INDUSTRIAL SECTION

Power Alcohol in India

By Dr. N. G. Chatterji
(*Harcourt Butler Technological Institute, Cawnpore*)

Introduction

THE problem of using alcohol as liquid fuel in internal combustion engines has long been engaging the attention of the people in India, and as far back as 1918, the Indian Industrial Commission, under the Chairmanship of Sir Thomas Holland, made recommendations regarding power alcohol in the following words:—

"On several occasions our attention was drawn to the possibility of making industrial alcohol from hitherto neglected vegetable materials, some of which appear to be sufficiently promising to justify investigation and experiment. We recommend that a more liberal policy should be followed by the excise authorities in respect of the class of denaturant prescribed, and more regard might be paid to the likelihood rather than to the mere possibility of frauds to the revenue, when the requirements of the commercial users conflict with excise regulations."

In pursuance of the above recommendation, the Government of India passed a resolution on October 1, 1927, to the effect that power alcohol should not be handicapped by the imposition of any excise duty except such as should be leviable upon any fuel adjunct which is separately liable to duty. It may therefore be concluded that the desirability of encouraging the use of power alcohol in the form of alcohol-petrol mixed fuel had been recognised by the Government even at a time when the entire production of molasses in India was being otherwise consumed, and there was no likelihood of any surplus quantity becoming available in the near future for the manufacture of power alcohol.

Availability of Raw Material.

Alcohol is essentially an agricultural product, as it can be manufactured from potatoes, beet, cereals, molasses, etc.; in fact from any product containing sugar and starch. Thus, potato forms the chief raw material for alcohol in Germany, beet and molasses in France and Czechoslovakia, maize in U.S.A., and molasses in almost every country. India is therefore most favourably situated so far as the availability of the raw materials is concerned, for, in addition to an inexhaustible supply of cheap cereals, molasses are now available in the country at a nominal cost to the extent of about 200,000 tons per year. Indeed, the disposal of this surplus quantity of molasses, for which at present there is no market, is one of the acute problems in the sugar industry and strangely enough, it is this problem which has brought into prominence the question of power alcohol manufacture in India.

The following table gives the figures for the production of molasses by central factories working with cane:—

Production of Molasses by Central Factories Working with Cane

	1937–38 tons	1936–37 tons	1935–36 tons	1934–35 tons	1933–34 tons	1932–33 tons
U.P.	215,700	207,900	182,600	125,500	110,052	64,600
Bihar	80,800	133,700	97,200	71,900	61,000	57,900
All India ..	364,000	414,600	337,100	233,900	190,400	130,400

It is therefore estimated that some 12 million gallons of power alcohol can at once be produced from surplus molasses, without reckoning into account the quantity that may become available with the progress of prohibition in the country and the better marshalling of such resources as mohua flowers, cane tops, etc.

At one time, hopes were entertained that a substantial quantity of molasses would be exported out of the country, but the working of a number of years has shown that in spite of substantial facilities given, the export scheme has been a virtual failure. The average price for molasses received by the sugar factories was about anna 1 and pies 2 only per maund, while even at this price, the exporting company declared the value of molasses on board the ship at Calcutta to be annas 7–11 per maund. It is understood that some of the distilleries favourably situated in the cane factory areas in the U.P. and Bihar have contracted for the supply of molasses at annas 2 per maund delivered at the distillery, while annas 4 per maund will be considered quite a satisfactory price by the sugar factories.

Method of Manufacture of Alcohol

Alcohol is manufactured by the rectification of the dilute solution obtained after the fermentation of sugar- or starch-bearing materials is complete. The usual strength of this fermented wash, as it is generally called, is about 6–8 per cent. Due to certain peculiar properties of a solution of about 96 parts by volume of alcohol and 4 parts of water, this is the maximum strength of alcohol that can be obtained by straight rectification of the 'fermented wash'.

The manufacture of industrial alcohol is, at present, being carried out in all distilleries in India equipped with patent continuous stills. In fact, the alcohol as it comes out of these stills, is what is known as 'rectified spirit' and the strength varies generally from 90 per cent. to 96 per cent. by volume. The subsequent manipulation of this spirit in warehouses by the addition of water, chemicals, or other substances, converts it into various forms of drinking spirit, 'methylated spirit', or 'specially denatured spirit'.

Further dehydration of rectified spirit was till recently a matter of considerable difficulty, and the usual process of getting 'absolute alcohol' was by distillation with lime. This was a costly process and entailed considerable losses in working. But within the last fifteen years or so, at least two different processes have been developed and have met with considerable commercial success. These are commonly known as the azeotropic process and the salt-dehydration process. The following table (*International Sugar Journal*, March 1938) gives the present annual production of absolute alcohol by these processes:—

World Production of Absolute Alcohol (1937)

I. Azeotropic Process

		Hectolitres*
(a) Melle system	..	5,250,000
(b) 'Drawinol' system	..	3,000,000
Total	..	8,250,000

II. Salt-Dehydration & Other Processes

		Hectolitres
(a) Hiag system (alkali acetates)	..	3,975,000
(b) I.G.F. system (gypsum)		265,000
(c) Merck Pressure system (lime)	..	120,000
Total	..	4,360,000

Importance of Commercial Dehydrated Alcohol

It may well be asked what was the necessity for the commercial manufacture of cheap dehydrated alcohol. The reason is, that dehydrated alcohol has a much wider range of miscibility with petrol than rectified spirit, which is found to be unsuited for the preparation of alcohol-petrol mixtures, in the proportions in which such mixtures were found to be suitable as motor car fuel. Mixtures of rectified spirit with petrol tend to separate easily. On the contrary, mixtures made with dehydrated alcohol and petrol have been found to be stable and perfectly satisfactory for all practical purposes.

As dehydrated alcohol is now almost exclusively used for the generation of power and as recent researches have evolved processes so that now there is little difference between the cost of manufacture of dehydrated alcohol and rectified spirit, 'power alcohol' has now become almost synonymous with dehydrated alcohol. It seems, therefore, that for power purposes the use of denatured rectified spirit of about 90 per cent. strength is an anachronism and should be given up.

Cost of Manufacture of Absolute Alcohol (power alcohol).—The estimated cost of manufacture of power alcohol (absolute strength) prepared directly from fermented wash by the fourth technique of Usines de

* Hectolitre = 22 gallons.

Melle azeotropic process, and for a plant of about 1,550 gallons per day are given below:

		Per gallon Pies
1.	Cost of steam .. (32.5 lbs. at 0.22 pie per lb.)	7.15
2.	Cost of cooling water, power, light, etc. ..	0.84
3.	Cost of chemicals .. (Acid, nutrients for yeast, etc.)	3.00
4.	Cost of entraining liquid for dehydration .. (0.00045 gallon at Rs. 3–4 per gallon)	0.28
5.	Cost of alcohol lost in dehydration .. .. (0.15% at As. 4–6 per gallon)	0.08
6.	Wages of labour and staff	7.60
7.	Cost of management ..	3.10
8.	Licence fee for the patent rights	0.20
9.	Depreciation charges ..	10.70
10.	Warehouse charges ..	1.80
	TOTAL (excluding cost of molasses) ..	34.75

It is therefore possible to manufacture power alcohol in the U.P. and Bihar sugar factory areas, in central distilleries at a cost of about annas 4–6 per gallon, after paying for molasses at annas 4 per maund delivered at the distillery.

Alcohol Fuels Suitable for Motor Cars.— It has now been established beyond dispute, both by careful bench experiments and long usage amongst the public, that mixtures of petrol and absolute alcohol within certain definite proportions are just as satisfactory fuels, if not better, as straight petrol. The optimum proportion of alcohol in the mixture would naturally depend upon the quality of the petrol, the make of the engine, the average atmospheric conditions of the country where the fuel is used, and similar other considerations. However, there is general agreement that fuels containing high portions of alcohol (25 parts in 100 parts of mixed fuel) and likely to give some trouble when used in cold countries would be found quite satisfactory in tropical countries like India.

ALCOHOL FUELS AND POWER DEVELOPMENT

Heat Value of Combustible Mixtures in the Engine and Power Output.—Pye, in his *Internal Combustion Engine* (1931, p. 54), has shown that the calculated power of an engine would be proportional to the heat generated per standard cubic foot of the mixture sucked into the cylinder, multiplied by the volume ratio on combustion, which is the ratio of the number of molecules of the various products of combustion to those of the combustible mixture. This may be regarded as potential source of increased power from an engine; the higher the ratio, the greater the assessment of the value of the mixture as a working substance.

By way of illustration, we may take the cases of heptane, C_7H_{16} of calorific value 10,700 C.H.U. per lb. and ethyl alcohol, C_2H_5OH, of 6,540 C.H.U. per lb. The combustion of the correct fuel-air mixtures, together with the heat generated, are as follows:—

(i) $2\ C_7H_{16} + 22\ O_2 + 82\cdot8\ N_2 = 14\ CO_2 + 16\ H_2O + 82\cdot8\ N_2 + 2\cdot155 \times 10^6$ C.H.U.

(ii) $2\ C_2H_6O + 6\ O_2 + 22\cdot6\ N_2 = 6\ H_2O + 4\ CO_2 + 22\cdot6\ N_2 + 0\cdot605 \times 10^6$ C.H.U.

Hence, the quantities of heat generated per mol of the fuel-air mixtures are:—

(i) For heptane:—

$$\frac{2\cdot155 \times 10^6}{106\cdot8} = 20{,}180 \text{ C.H.U.}$$

(ii) For alcohol:—

$$\frac{0\cdot605 \times 10^6}{30\cdot6} = 19{,}750 \text{ C.H.U.}$$

Taking into consideration the volume ratio of the products of combustion to the initial gas mixtures, the total energy of the fuel-air mixtures would be:—

(i) For Heptane, with a volume ratio of $\frac{112\cdot8}{106\cdot8}$ or $1\cdot056$:—

$$20\cdot108 \times 1\cdot056 \times \frac{1\cdot400}{359} = 83{,}100 \text{ ft.-lb.}$$

per standard cubic foot.

(ii) For Ethyl alcohol, with a volume ratio of $\frac{32\cdot6}{30\cdot6}$ or $1\cdot065$:—

$$19{,}750 \times 1\cdot065 \times \frac{1400}{359} = 82{,}200 \text{ ft.-lb.}$$

per standard cubic foot.

It would thus be seen that even though the calorific value of a substance is considerably lower than that of another, the correct combustible fuel-air mixture may have practically equal energy content on account of a smaller proportion of air required for combustion and consequently lesser dilution with the inert nitrogen. It is rather interesting to find that in the case of all the more common liquid fuels, the energy content of a correct mixture is almost identical, as shown in the following table compiled by Ricardo:—

Substance	Specific Gravity at 15° C.	Lower Calorific value in C.H.U.		Latent Heat of evaporation C.H.U. per lb.	Ratio by weight in correct mixture	Volume ratio on combustion	Heat liberated per S.C.F. of correct mixture C.H.U.	Total energy per S.C.F. of correct mixture C.H.U.
		per lb.	per gallon					
Petrol	0·76	10,430	79,200	73	14·6	1·047	57·0	59·7
Heptane (97 per cent.) ..	0·69	10,700	73,900	75	15·1	1·056	56·9	60·1
Benzol	0·88	9,640	85,200	95	13·2	1·013	57·6	58·4
Ethyl Alcohol (pure) ..	0·79	6,540	51,800	220	8·97	1·065	56·6	60·3
Rectified Spirit (95 per cent.) ..	0·815	6,040	48,900	246	8·4	1·065	54·5	58·0

Power Development in Motors

The development of power in motors depends a good deal upon the construction and working of the carburettor. The work of Ricardo, Hubendick and others has established the following facts and general relationships:—

(1) With most fuels, starting with low revolution speeds, the power developed at first rises quickly, reaches a maximum, and then falls down when the rate of revolution is still further increased.

(2) The maximum power is developed when the ratio of fuel to air is higher (4–6 per cent.) than that necessary for complete combustion.

(3) The maximum efficiency is obtained when the ratio of fuel to air is lower (about 4 per cent.) than the correct mixture.

(4) With alcohol the increase in power is very marked—much more than with petrol—amounting to nearly 10 per cent. with very rich mixtures.

(5) For smoothness and flexibility in running, multi-cylinder engines must be fed with mixtures slightly on the over-rich side.

Comparison of the Properties of Petrol and Alcohol-Petrol Mixed Fuel in Motor Car Engines.—Prof. Hubendick contributed a paper to the World Power Conference, London, 1928, on the 'Use of Ethyl Alcohol as Motor Fuel' (*Transactions*, 3, 724–48), based on the results of an exhaustive series of comparative experiments with petrol and petrol mixed with varying amounts of alcohol. For each mixture, the effect and the consumption of fuel per horse-power-hour for different sizes of the carburettor jet were registered graphically. The following is a summarised extract of a part of his paper:—

"Series of experiments were carried out with undiluted gasoline and with gasoline mixed with 10, 15, 20, 25 per cent., etc., of alcohol; for each type of fuel, tests were made with different sizes of carburettor jets. The series of graphs obtained in this manner is very instructive. It shows that, with a minimum fuel consumption, the results of the experiments with undiluted gasoline and with gasoline containing 10, 15 and 20 per cent. of alcohol very nearly coincide. In reality, the heat consumption decreases slightly within the above limits, as the percentage of alcohol in the fuel increases, although the difference is very small. Hence in the case of a carburettor adjusted for use with gasoline, not more than 23 per cent. of alcohol must be present in the gasoline-alcohol mixture, if good results are to be obtained. This fact can be explained by assuming that the characteristic properties of the alcohol, do not exert themselves appreciably until the proportion of the alcohol has increased to 23 per cent. If the percentage of alcohol be still further increased, the physical properties of the alcohol commence to exert their influence, and it becomes necessary to readjust the carburettor. It may be mentioned that the results given above do not refer to those obtained on one engine only, but are entirely consistent with results obtained with different types of motors, showing only slight variations in actual quantities.

"Summarising, it has been shown that gasoline can be mixed with alcohol in such proportions that the mixture contains upto 25 per cent. of alcohol without this proving detrimental to its use as fuel for petrol engines. It is therefore possible to use such a mixture in these engines without taking special precautions, and to obtain with it results as good as those obtained when using gasoline. To verify this statement, tests have been made in automobile engines of different makes and running under climatic conditions unfavourable for the use of alcohol mixture, that is, at a low air temperature. These experiments have shown that the engine runs as well on such a mixture as it does on gasoline alone, and that the driver has been unable to say which fuel was being used."

Experiments performed by Lichty and Phelps at the Yale University, and published in the *Industrial and Engineering Chemistry,* February 1938, confirm in a general way these results obtained by Prof. Hubendick. They write as follows:—

"Applying the multicylinder power and fuel consumption data to motor vehicles on the highway, and using air-fuel ratios equal to or richer than maximum power for gasoline and without adjustment of air-fuel ratio on substitution of the 10 and 20 per cent. blends, a decrease in volumetric fuel consumption of about 2 and 3 per cent. for the 10 and 20 per cent. blends respectively, should be obtained."

The following table gives the results of the experiments:—

Comparative Road Tests with Petrol and Alcohol-Petrol Mixed Fuels

The only carefully conducted experiment done in India was by Mr. J. Charlton, Agricultural Chemist to Government of Burma (now Director of Agriculture). The following is extracted from the *Agricultural Survey Bulletin No. 24 of 1936,* Department of Agriculture, Burma:—

"Absolute alcohol-petrol fuels not being available in Burma, in January 1935 the writer prepared such mixture on a small scale in the laboratory and tested them in a 20.9 H.P. car using a special small tank, so that consumption could be accurately recorded. The carburettor had been previously adjusted for economy and was not altered in any way for the tests. A circular course of approximately eight miles was arranged to minimise wind resistance effects and as far as possible a steady speed of 25 m.p.h. was maintained. Results were as follows:—

	Miles per gallon	Equivalent to
(1) Burma Oil Company Petrol (Pump) ..	21.13	100
(2) 15 : 85 mixture ..	22.50	101.5
(3) 25 : 75 mixture ..	22.73	107.6

Maximum speed was in all cases 57 m.p.h. and no difference could be distinguished in

Brake Thermal Efficiencies (in per cent.) at Comparable Conditions.

Fuel	Maximum Power			Richest complete combustion		
	1,000 r.p.m.	2,000 r.p.m.	3,000 r.p.m.	1,000 r.p.m.	2,000 r.p.m.	3,000 r.p.m.
			Full Load			
Gasoline	20·3	21·4	19·6	22·8	24·0	22·0
10 per cent. Blend	20·7	21·2	19·7	23·2	24·4	21·5
20 per cent. Blend	21·4	22·0	20·0	24·0	24·8	22·2
			Two-thirds Load			
Gasoline	18·0	18·7	17·4	22·2	21·2	19·0
10 per cent. Blend	18·8	18·8	16·9	21·6	21·2	18·8
20 per cent. Blend	19·5	19·0	17·4	21·8	20·5	19·2
			One-third Load			
Gasoline	14·1	14·1	12·4	15·9	14·2	..
10 per cent. Blend	14·0	13·9	12·3	16·1	13·3	..
20 per cent. Blend	14·4	13·9	12·6	15·0	14·2	..

acceleration from 10–30 m.p.h. Speed and acceleration tests were mean results obtained by running in opposite directions. It was noticed that with the 25 : 75 mixture it was impossible to make the engine pink (detonation); the 15 : 85 mixture was almost free from tendency to pink while using petrol alone careless opening of the throttle caused severe pinking. The car had done a considerable mileage at the time of the test and was in need of decarbonisation and valve grinding. The greater economy of the alcohol-petrol mixtures was beyond all doubt and driving was very much simplified since pinking disappeared."

Excise Duty and Power Alcohol.—Under the new Government of India Act of 1935, the revenue from excise duty on petrol and on alcohol destined for power or industrial purposes goes to the Central Government, who at present are firm in their decision to levy the full amount of excise duty on power alcohol as on petrol. The Provincial Governments which are vitally interested in the development of the alcohol industry are therefore confronted with this serious question of competing with imported petrol *on equal terms*—a situation which is unique in the world history of power alcohol. However the recent decision of the Federal Court of India regarding the powers of the Provincial Legislature to impose a sales tax on motor spirits may help the cause of power alcohol in those provinces which are vitally interested in the question of finding an important and economically sound outlet for surplus molasses.

Conclusion

Some interesting information regarding power alcohol and its use in other countries are given below:—

1. *Comparative Prices of Power Alcohol in Various Countries in 1936*

(Tokayer, *World Petroleum*, June 7, 1936)

Country	Price of Power Alcohol per gallon	
	In American Cents	Equivalent in Indian Currency
		Rs. A. P.
1. Austria ..	57	1 10 3
2. Czechoslovakia ..	76	2 3 0
3. France ..	27	0 12 6
4. Germany ..	76	2 3 0
5. Hungary ..	79	2 4 4
6. Italy ..	88	2 8 6
7. Jugoslavia ..	40	1 2 5
8. Latvia ..	59	1 11 2
9. Poland ..	19	0 8 9
10. Spain ..	52	1 7 11
11. Sweden ..	31	0 14 3

2. *Consumption of Power Alcohol in Various Countries*

(*Ind. & Eng. Chem.*, News Edition, July 20, 1936)

Country	Year	Quantity in Imperial gallons	Remarks
1. Austria ..	1934	1,018,000	
2. Brazil ..	1935	10,455,000	65,472,780 in 1936
3. Cuba ..	1934	2,367,000	
4. Czechoslovakia ..	1934	13,190,000	
5. France ..	1934–35	81,524,000	
6. Germany ..	1936–37	40,121,000	
7. Hungary ..	1934	2,106,000	
8. Italy ..	1934	1,402,000	Rapid increase since 1934
9. Latvia ..	1934	1,350,000	
10. Poland ..	1934	1,700,000	
11. Spain ..	1935	2,400,000	
12. Sweden ..	1934	2,400,000	
13. United Kindgom	1935	1,242,000	

3. *Power Alcohol Plants Installed in Various Countries*

Country	Azeotropic Process*		Salt-Dehydration Process†	
	No.	Capacity per day	No.	Capacity per day
		(In Hectolitres)		(In Hectolitres)
1. Argentine ..	1	300	..	..
2. Australia ..	1	150	..	..
3. Austria ..	1	220	..	..
4. Belgium ..	3	400	..	..
5. Bulgaria ..	..	..	2	180
6. Brazil ..	13	2,750	3	190
7. Chili ..	2	120	..	..
8. Columbia ..	..	..	2	60
9. Czechoslovakia ..	24	3,236	14	1,360
10. Denmark ..	1	40	..	..
11. England ..	3	580	..	..
12. France ..	45	14,535	2	1,200
13. ,, Colonies ..	5	430	..	..
14. Germany ..	10	3,900	1	300
15. Holland ..	1	3	..	..
16. Hungary ..	6	700	..	..
17. Irish Free State	5	150	..	..
18. Italy ..	14	3,455	1	40
19. Lettonia ..	2	440	..	..
20. Lithuania ..	1	75	..	..
21. Panama ..	1	40	..	..
22. Poland ..	3	530	..	..
23. Portugal ..	1	60	..	..
24. South Africa ..	3	360	1	60
25. Spain ..	1	30	4	900
26. Sweden ..	1	30	2	180
27. Yugoslavia ..	5	425	2	280
Total ..	153	32,959	34	4,750

* Information available upto the end of 1936.
† Information available upto 1935.

4. *Alcohol-Petrol Mixed Fuels in Different Countries*

Country	Commercial name of the mixed fuel	Composition			Whether alcohol mixing is compulsory
		Petrol	Benzol	Alcohol	
1. Austria	..	..	80–60	20–40	Yes.
2. Australia ..	Shellkol	85	..	15	No.
3. Brazil	..	..	..	..	Yes.
4. Bulgaria	..	75–70	..	25–30	Law not enforced.
5. Chili	..	..	..	..	Yes.
6. Cuba	Mofuco	37	3	60	No, but favourable.
7. Czechoslovakia ..	Dynalkol (i)	80	..	20	..
	(ii)	70	4	26	Yes.
8. Denmark	..	75	..	25	No, but State monopoly.
9. England	Cleveland Discol	70	15	15	No, but favourable.
10. Equador	..	80	..	20	Yes.
11. France	..	Various Proportions			Yes, State monopoly.
12. Germany	Monopoline	Various Proportions			Yes, State monopoly.
13. Hungary	Motalko	80–70	..	20–30	Yes.
14. Italy	..	80	..	20	Yes.
15. Lettonia	Latol (i)	50	..	50*	
	(ii)	67	..	33†	Yes, State monopoly.
16. Lithuania	Motorin	75	..	25	Yes.
17. Natal	Natalite	50	..	50	No, but favourable.
18. Panama	..	80	..	20	No, but favourable.
19. Philippines ..	Gasenol	70	..	30	..
20. Poland	(i)	85–70	..	15–30 ‡	..
	(ii)	15–30	..	85–70 §	No, State monopoly.
21. Sweden	Lattbentyl	75	..	25	No, but favourable.
22. Yugoslavia ..	..	80	..	20	Legislation favourable.

* Summer Time Mixture. † Winter Time Mixture.
‡ For Motor Cars. § For Tractors.