ALCOHOL FOR MOTOR FUEL, THE "ALKO-TIPID" WAY*

by

Cmdr. PROTACIO, A.C., AFP**

ABSTRACT
The oil crisis of the 70's created renewed interest in the use of fuel alcohol despite operational and technical problems experienced by many countries the past 70 years. In the Philippines, this crisis motivated experiments which led to the development of alko-tipid. Significant properties of alcohol and gasoline provided design parameters for a simple vapor generating device working on engine vacuum evaporation, permitting the use of low grade alcohol, a renewable fuel, without the need for its dehydration nor any engine modification. Dynamometer and road tests confirmed significant reductions in fuel consumption, increased power and mileage, smoother and cleaner engine performance, and fuel cost savings of 20-25%. While alko-tipid could be a practical answer to the fuel crisis, the availability of alcohol is a temporary problem.

Introduction

Fuel alcohol has been used either wet or dry in spark-ignition engines. In the dry form, it is used with gasoline in 5-10 up to 20% blends. In whatever form or blends its use has been, technical reports and documents spanning three quarters of this century have these common findings:

1. The substitution of alcohol for gasoline requires larger metering jets to maintain the same percentage of the stoichiometric air for proper combustion or the same equivalence ratio.

2. The use of straight alcohol or alcohol-gasoline blends would cause a number of operating difficulties in existing automobiles especially in starting, acceleration, and vapor lock. Corrosion and gumming up of the fuel distribution system are also a messy consequence especially in the straight alcohol mode and requires frequent cleaning of the carburetor.

3. The improvement in anti-knock value (octane) and consequent efficiency when alcohol is added to gasoline (employing suitable design and operating condition) is less than the decrease in efficiency as measured by fuel consumption rate. The overall effect is an increased fuel consumption.

4. Alcohol-gasoline blends has no over-all technical advantage over gasoline; the increased fuel consumption of a 10% alcohol-gasoline blends is approximately 4% higher than gasoline alone based on both road and block tests.

5. The handling and shipment of alcohol-gasoline blends are difficult because of the ease with which these components separate when traces of water are introduced. It is difficult to keep water out of bulk or storage tanks, filling stations

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**Philippine Navy and Project Sta. Barbara, Office of the President tanks and motor car tanks. Water in blends will certainly cause phase separation and will adversely degrade engine performance.

The cost of alcohol-gasoline blends is much higher than gasoline alone. It requires additional costly steps and a penalty in the form of higher fuel consumption for its use:

1. Dehydration of alcohol is a capital intensive and costly process.
2. The blending process requires additional infrastructure and capital equipment.
3. Transportation and handling from distillery to blending depots and then to distribution outlets is another added cost.
4. Higher fuel consumption amounting to about 4% for every 10% alcohol blend means that much more added cost.

Despite these many shortcomings and operating difficulties, and as a consequence of the worsening oil crisis, several countries are turning to alcohol as a gasoline substitute depending on the economics and the politics of its use. Brazil has been using a gasoline-ethanol blend of 80-20 called "PROALCO" since 1935. In the United States of America, the blend is 90-10 called "GASOHOL" and is being used in a very limited program. In the Philippines, the blend is 90-10 called "ALCO-GAS". This was launched last September 11 in the province of Negros Occidental as an experimental program. The Brazilian experience revealed that blending ratios are limited to 20% ethanol, beyond this, engine performance will degrade noticeably.

Not contented with its "PROALCO", Brazil introduced in 1980 a 100% ethanol-burning motor vehicle designed to remedy the existing shortcomings and operating difficulties in the use of alcohol in the conventional gasoline engines. Essentially, this engine is the basic spark-ignition engine designed to burn hydrous alcohol (5% water) instead of gasoline. The compression ratio was increased from 8:1 to 11:1. The carburetor became smaller to provide a 9:1 air-fuel ratio instead of the standard 15:1 and was provided with electric heating coils for cold weather operations; the fuel distribution system was made alcohol resistant; and the valves (inlet and exhaust) were stellite-tipped for harder wearability. The engine starts on gasoline and a liter-size gasoline tank was added for this purpose. The engine obviously will not run on gasoline and neither will it run properly on low grade alcohol.

In the Philippines, hydrous alcohol has been used directly as fuel in gasoline engines as early as the 2nd decade of this century. Teodoro, et al published several experiments done at UP Los Baños in the '20s.[2] Blended gasoline popularly known as "GASONOL" was sold and used by motor vehicles specially bus lines during that period. Again during the 2nd World War when petroleum supply was cut off, alcohol was used as motor fuel in the country. Very recently, as a consequence of the oil crisis, there were several devices that were introduced in the market basically utilizing the gasoline carburetor principle in directly inducting/injecting manifold. Alko-tipid, an energy-efficient device, does it differently however. Alko-tipid is an acronym of the words alcohol and tipid (thrift). It is essentially a vapor generating device for volatile liquids such as alcohol and the like through which air is aspirated by engine vacuum and thoroughly mixed with the vapor generated therein and directly introduced into the intake manifold of the engine, as supplemental fuel with the atomized gasoline in a dual fuel mode. It is a simple add-on device without the need for any engine adjustment and will permit immediate reversion to an all gasoline fuel mode by simply closing a cut-out valve should the alcohol fuel run out.

Early Experiments

Alko-tipid experiments started in April 1979 by a group of Filipino research engineers, in Cavite City, while exploring various possibilities of improving fuel economy and engine performance in response to the worsening fuel crisis. One of the initial tests involved the aspiration of intake air and bubbling it through ethanol in a dextrose bottle and leading it directly into the intake manifold immediately under the standard gasoline carburetor.

A Colt Galant 1975 vintage properly tuned and adjusted on gasoline fuel was used as a test vehicle. Surprisingly, a ten per cent increase in mileage were consistently realized. Excellent power, acceleration, and roadability were noted. Significantly, a little amount of liquid always remained at the bottom of the dextrose bottle refusing to be evaporated. Tests indicated that this remaining liquid was water. Condensation of moisture in the air outside the dextrose bottle was also observed. Immediately, laboratory tests were conducted to measure different parameters in a stationary engine. A 7-kw gasoline engine driven electric generator was used in this test.

A base data for an all-gasoline fuel run was first established. This was followed by a run using ethanol as a supplementary fuel with the intake air bubbled through it. Another run was made with the intake air skimming over the fuel ethanol with turbulence induced, followed by a similar run without turbulence. Air and fuel flow rates were computed. Significant comparative data are shown in Table 1.

Results were consistent on the ability of fuel ethanol to displace a bigger volume of gasoline up to one and a half times its volume utilization for the same power output as in the all gasoline fuel run. The temperature of liquid ethanol inside the vaporizing tank decreased to about 18.5°C and condensation of moisture in the air started to form outside the tank within a few minutes after the start of the test. Significantly, the volume of water remaining in the vaporizing tank was consistently greater than its original amount in ethanol at the start of the test. The moisture in the intake air was condensed inside the evaporating tank, accounting for the greater volume (.2795 l) of water remaining than the original water content (.1193 l) in alcohol in the bubbling test. The concentration of alcohol progressively decreased to 57% without degradation in power output.

Evidently low concentration and low grade alcohol could be as good a fuel as any. In some demonstration runs, fuel ethanol was diluted with 20-50% water and the car did still run. Even "lambanog" (a 45% alcohol drink), distilled from fermented coconut flower nectar has been used satisfactorily. The tank has to be drained of water more often when using dilute fuels however.

The design of a prototype system was the next step after these very informative experiments. An examination and comparison of the fuel properties of gasoline and ethanol provided some practical insights into combustion, design, and installation requirements. Fuel economy was a primarily design objective for it was recognized that while gasoline substitution alone is a very important national goal, positive fuel savings must be realized to enable the user of the device to recoup his investments.

Gasoline-Ethanol Fuel Properties

Table 2 shows the marked differences in several significant properties between ethanol and gasoline.

1. Different stoichiometric air to fuel ratio, gasoline being typically 15:1 while ethanol is 9:1. Ethanol will therefore require about 40% less air than gasoline for complete combustion; a separate carburetion system is therefore indicated.

2. Gasoline and ethanol have different energy values and the fuel of lower heating value will deliver less work per volume under the same operating conditions. Based on their heating values therefore, it would require 1.6 times as much alcohol by weight to do the same amount of work for an equivalent quantity of gasoline. Under different operating conditions however, this is not necessarily so. Combustion systems efficiency as an inherent carburetion design feature to which the particular fuel characteristics lends itself could make a big difference.

3. In comparison with gasoline, ethanol requires nearly 2.85 times more heat for vaporization than gasoline. This explains the poor performance of alcohol used in existing carburetors designed for gasoline. Not all of the atomized alcohol inducted into the combustion chamber is vaporized and therefore does not burn and is simply wasted. A separate vaporization tank working under engine vacuum could be designed to completely evaporate the alcohol. Ethanol however has a greater evaporative cooling effect which reduces the charge temperature and thus improves the engine volumetric efficiency.

4. **Volatility is another important factor in determining the amount of fuel which will vaporize. Gasoline possesses a rising volatility curve, its boiling point ranging from 35° – 200°C, whereas ethanol has a flat curve at 65°C.**

Complete vaporization of ethanol will therefore be easier to attain; combustion efficiency can be easier achieved and under vacuum conditions, volatility is further enhanced. Gasoline however has an advantage with the light components with boiling points of 35°C which are essential for severe cold starting of spark-ignition engines.

5. Hydrous alcohol specially secondary alcohol is more corrosive to some metals than gasoline. Using anodized aluminum and synthetic rubber will solve this problem.

Table 3 shows the composition of ethyl alcohol-water azeotrope at different pressure.

Note the pronounced effect of pressure on azeotropic composition: at 70 mm Hg, absolute alcohol boils at about 28°C and a complete separation of ethanol and water could theoretically be attained. Alcohol however need not be heated to boiling temperature to evaporate. Evaporation goes on at all temperatures and continues until the liquid disappears or until the space above the liquid has been saturated with vapor. Under vacuum in the internal combustion therefore, the affinity of water with alcohol is progressively decreased. Engine piston displacement creates a vacuum in the internal combustion engine; maximum vacuum when throttle is closed and minimum vacuum when throttle is fully open. Engine vacuum therefore is a very handy and inexpensive means of separating water from low grade alcohol and a separate vaporizing tank provided an innovative answer. The experimental runs show that indeed water is left behind at the bottom of the vaporizing tank to include water moisture that condensed from the intake air greatly enhancing charge efficiencies and consequently engine performance.

Obviously, the design requirements for the correct combustion of each fuel differs significantly. Operating difficulties in present ethanol fuel systems stem mainly in using this fuel in a carburetor designed for gasoline. In contrast the alko-tipid system is designed to operate independent of the gasoline fuel and carburetion system in all dual fuel mode or a 100% straight hydrous alcohol fuel utilization.

The Alko-Tipid System

The system in the dual fuel mode is composed of five major components: an alcohol vaporizing tank 2 having an alco vapor-air control valve 3, a backfire suppresor component 4, a manual control valve 5, and an alcohol tank 6 in communication with vaporizing tank 2.

ALCOHOL VAPORIZING TANK 2

The alcohol vaporizing tank 2 is basically an enclosed container having an inlet port 6, and an outlet port 8, an alcohol fuel inlet port 9, a pressure release valve 10, and a drain port 11 provided with a manual or a solenoid drain valve 12. Low grade alcohol fuel is maintained at a certain level in tank by a standard float valve. Under ordinary atmospheric pressure, there exist inside tank 2 a minor evaporation of the liquid alcohol that is limited by the equalizing pressure inside the closed tank 2. When a slight suction pressure is applied to tank 2, the surface tension of the liquid alcohol becomes low and more evaporation of the alcohol follows. The temperature of the liquid is decreased to as low as 18.5°C at strong vacuum conditions and or after a few minutes of operation suppressing the evaporation of water and even causing the condensation of water vapor in the intake air. Engine piston displacement develops the vacuum and sucks in air which is allowed to skim, splash or bubble through the liquid alcohol thereby increasing the surface area whereby the liquid can fully evaporate. Under these conditions, the air and alcohol vapor are mixed in combustible proportion as it is sucked into the engine intake manifold. Under reduced pressure-temperature condition, the heat of evaporation of alcohol is also reduced correspondingly such that ambient heat of the alcohol and air in the engine hood can provide sufficient heat for evaporation at low levels of alcohol utilization (10-30%) resulting thereby in a higher evaporation efficiency. Installing the vaporizing tank 2 adjacent to or above the exhaust manifold will provide additional heat that will enhance evaporation efficiency further. At higher alcohol utilization, engine cooling water leak-off in a small line to the bottom of the vaporizing tank will be adequate to provide supplementary heat to evaporate the alcohol as efficiency. During operation, the hydrous alcohol will be depleted of its volatile components and after a certain period, the liquid in tank 2 will be mostly water which is then discharged out from tank 2 by means of the manual or solenoid drain valve 12. The vaporizing tank serves as an excellent filtering medium as well – all the dust and grime that passed through the regular air filter including the colloidal impurities in the alcohol is trapped inside the tank and has to be cleaned out periodically.

ALCO VAPOR-AIR CONTROL VALVE 3

This component provides the necessary control either through vacuum leak by-pass actuation (constructed as a flexing diaphragm type, a plunger type, a ball type valve) or by a magnetic solenoid valve that can be actuated by a micro-switch located at the accelerator pedal of the vehicle. This permits fuel economy by allowing the air alcohol vapor mixture into the intake manifold only when it is needed. Pneumatic control through vacuum leak by-pass however, suffers from an inherent characteristic of shutting off the alco vapor-air mixture during acceleration and at high rpm when the vacuum is greatly reduced.

On the other hand, the solenoid controlled valve maintains the alco vapor-air line open to the inlet manifold so long as the throttle pedal is depressed. It closes automatically when the accelerator is released. Through this arrangement the engine will start and idle on gasoline and will respond to acceleration and decceleration demands almost instantaneously.

BACKFIRE SUPPRESSOR 4

This component protects vaporizing tank 2 from explosion in very rare cases when an engine backfire develops. The suppresor is essentially a wire mesh screen to stop (absorp) any flame from the engine backfire to propagate into and initiate an explosion in the vaporizing tank. The suppressor is connected in series with tank 2 and the manual control valve 5.

MANUAL CONTROL VALVE 5

A manually operated cut-out valve before the intake manifold permits the engine to operate on 100% gasoline when the alcohol fuel runs empty.

ALCOHOL FUEL TANK 6

Flexible lines connect fuel tank 6 through a manual control valve and a filter element to vaporizing tank 2.

Dynamometer and Road Tests

Dynamometer tests at the Delta Motor Plant on September 17, 1979, demonstrated alko-tipid's superior performance in terms of economy and power.

At 240 mm throttle opening (normal driving condition) using premium gasoline, the following were the averaged performance data:

Fuel Savings (Vol)	10.52%
Alcohol (ethanol 95%) Utilization (Vol)	23.33%

Gasoline Displaced (Vol)	30.16%
Torque Increased	9.50%
Horsepower Increased	9.52%

Hydrocarbon and carbon monoxide emissions are within allowable government limits.

Road Tests Data

Highway and city driving road tests indicated higher fuel savings, alcohol utilization, and gasoline displacement as shown in Table 4.

Technical and Economic Advantages

Alko-tipid eliminated the shortcomings and operating difficulties normally encountered in other methods of using motive alcohol. Technical and economic advantages are:

1. Smoother engine performance at low and high speeds at varying loads.
2. Greater volume of gasoline displaced than volume of alcohol utilized for the same mileage.
3. Cleaner combustion performance resulted in cleaner spark plugs, engine cylinders, and exhaust emissions.
4. Cooler engine temperatures resulted in better and longer lube oil performance and permitted higher engine speeds.
5. Higher octane rating of ethanol allowed the use of regular gasoline with resultant cost savings.
6. Renewable and indigenous fuel source.

Substantial savings

Substantial savings in fuel bills by as much as 20-25% has been attained. In terms of peso savings, this amounted to one peso per liter of fuel consumed at current prices.

Alko-tipid is now installed in more than 150 motor vehicles of over 40 different models and types: cars, jeeps, trucks, motorcycles, etc., to include stationary gasoline engine driven electric generator sets. While the device is now ready for mass production and proliferation, the availability of alcohol in sufficient quantities remains as the major problem.

Other Possibilities

A 100% straight hydrous alcohol configuration has a more complex vaporizing tank design. All the intake air is aspirated through this tank over the gasoline carburetor into the intake manifold. Normal throttle control by the accelerator pedal is maintained.

Experimental runs on gasoline engines using kerosene or coconut oil blended with either diesel fuel or gasoline, or diesel fuel blended with gasoline combined with the dual-fuel alko-tipid device is a very interesting and promising development.

Conclusion

Alko-tipid is basically a vapor generating device for volatile liquids. It is simple, reliable and economical. With it, even low grade alcohol can now be used directly without the need for its dehydration nor the necessity for modification or redesign of the spark-ignition engine as has been done in the past on higher grade alcohol. More than anything else, fuel rate consumption was significantly reduced while power and mileage was inversely increased, with smoother and cleaner engine performance, and a cost savings of 20-25% at current fuel prices. While the alko-tipid could be a practical answer to the motor fuel crisis of this decade, the availability of alcohol is a temporary problem.

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Table 1

Significant comparative data on engine performance test using the alko-tipid device

Run number and condition (1 hr. duration)	Load kwh	Fuel consumed liter/kwh			Fuel savings		Gasoline displaced by E+OH ltr/kwh	Ratio of gasoline displaced to E+OH used	Amt. of 94.% E+OH measured during test			E+OH remaining after test			Amt. of H_2O entering with air in A-T vapor tank (derived from humidity measurements), liter
		Gasoline	E+OH	Total	ltrs kwh	%			In A-T vapor tank (L)	added during test (L)	Total water content (L)	Vol. (L)	Conc %	Water content (L)	
I															
1. Without A-T device	6.6	1.003	-	-	-	-	-	-	-	-	-	-	-	-	-
2. With A-T device bubbling	6.6	0.666	0.376	0.941	0.062	6.18	0.337	1.225	0.870	1.339	0.1193	0.650	57	0.2795	0.5495
3. With A-T skimming with turbulence	6.6	0.679	0.242	0.921	0.082	8.18	0.324	1.339	0.870	1.179	0.1106	0.700	57	0.3225	0.5557
4. With A-T skimming withouth turbulence	6.6	0.662	0.241	0.903	0.100	9.97	0.341	1.415	0.800	1.350	0.129*	0.740	64.9	0.260	0.5752

*Alcohol used is 94% E+OH

Table 2

Selected properties of gasoline and ethanol.

	Typical gasoline	Ethanol	Ratio
Stoichiometer Air and Fuel Ratio	14.6	9.0	0.61
Combustion Heat Btu/lb	21,773	12,780	0.59
Heat of Vaporization Btu/lb	129	360	2.85
Boiling Temperature, °C	35-200	78	
Water Miscibility	NII	Infinite	

Table 3

Composition of ethyl + alcohol – water azeotrope at different pressure – temperature

Vapor Pressure		Boiling Temperature		% H_2O in Azeotrope
Inc Hg	mm Hg	°C	°F	Wi %
0.039	1	−31.3	−24.3	–
0.20	5	−12.0	10.4	+
0.39	10	−2.3	27.66	-
0.79	20	+8	46.4	-
1.57	40	19.0	66.2	--
2.36	60	26.0	78.8	–
2.75	70	28.0	82.4	0
3.15	80	31.0	87.9	0.24
3.54	90	33.0	91.4	0.48
3.93	100	34.9	94.8	0.80
5.00	127	38.4	101.1	1.40
7.87	200	48.4	119.1	2.70
10.00	254	52.8	127.0	3.08
11.80	300	56.4	133.5	3.32
15.00	381	62.0	143.6	3.66
15.74	400	63.5	146.3	3.72
19.67	500	66.2	154.8	4.00
20.00	509	68.8	155.5	4.02
23.61	600	72.8	163.0	4.20
25.00	636	74.0	165.2	4.26
29.9	760	78.4	173.1	4.45

Derived from Chemical Engineers Handbook by John H. Perry, 3rd Edition.

Table 4

Highway and city driving road test data.
Test vehicle – Toyota Mini-Cruiser (12R engine 1600cc)
(Average data from Oct.-Dec. 1979)

A. Highway Driving			B. City Driving	
W/o Device	W/ Device	Conditions	W/o Device	W/ Device
80 kph	80 kph	Average Speed	50 kph	50 kph
102 km	102 km	Distance Covered	70.2 km	70.2 km
		Fuel Consumed (ltrs)		
10.63 (Prem)	7.18 (Reg)	Gasoline	8.78 (Prem)	5.62 (Reg)
———	2.56	Alcohol	———	1.94
10.63 ltrs	9.74 ltrs	Total	8.78 ltrs	7.56 ltrs
9.59 km/1	10.47 km/1	Mileage	7.99 km/1	9.28 km/1

% Gasoline Displaced (Vol)	– 32.4%	% Gasoline Displaced (Vol)	– 35.9%
% Alcohol Utilization (Vol)	– 26.2%	% Alcohol Utilization (Vol)	– 25.7%
% Fuel Savings (Vol)	– 8.4%	% Fuel Savings (Vol)	– 13.9%

Test Vehicle — 1974 Colt Galant (Saturn Engine 1600cc)
(Average data from Oct.-Dec. 1979)

A. Highway Driving			B. City Driving	
W/o Device	W/Device	Conditions	W/o Device	W/ Device
80 kph	80 kph	Average Speed	50 kph	50 kph
102 km	102 km	Distance Covered	70.2 km	70.2 km
		Fuel Consumed (ltrs)		
6.84 (Prem)	5.10 (Reg)	Gasoline	5.73 (Prem)	4.35 (Reg)
—	1.12	Alcohol	—	0.68
6.84 ltrs	6.22 ltrs	Total	5.73 ltrs	5.03 ltrs
14.9 km/1	16.30 km/1	Mileage	12.25 km/1	13.95 km/1

% Gasoline Displaced (Vol)	— 25.4%	% Gasoline Displaced (Vol)	— 24.1%
% Alcohol Utilization (Vol)	— 18.0%	% Alcohol Utilization (Vol)	— 13.5%
% Fuel Savings (Vol)	— 9.1%	% Fuel Savings (Vol)	— 12.2%

NOTE:

1) The peso savings is much greater than the computed volume savings. At gasoline prices of ₱4.%/ (Prem)/₱4.50 (Reg) per liter, these savings will amount to 20-25%. (Denatured Alcohol—₱3.00 per liter).

2) Graduated translucent 20 liter containers for gasoline and alcohol fuel were used in these tests.