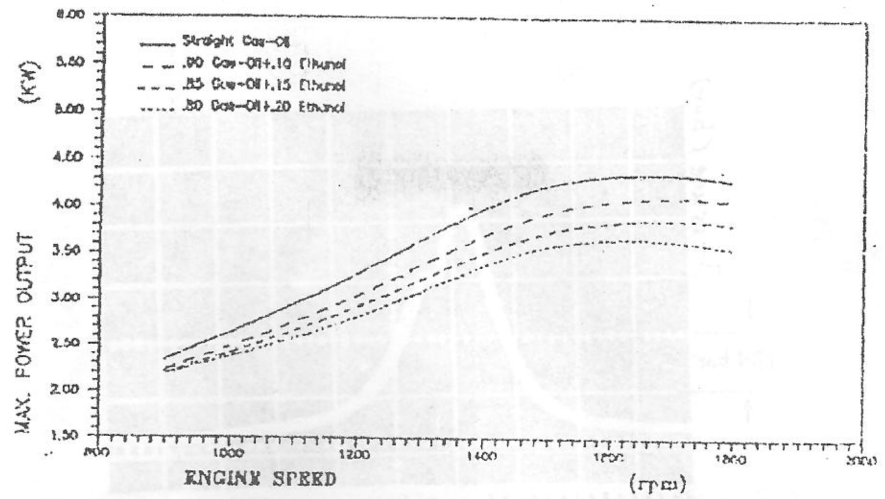


Fig. (5) MAXIMUM POWER VARAIION WITH ENGINE SPEED FOR DIFFERENT CONCENTRATION OF ETHANOL

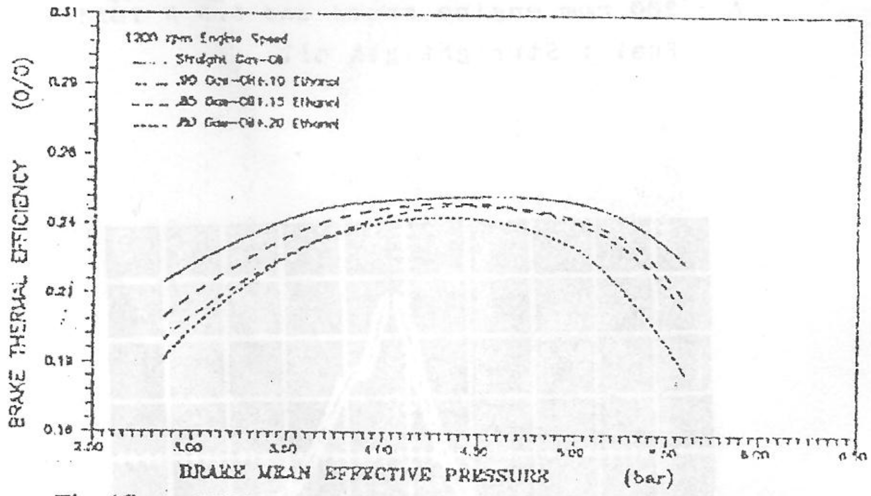


Fig. (6) EEEECT OF ETHANOL CONTENT ON THE BRAKE THERMAL EFFICIENCY AT CONSTANT SPEED

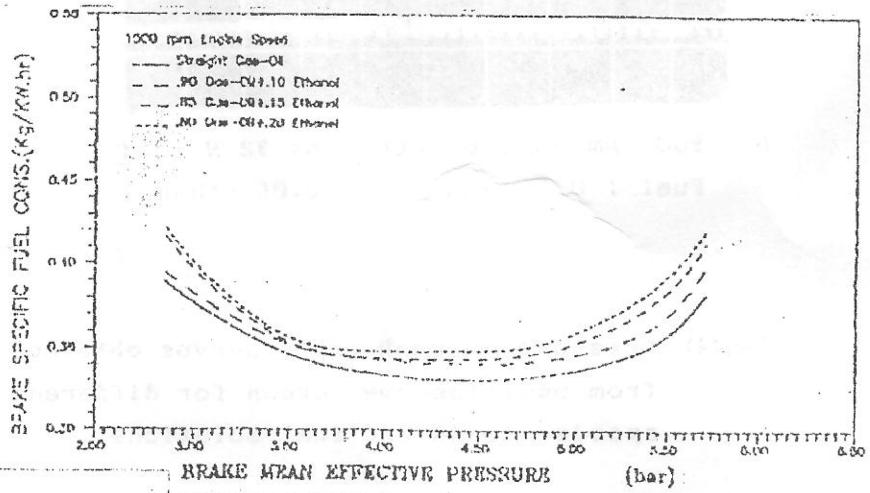


Fig. (7) EFFECT OF ETHANOL CONTENT ON THE BRAKE SPECIFIC FUEL CONSUMPTION AT CONSTANT SPEED

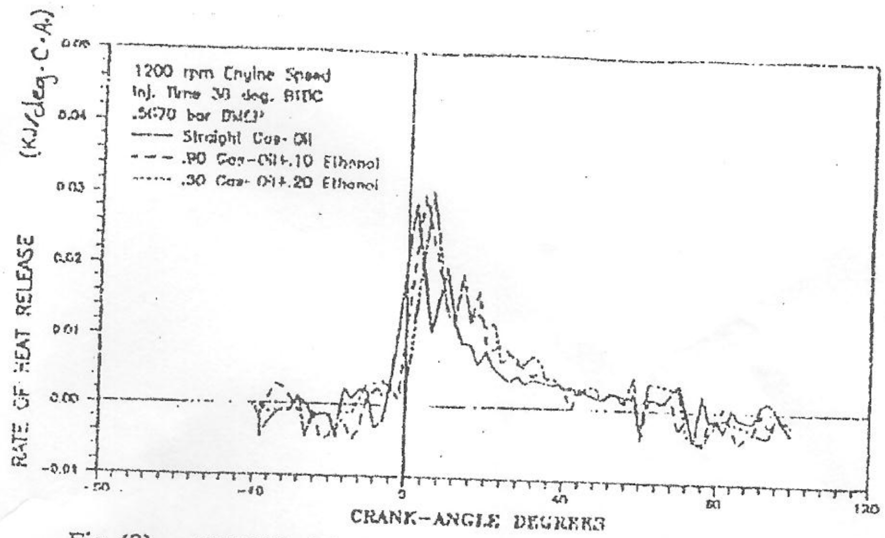


Fig. (8) EEEECT OF ETHANOL CONTENT ON THE RATE OF HEAT RELEASE AT LOW LOAD

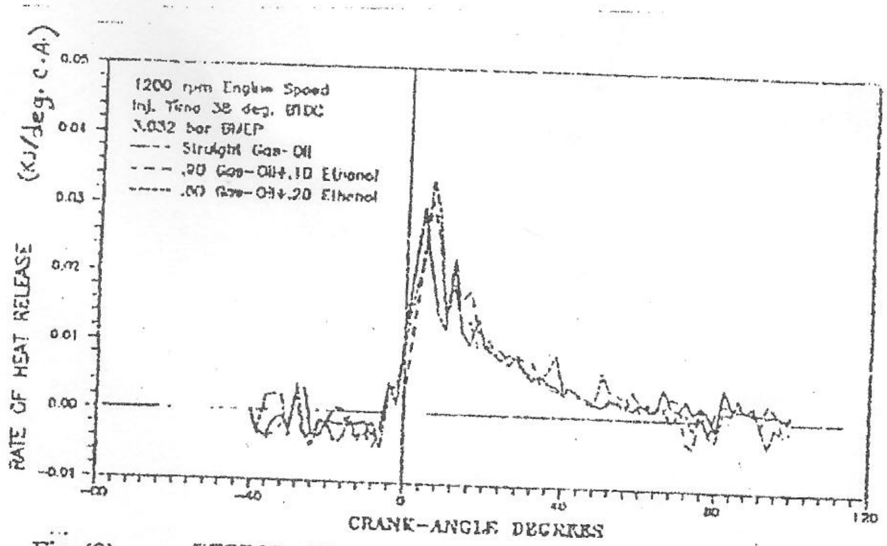


Fig. (9) EFFECT OF ETHANOL CONTENT ON THE RATE OF HEAT RELEASE AT INTERMEDIATE LOAD

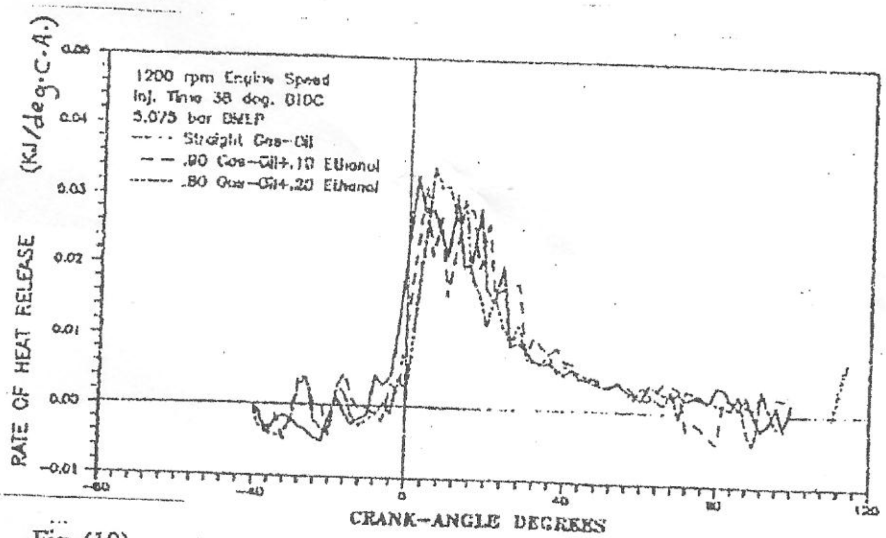


Fig. (10) EFFECT OF ETHANOL CONTENT ON THE RATE OF HEAT RELEASE AT HIGH LOAD