PERFORMANCE OF S. I. ENGINES
WITH
ALCOHOL GASOLINE BLENDS

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IN
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(STEAM AND I. C ENGINES)

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Certified that the dissertation entitled Performance of S.I. Engines with Alcohal - Gasoline blends which is being submitted by Shri H.B. Mathur in partial fulfilment for the award of the degree of Master of Engineering in Applied Thermodynamics (Steam & I.C.) of University of Roorkee is a record of students own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

This is further to certify that he has worked for a period of six months for preparing dissertation for Master of Engineering Degree at this University.

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ABSTRACT

With a view to assess the suitability of alcohol-gasoline blends as fuels for S.I. engines, the S.I. engine performance with various alcohol-gasoline blends was studied. Different percentages of alcohol-gasoline blends were tried to find if they bring about any reduction in the knocking tendency, improvement in power output, thermal efficiency and reduction in specific fuel consumption, under various engine running conditions. From the results obtained, various graphs were plotted to draw suitable conclusions regarding the performance of S.I. engines with various alcohol-gasoline blends.

One of the most important consideration regarding the suitability of a fuel for S.I. engines is its anti-knock characteristic. Therefore, first of all the anti-knock characteristic of various alcohol-gasoline blends was found by using Ricardo's method of knock rating which consisted in finding out the H.U.C.R. It was found that addition of alcohol in gasoline increases the H.U.C.R. showing thereby that higher the percentage of alcohol in the alcohol-gasoline blend, the better the anti-knock characteristic of the blend. The H.U.C.R. of these blends, ranging from 0 to 100 % alcohol, was found at two different engine speeds and it was noted that at higher engine speeds the value of H.U.C.R. increases.

In the second part of the investigation, experiment was done to find out the power output, thermal efficiency and specific fuel consumption obtainable with various alcohol-gasoline blends under given engine settings. This was done in order to find out as to which blend was most suitable to work on a given S.I. engine without altering its compression ratio, carburettor setting and ignition timing. The results were plotted and it was found that with the same engine settings a 10 % alcohol-gasoline blend is the best blend in as much as it gives greater power, better thermal efficiency and lesser fuel consumption than obtained with any other blend.

The maximum power obtainable from a given engine (fixed compression ratio) when using various blends was then found. In this part of the experiment the carburettor setting and ignition timing were adjusted to give optimum conditions for each blend and the resulting power output was recorded. This could be done only with alcohol-gasoline blends ranging from 0 to 60 % alcohol, because of limitations of the carburettor setting. From the results, it was concluded that maximum power obtainable increases with the percentage of alcohol in the blend.

Increase in the alcohol percentage in the alcohol-gasoline blend permits the use of higher compression ratios. The thermal efficiency is proportional to the compression ratio and it is important to consider the thermal efficiency at the highest compression ratio each blend would withstand. Hence the maximum output, thermal efficiency and specific fuel consumption was found for each blend at the optimum compression ratio, carburettor setting and ignition timing.

Specific fuel consumption and thermal efficiencies obtainable with each blend at full load, three fourth, half and quarter load were also plotted in order to get a comparative idea about the various blends.

CONTENTS

CHAPTER- 1

* INTRODUCTION *

INTRODUCTION

I - 1 S. I. ENGINE FUELS AND THEIR REQUIREMENTS :

In case of spark ignition engines an air fuel mixture is taken in during the induction stroke and combustion is achieved by applying a spark to this mixture after sufficiently compressing it. As such S. I. engines have some special fuel requirements. The most important of these requirements are :-

(i) Volatility
(ii) High Latent heat
(iii) Anti-knock tendency
(iv) High Calorific value
(v) Proper Distillation range for ease of starting the engine quickly
(vi) Higher heat value of the mixture

(i) S. I. engine fuels have to be volatile so that they may vaporise readily and form a mixture with air during the induction stroke. If the volatility of the fuel is low, it has to be warmed up before its entry to the cylinder so that it may not condense in the induction system. Hence with such fuels the charge temperatures are higher resulting in lower volumetric efficiencies and loss of power on this count. For this reason alone, the power obtainable with Kerosene is 15 % lower than that obtainable with any other hydrocarbon at the same compression ratio.

(ii) Latent heat is a very important consideration. The evoperation of fuel during the induction stroke brings about a lowering of the charge temperature and to that extent increases the density of the charge taken in. The lower the charge temperature greater will be the amount of charge that will be taken in. The weight of the charge that is taken into the cylinder is inversly proportional to the absolute temperature at the moment the inlet valve closes. This temperature depends upon the latent heat of the fuel. Hence a larger latent heat of the fuel is desirable.

(iii) One way of increasing the power output of an engine and its thermal efficiency, is to employ higher compression ratio. However, there is a limit to which this compression ratio can be raised for a given fuel. Increasing the compression ratio beyond this limit sets in detonation with a consequent lowering of power output and thermal efficiency. This compression ratio is called H.U.C.R. - the highest useful compression ratio and it is a measuse of the anti-knock characteristic of the fuel.

(iv) The calorific value of a fuel gives an indication of the consumption rate of the fuel. If a fuel has a lower calorific value a larger amount of it will be needed to do the same amount of work. Hence it is desirable to have a higher calorific value of the fuel.

(v) Starbility of an engine is related to the distillation range of the fuel used by it. Brown (1) has obtained an emperical relationship between startability and 10 % evaporation temperature when the fuel is distilled in the standard A.S.T.M. method. He states that this temperature must be less than (125 + 5/4 air temperature)°F. Brown's findings apply to various petrols.

(vi) The power output of an engine depends upon the heat value of the mixture that is taken in by the engine during inducation stroke. This heat value depends upon the calorific value of the fuel and the proportion of fuel and air in the mixture drawn in during the inducation stroke.

In the light of these requirements the range of volatile fuels available for high speed internal combustion carburettor engines are at present limited to petrol, benzol, kerosene and alcohol. Some of the properties of these fuels have been compiled and shown in table no. 1 which gives a relative idea about these fuels.

From table no. 1 it can be concluded that alcohol fuels are better than others because of their better anti-knock characteristic, higher volumetric efficiency (higher latent heat of vaporisation) and greater volitality. Apart from these, they have another advantage which as discussed below increases the need of alcohol fuels all the more.

I - 2. NEED OF ALCOHOL FUELS AND THEIR TYPES :

The fuels of table I can be divided into two classes. The first three belong to the category of 'stored' fuels while the Alcohol fuels are the unstored fuels. Stored fuels are the fuels which, as the name suggests, have been in the storage of earth for long periods. Major fuels of this type are coal and oil. The resources of both of these fuels are very vast but not unlimited. With our present known resources of coal and oil and the rate of consumption it is feared that both of these fuels will be exhausted soon. Undoubtedly more coal and oil will be discovered to add to our reserves with no less doubt that the worlds' consumption of these basic fuels will increase with increased industrialisation. It appears that while the discoveries grow arithmatically, consumption grows geometrically and when in near future the consumption overtakes discoveries the world will be heading for industrial disaster. No doubt in future alternate sources of power will be exploited; tidal, the worlds' internal heat and the most potent of

Fuel	Boiling point or distillation range 0°C.	Latent heat of evaporation at atm pressure BTU per lb.	H.U.C.R.	Calorific value in BTU per lb.	Air fuel ratio by weight for complete combus.	Vapour pressure at 0°C in mm of Hg.	Heat of combust. per cu. in. at N.T.P ft.lb.	Volume ratio i.e. Sp Vol. after combus/ Sp.Vol. before Combustion.	Total energy liberated by combustion/ per cu. inch at N.T.P. ft.lb.	Fall in temp. of the mixt. due to latent heat °F (calculated)
Petrol	164 to 300	133 to 145	4.7 to 5.5	18500 to 19200	14.7 to 15.05	17 to 28	46.08 to 46.39	1.04 to 1.053	48.15 to 48.53	32.4 to 36
Kerosene	180 to 300	108	3.5 to 4.2	19000	15.00	-	46.14	1.06	48.91	26.1
Benzol	79 to 170	190	6.4	18300	13.43	-	46.9	1.014	47.6	37
Methyl Alcohol	66	500	12	10000	6.5	26	45.5	1.06	48.2	252
Ethyl Alcohol	78	400	7.8	12000	9	12	44.5	1.065	47.39	153
Butyl Alcohol	117	450	-	10500	8	-	-	-	-	-

TABLE: 1- Properties of Volatile Fuels suitable for high speed Internal Combustion Carburettor Engines.

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It is, therefore, desirable to search out and investigate the possibility of the use of unstored liquid fuels for future use. Alcohol is one such fuel. It is an excellent fuel and it can be produced in sufficient quantity from vegetable matter, farm waste or water gas. Its use may be regarded as a direct method of obtaining energy from sun without the intermediary of storage in earth for long period of time. As long as the sun shines, plants will perform their synthesis of starch from the abundent carbon di-oxide and water that bathe our planet. From this annually renewed store of raw materials, alcohol can be readily produced. Its production from vegitable sources involves no drain on the world's storage as by using this fuel, we are using the sun's energy, as it is available from day to day, to develop motive power. As against this, the use of stored fuels involves a drain on our fixed assets. By using the stored fuels, we are squandering away our capital whereas by using the alcohol fuels as if it were, we are living within our income.

The alcohols which are of interest as motor fuels are for reasons of boiling range only the first few members of the monohydric series. Methyl alcohol (B.P. 65° C), Ethyl alcohol (B.P. 78° C), N-propyl alcohol (B.P. 97° C) and N-Butyl alcohol (117° C). Table II gives the important properties of the four alcohols mentioned :

Name	Methenol	Ethenol	Propanol	Butonol
Formulae	CH_4O	C_2H_6O	C_3H_8O	$C_4H_{10}O$
Molecular weight	32	46	60	74
Specific gravity	0.792	0.785	0.799	0.805
Boiling point	149	172	208	244
Gross Calorific value BTU/lb.	9770	12800	14500	15500
Latent heat of evaporation BTU/lb.	502	396	295	254
Air fuel ratio	6.4 to 1	9 : 1	10.5 : 1	11.1 : 1

TABLE II - Giving various properties of Alocohol fuels.

Out of these, the last two are not used as fuels because of their higher cost of production. Hence the alcohols of practical interest as fuels for S. I. engines are the first two members of the series.

Methyl alcohol is a product of destructive distillation of wood. It is a colourless volatile liquid which is partially soluble in water and having a B.P. 65° C and specific gravity 0.8 . It can also be made by synthesis from carbon monoxide and hydrogen (water gas).

Mixtures of methyl alcohol are often used in supercharged engines for racing purposes largely on account of the increased valumetric efficiency resulting from higher latent heat of evaporation of this fuel. However, methyl alcohol mixtures are more liable to preignition and this has been a major restriction in the use of it as a fuel.

I - 3 ETHYL ALCOHOL AS A FUEL - ITS ADVANTAGES AND DISADVANTAGES :

Ethyl alcohol is obtained by fermentation of vegetable matter. It is produced commercially from starches of cereals and potatoes and from molasses and sugar by process of fermentation.

Its use as a fuel mixed with hydrocarbon fuels was seriously restricted in the beginning because the straight distillation of ethyl alcohol (which was then in use for its production) could not yield a material richer in alcohol than 95.6 % by weight. The presence of water seriously limited the miscibility of alcohol with hydrocarbon fuel. Also the addition of further quantities of water even in small quantities caused separation of the components. However, now with the application of the methods of azeotropic distillation, it is possible to obtain 99.5 % spirit. With this almost complete miscibility is obtained in any proportion certainly well beyond the limits of the probable mixtures.

Ethyl alcohol as a fuel (when used alone or as a blend with hydrocarbon fuels) for I. C. engines offers the following advantages :-

(1) Greater safety by reason of its low degree of volitality and higher flash point (about 65°F). Its vapours are not quite half as heavy as those of petrol so it does not creep and accumulate in dangerous quantities on low levels, and a higher proportion is needed to form an explosive mixture.

(2) It mixes in all proportions with water and buring alcohol can be easily extinguished with water.

(3) Its uniformity of composition is another point in its favour.

(4) Higher volumetric efficiency is obtained with this fuel. Volumetric efficiency depends upon the charge density and this is effected by the charge temperature. Charge temperature is lowest with fuels of highest latent heat. Ethyl alcohol is a fuel having a high latent heat (396 BTU/lb. while that of petrol is only about 135 BTU/lb.). If during the induction stroke, we assume complete vaporisation then the fall in temperature will amount to 21° C for petrol

and 86° C for Ethyl alcohol. Ricardo has recorded for a certain engine operating at a compression ratio 5 : 1 with jacket temperature of 140°F, induction temperatures for petrol 258°F and Ethyl alcohol 150°F. With Petrol, he obtained volumetric efficiency ranging from 75.5 % to 78 % for mixture strengths varying from 20 % weak to 30 % rich respectively. With Ethyl alcohol the volumetric efficiency for the same range of mixture strength was between 80.5 % to 86 %. Moreover, by richening the mixture, volumetric efficiency increased faster with alcohol fuel than with petrol fuel.

(5) It is an anti-knock fuel and has the ability to stand very high compression ratios. The Octane rating of Ethyl alcohol is above 100 (2). This advantage coupled with the advantage of high volumetric efficiency has made alcohol fuels hot favourities for racing car engines. Discol (R.D.1) and P.M.S. 2 are two well known racing fuels composed of mainly Ethyl alcohol. Natalite is another alcohol fuel composed entirely of Ethyl alcohol which has been partially oxidised to ether.

(6) There is no fear of preignition in case of Ethyl alcohol even at the high compression ratio that can be employed with this fuel.

(7) In many hot contries the use of more volatile spirits is almost impossible whilst in hotest climate alcohol is perfectly safe.

(8) Alcohol fuels tend to give less carbon monoxide in the exhaust gases than petroleum motor spirits. Lichty and Phelps (3) have recorded the effect of adding 20 % of ethenol to unleaded petrol. Their general conclusion is that the percentage of CO is 1 to 2 % less at all loads and speeds and that this means a lower thermal loss of 2 to 4 %. This is valuable in itself, but the gain in atmospheric purity is important since an engine under full load will give an exhaust gas which contains 2 - 3 % CO which may increase to three times this value at half speed.

(9) Alcohol blends tend to produce less carbon deposits than normal petrols and that the deposits are softer and easier to remove. Mantell (4) has suggested that carbon deposits in an engine may be removed by periodic running on alcohol blend. The alcohol softens the carbon which is eventually burnt away.

(10) The startability of the engine improves with addition upto a maximum of 20 % of alcohol. Howes (5) has stated that an addition of 10 % ethyl alcohol improves the startability of petrol at temperature down to 0°F. Haffort and Claxton (6) report that ethyl alcohol improves the

startability of benzol blends. Thus a certain petrol permitted a start at an air temperature of 10° C within twenty revolutions of the engine. The addition of 20 % benzol allowed a start to be made within fifteen revolutions. The addition of ethyl alcohol to the benzol blend reduced the number of engine revolutions to start, unless the ethanol content of the blend exceeded 40 %, when it caused the startability to be impaired. At zero degree centigrade, the addition of ethyl alcohol upto 20 % improved the startability of normal petrol. At 50°F some what similar results were obtained except that the difference between various fuels became less marked.

However, the use of ethyl alcohol as fuel involves the following difficulties :-

(1) Its calorific value is only two thirds that of gasoline hence the quantity of work produced in the combustion of a given weight of alcohol will be less than that produced by the combustion of an equal weight of gasoline and as a practical result the fuel consumption in terms of m.p.g. would be lesser than that obtained with petrol.

(2) Owing to its low hydrogen content the ratio of alcohol to air in the working mixture is greater than with normal petroleum base fuels. The ratio for complete combustion being in the region of 9 to 1 or in terms of fuel

to air 0.11. This characteristic demands the use of a metering jet orifice of considerably larger area than when petrol is used.

(3) It has a higher surface tension and is less easy to atomise.

(4) It will not mix with oil and cause lubrication difficulties in the upper parts of the cylinder.

(5) It has a high solvent power which affects joints and can wash previously deposited gum from tanks and transform them to the engine.

(6) One of the troubles which have arisen with alcohol in engines has been that of corrosion of valves etc, due to production of acid bodies. The partial oxidation of alcohol takes place at low temperature and leads to the formation of aldehydes, which subsequently become acids. Ethyl alcohol begins to show formation of aldehydes at 300°C, but methyl alcohol, which oxidises more readily, at 160° C.

Aldehyde formation is due to incomplete combustion. Given an excess of air it should not occur. With even a small deficiency at a moderate temperature, some aldehydes and acetic acid are certain to be formed from ethyl alcohol and the exhaust gases are always liable to contain traces of acids. Running a few revolutions on petrol or benzol before stopping the engine is found to overcome the trouble of corrosion, and this actually offers no great difficulty, for in many cases such fuels are necessary for starting up. It must be remembered that while the engine is hot, these acid products will not affect the metal. It is only on cooling, which leads to their condensation on the surfaces, that action will set up. For this reason, the silencer is generally found to suffer most. To neutralise the acid products which cause corrosion, Various basic volatile bodies, concentrated ammonia, nicotine etc. are sometimes added in very small quantities.

(7) Another type of corrossion is that which sets up by the fuel itself on tanks, pipings etc. In extensive trials of power alcohol or alcohol benzol mixtures carried by the London General Omnibus Company, Copper and Iron were found to be badly attacked. By 'tinning' with lead or lead tin alloy, this was prevented. The action appears to be due to esters in the wood naptha, which on hydrolysis, give rise to traces of organic acids. It should not, therefore, occur with synthetic methanol. The addition of a small quantity (0.2 to 0.3 %) of sodium benzoate is stated to be a preventive. Oomandy (7) claimed that corrosion did take place if anhydrous alcohol were used.

Almost all of these disadvantages can be overcome in one way or the other and will not prevent the use of alcohol in I. C. engines.

However, considering all these factors and also the higher cost of alcohol, it is not desirable to use alcohols in their pure state as fuels in S. I. engines. They should be used mixed with other fuel or fuel mixtures so as to impart some of the important properties to the resulting mixture namely higher compression operation without knock, greater fuel economy and lower exhaust temperatures. The higher latent heat of the alcohol content plays an important part in the effectively cooling of the cylinder under the high compression and engine speed conditions. In this the alcohol-gasoline blends have an advantage over those which derive their high Octane rating by addition of Tetra-ethyl lead. It is, therefore, worth-while to study the performance of the S. I. engine with various alcohol-gasoline blends so as to assess their effect on engine performance to find the most suitable blend. With this view the following experimental work was undertaken.

I - 4 STATEMENT OF PROBLEM :-

(1) To investigate the anti-knock value of various alcohol-gasoline blends by finding their H.U.C.R. values and to corelate the H.U.C.R. with percentage of alcohol in the blend.

(ii) To determine for a given S. I. engine (carburettor setting, Ignition timing and compression ratio fixed) which blend of alcohol-gasoline is most suitable.

(iii) In view of the higher anti-knock value of various alcohol-gasoline blends, to find the gain in power and thermal efficiency if the engine is run at the higher compression ratios which the various blends permit.

(iv) To study the engine performance with various blends.

CHAPTER- II

* REVIEW OF LITERATURE *

REVIEW OF LITERATURE

Considerable work has been done regarding the use of alcohol and alcohol-blends as I. C. engine fuels. This work has mostly been carried out in the countries having no or little indigenous oil. Countries rich in oil or having control of oil fields in other countries have discouraged the use of alcohol blends as fuel and have emphasised the disadvantages in the utilisation of such fuels.

In several European countries and in Japan, which have to import gasoline the law requires that a certain amount of alcohol varying from 3.2 to 25 %, depending upon the country, be added to gasoline whensold as motor fuel. In Czechoslavokia the law requires that a 20 % inclusion of ethyl alcohol to all the petrol sold. In Sweden, it is usual to include about 25 % of alcohol in motor spirit. In France the three motor fuels which contain alcohol are (i) Carburant Touriseme - containing 11 - 20 % alcohol ; (ii) Carburant poid Lourd - with less than 35 % alcohol ; and (iii) Super carburant alcohol over 15 %.

Hubendik (8) in Sweden has worked on alcohol blends. He examined a number of alcohol blends on a high compression engine. He found that the power outpout increases as the percentage of alcohol in the blend increases upto 15 % alcohol. Maximum power is obtained with 15 % ethanol blend. Increasing the ethanol content thereafter causes a decrease in power output, although a 25 % ethanol blend is again equal to basic petrol. He further found that ethanol blends containing not more than 25 % ethanol give no higher consumption than basic petrol, the optimum value being 15 %. Increasing the ethanol content thereafter causes an increase in fuel consumption. Upto 25 % blend, the consumption is lower than that obtained with basic petrol.

The Swedish Government marketed a 25 % ethanol blend called "Lattbentyl". Hubendik published a report of ten years operation of this blend. He stated that the performance was satisfactory and that a driver could be aware that he was running on alcohol fuel only because of its smooth running.

In Japan, Suwa (9) has done work with alcohol blends on a standard C.F.R. Engine. His results showed that when knock was absent, the addition of ethanol to petrol merely increased the fuel consumption, but by taking advantage of increase in ignition advance possible with the alcohol blend, power output was increased and fuel consumption reduced as compared with the petrol. This effect was more marked at higher compression ratios permissible with high anti-knock alcohol blends. Blends upto 30 % alcohol gave specific fuel consumption less than that of petrol alone. Tests on road with normal cars gave similar results. The smoothness of running was most marked with the alcohol blends.

Similar results have been obtained by Teodore (10) in Phillipines. He concludes that blends containing 5 to 30 % alcohol are superior to petrol alone. The smallest specific fuel consumption was obtained with a blend containing 15 % alcohol.

Inthe U.K., work on this has been carried out by Ricardo, Tizard, Pye and Ormandy with similar results. Ricardo's racing fuels $R.D_1$ and $R.D_2$ containing ethyl alcohol have been widely used.

Fritzweir (11) in Germany has expressed the opinion that few motorists who have used a good alcohol blend will ever desire to change.

In South Africa, Walker (12) has reported on excellent results with a blend of 40 % ethyl alcohol, 40 % benzol and 20 % petrol. Hobbs (13) has expressed the opinion that alcohol blends make excellent motor fuels producing higher outputs and no more corrosion than experienced with petrol.

In United States of America, petrol-alcohol blends have been extensively investigated. Christiansen (14) has obtained favourable results. The Chemical Foundation has produced an alcohol blend called Agrol (having 10 % alcohol). However, Gustav Egloff (15) has disputed the suitability of alcohol blends and has stressed the difficulty of separation, inferior acceleration, cold corrosion and increased cylinder wear. In one series of tests extending over ninety days using 28,000 gallons of mixture containing 10 % alcohol with car speeds of 30 m.p.h., the fuel gave about 10 % less mileage. One pint of commercial anti-knock petrol gave a mileage of 3.2 ; 60 - 62 U.S. petrol gave 3.175 and alcohol-petrol blend 2.9 miles.

On the other hand, it has been claimed (16) that German Monopolin 20 % absolute alcohol and 80 % petrol showed a saving of 1.7 % over petrol and 10 % over petrol benzol mixture. In tests carried out on the standard C.F.R. engine the 10 % alcohol-petrol blend gave 5 % higher octane value.

The above review indicates that the parallel works carried out in different countries show the presence of two schools of thought over alcohol blends, but from the literature available there seems to be an overwhelming case for the petrol-alcohol blends.

CHAPTER- III

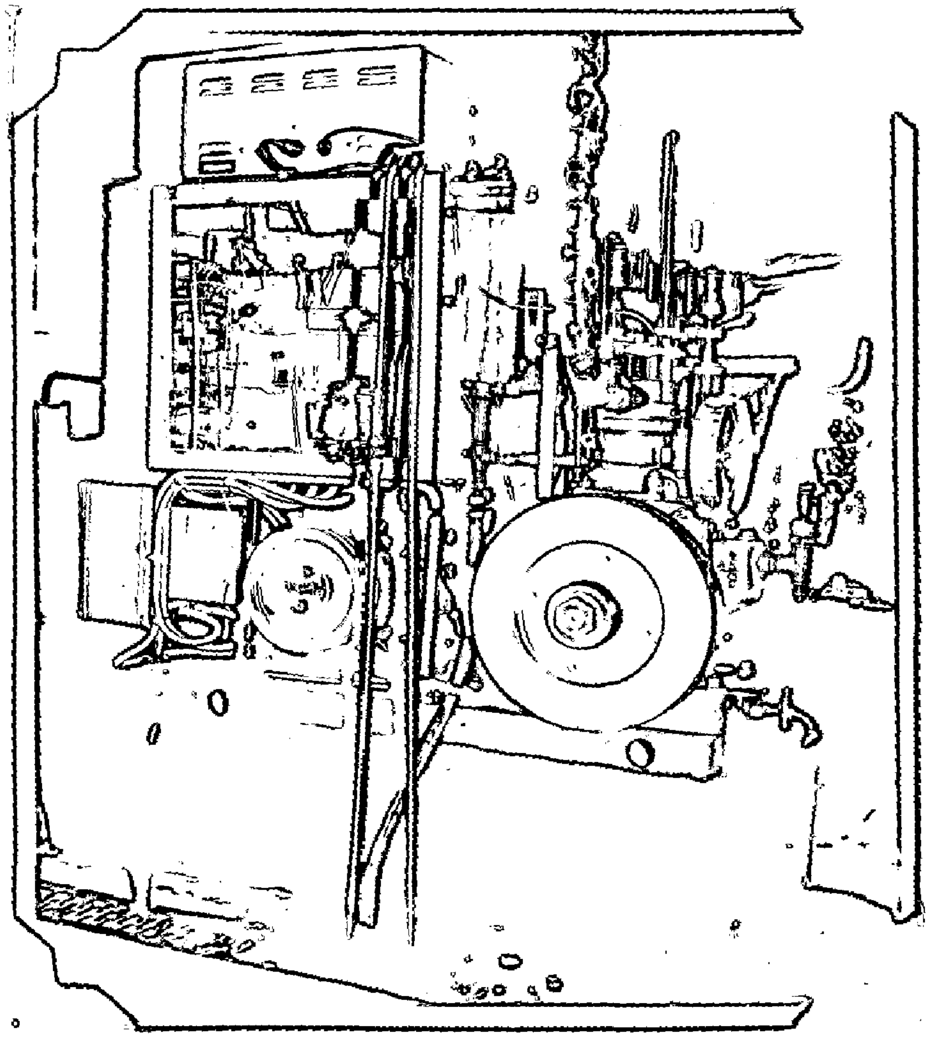
* EXPERIMENTAL APPARATUS AND * TECHNIQUE.

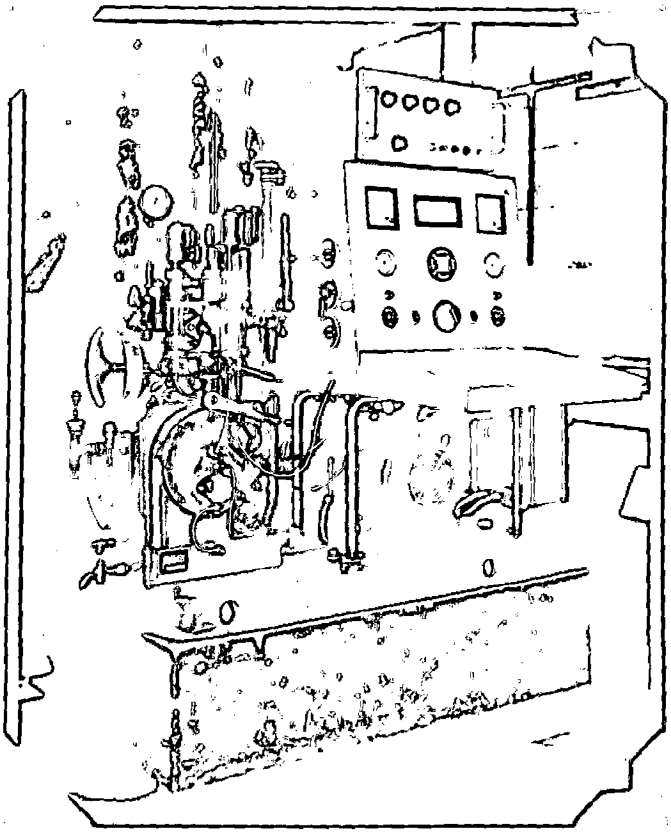
EXPERIMENTAL APPARATUS AND TECHNIQUE

III. - 1 - EXPERIMENTAL APPARATUS :

The investigations have been carried out on Knock Testing Engine B.A.S.F. The complete unit consists of the testing engine, electrical loading and accessory equipment. The engine is single cylinder having a bore 2-9/16", stroke 3-9/16" and a displacement of 20.38 cu.in. The output of the testing engine is 0.6 K.W. at 600 r.p.m. and 0.9 K.W. at 900 r.p.m. with a fuel consumption of about 400 ml./hr. at 600 r.p.m. and about 600 ml/hr. at 900 r.p.m. The compression ratio is continously variable from 4 : 1 to 11 : 1 while the engine is operating. This is achieved by rotating the cylinder adjusting crank, which drives a worm gear. The cylinder may be raised or lowered in this manner and any compression ratio between 4 and 11 obtained.

The engine is fitted with a carburettor with three adjustable fuel containers to change the knock intensity by varying the level. Each of the fuel container may be connected by a fuel selector valve to the main jet. Every





container is emptied by a float actuated needle valve on the bottom. Each container is adjustable in height position by a thread in the outlet socket. In this way the fuel level in the float chamber is variable for alternating mixture ratios. By varying it the fuel quantity, which flows from the main atomising jet into the manifold socket, may be changed. The air volume remaining constant, this procedure modifies the fuel-air ratio and at the same time the knock intensity. The float and floating chamber walls are made of glass. So the adjusted fuel level is visible. Every set of the level is indicated on the etched glass scale of the floating chamber wall. One full turn of the fuel container changes the level for 2 mms. = 1 division on the scale.

The engine is cranked, motored and loaded by a three phase inducation motor, driven over 2 V-belts. A watt-meter indicates power delivered. The engine speed can be adjusted at 600 r.p.m. or at 900 r.p.m. by changable V-belt pulleys.

For complete details of the apparatus and the instrumentation, reference may be made to "Knock Testing Engine B.A.S.F. Fuel Rating and Operation" by Franz Janstch.

III - 2. EXPERIMENTAL TECHNIQUE

The experiment was carried out in the following stages :-

(i) To find the effect of various alcohol-gasoline blends on the knocking tendency of the engine.

(ii) To find the power out-put, fuel consumption and thermal efficiency with various alcohol-gasoline blends at same engine settings viz. same setting of the carburettor, ignition advance and compression ratio, for each blend.

(iii) To find maximum power, corresponding thermal efficiency and specific fuel consumption obtainable with each blend at same compression ratio but optimum mixture strength and ignition setting.

(iv) To find maximum power, thermal efficiency and specific fuel consumption at the most optimum conditions for each blend i.e. at the H.U.C.R. of each blend with mixture strength and ignition timing adjusted for maximum power.

(v) To plot consumption loops and thermal efficiency curves for zero, twenty, forty, sixty, eighty and hundred percent alcohol-gasoline blends.

(vi) To determine the calorific value and specific gravity of each blend and to corelate them with the percentage of alcohol in the blend.

(vii) To perform the open curcuit and hold on test on the 3-phase induction generator coupled to engine in order to draw the circle diagram for finding the input to the generator (output of the engine) corresponding to various watt-meter readings (output of the generator).

In thefollowing pages is given in brief the experimental procedure adopted in each experiment.

(i) Ricardo showed that fuels could be made to knock if the compression ratios were sufficiently high. He designed the first continously variable compression ratio engine and with its help, rated the fuels in accordance with the maximum compression ratio they could withstand without knock. He invented the first system of knock rating and coined the phrase H.U.C.R. His system of 'Knock Rating' is in some ways superior in assessing fuels than the Octane scale now fashionable.

Ricardo's method of knock rating consisted in determining the highest useful compression ratio to which a fuel may be subjected before the increase in knock causes a reduction in Power output from the engine under certain defined conditions. It is not the highest compression ratio the fuel would withstand, but the highest ratio that is worth while to employ.

It may be better understood by considering the test procedure.

The engine was set at a low compression ratio so that the fuel would operate without knock. It was allowed to run for half an hour to warm up. Then the compression ratio was varied and the watt-meter reading noted, adjusting mixture strength and ignition setting for maximum power. At some ratio 5.45 knock was heard. Previous to this at 5, a slight harshness to running was observed, but increase in compression ratio still resulted in increase in power. At this compression ratio 5.45; the engine continued to run at full power without distress or danger to the engine, the knock remaining slight. On increasing the ratio beyond 5.45 the knock became more pronounced and after a few minutes drop in power was observed. By retarding the ignition and enrichenning the mixture, the knock could be suppressed and even higher ratios could be used upto 5.8, but the power output was reduced and fuel consumption increased. Hence it was concluded that the compression ratio 5.45 was themost efficient for that fuel (Petrol) as higher ratios offered no benefit in power or consumption. Its H.U.C.R. was therefore recorded as 5.45.

By examining samples of 10%, 20%, 30%, 40%, 50% ..... 100% alcohol, their H.U.C.R. was found in the same manner and recorded in table no. iii & iV

(ii) This part of the experiment was performed with a view to find out the most suitable alcohol-gasoline blend which may give higher thermal efficiency and lower consumption without, however, requiring any alternations in the engine settings.

The engine was started with gasoline for this experiment and was allowed to run at full load for about half an hour to warm up. The carburettor fuel container level was then set for maximum power for gasoline. The power output and the time required to consume 100 cc. of gasoline were noted. In the mean-while a 5 % alcohol-gasoline blend was filled in the second fuel container of the carburettor. The float level in this container was kept at the same level as in the first container. The main jet was connected to the second fuel container and allowed to run on that blend for fifteen to twenty minutes.. When the level of fuel in the container came to a premade mark on it, then 100 c.c. of blend was put into the container and the time taken for it to be consumed was noted by a stop watch. In the mean while, the first container was drained of its residual fuel and refilled with 10% blend. After the time of consumption of 5 % blend had been noted, the jet was connected again to the first container by the fuel selector valve and the same procedure was repeated. With different blends upto 100 % alcohol, the datas so obtained were tabulated as shown in table no. From this the power outpout, thermal efficiency and specific consumption were calculated and results tabulated in Table No.XX

(iii) The general test procedure adopted was the same as in the previous case except for the fact that for each blend the mixture strength and ignition timing were adjusted to give maximum power. The results obtained have been tabulated in the Table No.XXIII

(iv) To find the maximum power at optimum conditions, use was made of the H.U.C.R. values which had been obtained earlier. The engine was run at the H.U.C.R. of each blend and the output and fuel consumption time were recorded with the ignition timing and mixture strength adjusted for optimum power in each case. The observations were recorded in Table No.XXV

(v) In order to plot the consumption loops, one fuel blend was taken at a time. The load was varied and the output and consumption at each load was recorded. The output was varied by adjusting the carburettor fuel container level setting. The engine was allowed to run for about half an hour at each load before a reading was recorded. Observations were recorded in Table No.XXVII

(vi) The calorific value of each blend was found experimentally by the B.T.L. bomb calorimeter for a complete description of which reference may be made to B.T.L. bomb calorimeter outfit Brochure No. N 2 0 9.

First of all the water equivalent of the calorimeter was found by burning a known weight of Benzoic acid the calorific value of which is known precisely (6319.1 cal./gm.). The crucible was weighed accurately and was then filled with about 1 to 1½ gms. of Benzoic acid and reweighed to find accurately the weight of benzoic acid put in. The crucible was placed in the bomb which was reassembled and charged with oxygen to about 25 atmospheres. The bomb was immersed in water to test for leaks. The electric connections were made and stirring gear started. The charge was fired by closing the switch and the observations were recorded as shown in table no.V

The experiment was then performed with various blends and the observations recorded as shown in the table no.VI-XVIThe calculations for the calorific value have also been shown below each set of observations.

(vii) Open circuit and hold on tests were made on the three phase induction machine so as to find out the input of the generator corresponding to various values of the output.

In the open circuit test, the machine was run without load. Rated voltage of 400 volts was applied and radings of the ammeter and the two watt-meters provided in the circuit were recorded as shown in table no.XVIII.

In the hold on test, the machine was prevented from rotating, by holding the pulley on its shaft by hands. A reduced voltage was applied to obtain the rated current which was read in the am-meter provided. The power supplied was obtained from the readings of the two watt-meters incorporated in the circuit. The observations were recorded as shown in the table no.XIX.

From this data the circle diagram shown in figure no. 1*(a)* was drawn in the following manner. No load current vector OA was drawn at an angle of $84^{o}12'$ with the voltage vector. Vector OC represented the hold on current-I_s' corresponding to the rated voltage. BC was joined and its right bisector DE was drawn. Its point of intersection, E, with a horizontal drawn from A was obtained. With contre

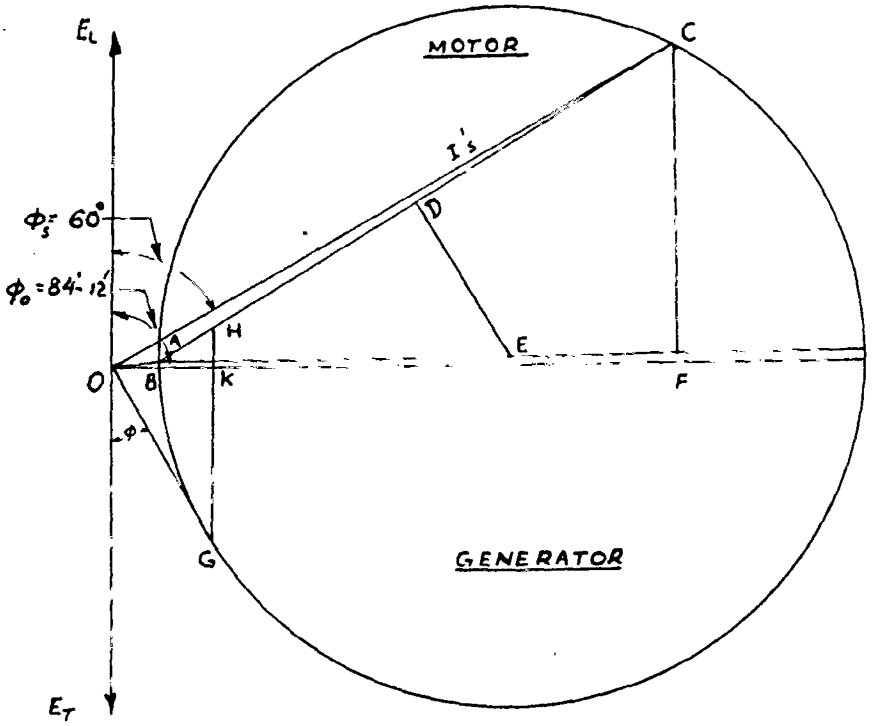


FIG. No 1(a) CIRCLE DIAGRAM OF INDUCTION GENERATOR

E and radius EA a circle was drawn. CF represented the 'hold on' power corresponding to the rated voltage. From this length of vector CF the power scale was obtained. The lower half of this circle diagram is for the generator while the upper half represented the motor. For any generator, output GK the generator power input is represented by GH. Hence by making use of this diagram the power input to the generator corresponding the various watt-meter readings could be obtained.

CHAPTER- IV

* OBSERVATIONS & RESULTS* TABLES.

OBSERVATIONS AND CALCULATIONS

IV - 1. OBSERVATIONS TAKEN FOR FINDING H.U.C.R.

TABLE NO. III

1. Engine speed 600 r.p.m.
2. Mixture strength adjusted for maximum power in each case.
3. Ignition timing adjusted for optimum power in each case.

Serial Number	Percentage of Alcohol	H.U.C.R.
1	0	5.35
2	10	5.50
3	20	5.80
4	30	6.10
5	40	6.35
6	50	6.50
7	60	6.75
8	70	6.95
9	80	7.10
10	90	7.40
11	100	7.65

TABLE NO. IV

1. Engine speed 900 r.p.m.
2. Mixture strength adjusted for optimum power in each case.
3. Ignition advance adjusted for optimum power in each case.

Serial Number	Percentage of alcohol	Highest useful compression ratio
1	0	5.45
2	10	5.70
3	20	5.90
4	30	6.20
5	40	6.40
6	50	6.60
7	60	6.95
8	70	7.10
9	80	7.30
10	90	7.50
11	100	7.80

IV - 2 OBSERVATIONS TAKEN FOR FINDING THE CALORIFIC VALUE OF VARIOUS BLENDS BY BOMB CALORIMETER :

TABLE NO. V

Water equivalent of calorimeter - W'

Observations :

1. Weight of the empty crucible = 9.5 gms.
2. Weight of the crucible plus benzoic acid =10.829 gms.
3. Weight of benzoic acid (w) = 1.329 gms.
4. Standard calorific value of benzoic acid (C) = 6319.1 cal/gm.
5. Weight of water in the container (W") = 1800 gms.
6. Corrected temperature rise = 4° C

Calculations :

$(W' + W'') \times$ temperature rise $= w \times C$

or $(1800 + W') \times 4 = 1.329 \times 6319.1$

or $W' = \frac{8400 - 7200}{4}$

$= 300$ gms.

TABLE NO. VI

Calorific value of Gasoline - C

Observations :

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel = 11.5 gms.

3. Weight of gasoline (w) = 2 gms.

4. Weight of water in the container = 1800 gms. = W''

5. Corrected temperature rise = 9.8° C

Calculations :

$$(W' + W'') \times \text{temperature rise} = w \times C$$

or

$$C = \frac{(W' + W'') \times \text{temp. rise}}{w}$$

$$= \frac{2100 \times 9.8}{2}$$

$$= 10300 \text{ cal/gm.}$$

$$= \underline{18{,}550 \text{ BTU/lb.}}$$

TABLE NO. VII

Calorific value of Ethyl Alochol - C

Observations :

1. Weight of empty crucible = 9.5 gms.

2. Weight of crucible plus fuel = 11.8 gms.

3. Weight of fuel alone (w) = 2.3 gms.

4. Weight of water in the container = 1800 gms. = W''

5. Corrected temperature rise = 7.3° C

Calculations :

$$(W' + W'') \times \text{temperature rise} = w \times C$$

or

$$(1800 + 300) \times 7.3 = 2.3 \times C$$

or

$$C = \frac{2100 \times 7.3}{2.3}$$

$$= 6{,}670 \text{ cal./gm.}$$

$$= \underline{12{,}000 \text{ B.T.U./lb.}}$$

TABLE NO. VIII

Calorific value of 10 % Alcohol-gasoline blend - C

Observations :

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel blend = 11.25 gms.
3. Weight of fuel (w) = 1.75 gms.
4. Weight of water in the container W'' = 1800 gms.
5. Corrected temperature rise = 8.3° C

Calculations :

(W' + W'') x temperature rise = w x C

or C = $\frac{2100 \times 8.3}{1.75}$

= 9950 cal./gm.

= 17,900 BTU/lb.

TABLE NO. IX

Calorific value of 20 % Alcohol-gasoline blend - C

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel blend = 11.0 gms.
3. Weight of the fuel blend = 1.5 gms.
4. Weight of water in the container W'' = 1800 gms.
5. Corrected temperature rise = 6.85° C

Calculations :

(W + W'') temperature rise = w x C

Therefore, C = $\frac{2100 \times 6.85}{1.5}$

or $C = \frac{13385}{1.5}$

$= 9580$ cal/gm.

$=$ 17,250 BTU/lb.

TABLE NO. X

Calorific value of 30 % Alcohol-Gasoline blend - C

Observations :

1. Weight of crucible = 9.5 gms.
2. Weight of crucible plus fuel b blend = 11.31 gms.
3. Weight of fuel blend (w) = 1.81 gms.
4. Weight of water in the container, W'' = 1800 gms.
5. Corrected temperature rise = 8°C

Calculations :

$$(W' + W'') \times \text{temp.rise} = w \times C$$

or $C = \frac{2100 \times 8}{1.81}$

$= 9,275$ cal./gm.

$=$ 16,700 BTU/lb.

TABLE NO. XI

Calorific value of 40 % Alocohol-gasoline blend - C

Observations :

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel = 11.1 gms.
3. Weight of fuel alone (w) = 1.6 gms.
4. Weight of water in the container W'' = 1800 gms.

5. Corrected temperature rise = 6.7° C

<u>Calculations</u> :

$(W' + W'') \times$ temperature rise $= w \times C$

or C $= \frac{(W'+W'')\text{temp.rise}}{w}$

$= \frac{2100 \times 6.7}{1.6}$

= 8800 cal./gm

= <u>15,850 BTU/lb.</u>

<u>TABLE NO. XII</u>

<u>Calorific value of 50 % Alcohol-gasoline blend - C</u>

<u>Observations :</u>

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel = 11.5 gms.
3. Weight of fuel alone (w) = 2.0 gms.
4. Weight of water in the container = 1800 gms. = W''
5. Corrected temperature rise = 8.1° C

<u>Calculations</u> :

$(W' + W'') \times$ temp. rise $= w \times C$

or C $= \frac{(W' + W'')\text{ temp. rise}}{w}$

$= \frac{2100 \times 8.1}{2}$

= 8500 cal./gm.

= <u>15,300 BTU/lb.</u>

TABLE NO. XIII

Calorific value of 60 % alcohol-gasoline blend - C

Observations :

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel = 10.9 gms.
3. Weight of fuel alone (w) = 1.4 gms.
4. Weight of water in the container = 1800 gms. = W''
5. Corrected temperature rise = 5.4° C

Calculations :

$$(W' + W'') \times \text{temperature rise} = w \times C$$

or

$$C = \frac{(W' + W'')\ \text{temp.rise}}{w}$$

$$= \frac{2100 \times 5.4}{1.4}$$

$$= 8100 \text{ cal./gm.}$$

$$= \underline{14{,}600 \text{ BTU/lb.}}$$

TABLE NO. XIV

Calorific value of 70 % alcohol-gasoline blend (C)

Observations :

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel = 11.2 gms.
3. Weight of fuel alone (w) = 1.7 gms.
4. Weight of water in the container = 1800 gms. = W''
5. Corrected temperature rise = 6.3° C

Calculations :

$(W' + W'')$ x temp. rise $= w \times C$

or $$C = \frac{(W' + W'')\text{temp.rise}}{w}$$

$$= \frac{2100 \times 6.3}{1.7}$$

= 7780 cal./gm.

= 14,000 BTU/lb.

TABLE NO. XV

Calorific value of 80 % Alocohol-gasoline blend - C

Observations :

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel = 11.8 gms.
3. Weight of fuel alone (w) = 2.3 gms.
4. Weight of water in the container = 1800 gms. = W''
5. Corrected temperature rise = 8.1° C

Calculations :

$(W' + W'')$ temperature rise $= w \times C$

or $$C = \frac{(W' + W'')\text{ temp.rise}}{w}$$

$$= \frac{2100 \times 8.1}{2.3}$$

= 7390 cal./gm.

= 13,300 BTU/lb.

TABLE NO. XVI

Calorific value of 90 % Alcohol-gasoline blend - C

1. Weight of empty crucible = 9.5 gms.
2. Weight of crucible plus fuel = 11.1 gms.
3. Weight of fuel alone (w) = 1.6 gms.
4. Weight of water in the container = 1800 gms. = W''
5. Corrected temperature rise = 5.4° C

$$C = \frac{(W' + W'')\text{temp. rise}}{W}$$

$$= \frac{2100 \times 5.4}{1.6}$$

$$= 7080 \text{ cal./gm.}$$

$$= \underline{12,750 \text{ BTU/lb.}}$$

TABLE NO. XVII

Calorific value (BTU/lb.) and specific gravity of various Alcohol-gasoline blends

S.No.	Percentage of alcohol	Specific gravity	Calorific value (BTU/lb.)
1	0	0.74	18,550
2	10	0.746	17,900
3	20	0.751	17,250
4	30	0.756	16,700
5	40	0.761	15,850
6	50	0.768	15,300
7	60	0.772	14,600
8	70	0.777	14,000
9	80	0.7825	13,300
10	90	0.788	12,750
11	100	0.794	12,000

IV - 3. OPEN CIRCUIT AND HOLD ON TESTS ON THE INDUCTION GENERATOR TO DRAW THE CIRCLE DIAGRAM :

TABLE NO. XVIII

Open circuit test observations :

1. No load current I_o = 2.1 Amperes
2. Reading of watt-meter no.1 = 500 watts
3. Reading of watt-meter no.2 =-350 watts
4. No load voltage (V) = 400 volts

Open circuit test calculations :

Phase angle between voltage and current vector at open circuit $= \phi_o$

$$\tan \phi_o = \frac{(W' - W'')\ /3}{(W' + W'')}$$

$$= \frac{(500 + 360)\ /3}{(500 - 300)}$$

$$= 9.84$$

Therefore, $\phi_o = 84^\circ\ 12'$

TABLE NO. XIX

Hold on test observations :

1. Hold on voltage V_s = 90 volts
2. Hold on current I_s = 7.6 amps
3. Reading of watt-meter No-1 = 0
4. Reading of watt-meter No.2 = 600 watts

Hold on test calculations :

Phase angle between voltage and current vector at hold-on position $= \phi_s$

$$\tan \phi_s = \frac{(W' - W'')\ /3}{(W' + W'')}$$

$$= \frac{(600 - 0)\ /3}{600}$$

Therefore, $\phi_s = \underline{60^\circ}$

Hold on power corresponding to rated voltage

$$= 600 \cdot \frac{400 \times 400}{90 \times 90}$$

$$= \underline{11{,}851 \text{ watts}}$$

Hold on current at rated voltage (I'_s)

$$= 7.6 \times \frac{400}{90}$$

$$= \underline{33.77 \text{ amps.}}$$

IV - 4. OBSERVATIONS AND CALCULATIONS FOR FINDING THE MOST SUITABLE BLEND AT SAME ENGINE SETTINGS :

TABLE NO. XX

1. Compression ratio = 5
2. Engine speed = 900 r.p.m.
3. Ignition timing - fixed
4. Carburettor fuel container level - fixed

Serial Number	Percentage alcohol	Watt-meter reading W'	Time in secs.(t) to consume 100 c.c of fuel
1	0	1.15	442
2	5	1.20	433
3	10	1.225	434
4	15	1.20	435
5	30	1.175	425
6	50	1.125	409
7	70	1.00	398

Calculations :

1. Fuel per hour $= \frac{c.c}{(2.54)^3} \times \frac{1}{(12)^3} \times \text{sp. gravity} \times 62.4 \times \frac{3600}{t}$ lbs.

$$= 7.93 \times \frac{c.c.}{t} \times \text{sp. gravity lbs.} \qquad \text{..........(1)}$$

2. Specific fuel consumption

$$= \frac{\text{fuel per hour}}{\text{KW of engine}} \times .746$$

$$= \frac{5.92 \times (c.c) \times \text{sp.gravity}}{KW \times t} \text{ lbs/BHP/hr.}$$

$$= \frac{K'}{KW \times t} \text{ for 100 cc. of fuel} \qquad \ldots\ldots\ldots (2)$$

Constant K' has been calculated for various blends and tabulated in Table No. XXI.

3. Thermal efficiency

$$= \frac{KW \times 3413 \times 100}{\text{fuel/hr.} \times C.V.}$$

$$= \frac{4.3 \times (10)^4 \times KW \times t}{(c.c) \times \text{sp.gravity} \times C.V.}$$

$$= K'' \times 10^{-2} \times KW \times t \text{ for 100 cc. of fuel} \qquad \ldots\ldots\ldots (3)$$

Constant K'' has been calculated for various blends and tabulated in Table No. XXI.

TABLE NO. XXI

CALCULATED VALUES OF CONSTANTS K' AND K'' FOR b. s. f. c. AND THERMAL EFFICIENCY

Sl. No.	% alcohol	Sp. gravity	C.V. BTU/lb.	b.s.f.c. constant K'	Thermal efficiency constant K''
1	0	0.74	18550	437.5	3.14
2	5	0.743	18230	439.0	3.17
3	10	0.746	17900	441.0	3.22
4	15	0.748	17550	442.5	3.28
5	20	0.751	17250	445.0	3.32
6	25	0.754	16900	446.0	3.38
7	30	0.756	16600	447.5	3.42
8	40	0.761	15950	452.0	3.54
9	50	0.767	15300	454.0	3.67
10	60	0.772	14650	457.5	3.81
11	70	0.777	13950	460.0	3.97
12.	80	0.783	13300	463.0	4.13
13	90	0.788	12650	465.0	4.32
14	100	0.794	12000	470.0	4.52

TABLE NO. XXII

Calculated Thermal Efficiencies and b. s. f. c. obtained with various blends.

1. Engine speed	900 r.p.m.
2. Compression ratio	5
3. Ignition setting	fixed
4. Carburetter fuel container level	fixed

S.No.	% alcohol	watt-meter reading W'	Engine output in KW obtained from circle diagram W'' (corresponding to W')	W''xt	b.s.f.c lbs./BHP per hr.	% Thermal efficiency
1	0	1.15	1.665	735	0.595	23.1
2	5	1.20	1.715	744	0.590	23.6
3	10	1.225	1.740	755	0.585	24.3
4	15	1.20	1.715	745	0.593	24.4
5	30	1.175	1.700	722	0.620	24.7
6	50	1.125	1.630	667	0.680	24.5
7	70	1.00	1.560	622	0.740	24.7

IV - 5. OBSERVATIONS AND CALCULATIONS FOR FINDING MAXIMUM POWER OUTPUT, SPECIFIC FUEL CONSUMPTION AND THERMAL EFFICIENCY OBTAINABLE WITH VARIOUS BLENDS AT SAME COMPRESSION RATIO.

1. Compression ratio 5
2. Engine speed 900 r.p.m.
3. Ignition setting adjusted for optimum power with each blend
4. Mixture strength adjusted for optimum power with each blend

TABLE NO. XXIII

Observations :

Serial Number	Percentage alcohol	Watt-meter reading W' in K.W.	Time in seconds (t) to consume 100 c.c. of fuel
1	0	1.200	429
2	20	1.275	398
3	40	1.325	366
4	50	1.350	348
5	70	1.250	342

Results :

TABLE NO. XXIV

Sl. No.	% alcohol	Watt-meter reading W'	Engine out-put W'' from the circle diagram	Percentage thermal efficiency	b.s.f.c. lbs./BHP per hr.
1	0	1.200	1.71	23.0	0.597
2	20	1.275	1.75	23.1	0.640
3	40	1.325	1.80	23.3	0.686
4	50	1.350	1.825	23.3	0.715
5	70	1.250	1.735	23.5	0.777

IV - 6. OBSERVATIONS AND CALCULATIONS FOR FINDING MAXIMUM POWER, THERMAL EFFICIENCY AND SPECIFIC FUEL CONSUMPTION WHEN THE ENGINE RUNS AT THE H.U.C.R. OF EACH BLEND.

TABLE NO. XXV

1. Engine speed 600 r.p.m.
2. Compression ratio variable
3. Carburettor fuel level adjusted for optimum power in each case
4. Ignition timing adjusted in each case for maximum power

Serial Number	% alcohol	Compression ratio H.U.C.R.	Consumption Time in seconds (t) for 100 c.c of fuel	Watt-meter reading W' in watts
1	0	5.36	624	0.625
2	10	5.50	576	0.700
3	20	5.80	557	0.750
4	30	6.10	535	0.820
5	40	6.35	522	0.850
6	50	6.50	509	0.870
7	60	6.75	495	0.880
8	80	7.10	470	0.890
9	100	7.65	445	0.913

Calculations and results :

TABLE NO.XXVI

1. Engine speed 600 r.p.m.
2. Compression ratio - variable
3. Carburettor fuel container level adjusted for optimum power in each case
4. Ignition timing adjusted for optimum power in each case.

S. No.	% alcohol	H.U.C.R.	+W'	*W''	W''x t	b.s.f.c. lbs./BHP per hr.	Thermal efficiency %
1	0	5.35	0.625	1.25	780	0.560	24.5
2	10	5.5	0.700	1.345	775	0.570	25.0
3	20	5.8	0.750	1.390	775	0.575	25.7
4	30	6.1	0.820	1.436	769	0.583	26.3
5	40	6.35	0.850	1.465	765	0.592	27.1
6	50	6.50	0.870	1.475	750	0.605	27.5
7	60	6.75	0.880	1.490	738	0.620	28.1
8	80	7.10	0.890	1.510	710	0.650	29.4
9	100	7.65	0.913	1.522	677	0.695	30.6

+ W' represents watt-meter reading in K.W.

* W''represents engine output in K.Ws obtained from circle diagram (corresponding to W')

IV - 7. OBSERVATIONS AND CALCULATIONS FOR FINDING THERMAL EFFICIENCY AND SPECIFIC FUEL CONSUMPTION OBTAINED WITH DIFFERENT BLENDS AT VARIOUS LOADS.

TABLE NO. XXVII

1. Engine speed	900 r.p.m.
2. Compression ratio	5
3. Alcohol percentage	NIL

S.No.	Watt-meter reading (W') in K.Ws	Time in seconds (t) to consume 100 c.c of fuel
1	0.9	513
2	0.7	556
3	0.5	617
4	0.3	708

Alcohol percentage in the blend 20

S.No.	Watt-meter reading (W') in K.Ws	Time in seconds (t) to consume 100 c.c of fuel
1	0.9	487
2	0.7	525
3	0.5	586
4	0.3	670

S.No.	Watt-meter reading (W') in K.W.	Time in second (t) to consume 100 c.c. of fuel
	40 % ALCOHOL BLEND	
1	0.9	457
2	0.7	495
3	0.5	545
4	0.3	628
	60 % ALCOHOL BLEND	
1	0.9	427
2	0.7	460
3	0.5	510
4	0.3	582
	80% ALCOHOL BLEND	
1	0.9	393
2	0.7	420
3	0.5	46[illegible]
4	0.3	538
	100% ALCOHOL BLEND	
1	0.9	364
2	0.7	395
3	0.5	437
4	0.3	500

TABLE NO. XVIII

Calculations and results :

S.No.	Watt-meter reading W'	Engine out-put W'' in K.W. from circle diagram	b.s.f.c. lbs./BHP per hr.	% thermal efficiency
		GASOLINE		
1	0.9	1.5	0.568	24.2
2	0.7	1.345	0.585	23.5
3	0.5	1.135	0.625	22.0
4	0.3	0.900	0.686	20.0
		20% ALCOHOL BLEND		
1	0.9	1.5	0.610	24.25
2	0.7	1.345	0.630	23.5
3	0.5	1.135	0.670	22.1
4	0.3	0.900	0.740	20.0
		40% ALCOHOL BLEND		
1	0.9	1.5	0.660	24,25
2	0.7	1.345	0.680	23.55
3	0.5	1.135	0.728	22.10
4	0.3	0.900	0.800	20.00

Continued ..

S.No.	Watte-meter reading W'	Engine out-put W'' in K.W. from circle diagram	b.s.f.c. lbs./BHP per hr.	% thermal efficiency
		60% ALCOHOL BLEND		
1	0.9	1.50	0.715	24.4
2	0.7	1.345	0.740	23.56
3	0.5	1.135	0.783	22.10
4	0.3	0.900	0.876	20.00
		80% ALCOHOL BLEND		
1	0.9	1.50	0.786	24.4
2	0.7	1.345	0.820	23.55
3	0.5	1.135	0.880	21.8
4	0.3	0.900	0.960	20.0
		100% ALCOHOL BLEND		
1	0.9	1.50	0.863	24.7
2	0.7	1.345	0.886	24.0
3	0.5	1.135	0.950	22.4
4	0.3	0.900	1.050	20.3

CHAPTER- V

* DISCUSSION OF RESULTS *

DISCUSSION OF RESULTS

V - 1. KNOCKING CHARACTERISTIC OF BLENDS :

The value of H.U.C.R. for various alcohol-gasoline blends was found and the results plotted in figure 3&4 This graph indicates that the H.U.C.R. value increases with the percentage of alcohol in the blend. This increase is in direct proportion to the increase in the alcohol percentage. The value of H.U.C.R. was found to be 5.45 at 900 r.p.m. for gasoline alone. This value rose to 7.8 with absolute alcohol. The value of H.U.C.R. was again found for various blends at a speed of 600 r.p.m. It was observed that the H.U.C.R. decreased slightly and the trend of its value increasing with increase in alcohol content was maintained.

These results show that alcohol is an anti-knock fuel and acts as an inhebitor when added to gasoline. It suppresses knocking. This is because of the following two reasons.

1. Alcohol has a higher self-ignition temperature. Its self ignition temperature is 1.44 times that of patrol. The tendency of knocking depends on the self-ignition temperature. According to Ricardo, knocking

occurs due to the auto-ignition of the unburnt portion of the charge. He stated that when a mixture of inflamable vapour and air is compressed and then ignited at one point, the flame at first spreads by normal process of combustion compressing before it the unburnt portion of the charge. If the rise of temperature of the unburnt portion of the charge is sufficiently high a sponteneous ignition takes place and an explosion weave is set up which strikes the cylinder walls and causes the metallic ringing sound called knocking. Ricardo pointed out that the knocking tendency depends on S.I.T. and alcohol having a higher value of S.I.T. should normally be more knock resistent than gasoline.

2. However, there are certain fuels which have a high S.I.T. and yet detonate heavily and conversely some fuels have a low S.I.T. yet they show remarkable anti-knock property. Tizard and Pye conducted a series of experiments and in the light of these arrived at the conclusion that knocking does not depend on S.I.T. alone but also on the delay period of the fuel-air mixture. They found that if the temperature of a fuel-air mixture is raised above, the S.I.T. by compression, even then combustion would not start immediately but would only occur after some delay. This delay varies from fuel to fuel and becomes shorter as the temperature of combustion is raised.

Auto-ignition of the end charge in the engine cylinder will naturally depend, apart from the S.I.T., on this delay periods. It will only take place if three conditions are satisfied :

1. The end charge has attained the S.I.T. ;
2. the S.I.T. or higher temperature is maintained till the delay period of the end charge is over; and
3. the flame has not reached the end charge till this delay period is over.

Thus, larger the delay period lesser will be the chances of auto-ignition occuring as by the time the end charge's delay period is completed, the flame will reach there and it will have normal combustion.

As pointed out earlier, this delay period depends upon the nature of the fuel, on the temperature prevelent, and the rate of pressure rise. It decreases with the increase in temperature. Alcohol has a larger delay period than petrol. Moreover, the flame temperature is much lesser with alcohol than with petrol. So that the end charge gets less heat in case of alcohol, as the flame progresses. Further, the rate of pressure rise of the end charge, as combustion proceeds, is also lesser with alcohol fuel. Hence, it takes still longer time to attain its S.I.T. which is already much higher than that of petrol. Thus, we conclude that alcohol is a better anti-knock fuel because :

1. Its self ignition temperature is higher;
2. Its delay period is more ; and
3. Its rate of pressure rise during the combustion is lesser so that the end charge is compressed lesser and to that extent the temperature rise due to compression is lesser.

The anti-knock nature of alcohol-gasoline blends can be also explained in the light of Lewis's chain reaction theory (17). The theory postulates that the advancing wave front projects into the unburnt gas hot reaction products rich in energy. Each of these start a reaction chain which initiates combustion ahead of the flame front. Under certain conditions of high temperatures and pressures, these chains branch and form more energy chains in geometric progression. As the wave front can project reactant moluculees at velocities considerably higher than its own, pre-flame front combustion can proceed at extremely high velocities attaining 10,000 ft./sec.- the detonation wave.

According to this theory, the flame front advancing from the initiating spark, projects, reactive combustion products into the unburned portion of thecharge. While the cylinder temperatures and pressures remain low, these chains are completed or destroyed by the cylinder walls, (18). At higher temperatures and pressures, which we know are condusive to knock, the chains may commence to increase geometrically and a condition be induced which is knock.

The latent heat of alcohol is 2½ times that of petrol and in consequence the liquid though highly volatile (B.P. 78° C) does not become fully evoperated before the inlet valve closes. The evoperation process is completed during compression and the amount of heat absorbed is so large as to produce a general lowering of temperatures throughout the cycle. This is equivalent to working with a weak mixture in so far as the lower temperatures of the cycle reduce the cylinder and exhaust wall temperatures. When running with alcohol at full load, it is noticeable that exhaust valves remain far cooler than on petrol. They continue to look black under conditions when with petrol they would be glowing a good cherry red. Due to these lower all round temperatures, the chain reactions are broken by the cylinder walls.

Another reason for the anti-knock behavour of alcohol can be the peculiar mode of combustion of this type of fuel (19). With petrol during ombustion certain unstable organic peroxides like alkyle hydrogen peroxide or dialkyle hydrogen peroxide are formed. These compound molecules are unstable bodies in a high energy state. They collide with other oxygen or fuel molecules and produce further highly active products thereby activiating other molecules. They collide, explode and release more and more energy thus propogating a chain and ultimately bringing about detonation. It is quite likely that alcohol during combustion does not form these particular peroxides. Alcohol and petrol during combustion produce different chains, one ending rapidly with a stable end product and the other branching and producing more & more energy chains in geometric progression until the velocity of reaction attains detonation point. Thus the difference in behaviour of alcohol as far as knocking tendency is concerned may be due to :

1. The lower temperature of the combustion.
2- Lower rate of flame travel;
3. The peculiar mode of combustion of this type of fuel such as its inability to form suitable peroxides; and
4. Its self-ignition temperature being higher and its delay period being longer than that of petrol.

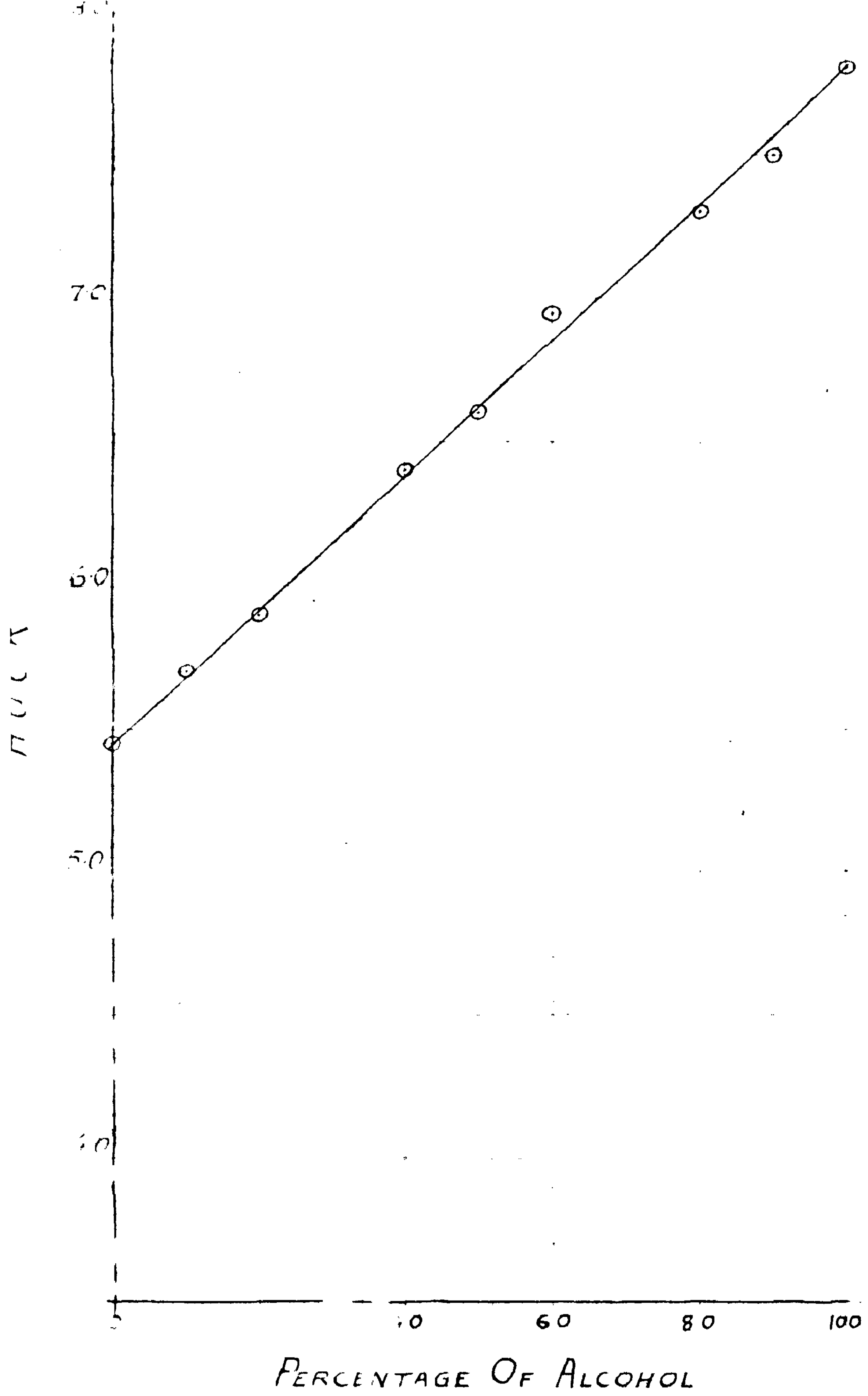


Fig: 4 Variation Of H.U.C.R With Percentage Of Alcohol
Engine Speed 900 R.P.M

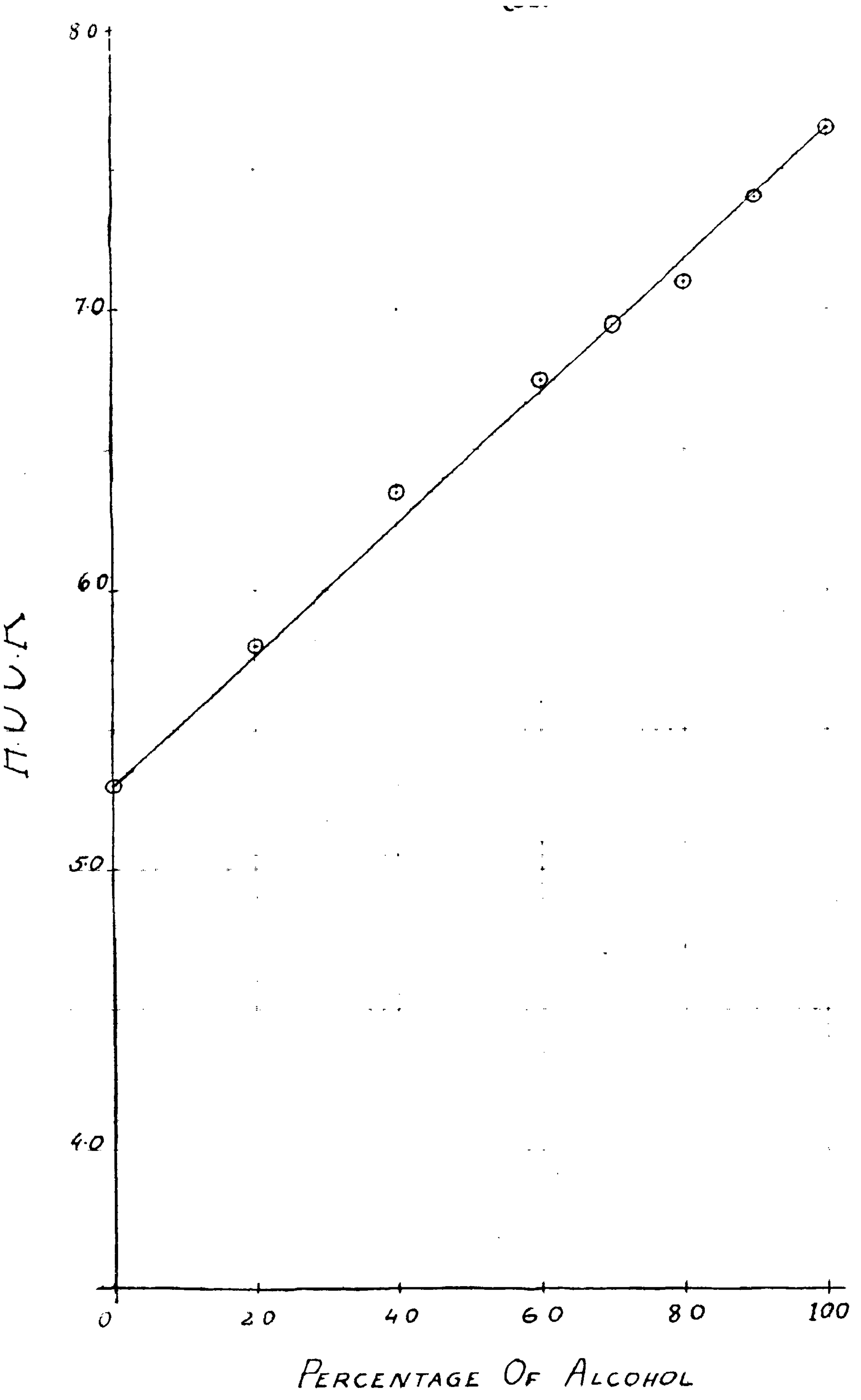


Fig 3 Variation Of H.U.C.R With Percentage Of Alcohol

F S 600 R.P.M

V - 2. POWER OUTPUT AND SPECIFIC FUEL CONSUMPTION AT GIVEN ENGINE SETTINGS :

With a view of finding the most suitable blend of alcohol-gasoline for a given engine setting, various blends were tried keeping the compression ratio, ignition timing and carburettor fuel container level fixed. This trial was made at a compression ratio of 5, ignition set at 26° B.D.C. and fuel level in the carburettor fuel container set near a level that gives the rated output with gasoline. The power output and specific fuel consumption obtained with various blends were plotted and graph no. 5 on page 64 was prepared. From the graph, it is seen that the power output rises from 1.665 KW with petrol to 1.74 KW with 10 % alcohol-gasoline blend. Increasing alcohol content, thereafter, causes a decrease in power output. The specific fuel consumption also decreases from 0.595 lbs./BHP/hr. to 0.585 lbs./BHP/hr. at 10 % blend and then starts rising again.

The power output of an engine depends upon :

1. The heating value of the mixture of air and fuel ;
2. The proportion required to give complete combustion ; and
3. The volumetric efficiency of the engine.

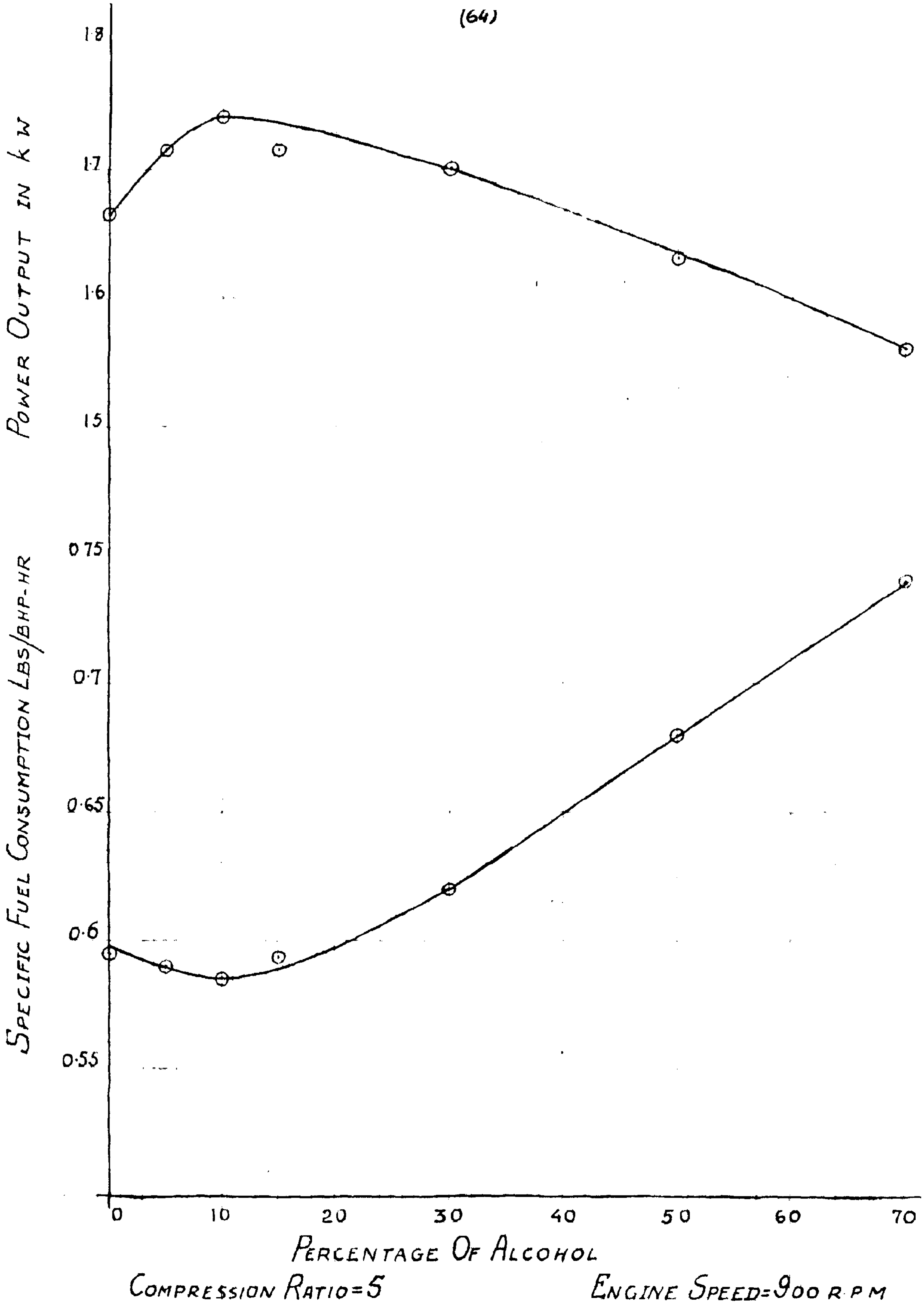


Fig:5 Power Output. and Specific Fuel Consumption Obtained With Various Alcohol-Gasoline Blends at Constant Engine - Settings

If the heating value of the mixture is reduced the power output tends to fall. The air-fuel ratio effects the power output in that, if the mixture is enrichened the output increases (upto a limit) while if it is made leaner, there is a lowering of output.

The volumetric efficiency is an indication of the extent to which the filling of the cylinder with charge during induction is complete. It depends partly on mechanical features such as shape, size of the induction pipe and branches, inlet valve and partly on the density of the incoming charge. For a given engine, the greater the charge density the higher the volumetric efficiency. Charge density depends upon the temperature of the mixture when the inlet valve closes. This temperature in turn depends on the exhaust temperature and the extent of lowering of temperature caused due to the evoperation of fuel during induction stroke. Fuels having higher latent heat of evoperation bring about a lowering of the induction temperature by their evoperation. Any lowering of temperature of the mixture in the cylinder, at the moment the inlet valve closes, means an increased density of the fresh charge and proportionately more heat generated in the cylinder/cycle. At a given compression ratio, therefore, the indicated power will be increased nearly in inverse proportion to the mean absolute temperature of the charge at the moment when the valve closes. Charge temperature is lowest with fuels of highest latent heat. Ethyl alcohol has a high latent heat (396 BTU/lb. as against that of petrol which is only 135 BTU/lb.). Complete vaporation of ethyl alcohol would result into a fall of 86° C. in the induction manifold temperature while with petrol, this fall in temperature would be only 21° C. Obviously, therefore, the volumetric efficiency obtained with ethyl alcohol blends is much higher than that obtained with petrol. The greater the proportion of alcohol in the blend, the higher will be the volumetric efficiency obtained. An increase in volumetric efficiency brings about an increase in the power output.

Reverting back to the graph no. 5 on page 64 and the experiment we break up the graph into two portions : (i) from 0 % alcohol to 10 % alcohol blend and (ii) from 10 % alcohol onwards. From 0 to 10 % alcohol blend, the following things are happening

1. The heating value of the mixture is decreasing but very gradually.

   The calorific value of petrol is 18,550 BTU/lb. of 5 % blend it is 18,230 BTU/lb. and 10 % blend 17,900 BTU/lb. As the carburettor fuel container setting is fixed, the heating value of the mixture will be varying in direct proportion of the fall in the calorific value of the fuel blends. So this factor will tend to lower the power output.

2. Volumetric efficiency is increasing with increased alcohol content and this has a tendency to increase the power output.

3. The cycle temperatures are lowered with increased alcohol content in the blend. This may result in a reduction of heat losses and a consequent improvement in thermal efficiency. This may also result in an improvement of power output.

This increase in output due to the last two results is more than the fall in output due to slight lowering of the calorific value of the blend. Hence, power output increases upto 10 %alcohol blend.

In this region, the specific fuel consumption is also decreasing because of an improvement in the volumetric efficiency and the power output.

From 10 % blend onwards the following reasoning apply :

1. As the alcohol percentage increases, the heating value of the fuel decreases and with the carburettor fuel container setting fixed this implies a lowering of the heating value

of the mixture in the same proportion as the increase of alcohol oontent for the blend. Hence, with higher and higher percentages of alcohol, there will be lesser and lesser heat value of the mixture, hence lesser and lesser output.

2. The air-fuel ratio for complete combustion of petrol is 15 : 1. For complete combustion of alcohol, it is 9 : 1. The amount of air which is being drawnin by the engine during suction is constant. As the fuel level in the carburettor fuel container is contant, the air-fuel ratio is almost constant. Now as we progressively add alcohol to the blends, the fuel-air mixture tends to become weaker and weaker because the more the alcohol in the blend, the lesser is the air needed for combustion. With progressive weakening of the mixture the power output tends to fall.

3. The volumetric efficiency depends upon the mixture strength. Alcohol has a very high volumetric efficiency with very rich mixtures. The difference in the volumetric efficiency obtained with petrol and alcohol is very wide at rich mixtures and the difference is not so

much with weak mixtures. As we increase the alcohol content in the blend, the fuel-air mixture becomes weak. At weaker mixtures the difference in the volumetric efficiencies is lesser.

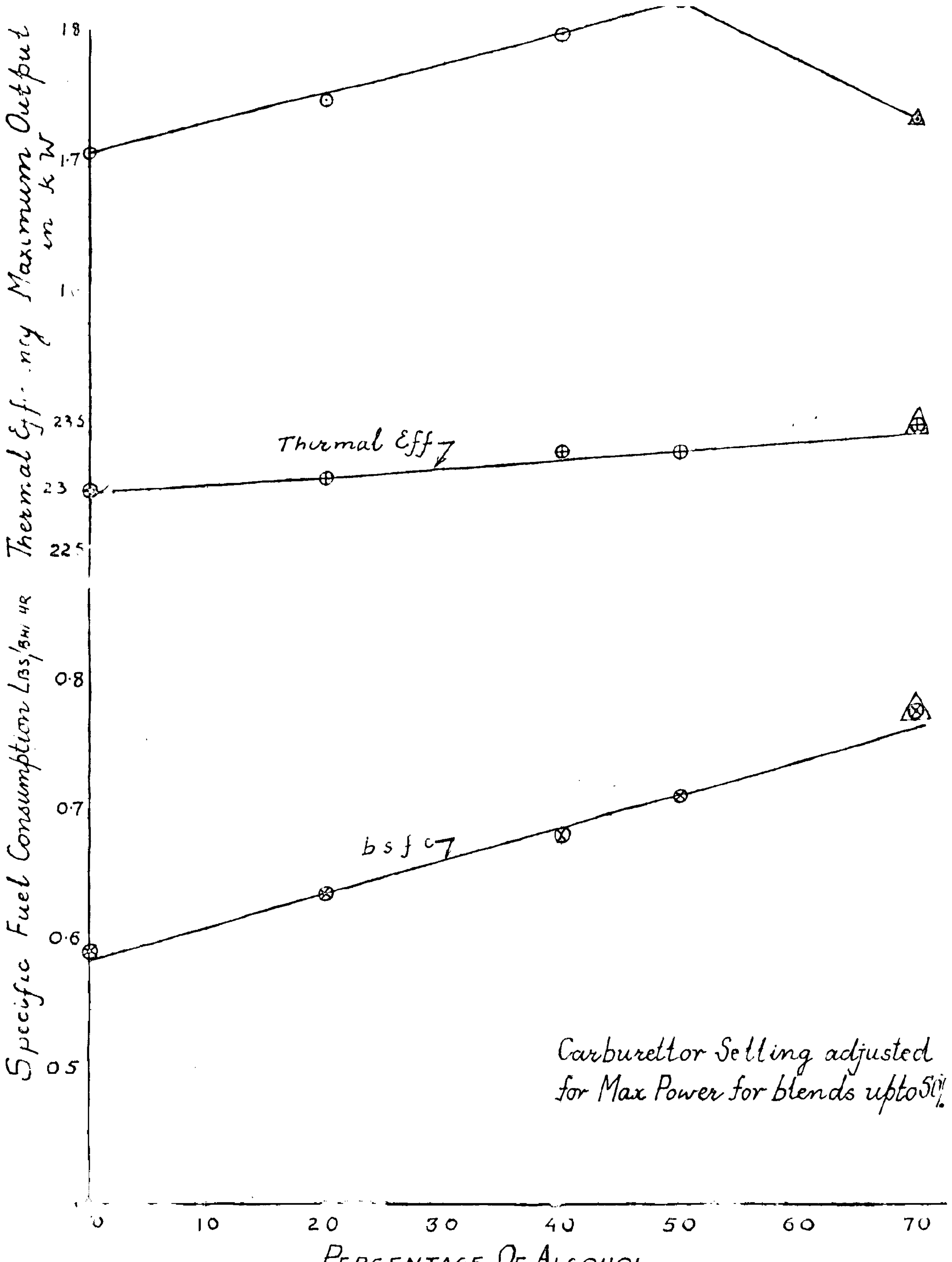
4. It has been found in practice that alcohol is not completely evaporated by the end of the suction stroke, due to lower temperatures and the short time available. Hence, the volumetric efficiency obtainable with alcohol is much lower than theoritically expected. It is about 82 - 83 % as compared with 78 % obtainable with petrol. Thus with greater alcohol in the blends, the difference in the volumetric efficiencies is further narrowed down because of the non-evaporation, of the large proportion of alcohol present, during suction stroke.

The overall effect of these factors is to lower the power output with blends having more than 10 % alcohol. The fuel consumption with these blends increases rapidly because of the rapid lowering of the heat value of these blends. Both of these effects are clearly revealed by the graph.

V - 3. MAXIMUM POWER OBTAINABLE WITH EACH BLEND AT THE SAME COMPRESSION RATIO :

From the point of view of finding the maximum power obtainable at a given compression ratio, the engine was run on various blends and the maximum power output and fuel consumption were recorded and plotted as shown in graph no. 6 on page 71. The compression ratio was kept same for the different blends, only the ignition timing and carburettor fuel container setting were adjusted in each case to get maximum power. The carburettor fuel container setting could only be adjusted upto 50 % blend of alcohol, hence the conclusions to be drawn from the results should be confined upto 50 % alcohol-blends only. From this graph, we observe that as the percentage of alcohol increases, the maximum output also increases. The maximum output increased from 1.7 K.W. for petrol to 1.825 K.W. for 50 % alcohol blend. The specific fuel consumption increased from 0.59 lbs./BHP/hr. to 0.715 lbs./ BHP/hr. The thermal efficiency also showed a slight improvement.

The calorific value of the blends decreases with increase in the alcohol content. However, from the graph we observe that the maximum output keeps on increasing. This is because of the following reasons :



Carburettor Setting adjusted for Max Power for blends upto 50%

Compression Ratio=5

Engine Speed 900 R.P.M

Fig: Maximum Power Output, Thermal Efficiency and Specific fuel consumption with various Alcohol

As already discussed in V - 2, the power output depends upon the heat value of the charge. In addition to that, it also depends on the latent heat of the fuel (volumetric efficiency in a way depends on it) and the final volume of the products of combustion.

1. The air-fuel requirements vary with the alcohol percentage in the blend. For example, complete combustion of one lb. of petrol requires about 15 lbs. of air while for complete combustion of 1 lb. of ethyl alcohol, only 9 lbs. of air is required. Thus for a given cylinder volume of gaseous charge derived from petrol, one-fifteenth is the heat giving fuel, while for the same volume of the charge derived from ethyl alcohol, one-ninth represents the heat giving fuel. But ethyl alcohol has a calorific value some 60 % that of petrol. Applying this factor, it will be seen that each charge has approximately the same heat content. Ricardo has calculated these values more accurately. He has shown that when mixed with the amount of air required for complete combustion, gasoline gives between 46.7 to 47 ft. lbs./cu.inch while ethyl alcohol gives 44.5 ft. lbs./cu.inch which are very nearly equal.

2. The internal total energy available from a fuel depends upon the final volume of the products of combustion. With increasing ethyl alcohol content, this value keeps on increasing. Aromatic hydrocarbons have a smaller volume increase, the ratio of initial to final volume varying for different substances between 1.013 for benzene to 1.03 for xylene. Paraffin hydrocarbons give ratios varying between 1.04 to 1.06. A typical petrol has a ratio 1.05. For alcohols the value is higher being 1.065. Applying these correction factors to heat energy per cubic inch, we see that petrol contains 48.5 ft.lbs./cuinch and ethyl alcohol 47.4 ft. lbs/cu.inch.

3. Another important factor on which the maximum power output depends is the latent heat of evoperation of the fuel. In fact the maximum power output depends almost exclusively on the latent heat of evoperation of the fuel and the internal energy of the working fluid. This internal energy, as shown above, varies very little from petrol to alcohol but the latent heat variation is very large. In hydrocarbons fuels, the variation in internal energy and latent heat just about balance, with the

result that the maximum power output is the same for all. For example the internal energy of benzene is 1.5 percent less than that of Hexane, on the other hand, latent heat of benzene is considerably greater and a greater weight of mixture is, therefore, retained in the cylinder, with the result that, under identical temperature and other conditions both give, at the same compression ration, the same power output.

In case of alcohol blends, the total internal energy of the air-fuel mixture is a little lower than that of petrol, but the latent heat is so much greater that a much denser charge is retained in the cylinder and the power output of the blends is greater than that of petrol.

As shown by the specific fuel consumption curve in the above mentioned graph, the specific fuel consumption increases with increase of alcohol in the blends for obvious reasons. This is so because the amount of fuel consumed is dependant upon the heat value of the fuel. In the alcohol-gasoline blends the heat value of the fuel falls rapidly with increase in the alcohol content. That is why, the specific fuel consumption increases.

The thermal efficiency shows a slight improvement with an increase in the alcohol content of the blends.

Thermal efficiency depends, apart from compression ratio, on the heat losses through the cylinder, heat carried away by exhaust and heat losses due to incomlete combustion. Heat losses through the cylinder walls decrease with alcohol blends. This is because alcohol has a high latent heat of vaporisation. It is about 2.72 times that of petrol. During the inducation stroke the fuel vaporises and in so doing picks up the latent heat of vaporisation from the incoming air and surrounding metal. This lowers down the temperature of the charge. If we assume complete vaporisation which rarely occurs with higher alcohol percentages, the fall in temperature would amount to 21° C for petrol and 86° C for ethyl alcohol. The fall in temperatures recorded in practice are much smaller than these. Typical charge temperatures in the induction manifold are for petrol 25° C and for ethyl alcohol 10° C. The greater the percentage of alcohol in a blend, the lower will be the initial temperature. Temperature at the end of compression stroke depends upon the initial temperature and the compression ratio. For the same compression ratio, this temperature will be lower for alcohol than for petrol. At a compression ratio of 6, this temperature will be 407° C for petrol and only 246° C for alcohol (20).

The explosion temperature is also considerably lower with alcohol than with petrol. At a compression ratio

5 : 1 Pye has estimated the maximum explosion temperature as 2600° C. for petrol and 2500° C. for ethylalcohol. Thus, we observe that the all round cycle temperatures and hence the cylinder temperature is lower with alcohol and alcohol blends than with petrol as fuel. The greater the percentage of alcohol in the blend, the lesser will be the cylindertemperatures, and hence lower will be the heat losses to the cylinder walls.

Alcohol blends tend towards more complete combustion, specially at high speeds (21) and, therefore, lower thermal losses. Complete combustion of hydro-carbons may be represented as in equation (1) and (2) for petrol and alcohol respectively :

$$(1)\quad 2\ C_8H_{18} + 25\ O_2 = 16\ CO_2 + 18\ H_2O + 2\times 1302\ \text{K-Cal.}$$

$$(2)\quad C_2H_5OH + 3\ O_2 = 2\ CO_2 + 3\ H_2O + 327\ \text{K-Cal.}$$

Incomplete combustion is, too, variable to be represented by a simple formulae, but for purpose of calculating the heat loss, it is sufficient to consider the formulae (3)

$$2CO + O_2 = 2CO_2 + 68\times 2\ \text{K.Cal.} \ \ldots\ldots\ldots \ (3)$$

Thus every 28 gms. of CO present in the exhaust represents 68 K.Cal. of heat lost.

Considerable thermal losses occur with petrol and its substitution by alcohol blends results in a lower carbon-monoxide content in the exhaust gases and obviously a lesser thermal loss. Litchy investigated the problem of thermal loss with petrol and the effect of alcohol blends. He worked on the C.F.R. engine with normal unleaded petrol and 10 and 20 % blends of this alcohol and petrol. He found that the blends containing 20 % alcohol gave a lower thermal loss than the ten percent blend which in turn was better than the straight run petrol. Thus with alcohol blends, the heat loss on this count is lesser.

The temperature of exhaust gases is much lower with alcohol than the petrol. In the experiment carried out by the author, it was found that at a compression ratio 5, the temperature of exhaust gases was 730° F. for petrol while that for alcohol was only 670° F. Due to this lower exhaust temperature, the heat carried away by the exhaust gases is lower in case of alcohol than with petrol.

Table below gives some of the Ricardo's results on heat balance for two fuels at different compression ratios :

Fuel	Compression ratio	I.H.P.	Heat to Jacket water %	 Exhaust %
Petrol	6.45	32	24	44
Alcohol	6.45	34	23	43
Alcohol	7.00	38	22	40

Comparing these results at the same compression ratio, it will be seen that the heat losses both to jacket water and exhaust are lower with alcohol than with petrol. At higher compression ratio, this effect is more marked.

Thus we observe that with alcohol, the heat losses through the cylinder walls, the heat carried away by the exhaust gases and the heat losses due to incomplete combustion, are lower than those obtained with petrol. Hence, thermal efficiency obtained with alcohol and alcohol-blends is a little higher than that obtained with petrol.

V - 4. MAXIMUM POWER AND THERMAL EFFICIENCY OBTAINED WITH VARIOUS BLENDS AT THEIR H.U.C.R. :

Alcohol is an anti-knock fuel and its addition to gasoline, as we have discussed in V-1 increases H.U.C.R. With a view, therefore, to investigate the improvement in power output and gain in thermal efficiency obtainable by using blends of alcohol and gasoline at their H.U.C.R., experiment was conducted and the results that were obtained have been plotted in graph no.7 on page 79. From these results, we observed that the power output obtained with

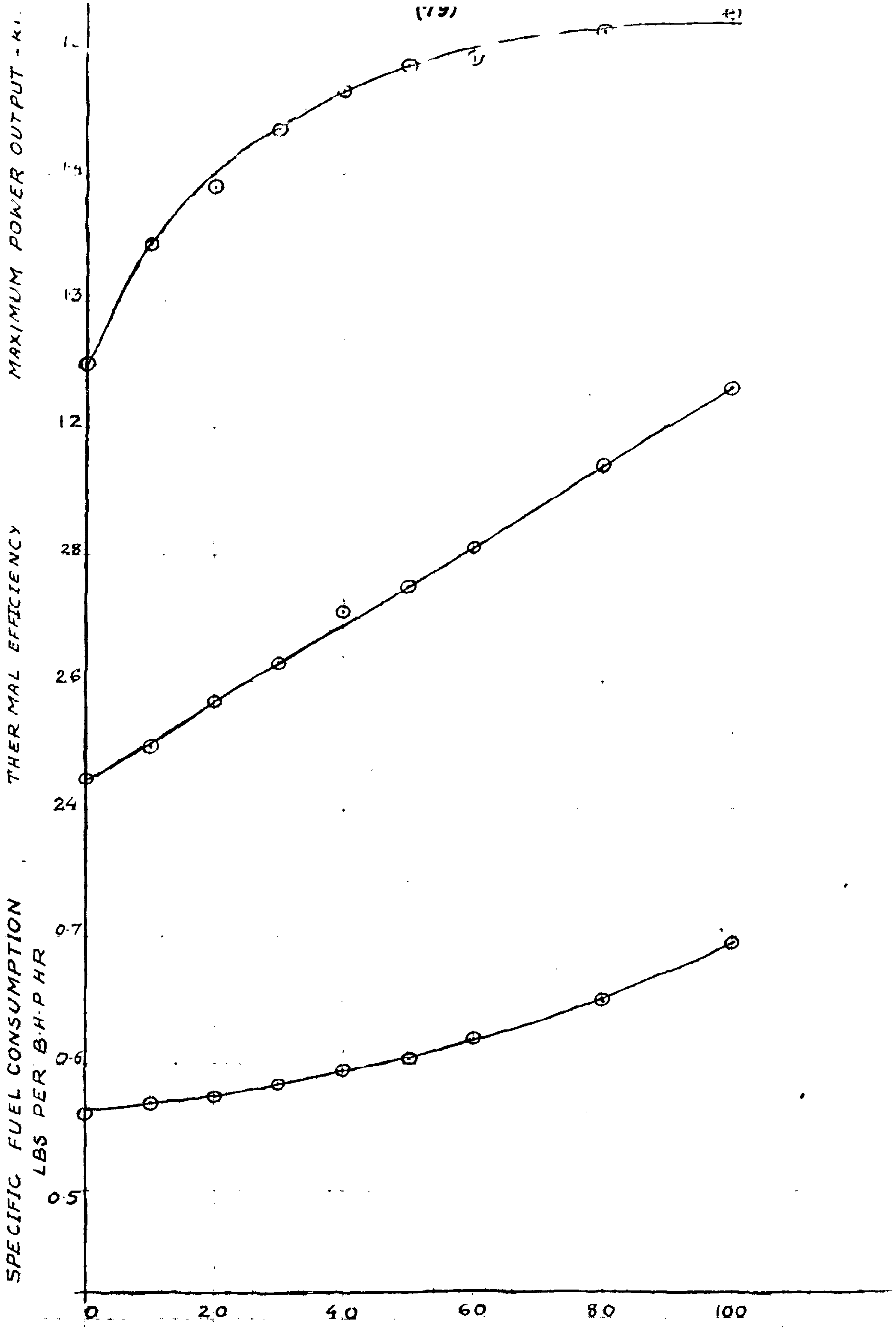


FIG 1 MAXIMUM OUTPUT THERMAL EFFICIENCY AND SPECIFIC FUEL OBTAINED WITH VARIOUS

petrol at 5.35 (its H.U.C.R) increased from 1.25 to 1.522 on 100% alcohol when used at its H.U.C.R 7.65. The thermal efficiency showed an improvement from 24.5 to 30.6% . In the results plotted it may be noted that the power output readings for 80 & 100% blends do not correspond to the maximum value, because of the limitations of the carburettor fuel conainer which did not permit further enrichening of the mixture. Had that been possible the power output with 80% & 100% blends might have been greater than that recorded.

These graphs reveal the utility of alcohol gasoline blends when used at their optimum compression ratio. There is an improvement in the power output and also in the thermal efficiency as the compression ratio increases. As alcohol blends permit the use of higher compression ratios we can obtain greater output & better thermal efficiency by using these blends.

V-5 THERMAL EFFICIENCY AND SPECIFIC FUEL CONSUMPTION CURVES

The specific fuel consumption obtained with various alcohol gasoline blends have been shown plotted in graph No. 8 on page 81. From these curves we observe that the specific fuel consumption increases at all loads, with the increase of alcohol content in the blend. Thus at rated load the specific fuel consumption which was 0.57 Lbs/BHP/Hr with petrol rose progressively with alcohol addition in the blends till it reached 0.863 lbs/BHP/hr with 100% alcohol. This is quite obvious because alcohol has a much

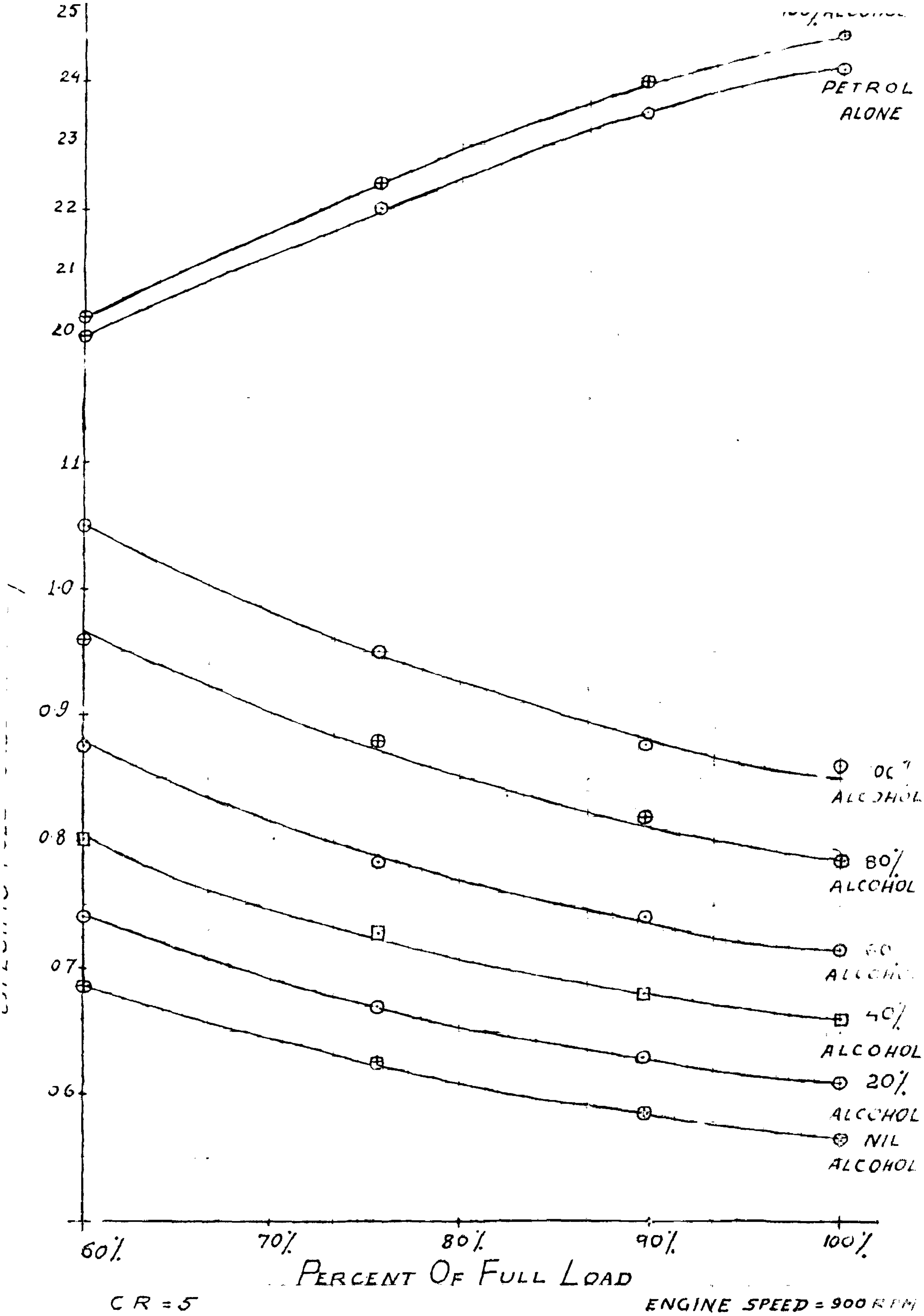


FIG: SPECIFIC FUEL CONSUMTION AND THERMAL EFFIC VS PERC
OF RATED LOAD FOR VARIOUS ALCOHOL-GASOLINE BLENDS

lower calorific value. While the calorific value of gasoline is 18550 BTU/lb that of alcohol is only 12000 BTU/lb. The heat value of a fuel is a measure of the quantity of fuel required; the lower the heat value the greater being the quantity needed to do the same work.

The thermal efficiencies obtained with petrol alone and with alcohol alone have been plotted in the same graph. From the graph we find that the thermal efficiency is higher with alcohol at all loads. At the rated load, the thermal efficiency obtained with petrol was 24.2% while that with alcohol 24.7% . This is because thermal efficiency depends apart from the compression ratio, on the heat losses through the cylinder, heat carried away by exhaust gases. As already discussed earlier both these losses are smaller with alcohol. The difference in thermal efficiencies is not so much marked with lower alcohol content blends, but becomes significant with higher percentages of alcohol. This is so because with higher proportions of alcohol in the blend all the fuel does not vaporise during induction stroke because of less temperature and also shorter time available. Hence most of this fuel evoperates during compression stroke taking its latent heat of evoperation from the cylinder walls. The net effect of this is a considerable lowering of the cylinder wall temperature and hence lesser heat losses through the cylinder walls. This improves the thermal efficiency. With smaller alcohol content blends all of the alcohol present in the blend gets evoperated during induction stroke improving the volumetric efficiency very much (See V-2) but none of it is available for internal cooling of the cylinder. Hence there is no appreciable improvement in thermal efficiency.

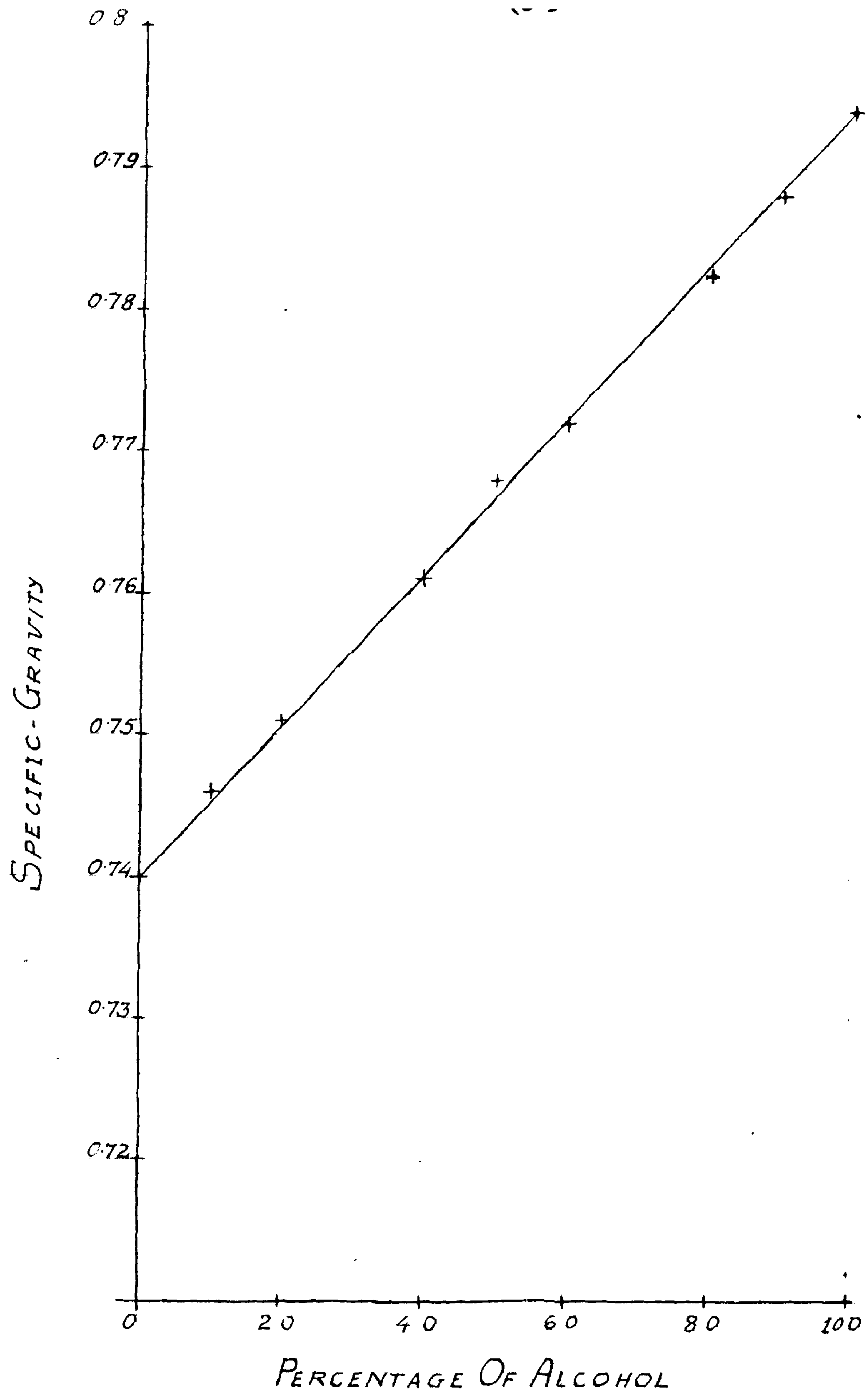


Fig: 2 Specific Gravity Of Alcohol-Gasoline Blends

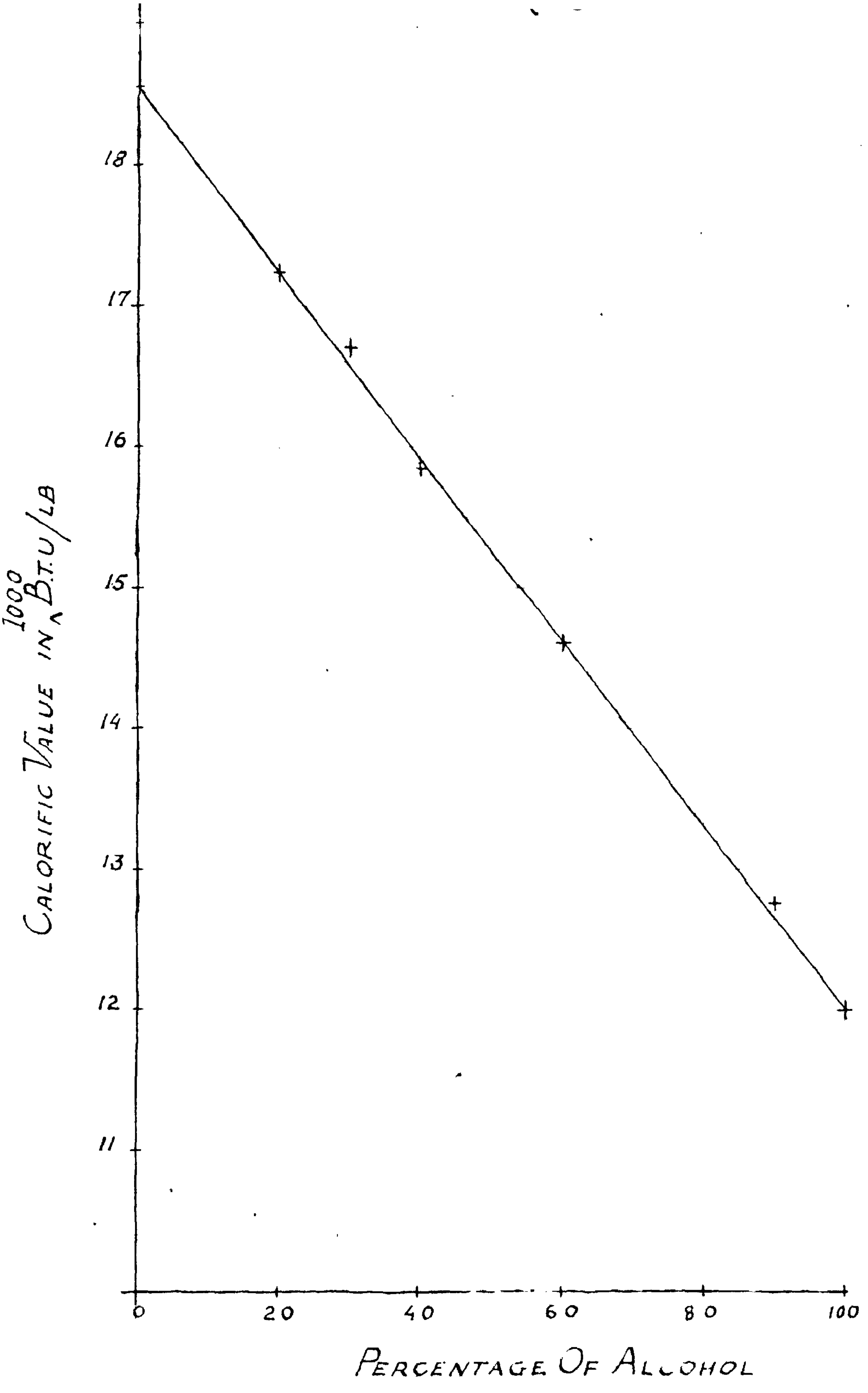


Fig:1 Calorific Value Of Alcohol-Gasoline Blends

CHAPTER-VI

* CONCLUSIONS *

CONCLUSIONS

From the experimental work done, the following conclusions have been drawn:-

1. The anti-knock value of the blend improves with the increase in the percentage of alcohol added. This variation is almost linear. The H.U.C.R. increases by about 47% as the alcohol addition increases from zero to 100%. This shows that alcohol is a very effective knock supressor and that unlike Tetra-ethyl lead, its effectiveness keeps on increasing with the increase in its percentage in the blend (22). To that extent it is superior to Tel and has an additional advantage that it is itself a fuel.

2. For a given engine settings (Carburettor fuel contaner level, ignition advance & compression ratio) the power output increases with the addition of alcohol upto 10%. Maximum power is obtained with a 10% blend. The specific fuel consumption also decreases and is minimum for a 10% blend. However for blends containing more than 10% alcohol the power output starts decreasing and the specific fuel consumption also starts rising. It may be noted that till 30%

alcohol blend the specific fuel consumption is lower than that obtained with petrol. This suggests that a 10% blend is the ideally suited one. Even looking from the economic aspect the cost of gasoline is 0.75nP per litre while that of alcohol is 1 Re. per litre (Excise free). Hence the cost of 1 litre of 10% alcohol blend will be 77.5 nP. per litre which will be only 2.5 nP. per litre more than that of gasoline. However as the consumption per BHP/hr is lesser with 10% blend the overall cost will come out to be cheaper than that of gasoline.

3. For a given compression ratio if the Carburettor Setting and ignition advance is allowed to be altered than the power output increases with the percentage of alcohol added.

4. For optimum conditions for each blend (compression ratio adjusted to its HUCR, Carburettor setting and ignition advance adjusted for maximum power in each case) the improvement in power output and thermal efficiency is very much marked. There is an improvement in power output of about 21.8% with alcohol at its HUCR 7.65, over that obtained with Petrol at its HUCR 5.35. The thermal efficiency also improves by about 25% with 100% alcohol when used at its HUCR over what is obtainable with gasoline at its HUCR.

5. When working at the same compression ratio there is not much of an improvement in the thermal efficiency. The thermal efficiency of all blends almost comes to the same figure. At full load an improvement of about 2.% was noted as the percentage of alcohol was increased from 0 to 100%. The fuel consumption however keeps on increasing with increasing alcohol content in the blend. This is because the calorific value of alcohol blends keeps on falling with an increase in the alcohol content.
6. The calorific value of the various alcohol- petrol blends was found and the graph shown on page 84 was plotted. From this graph it is clear that the drop in the calorific value is almost linear.
7. Engine design and fuels are still within their experimental period and we cannot tell when finality will be reached. Higher thermal efficiency is the continuous aim and in I.C.Engines it can only be attained by increasing compression ratios or by super-charging. In either case enhanced combustion pressures are produced which must be provided for by stiffer constructions of the engines and bearings. Coupled with this we have the fact that an increase of one compression ratio at the upper end of the scale brings a smaller percentage

yield of efficiency,and we reach the conclusion that there is an economic limit for compression ratios economically feasible. This limit is 7 to 8. The fuel chemist can readily produce fuels that would withstand such compression without undue knock,but it must be understood that the knock rating scale is also a scale of fuel cost. The engine designer is always striving to utilise fuels of lower Octane rating (and therefore of lower cost) in his high compression engine.

Meanwhile we must produce fuels capable of withstanding a compression ratio upto 8. The quantity of fuel produced to meet this demand is insufficient, despite the liberal use of anti-knock 'dopes'. In ethyl alcohol we have a fuel which despite its drawbacks,can provide the low knock fuel,with the power to withstand high compression ratios. Capable of being produced in any country that can support growing crops of within access to by-products of tropical zones it enables countries with no indigneous oil deposits to provide a satisfactory motor spirit at the minimum cost in imported low knock fuels.

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