PERFORMANCE TESTS ON A MODIFIED VEHICLE FUELED WITH A HYDROUS ALCOHOL-GASOLINE BLEND

by

Ibarra E. Cruz*

INTRODUCTION

In a Final Report on a research project funded by PCIERD on the Production, Usage and Determination of Long-Term Technical Viability of an Alcohol-Gasoline Blend (ALGAS) as Fuel for Motor Vehicles, among the conclusions made was the following:

> Technically, Algas fuel (50% regular gasoline, 48% hydrous alcohol and 2% additive) when used in unmodified stock cars exhibited comparable and sometimes slightly improved thermal efficiencies except in very low compression-ratio engines such as the Willys Jeep engine. Full potential of significant increases in thermal efficiencies can be attained by increasing the engine compression ratio to take advantage of the high octane rating of Algas.

Among the recommendations of the report are the following:

1 Since the ultimate national objective is to use straight hydrous alcohol in cars (with high compression ratio engines) designed to run on this fuel, it is recommended to start Algas fuel road and dynamometer tests on modified stock cars (with increased compression ratio) and later on, to monitor performance of modified vehicles on straight hydrous alcohol.

2. As a transition to future nation-wide use of straight hydrous alcohol, it is recommended to allow limited marketing of Algas for use in specified models of vehicles which have exhibited compatibility to this fuel as reported in past experiments, on condition that (a) proven precautions should be observed to prevent operational problems (such as initial and thorough cleaning of fuel tanks of old vehicles; replacement of alcohol-incompatible materials in the fuel system; correct sizing of the carburetor jets; etc.); (b) close monitoring of Algas users should be implemented; and (c) quick assistance should be provided to those who would experience problems.

---

* Chairman, Department of Mechanical Engineering, University of the Philippines

OBJECTIVES

The objectives of this project are:

1. To improve the performance of a·commercial gasoline engine when run on an alcohol-gasoline blend by increasing its compression ratio.

2. To compare the performance of the engine before and after modification by chassis dynamometer tests.

3. To conduct a limited road test on the modified engine.

SIGNIFICANCE

The Philippines is still heavily dependent on imported petroleum-based fuel for transport. A number of alternative fuels (e.g. anhydrous alcohol blended with gasoline; coconut oil blended with diesel; producer gas from charcoal) have been studied and demonstrated in pilot areas or in fleet tests, but the unfavorable economics is a big deterrent in the widespread use of these alternatives. Anhydrous alcohol, for example is more expensive than gasoline at present. To improve the economics of using alcohol, hydrous alchohol (containing 7% water) blended with gasoline has been demonstrated to be technically feasible. The full potential of improving engine performance with the use of alcohol blends, however, has not been realized because commercial engines have been designed to run on petroleum-based fuel thus limiting the engine compression ratio to levels which would prevent engine knock on gasoline. The advantage of high octane number in alcohol fuel blends could be fully exploited by designing engines with compression ratios higher than normal. Commercially-available engines can easily be modified to increase their compression ratios. In this project, one such engine was modified to increase its compression ratio and the extent to which engine efficiency improved was measured.

METHODOLOGY

The activities undertaken were as follows:

1. An engine with an inherently low compression ratio (Willys jeep engine) was chosen as the test engine.

2. The performance of the unmodified engine (thermal efficiency versus load) was measured in a chassis dynamometer when using gasoline and the alcohol blend as fuels.

3. The engine was modified by changing the cylinder head so that the clearance volume of the cylinders when the pistons are at their Top Dead Center (TDC) positions were reduced. The reduction was estimated such that the resulting compression ratio would not give rise to engine knock when the alcohol-fuel blend was used.

4. The performance of the modified engine was compared when using the alcohol fuel blend with that obtained in Step 2 with the unmodified engine.

5. Road tests were conducted to confirm results obtained from the chassis dynamometer tests.

EXPERIMENTAL

The Willys Jeep engine was chosen as the experimental vehicle for the reason that it has a low-compression engine, is readily available at the M.E. Power Laboratory and could be rehabilitated at minimum cost. The compression ratio of the engine was measured by obtaining the piston displacement and the volume of the space above the piston at top dead center (TDC) position. A practical method of measuring piston displacement was by filling up the engine cylinder with oil when the piston was at bottom dead center (BDC) position and noting the volume of oil used. The volume above the piston at TDC was likewise measured by removing the cylinder head wih the gasket and spark plugs attached to it, and filling the space in the cylinder head with oil up to the level of the gasket. It was noted that at TDC, the piston and valve surfaces were flush with the cylinder block surface. Therefore, the volume above the piston at TDC is equal to the volume in the cylinder head. Appendix 1 shows the calculations made to determine the compression ratio.

The compression ratio of the engine was increased by machining off a given thickness from the cylinder head surface. Appendix 1 also shows the approximate thickness to be machined off to obtain a desired compression ratio. Thus, by shaving and grinding off about 1 millimiter thickness from the cylinder head, the compression ratio of the Willys jeep engine was increased; the first time from 6.19 to 6.75; the second time from 6.75 to 6.92.

The jeep engine performance at the above compression ratios was then determined by means of chassis dynamometer tests. Two alcohol blends were used:

1. Percent by weight 50% regular gasoline, 50% hydrous alcohol with a gross heating value of 16,683 Btu/lb and a specific gravity of 0.745.;

2. An alcohol-gasoline blend supplied by Mr. Rudy Lantano called "Algas" with a gross heating value of 14,997 Btu/lb and a specific gravity of 0.764.

The specific gravity of the hydrous alcohol used was 0.800 compared to pure ethyl alcohol which is 0.794 at 15.5^{o}C. It is estimated that hydrous alcohol contains about 5% water with a gross heating value of 12,130 Btu/lb.

RESULTS

The results of the chassis dynamometer tests of the Willys jeep at various wheel power and at a constant speed of 60 kilometers per hour are shown graphically in Figures 1, 2, 3 and 4. Figure 1 compares the performance between compression ratio (CR) = 6.19 and CR = 6.75 when using alcohol-gasoline blend of 50%-50% by volume. Figure 2 compares the performance when the alcohol-gasoline blend was 50%-50% by weight. It is evident that there is a significant improvement in performance (increase in thermal efficiency) as a result of increasing the compression ratio.

Figure 3 compares the performance of the modified engine at CR = 6.75 when using the alcohol blend with that when using premium gasoline. It is shown that the thermal efficiency was higher for premium gasoline than for the alcohol blend. This indicates that increasing the compression ratio from 6.19 to 6.75 did not result in engine knock even with premium gasoline. It was possible to raise the compression ratio still some more. Care was taken however not to increase it too much lest the clearance between the engine valves and the cylinder head disappear and cause the valves to hit the cylinder head. The compression ratio was increased for the second time from 6.75 to 6.92.

Figure 4 compares the performance of the engine corresponding to compression ratios of 6.19, 6.75 and 6.92 respectively. It is evident that there is a consistent increase in thermal efficiency with increase in compression ratio. To confirm these results, road test data were taken at CR = 6.75 and CR = 6.92, data for which are shown in Tables 1 and 2 respectively. These were compared with the road test data at the original compression ratio (CR = 6.19).

Table 3 summarizes the road test data at CR = 6.19 and alcohol - gasoline fuel blend of 50%-50% by volume. The performance was expressed in kilometers per liter of fuel blend (km/1) and the average was 3.64 km/1.

Table 1 combines the road test results for CR = 6.75 and CR = 6.92 when using alcohol-gasoline blend of 50%-50% by weight. The average performance was 3.71 km/1 at the higher CR's which was only slightly higher than 3.64 km/1 for the lower CR. Although admittedly road conditions could have been widely different during the tests, it was observed that in the first 3 sets of data for CR = 6.75, the fuel economy were consistently lower than 3.64 km/1 which was the average performance when CR was 6.19. Close inspection of the fuel system led to the discovery of a leak in the fuel tank. The leak was fixed and the next 2 sets of data for CR = 6.75 showed an average fuel economy of 4.46 km/1 which is now significantly better than for CR = 6.19.

Table 2 shows the road test data for CR = 6.92 only. For a total distance travelled of 1092 kilometers accumulated in a series of short trips, the fuel economy averaged 4.04 k/1 which is lower than that for CR = 6.75 which was 4.46 km/1. This seeming inconsistency may be explained by the fact that the total distance travelled at CR = 6.75 was only 658 kilometers which included a couple of long-distance trips.

CONCLUSIONS

Dynamometer tests consistently showed that increasing the compression ratio of the Willys jeep engine improved the thermal efficiency or fuel economy. This was supported by the results of the road tests although results were not as consistent as in the dynamometer tests. The inconsistency may be explained by varying road conditions and distances travelled by the vehicle during the road tests.

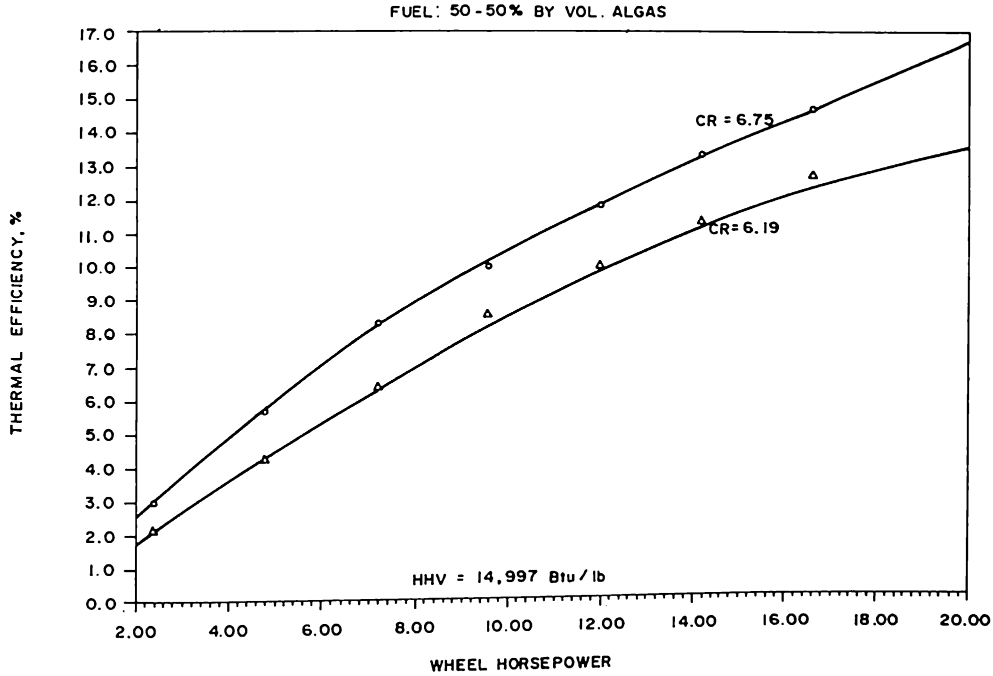

Figure 1 CHASSIS DYNAMOMETER TEST OF WILLYS JEEP

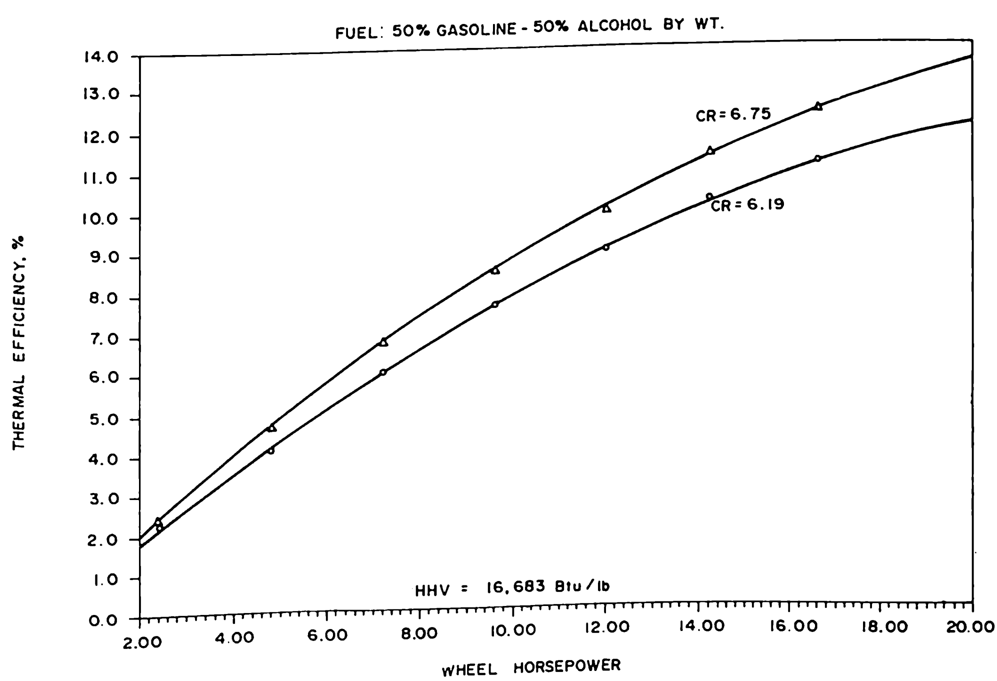

Figure 2 CHASSIS DYNAMOMETER TEST OF WILLYS JEEP

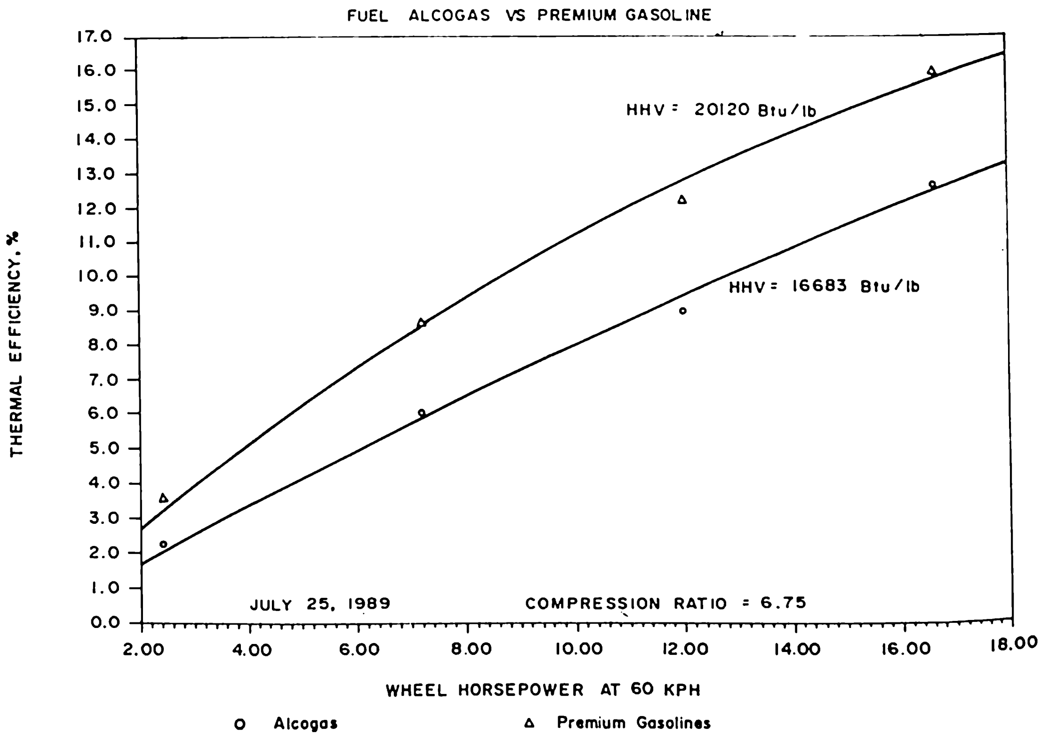

Figure 3 CHASSIS DYNAMOMETER TEST OF WILLYS JEEP

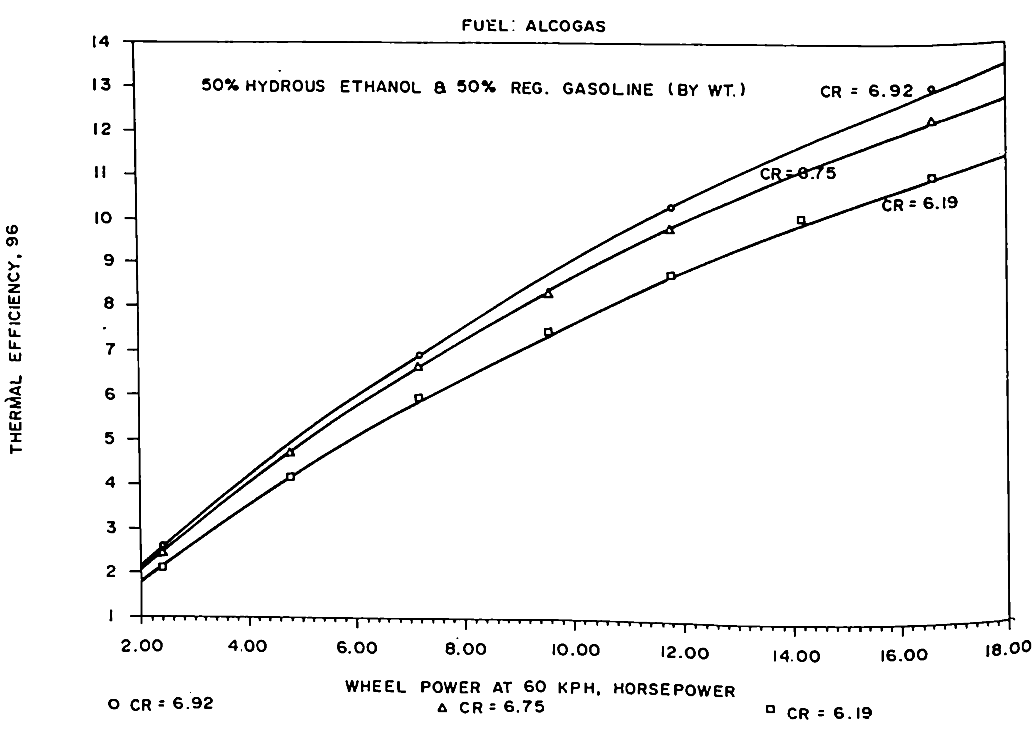

Figure 4 WILLYS JEEP CHASSIS DYNAMOMETER TESTS

APPENDIX I

Table 1. Data in the Measurement of Compression Ratio

Cylinder No.	1	2	3	4
Volume above Piston at BDC, milliliters	545	545	545	545
Volume above Piston at TDC, milliliters	105	105	105	105

Let volume above piston at TDC = V_1
volume above piston at BDC = $V_1 + V_2$

Compression Ratio, CR = V_2/V_1 = $(545 + V_1)/V_1$

or

$V_1 = 545/(CR - 1)$

Cross-sectional area (A_1) of section of combustion chamber at cylinder head surface was measured by a polar planimeter to be equal to 14.48 sq. in. or 93.40 sq. cm.; therefore the thickness to be shaved off the cylinder head surface to give a desired CR estimated as:

Thickness = $(105 - V_1)/A_1 * 10$ millimeters.

Table 2. Thickness to Machined Off Cylinder Head Surface

CR	6.25	6.50	6.75	7.00
V_1, ml.	103.8	99.1	94.8	90.8
Thickness, mm.	0.13	0.63	1.09	1.50

TABLE 1

PERFORMANCE OF TEST VEHICLE (BROWN ARMY JEEP PLATE NO. SBB-725 USING ALGAS FUEL

Date	Kilometers	Liters	Km/Liter	Places Events
06/01/1989	231.00	69.53	3.32	Metro Manila CR = 6.75, U.P. mix
06/14/1989	354.40	103.10	3.44	Metro Manila
07/03/1989	196.40	81.17	2.42	Metro Manila CR = 6.75, U.P. mix
07/11/1989	184.20	59.81	3.08	Metro Manila CR = 6.75, U.P. mix
07/31/1989	485.30	102.14	4.75	Metro Manila Fuel tank leakage fixed
08/08/1989	172.50	45.45	3.80	Metro Manila CR = 6.75, U.P. mix
08/14/1989	178.60	43.77	4.08	Metro Manila CR = 6.92
08/22/1988	178.00	42.04	4.23	Metro Manila CR = 6.92
08/25/1989	223.90	51.59	4.34	Metro Manila CR = 6.92
08/31/1989	135.80	35.01	3.88	Metro Manila CR = 6.92
09/11/1989	162.10	43.77	3.72	Metro Manila CR = 6.92
09/25/1989	213.70	53.99	3.96	Metro Manila CR = 6.92
TOTAL	2715.90	731.37		
MINIMUM	135.80	35.01	2.42	
MAXIMUM	485.30	103.10	4.75	
AVERAGE			3.75	

TABLE 2

PERFORMANCE OF TEST VEHICLE (BROWN ARMY JEEP PLATE NO. SBB-725 USING ALGAS FUEL

Date	Kilometers	Liters	Km/Liter	Places Events
08/14/1989	178.60	43.77	4.08	Metro Manila CR = 6.92
08/22/1989	178.00	42.04	4.23	Metro Manila CR = 6.92
08/25/1989	223.90	51.59	4.34	Metro Manila CR = 6.92
08/31/1989	135.80	35.01	3.88	Metro Manila CR = 6.92
09/11/1989	162.10	43.77	3.72	Metro Manila CR = 6.92
09/25/1989	213.70	53.99	3.96	Metro Manila CR = 6.92
TOTAL	1092.10	270.17		
MINIMUM	135.80	35.01	3.72	
MAXIMUM	223.90	53.99	4.34	
AVERAGE			4.04	

TABLE 3

PERFORMANCE OF TEST VEHICLE (BROWN ARMY JEEP PLATE NO. SBB-725 USING ALGAS FUEL

Date	Kilometers	Liters	Km/Liter	Places Events
08/03/1988	336.45	90.73	3.74	Metro Manila
08/12/1988	159.00	46.23	3.44	Metro Manila
08/22/1988	134.65	37.83	3.56	Metro Manila
08/25/1988	170.75	50.46	3.38	Metro Manila
09/02/1988	199.30	53.58	3.72	Metro Manila
09/07/1988	190.10	49.07	3.87	Metro Manila
09/14/1988	110.20	35.95	3.07	Metro Manila
09/19/1988	164.60	45.32	3.63	Metro Manila
09/23/1988	198.65	53.59	3.71	Metro Manila
10/03/1988	190.95	53.93	3.36	Metro Manila
10/03/1988	180.95	53.93	3.36	Metro Manila
10/06/1988	221.90	61.94	3.58	Metro Manila
10/12/1988	123.00	48.81	3.54	Metro Manila
10/19/1988	218.95	46.51	4.71	Metro Manila
11/07/1988	104.10	32.01	3.25	Metro Manila
11/16/1988	126.30	41.72	3.03	Metro Manila
11/21/1988	168.50	38.00	4.43	Metro Manila
12/01/1988	165.35	43.18	3.83	Metro Manila
12/07/1988	209.80	50.13	4.19	Metro Manila
12/15/1988	126.80	44.32	3.07	Metro Manila
12/21/1988	142.40	39.47	3.61	Metro Manila
TOTAL	3692.70	1013.72	3692.7/1013.72 = 3.64 KM/1.	
MIMIMUM	104.10	32.01	3.03	
MAXIMUM	336.45	90.73	4.71	
AVERAGE			3.62	