Ethanol VW Report 21 – Economic Summary (Old tires) Gary W. Johnson 5-07-07

Objective / Purpose

The overall objective of this experiment is to demonstrate that this type of equipment can successfully be operated on E-85 ethanol blend fuel instead of gasoline. The objective of this report is to summarize all data obtained to date for "Configuration 4" on E-85 ethanol, with the old 165R15 tires. The ultimate technical objective is to compare in a traceable manner both power and fuel economy on ethanol with the gasoline baseline.

Equipment

The equipment was a 1973-vintage Volkswagen Type 1 standard "beetle" in more-or-less factory configuration. The vehicle is fitted with an intake manifold vacuum gage, and the trigger and power wires for a tachometer. "Configuration 4" comprises the 30 PICT-2 carburetor rigged stock for gasoline, and the same unit re-jetted for ethanol, plus extra intake air preheat, and the timing reset from 30 BTDC all-in to 45 BTDC all-in, on a Bosch 009 aftermarket distributor. No modifications whatsoever were made to compression ratio or valve timing. The total cost of these modifications was $0 out of pocket, plus some labor hours on this investigator's part.

Theory

Overall, this type of conversion need only address three specific issues: (1) metering ratio of the fuel, (2) cold start capability, and (3) materials compatibility concerns.

However, this particular experiment was aimed at obtaining quantitative data for power and economy. Economy (fuel mileage) is determined from a straightforward fuel mileage log kept over a long period of time on a specific and repeatable driving cycle. Relative power performance can be obtained from carefully calibrated intake vacuum measurements, and can confirm that the carburetor re-jetting is appropriate, if results are similar to those from mileage.

Given adequate octane rating to prevent knock, there is no effect of gasoline grade upon efficiency and fuel mileage (miles per gallon, "mpg"). This particular test vehicle does not knock on 87 pump octane grade unleaded regular (ULR). There is, therefore, no effect except fuel cost per gallon upon fuel cost per mile for mid-grade (MG) and premium grade (Prem).

Procedure

Mileage records were meticulously kept for both the gasoline baseline and the E-85 ethanol blend fuels. The driving cycle was scrupulously controlled to be 5 trips from home to work in McGregor each week, plus two trips from home to work at MCC two evenings a week, and nothing else. The same routes were scrupulously observed for each of these two types of trips, as well. The relative efficiency (ethanol-to-gasoline) can be derived from the experimentally-observed mileage ratio ethanol-to-gasoline, and the volumetric lower heating value ratio ethanol-to-gasoline (these are simple fuel properties).

Relative efficiency can also be derived from point measurements of intake vacuum on ethanol, compared to point measurements of intake vacuum on gasoline. The test site, weather conditions, and test speed must be strictly controlled.

If the vacuum point results have the same efficiency trends and basic levels, then both economy and power are affected in the very same way. This allows us to conclude that any mileage-based energy efficiency changes are "real", in the sense that the ethanol conversion has been correctly done without over-leaning the ethanol mixture. An over-leaned configuration would show a vacuum-based relative performance drop, while showing a mileage-based relative performance improvement.

Data collected

Data were collected on ethanol from January 2007 to March 2007, all on the same "old tires" as the gasoline baseline. The gasoline baseline was collected between August 2006 and late October 2006, with precisely the same carburetor and tires. The basic sense of the fuel mileage results up to the tire replacement in mid-March is about 18 mpg on E-85 vs 24 mpg on unleaded regular (ULR) gasoline in very cold weather (morning lows typically 20 F), and 20 mpg on E-85 mileage in warm weather (morning lows in the 60-70 F range). There was no change in gasoline mileage from cold to warm weather, and there never has been, in the entire history of this vehicle.

There is some scatter and some uncertainty in the point vacuum data, but the trends from both test sites confirm the morning low temperature effect on fuel mileage. These trends with temperature and the values from one test site confirm the basic levels of efficiency as obtained from fuel mileage. The second site probably has a bad gasoline baseline vacuum value, as it confirms trend, but not basic efficiency level.

During this entire ethanol testing period (January through March 2007), the price of ULR gasoline varied from a low of about 191.9 cents/gallon to a high of about 233.9 cents/gallon. The arithmetic average of recorded prices during this interval is 213.9 cents/gallon. The increment from ULR to mid-grade (MG) was 10 cents/gallon, as was the increment from MG to premium (Prem). More recently, prices have been substantially higher, and the increments from grade to grade are now closer to 11 or 12 cents/gallon. The most recent price observations (as of this report date) are 283.9 cents/gal ULR, 295.9 cent/gal MG, and 307.9 cents/gal Prem.

All during this time interval, the price decrement from ULR to E-85 has been 30 cents/gallon, in accordance with HEB corporate policy, and it still is today (for 253.9 cents/gal as of this report date). Whether this is profitable for HEB is beyond the scope of my activities. This pricing is, however, what has been available to the public in McLennan County, Texas, and it is hard "in-the-field" data for this locality. It is very hard to discount "in-the-field" data!

Calculations

Mileage is simply the total fuel added between fill-ups, divided into a difference in odometer readings from this fill-up to the previous one. If fuel is added between fillips, this is added directly to the fuel total between fill-ups, and so noted in the logbook. For testing purposes, "fill-up" means filling the tank to the very same mark each and every time.

mpg = total miles traveled / total fuel used (measured to the same mark)

The direct fuel cost per mile depends upon fuel mileage and also upon fuel cost per gallon. Divide the price per gallon by the average fuel miles/gallon. In the US, we use statute miles of 5280 feet, and US gallons of 231 cubic inches (not "Imperial" gallons, as in Canada).

direct fuel cost/mile =($/gallon price) / (average mpg)

Presentation of Results

Figure 1 shows the technical results for fuel miles/gallon (mpg) as obtained during the testing interval. "Warm" weather means typical predominant morning lows near 60 F, and "cold weather" means typical predominant morning lows near 20 F. These are independent of fuel price, and reflect fuel vaporization effects inside the intake manifold. In cold weather, inadequate extra added intake heat on E-85 results in less fuel vaporization, leading to lower efficiency and mpg, and to some extent, decreased driveability, as recorded in the log. On E-85, this is in fact exactly what was observed. The fact that there was no temperature effect upon gasoline performance simply means intake air heat was adequate for that fuel.

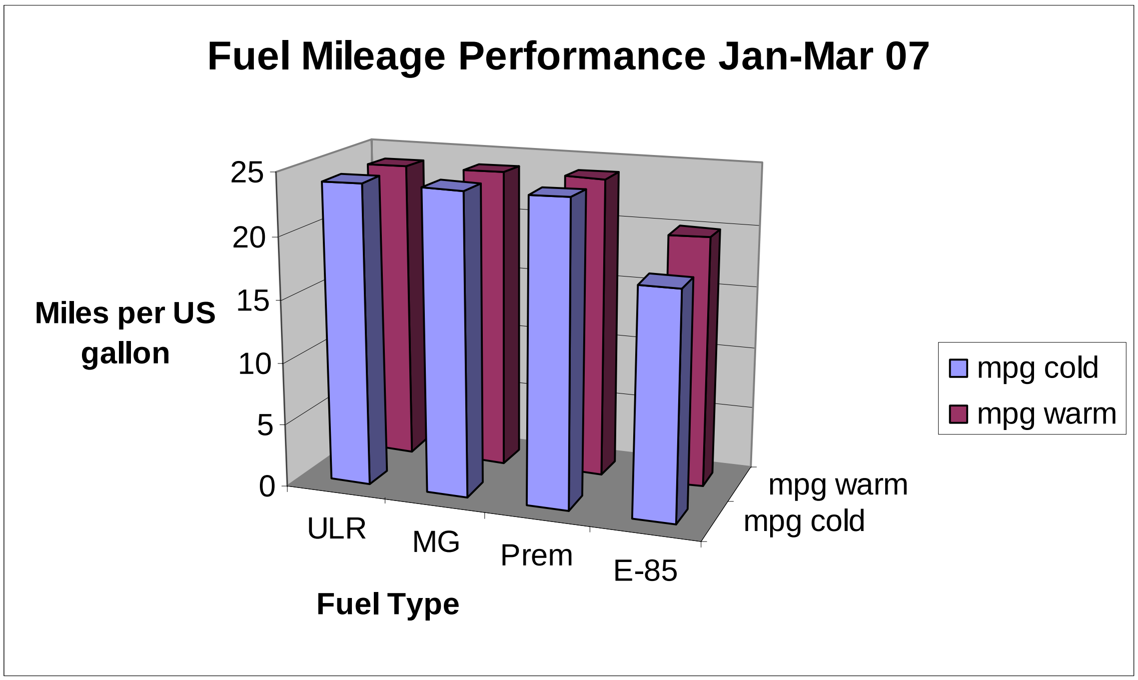

Figure 1 – Fuel Mileage Results Show an E-85 Temperature Sensitivity Not Evident on Gasoline

During the test interval, the HEB price decrement from ULR to E-85 was a constant 30 cents/gal, and still is as of this writing. With that pricing policy, and the demonstrated warm-weather mileage figures, the direct fuel operating cost for E-85 was nearest that for MG gasoline during the testing period, as shown in Figure 2. With today's prices, the E-85 direct fuel operating cost is nearer that for Prem gasoline. One should note that Prem is typically a 91 to 93 pump octane fuel, while E-85 is much superior in its anti-knock performance, at well over 100 pump octane.

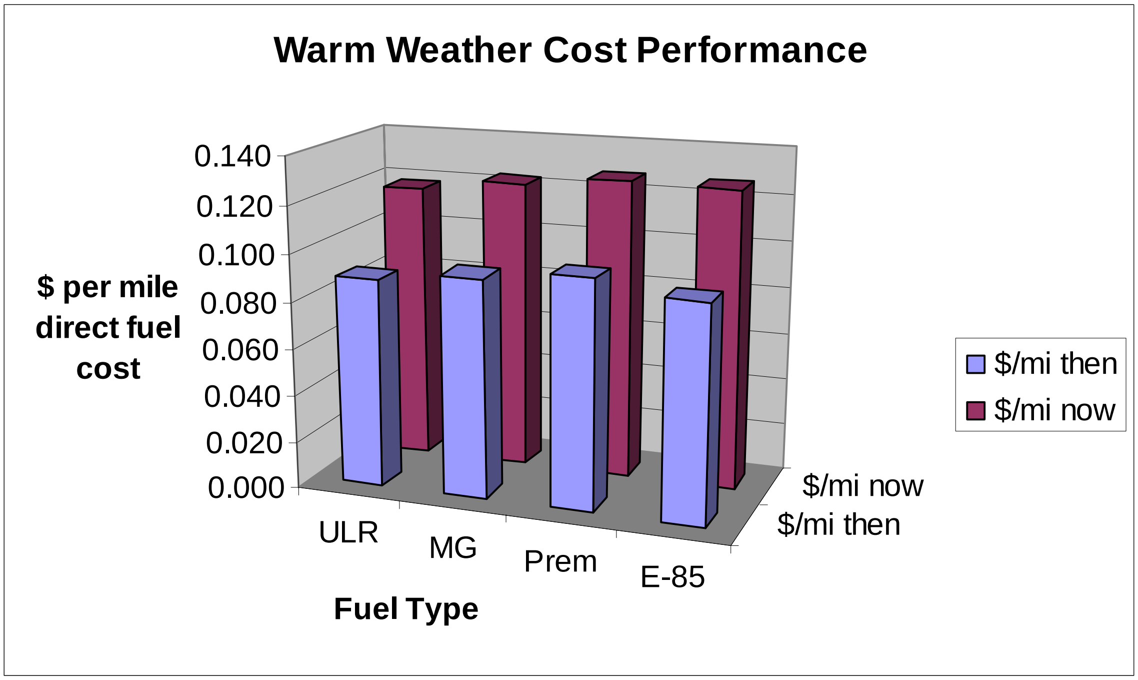

Figure 2 – Warm-Weather-Based Results Show E-85 Direct Fuel Operating Costs to be Roughly the Same as Mid-Grade Gasoline During the Test Interval, and Premium Grade at Today's Prices

The cold weather results show E-85 direct fuel operating costs about the same as premium gasoline during the test interval, and a little higher than that, at today's prices, per Figure 3. The same octane/anti-knock considerations apply, however. Had this investigator been able to add a little more intake air heat in his modification, his mileage in cold weather would have matched his mileage warm, and Figure 2 would apply, instead.

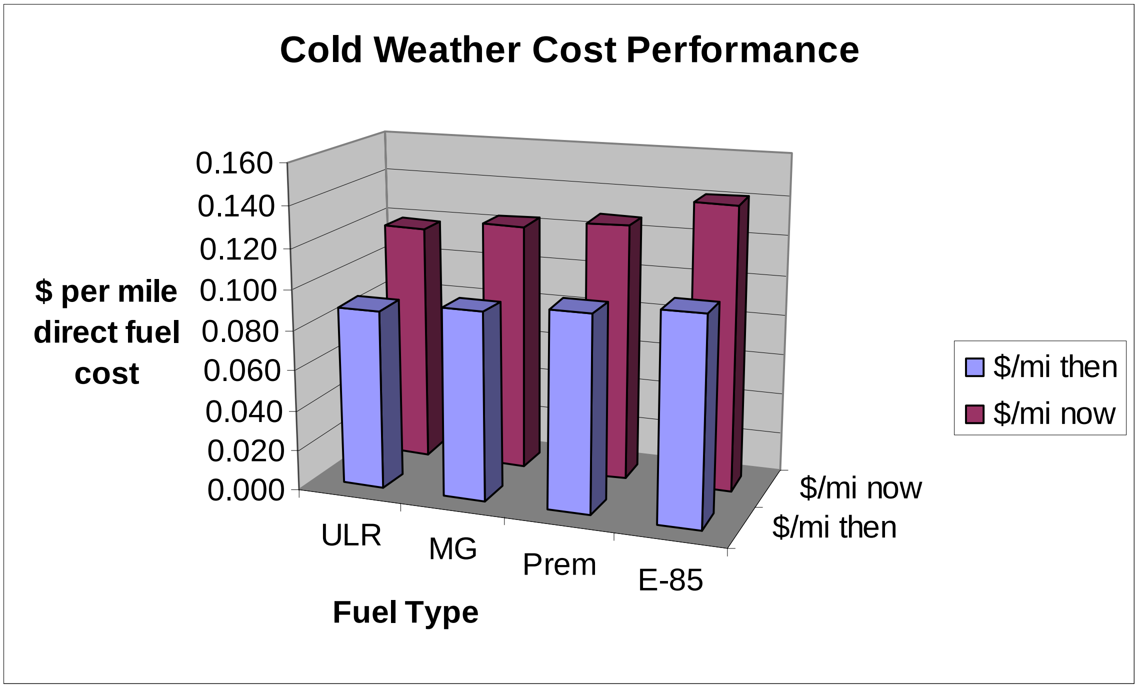

Figure 3 – Cold-Weather-Based Results Show E-85 Direct Fuel Operating Costs to be a Little Higher Than Premium Gasoline

Conclusions / Recommendations

There are three conclusions that can be drawn from these results, which are immediately apparent from the charts above.

1. Using E-85 ethanol fuel is quite cost-competitive with any gasoline grade, under HEB's pricing policy, <u>especially considering the pump octane of the fuel</u>.

2. The difference between the warm weather and cold weather E-85 fuel mileage performance indicates a sensitivity to cold conditions. This can be attributed to inadequate fuel vaporization cold, which reduces air/vapor ratio far below the nominal air/fuel ratio delivered by the carburetor. The intake air heat modification made to this particular vehicle was clearly inadequate for 20 F conditions. <u>A factory re-design, or a better aftermarket modification than this one, would have cold weather performance about the same as warm weather performance</u>!

3. HEB should consider pricing its E-85 at a constant ratio to ULR, rather than a constant 30 cent/gallon decrement. The decrement approach makes the alternative fuel look less attractive as gasoline prices rise. <u>This is opposite to what is in the natural interest</u>.

The remaining issues with this experiment are the effects of the new 185/65R15 tires recently installed (mid-March 2007). A simple zero-speed drag pull in the shop indicates noticeably higher drag on these new tires than on the ones used in the experiment described above. Continued monitoring into the hot weather at end of May is suggested, as well as new formal and informal vacuum characterizations, including a new gasoline baseline. <u>Both the effects of the tires, and of truly hot weather, need to be defined</u>.

The remaining practical issue is the availability of ethanol to support E-85 supplies. This is especially true as E-85 is currently made with ethanol made from corn. The increased demand for E-85 has driven up demand for ethanol, which in turn has driven up corn prices, which in turn is driving up food prices, according to all published information. This is the classic food vs fuel dilemma.

The only logical way out of this food vs. fuel dilemma is for the ethanol supply not to be based on corn or any other food crop grains. That means we must have sugar cane production (as is done in Brazil), and that we also must have massive cellulose-based ethanol production, in order to support truly massive production of E-85 ethanol blend fuel. That is a *separate* problem from the one this investigator has addressed.

Otherwise, excepting long-term monitoring for materials compatibility, this experiment is essentially complete. The overall conclusion is this: any knowledgeable mechanic can convert a carbureted car to use E-85 ethanol blend fuel successfully and very, very economically.

Questions and comments should be directed at the author/experimenter:

Gary W. Johnson, PE, PhD
Owner, *Expert Technical Services*
a consulting firm located at:
5886 New Windsor Pkwy
McGregor, TX 76657

gwj5886@gmail.com