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COMPARATIVE DRIVE CYCLE FUEL ECONOMY OF IN-USE PUBLIC UTILITY JEEPNEYS USING 2% AND 5% CME-DIESEL BLENDS

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ABSTRACT

This study presents the results of drive cycle tests conducted on in-use public utility jeepneys running on 2% (B2), and 5% (B5) by volume Coconut Methyl Ester (CME)-Diesel blends. The tests measured fuel consumption of sample jeepney units on a chassis dynamometer driven following the European ECE1504 Drive Cycle fueled with B2 and B5 CME-Diesel blends. These tests were part of an overall study examining the effects of B2 and B5 blends on the economic operation and fuel economy, measured on-road and in the laboratory, of jeepneys conducted by the UP National Center for Transportation Studies (UP NCTS) and UP Vehicle Research and Testing Laboratory (VRTL) for the Philippine Coconut Authority (PCA). Data from the study will be used as one of the inputs, among others such as economic, logistics, and fuel quality issues, to deliberations to decide for the introduction of 5% CME-Diesel blend in commercial diesel fuel. The drive cycle tests of seven (7) jeepney units range from about 0.5% to 11% specific fuel consumption (gm/km) improvement for B5 relative to B2 for an overall average SFC improvement of 4.6%. The change in mileage for B5 relative to B2 ranged from -2.40 to +11.91 percent for an overall average of around 3.0%. The mileage results were affected by the observed relative density of B5 with respect to B2 – a less B5 density than B2 adversely affects B5 mileage versus B2. "Mixed" mileage results were observed. The amount of fuel economy change when using B5 compared to B2 in jeepneys is thought to also depend on in-use engine conditions and drivetrain configuration. While the observed overall better fuel economy of B5 relative to B2 tends to favor a shift to B5 diesel blend implementation, the authors recommend further detailed studies on CME-diesel blend effects on engine/vehicle performance and emissions for a more sound technical basis for policy decisions.

Key words : CME, biodiesel, jeepney, fuel economy, drive cycle

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I. BACKGROUND

The Philippines signed into law in January 2007 the "Biofuels Act of 2006" which declared as a state policy to reduce dependence on imported fuels with due regard to the protection of public health, the environment, and natural ecosystems consistent with the country's sustainable economic growth that would expand opportunities for livelihood by mandating the use of biofuels [1]. This law mandated the use of biodiesel, which since 2009 up to now is at 2% by volume (B2), in commercial diesel fuel. Prior to the enactment of the Biofuels Act various papers and studies discussed various aspects of CME biodiesel use. Carandang, E. [2] identified issues regarding biodiesel adoption in the Philippines. Bulan, C.A. [3] mentions a collaborative study by PCA, Dept. of Energy, Technological University of the Philippines, and the Metro Manila Development Authority on the use of 1% CME in diesel as a fuel enhancer for smoke reduction in buses. Yoshida, et. al. [4] in a single cylinder diesel engine tests using 1%, 5%, 10%, 20% and 100% CME-diesel blends observed a 50 to 60 percent reduction in smoke emissions, a NOx reduction of 20% and a power reduction averaging 20%. Philippine biodiesel is primarily coconut methyl ester whose specifications are covered by PNS/DOE QS 002:2007. The shift to 5% biodiesel (B5), although scheduled by the end of 2013, is still under review by the National Biofuels Board (NBB). With the recommendation in 2013 to increase the biodiesel blend from B2 to B5, one of the requirements is the testing of B5 in public transport vehicles. In this regard, the Philippine Coconut Authority has commissioned the UP NCTS to conduct a short-duration on-road and chassis dynamometer testing of the B5 blend [5][6]. Data from this study will be used as one of the inputs, among others such as economic, logistics, and fuel quality issues, to deliberations on actual B5 diesel blend implementation.

This paper presents only the chassis dynamometer testing conducted for seven (7) sample jeepney units between September 2013 and May 2014 at the UP VRTL to measure vehicle fuel economy using B2 and B5 diesel blends. The sample jeepney units were selected in collaboration with the jeepney transport groups plying the chosen on-road test route. The results of the on-road tests will be presented in another paper for a more focused discussion and to keep this paper's length reasonable. Detailed technical analysis of fuel economy in relation to engine or vehicle design and operating parameters are not part of this study. At the time this study was commissioned by PCA, preparations for a separate, independent, more detailed and controlled study of CME-diesel blend effects on engine performance and emissions were underway at the VRTL as part of graduate research work. The results of this more detailed research work will be published separately.

II. METHODOLOGY

2.1 Test Vehicles and Fuel

The in-use jeepney units used in the tests study were chosen from those nominated by operators belonging to transport groups identified by Philippine Coconut Authority and the Department of Energy (DOE). The chosen jeepney samples were of the typical in-use jeepney dimensions, passenger capacity, drivetrain, in good running condition, and whose owners were willing to participate in the on-road and/or chassis dynamometer tests. The jeepneys involved in the study underwent and passed inspection at the North Motor Vehicle Inspection Center (MVIC) of the Land Transportation Office to ensure compliance with roadworthiness and smoke opacity standards, see Fig.1. Table 1 shows summary information of the jeepney units that underwent testing on the chassis dynamometer. The calculated gross vehicle weight (GVW) values shown in the table are used in the chassis dynamometer runs to simulate fully-loaded condition of respective jeepney units.

Figure 1. *Jeepney unit during MVIC "pass/fail" smoke opacity tests*

TABLE 1. Summary Information of Jeepney Units Tested

	Jeepney Plate No.	Passenger Capacity	Engine	GVW (kg) @ 70 kg/Pax	ROUTE	Assoc'n.
1	**TWN 720**	22	Isuzu 4BC2, 1992	4190	Pandacan-Leon Guinto	Fejodap Pandass
2	**PYK 641**	20	Toyota 4D30 1995	4400	Pandacan-Leon Guinto	Fejodap Pandass
3	**TWF 876**	20	Isuzu 4DR5	3820	Nichols - Baclaran	Ajodap/Fejodap 1-Utak
4	**NYK 359**	21		4470	UP-Pantranco	
5	**NYC 714**	19	Isuzu	3580	UP-SM North	
6	**TVR 974**	21		3970	Montalban - QC Hall	
7	**TVW 611**	23		4260	Montalban - QC Hall	

Samples of pure CME (B100), B2, and B5 (made from B2) fuel blends provided by PCA were sent to the Processed Fuels Section of the Geoscientific Research and Testing Laboratory of the Department of Energy for analysis. Results of the fuel analyses shown in Appendices A and B indicate conformance of the fuels to Philippine National Standards.

2.2 Dynamometer Test Set Up and Procedure

The present study, together with the on-road tests (not presented here), was conducted to determine (the “what”) jeepney fuel consumption of B2 versus that of B5 under conditions close to actual operating conditions and not the reasons for the fuel consumption (the “why”). The motivation was to find out if the measured fuel consumption of B5 is better than that of B2, for whatever reason, and the corresponding fuel cost savings (not discussed here) could offset the higher cost of B5 - it would then be easier to promote and for jeepney operators to accept the shift to B5.

Considering the planned short duration of the study, limited logistics, availability schedule of the chassis dynamometer, and an ongoing separate more detailed study of CME-diesel blends using an engine dynamometer, it was decided to limit the controlled test variables to jeepney load, driving pattern (i.e., drive cycle), and fuel supply temperature. Fuel quality was not strictly controlled in an attempt to simulate fuel variability that jeepney drivers actually encounter. The B2 blends were purchased from different commercial gas stations right before the chassis dynamometer tests while the B5 blend was prepared one time by PCA. Since the jeepney load, driving pattern, and fuel supply temperature were similar during the laboratory tests, the fuel consumption data obtained reflect the effect of the fuel blends only, subject to approximately the same fuel quality variability encountered by jeepney drivers.
The laboratory test results are considered as complimentary to on-road, or “real world”, test results in providing information for sound policy-making and implementation decisions regarding biodiesel.

Fuel economy tests were conducted in the UPME VRTL using the AVL AN 40720 48" Chassis Dynamometer where the jeepney units were run on a selected driving cycle. Fuel consumption during the chassis dynamometer runs was measured with the AVL 735 Fuel Mass Flow Meter together with the AVL 753 Fuel Temperature Control unit.

Prior to the chassis dynamometer runs, a pre-test inspection of the test jeepney unit was conducted to reasonably ascertain that the vehicle was in good running condition. This included general inspection of the tires, checking of tire pressures, and checking for smooth and stable running of the engine. The test vehicle was then mounted on the chassis dynamometer, secured, and instrumentation attached. After a pre-set warm up time, a baseline run is conducted by driving the vehicle on commercial B2 diesel blend using the European ECE1504 drive cycle three times and the measurement results averaged. Initial trial runs using the Japanese 10-15 Mode driving cycle indicated failure of some jeepney units to completely follow this drive cycle at higher speeds. The European ECE1504 drive cycle, or ECE150 repeated four times [4], was eventually selected for the tests as this was what the jeepneys could completely follow on the dynamometer. This particular cycle, among the standard drive cycles available was also thought to have some semblance to actual jeepney on-road driving. The chassis dynamometer runs were set assuming the jeepney units were fully loaded. Figures 2 and 3 show respectively the Japanese and European drive cycles mentioned.

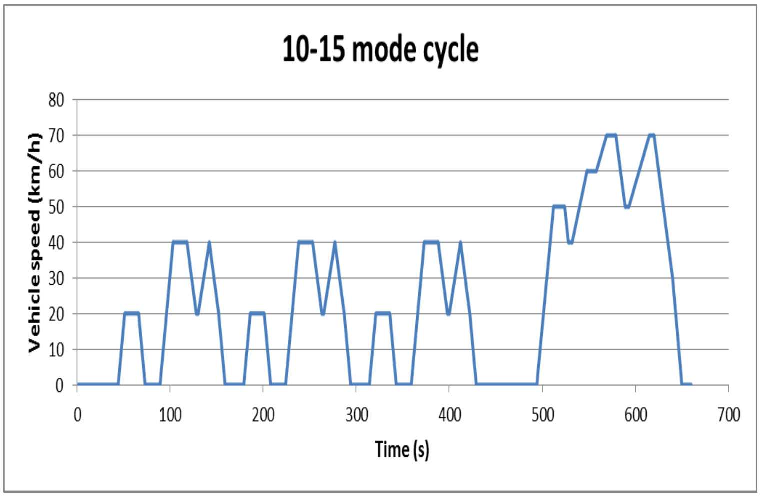

Figure 2. *Japanese 10-15 Mode driving cycle*

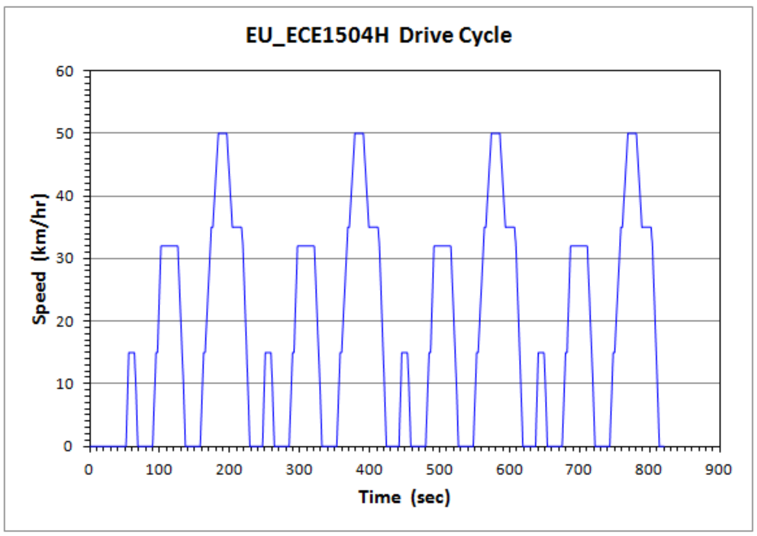

Figure 3 *European ECE1504 driving cycle*

After the baseline test runs, a similar set of runs using B5 diesel blend were conducted to determine the same performance parameters. Figs. 4 and 5 show a jeepney unit being tested on the chassis dynamometer.

Figure 4. *Test jeepney on chassis dynamometer, front view*

Figure 5. *Test jeepney on chassis dynamometer, rear view*

III. RESULTS AND DISCUSSION

The fuel economy of the jeepneys tested was measured as mass flow rate in kg/hr but are presented here both in terms of specific fuel consumption (SFC), in grams/kilometer (g/km), and mileage, in kilometers/liter (km/l or km/ltr).

Figure 6 shows the SFC of the jeepney units for B2 and B5 diesel blends. It can be seen from this graph that all jeepney units showed reduced SFC when using B5 relative to B2. The authors consider, as many others, gravimetric fuel consumption (SFC) in gm/km as the definitive measure of how much fuel a driven vehicle consumes. Figure 6 shows a consistent better fuel performance of B5 versus that of B2 for the jeepney units tested.

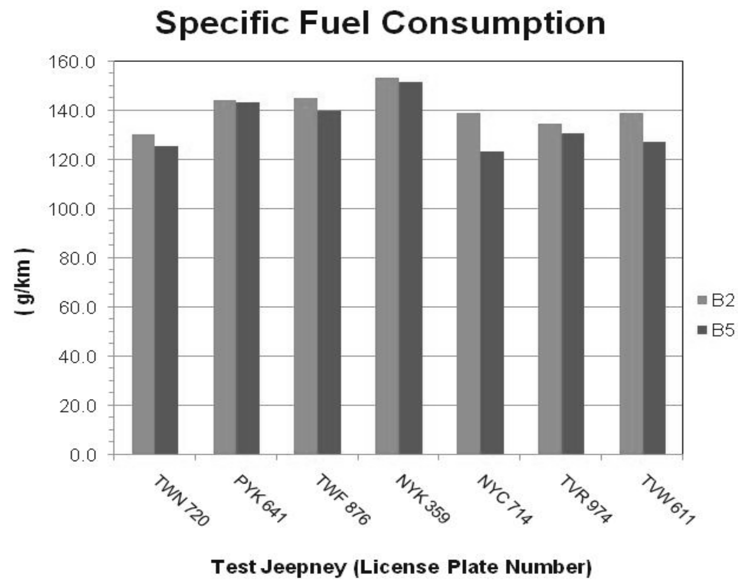

Figure 6. *Specific fuel consumption, B2 vs. B5*

Figure 7 shows the same data in terms of B5 SFC percent change relative to B2. All the jeepney units gave improvement in SFC ranging from about 0.5 to 11%. The drive cycle tests indicate that the seven (7) jeepney units tested gave an overall average specific fuel consumption improvement from 140.3 to 133.8 g/km (4.6%) [5]. In comparison, Aguila, R., [8], found a 2.4% improvement in SFC for B5 versus B2 fuel for an 11-passenger van with a turbocharged common-rail direct injection engine driven on the Japanese 10-15 Mode drive cycle. Laguitao, J.J.C., [9] found practically similar SFC for B5 and B2 on an in-use Asian utility vehicle with a 2.5-liter naturally-aspirated direct injection diesel engine following the same Japanese drive cycle.

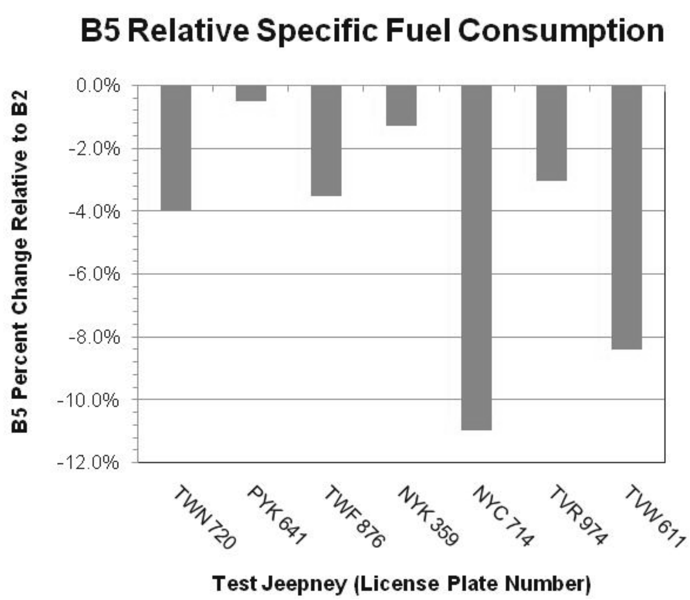

Figure 7. *B5 relative specific fuel consumption*

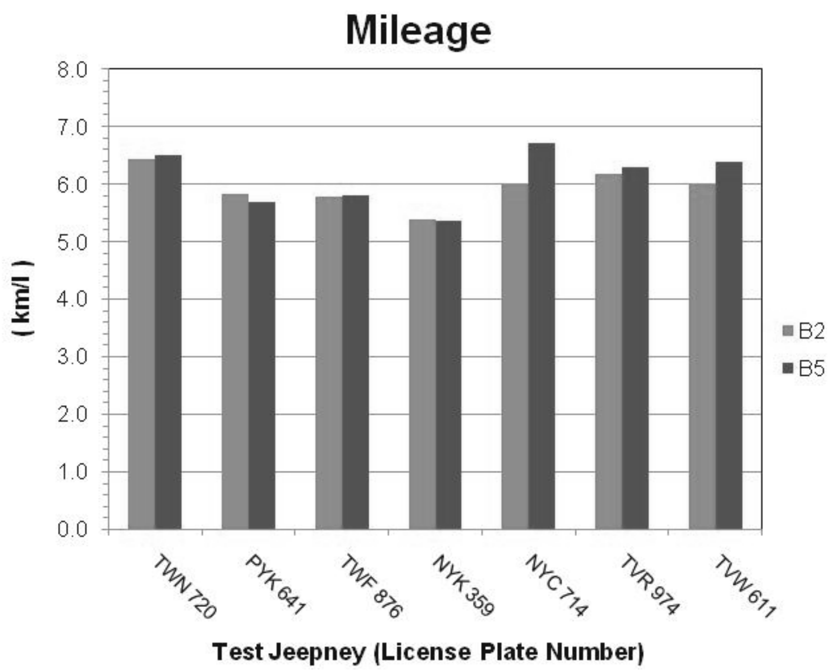

Figure 8. *Mileage, B2 vs. B5*

Figure 8 shows the mileage obtained for the jeepneys tested while Fig. 9 indicates the B5 mileage percent change relative to B2. It is seen that four jeepneys have better, two units about similar, and one jeepney less mileage with B5.

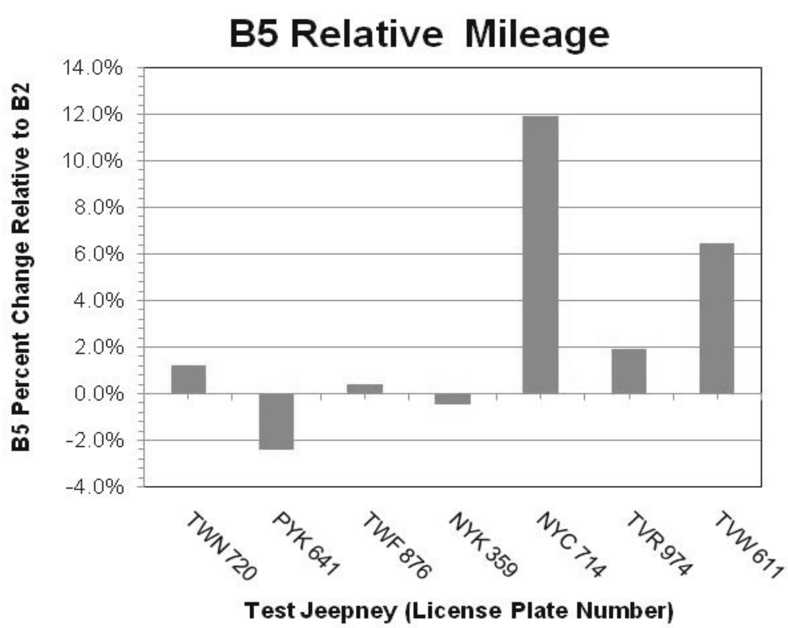

Figure 9. *B5 relative mileage*

The B5 mileage change relative to B2 ranged from -2.40% to 11.91%. Such negative and positive values are described as "mixed" results. On an overall basis, an improvement in mileage from 5.97 km/ltr to 6.15 km/ltr was seen, or about 3.0% improvement for B5 relative to B2 [5].

This "mixed" behavior of mileage, compared to SFC's consistently lower value for B5 versus B2, may be due to the variation in fuel densities observed during the tests. Figures 10 and 11 show respectively the measured and corresponding B5 relative fuel densities for the tests. The B2 blends were purchased from commercial gas stations right before the tests while the B5 blend was prepared one time. The first three jeepneys were tested in September 2013, the fourth in November 2013, and the last three in May 2014. The fourth to the seventh jeepneys used B5 fuel blend leftover from the September tests. Leftover B5 blend fuel properties may have been affected by handling and storage prior to the dynamometer tests. It was decided not to "correct" the measured density values used in the calculations and consider the fuel density variation as being lumped together with the other factors, such as ambient weather conditions and B2 blend source affecting fuel economy. Such variable factors are what jeepney drivers encounter in actual operation as they estimate their fuel consumption. The parameters that were repeatable in the chassis dynamometer tests for fuel economy are then vehicle load, driving cycle, and fuel supply temperature (set at 30° C).

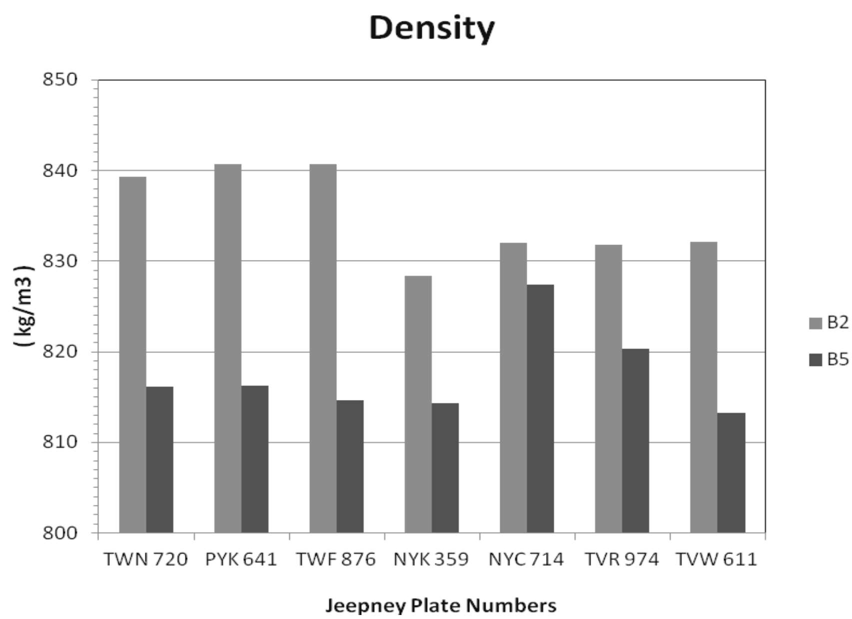

Figure 10. *Measured fuel blend density*

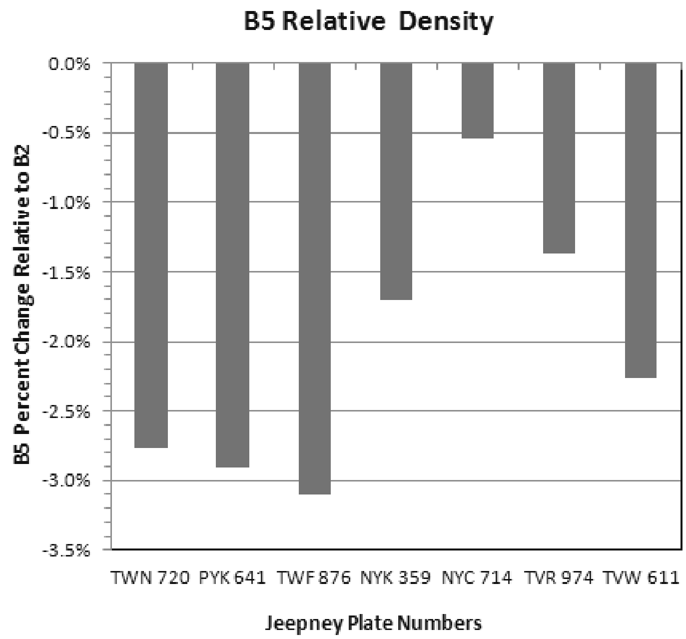

Figure 11. *B5 relative fuel density*

Examination of Figs. 11 & 9 shows that as the relative density of B5 becomes lesser than B2, B5 relative mileage becomes adversely affected. The improvement in fuel economy of B5, expressed as SFC in gm/km, may be offset by B5's lower density when expressed as mileage in km/ltr.

Figure 12 shows a comparison of the specific energy consumption in kJ/km of B2 and B5 diesel blends. The energy consumption was estimated using fuel heating values calculated by Laguitao, J. [9], in his CME-diesel blends studies of a vehicle with a direct injection diesel engine. The figure indicates B5 consistently giving about 0.5% to 11% lower energy consumption than B2.

The varying SFC, energy consumption, and mileage changes of B5 relative to those of B2 shown by the different jeepney units are thought to be also related to the vehicles' differences in engine conditions and drivetrain configurations.

IV. CONCLUSION

A study commissioned by the Philippine Coconut Authority to the UP NCTS and UP VRTL was conducted to examine, among other things, the drive cycle fuel economy of in-use public utility jeepneys running on B2 and B5 CME-Diesel blends. Data from this study will be used as one of the inputs, among others such as economic, logistics, and fuel quality issues, to deliberations on actual B5 diesel blend implementation as mandated by the Biofuels Act of 2006. The study measured fuel consumption of seven (7) sample jeepney units on a chassis dynamometer driven following the European ECE1504 Drive Cycle fueled with B2 and B5 diesel blends.

The drive cycle tests of the jeepney units gave a range of about 0.5% to 11% specific fuel consumption (gm/km) improvement for B5 relative to B2. An overall average SFC improvement of 4.6% for B5 relative to B2 was calculated. The change in mileage for B5 relative to B2 ranged from -2.40 to +11.91 percent for an overall average of around 3.0%. The mileage results were affected by the observed relative density of B5 with respect to B2 – a less B5 density than B2 adversely affects B5 mileage versus B2. "Mixed" mileage results were observed. For the specific energy consumption in kJ/km, B5 consistently gave values lower than B2 ranging from about 0.5% to 11%. The amount of fuel economy change when using B5 compared to B2 in jeepneys is thought to also depend on in-use engine conditions and drivetrain configuration.

While the observed overall better fuel economy of B5 relative to B2 in this limited study tends to favor a shift to B5 diesel blend implementation, the authors recommend more detailed studies on the effects of (and reasons behind) CME-diesel blends on engine/vehicle performance and emissions. These further studies would include both engine and chassis dynamometer testing in the laboratory for a representative sample of the diesel vehicle population. Endurance testing could help provide information on the long-term effects on engines of biodiesel blends. Information from these recommended studies will yield a more sound technical basis for policy decisions.

V. ACKNOWLEDGMENT

This study was part of a B5 on-road vehicle testing project conducted and administered by the UP National Center for Transportation Studies, c/o Dr. Karl B.N. Vergel, funded by the Philippine Coconut Authority.

REFERENCES

1. Republic Act 9367 (July 2006). "An Act to Direct the Use of Biofuels, Establishing for the Purpose the Biofuel Program, Appropriating Funds Therefor, and for Other Purposes", Congress of the Philippines, Metro Manila.
2.
3. Carandang, E.V., "Biodiesel for Transportation", Paper presented during the Technical Forum in celebration of the PCIERD 21st Anniversary, March 17, 2003, EDSA Shangri-la Hotel, Mandaluyong City, Philippines.
4.
5. Bulan, C.A., "Biodiesel as an Alternative Fuel Leading to Cleaner Environment", (unpublished report), Chemical and Mineral Division-Industrial Technology Development Institute, Department of Science and Technology, Taguig City, Philippines.
6.
7. Yoshida, K., Argamosa, F., Hizon, R., and Zapanta, C. (January, 2004). "Effect of Blending Low Sulfur Diesel Fuel with Coconut Methyl Ester on the Engine Performance Characteristics of a Single Cylinder, 4-Stroke Diesel Engine". Philippine Journal of Industrial Education and Technology, Volume 14 (1),15-27.
8.
9. National Center for Transportation Studies, UP-Diliman (June 2014). "On-Road and Vehicle Testing of 5% Coco-Methyl Ester (CME) Biodiesel Blend (B5) in Public Transport". Draft Final Report to Philippine Coconut Authority.

1. "PCA TO LAUNCH ON−ROAD TEST OF 5% BIOFUEL BLEND", http://www.pca.da.gov.ph/pr073013a.php, Accessed April 27, 2015.
2.
3. Barlow, T.J., Latham, S., McCrae I.S., Boulter, P.G. "A Reference Book of Driving Cycles for Use in the Measurement of Road Vehicle Emissions" Version 3 (June 2009), Published Project Report (PPR) 354, TRL Limited, Wokingham, Berkshire RG40 3GA, IHS, Berkshire RG12 8FB, United Kingdom.
4.
5. Aguila, R.K.D., "Coconut Methyl Ester (CME) Performance and Emission Characteristics Using Common Rail Direct Injection (CRDI) Engine", M.S.M.E. Thesis, College of Engineering, University of the Philippines, Diliman, Q.C., (November 2010).
6.
7. Laguitao, J.J.C., "Performance and Emission Characteristics of a Direct Injection Diesel Vehicle with Different Blends of CME Biodiesel", M.S.M.E. Thesis, College of Engineering, University of the Philippines, Diliman, Q.C., (November 2009).
8.

APPENDIX

A. Fuel analysis for B100 used in the study
B. Fuel analysis for B2 and B5 used in the study

Geoscientific Research and Testing Laboratory
PROCESSED FUELS SECTION

Laboratory Analysis/ Test Report

Date : August 5, 2013
Lab. Work Order No.: 2013-07-081
Lab Code No.: 1307-1472

Sample Description : B100
Date Received : July 26, 2013
Date Test Completed : August 2, 2013

Results:

Test/ Analysis	Method	Result	PNS/DOE QS 002: 2007 limits
Acid Number, mg KOH/g	PNS ASTM D 664	0.08	0.50, max.
Carbon Residue on 100% sample, % mass	PNS ASTM D 4530	0.012	0.050, max.
Cloud Point, °C	PNS ASTM D 2500	-2	5, max.
Copper Strip Corrosion, 3 hrs. at 50°C	PNS ASTM D 130	1a	No.1, max.
Density at 15°C, kg/L	PNS ASTM D 4052	0.875	0.86 – 0.90
Distillation AET 90% recovered, °C	PNS ASTM D 86	313	360, max.
FAME Content, % mass	PNS EN 14103 modified	96.5	96.5, min.
Flash Point (PM), °C	PNS ASTM D 93	103	100, min.
Glyceride Content, % mass	PNS EN 14105 modified		
Monoglycerides		ND*	0.80, max.
di-glycerides		1.03	0.20, max.
tri-glycerides		ND*	0.20, max.
Glycerin, % mass	PNS EN 14105 modified		
Free Glycerin		ND*	0.02, max.
Total Glycerin		0.15	0.24, max.
Kinematic Viscosity at 40°C, mm²/sec.	PNS ASTM D 445	2.82	2.0 – 4.5
Methanol, % m/m	PNS EN 14110	0.006	0.20, max.
Methyl Laurate, % mass	PNS EN 14103 modified	50	45, min.
Oxidation Stability at 110°C, hours	PNS EN 14112	ND**	6, min.
Sulfated Ash, % mass	PNS ASTM D 874	0.003	0.020, max.
Sulfur, ppm	PNS ASTM D 5453	19.11	500, max.
Water, % volume	PNS ASTM E 203	0.08	0.05, max.
Water and Sediments, % volume	PNS ASTM D 2709	<0.05	0.05, max.

This report relates specifically to the sample/s tested.

Remarks:
ND* - not detected
ND** - not determined

Analyzed by:

L.S.Pangilinan / V. P. Grego / R. M. C. Briones / M. I. Abong / A. M. B. Sabino / J. V. Flores / K. J. B. Dado
Supvg. SRS Sr. SRS Sr. SRS Sr. SRS Sr. SRS SRS II SRS II

K. C. D. Laserna
SRS I

Reviewed and prepared by:

V. S. Llamo
Supvg. SRS

PROCESSED FUELS SECTION
Geoscientific Research and Testing Laboratory
LABORATORY REPORT

Lab Work Order No. : 2013-07-081
Sample Description : FAME- Blended Diesel Oil (Automotive)
Date Submitted : July 26, 2013
Date Test Completed : July 31, 2013
Date Sampled : July 25, 2013

RESULTS OF ANALYSIS:

TEST/ANALYSIS	PNS/DOE QS 004:2009 limits	Test Method	Sample Label / Lab. Code			
			B2 Tk 3 1307-1473	Remarks	B2 TTk 1307-1474	Remarks
Calculated Cetane Index or Cetane Number, min.	50	ASTM D 4737	52	Passed	52	Passed
Carbon Residue on 10% Dist'n. Residue, % mass, max.	0.15	ASTM D 4530	0.01	Passed	0.01	Passed
Color, ASTM, max.	2.5	ASTM D 1500	L0.5	Passed	L0.5	Passed
Copper Strip Corr., 3 hrs. at 50°C, max.	No. 1	ASTM D 130	1a	Passed	1a	Passed
Density @ 15°C, kg/L	0.820 - 0.860	ASTM D 4052	0.824	Passed	0.824	Passed
Distillation, 90 % recovered, max.	370	ASTM D 86	342	Passed	339	Passed
FAME Content, % volume	1.7 - 2.2	FTIR	1.8	Passed	2.0	Passed
Flash Point (PM), °C, min.	55	ASTM D 93	70	Passed	68	Passed
Kinematic Viscosity at 40°C, mm^2/s	2.0 - 4.5	ASTM D 445	2.8	Passed	2.8	Passed
Sulfur, % mass, max.	0.05	ASTM D 4294	<0.01	Passed	<0.01	Passed
Water, % volume, max.	0.05	ASTM E 203	0.02	Passed	0.02	Passed
Water and Sediment, % volume, max.	0.10	ASTM D 2709	<0.05	Passed	0.0	Passed

Analyzed by:

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Velpa P. Grego

Report prepared by:

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Reviewed by:

Virginia S. Llamo

PROCESSED FUELS SECTION
Geoscientific Research and Testing Laboratory
LABORATORY REPORT

Lab Work Order No. : 2013-07-081
Sample Description : High FAME- Blended Diesel Oil (ADO-B5)
Date Submitted : July 26, 2013
Date Test Completed : July 31, 2013
Date Sampled : July 25, 2013

RESULTS OF ANALYSIS:

TEST/ANALYSIS	DPNS/DOE QS 010:2013 limits	Test Method	Sample Label / Lab. Code			
			B5 1307-1475	Remarks	Lab Scale B5 1307-1476	Remarks
Calculated Cetane Index or Cetane Number, min.	50	ASTM D 4737	52	Passed		
% mass, max.	0.15	ASTM D 4530	0.02	Passed		
Color, ASTM, max.	2.5	ASTM D 1500	L0.5	Passed		
Copper Strip Corr., 3 hrs. at 50°C, max.	No. 1	ASTM D 130	1a	Passed		
Density @ 15°C, kg/L	0.820 - 0.860	ASTM D 4052	0.826	Passed		
Distillation, 90 % recovered, max.	370	ASTM D 86	341	Passed		
FAME Content, % volume	4.7-5.2	EN 14078	4.9	Passed	4.7	Passed
Flash Point (PM), °C, min.	55	ASTM D 93	69	Passed		
Kinematic Viscosity at 40°C, mm^2/s	2.0 - 4.5	ASTM D 445	2.8	Passed		
Sulfur, % mass, max.	0.05	ASTM D 4294	<0.01	Passed		
Water, % volume, max.	0.05	ASTM E 203	0.03	Passed		
Water and Sediment, % volume, max.	0.10	ASTM D 2709	<0.05	Passed		

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