Interim Report on BriTek Wheel

May 21, 2007

1.0 Introduction

This interim report is based on discussions and visits with David Burros, Brian _____ and Larry _____ as well as some preliminary analysis of the potential mileage savings and patentability of the BriTek wheel. Frank Donnelly, an independent mechanical/electrical engineer also visited the BriTek facility and contributed to this interim report.

2.0 Background

BriTek has made several prototypes of their energy restoring wheel based on principles first discovered when the inventor, Brian was developing an energy-return running shoe.

The BriTek wheel is claimed to be capable of replacing existing pneumatic tires and providing better fuel economy while maintaining or exceeding the ride quality of a pneumatic tire. There are suggestions of other performance possibilities involving new modes of energy transfer.

The closest competitor appears to be the Michelin Tweel. The principal claims of the Tweel are that it: is an airless tire that will not develop a flat; provides a ride comparable to a pneumatic tire; and gives mileage performance nearly that of a pneumatic tire.

The Tweel is based on polyurethane blades that connect an inner wheel to an outer wheel.

3.0 The BriTek Wheel

The BriTek wheel claims that it: is an airless tire that will not develop a flat; provides a superior ride to that of a pneumatic tire; and delivers mileage performance superior to that of a pneumatic tire.

The BriTek wheel, in its simplest form, is based on a sheet of membranes that connect an inner wheel to an outer wheel. Currently, the membrane sheet is fabricated from a rubber compound.

4.0 Potential for Performance Improvement

Membranes are, in general, better elastic members for handling difficult stress-strain situations such as twisting and bending compared to columns (spokes and blades belong to this class) or springs. Membranes are capable of being pre-loaded (as are springs and columns) and can be designed for large deflections.

Much of the technology of elastic membranes has been developed by the aircraft industry. For example, an aluminum skin is used to carry much of the load applied to the fuselage and wings. In addition, the material properties of aluminum are highly evolved and have excellent fatigue resisting properties. The methods for connection of aluminum membranes is also highly evolved.

Because the BriTek wheel uses membranes to control the deformation of the wheel, it has the potential for superior performance in difficult road conditions compared with other airless tire designs.

5.0 Potential for Mileage Improvement

If the BriTek wheel is constructed from elastic membranes, such as for example aluminum membranes, then the BriTek wheel can operate as a fully elastic system and return all deformational energy without hysteresis loss. This would give the BriTek wheel a potential energy saving advantage over pneumatic tires.

In the rail industry, the forces resisting forward motion are described by the Davis formula which is of the form:

$$R_f = k_1 + k_2 v + k_3 v^2$$

for constant velocity on a flat surface. There are additional terms for acceleration, grades and curves. Here R_f is the total resistive force and v is the velocity.

The first term is independent of velocity and is associated with losses between wheel and surface, bearings, wheel deformational losses.

The second term is proportional to velocity and is associated with losses such as sway and bumps.

The third term is proportional to velocity squared and is associated primarily with wind resistance.

There are corresponding equations available with constants appropriate to buses, trucks and cars.

The BriTek wheel, if perfectly elastic, can be expected to save energy resulting from the first term and possibly from the second term. An analysis for buses, trucks and cars is attached and shows that there is room for substantial mileage improvement with a fully elastic wheel. However, the analysis does not separate the loss components between the tire and the remaining elements of the drive train.

Thus, the potential for an energy saving advantage of the BriTek wheel over pneumatic tires is there and can be substantial (2 to 5 mpg depending on the vehicle) but requires further analysis to determine how much is possible from the wheel/tire alone.

6.0 Patentability

Since the BriTek wheel is based on a sheet of membranes that connect an inner wheel to an outer wheel, it has strong patent potential. The other wheel patents that we have seen do not claim membranes as the deformational member.

7.0 Conclusions

The BriTek wheel has some interesting potential because of its creative use of membranes. The potential is there to construct a wheel that gives a superior ride and superior gas mileage over both the pneumatic tire and the Michelin Tweel.

The rubber membranes may have to be replaced by aluminum membranes to take full advantage of energy restoring potential.

No conclusions have been made as to other performance possibilities involving new modes of energy transfer.

Further research can probably better quantify the potential gas mileage advantage. For example, the required information may be obtained from the research literature available on the Freedom Car project.

Another way to determine the fuel advantage of the BriTek wheel is to do actual road testing. For example, a BriTek wheel and a high performance pneumatic tire test assembly could be constructed, instrumented and thoroughly road tested for a relatively low cost (a few hundred thousand dollars).

THE VEHICLE –PROPULSION AND RESISTANCE

Here we are concerned with the motion of a vehicle, i.e., its acceleration, deceleration, and the amount of weight it can carry. Also we are concerned with the selection and sizing of propulsion systems for a vehicle.

To look at propulsion and resistance, use Newton's laws of motion and mechanics:

$$\text{velocity} = v = \frac{dx}{dv} = \text{rate of change of distance over time}$$

$$\text{acceleration} = a = \frac{dv}{dt} = \frac{d^2x}{dt^2} = \text{rate of change of velocity over time}$$

$$\text{Newton's second law, } F = ma$$

$$F = \frac{\text{wgt.} * a}{g}$$

Concerned with net force on a vehicle or the difference between what is available from the propulsion system and the resistance encountered.

$$F_{net} = TF - R$$

$$.\ .\ a = F_{net} * \frac{g}{\text{wgt.}}$$

There is a circular problem. Since force and resistance are functions of velocity, velocity is a function of acceleration, acceleration is a function of force. So you need to know V to compute F, F to compute a, a to compute V.

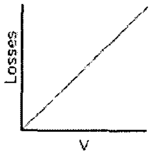
<u>Resistance to Motion</u>

- Elements of resistance to motion

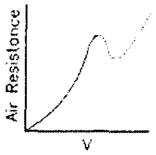
1) Friction, not a function of velocity--fixed in quantity, between wheel and surface, bearings, etc., friction depends upon (weight, form, and type of surface)

$$F_R = \mu N$$

2) Losses varying with speed, i.e., sway, flange friction, bumps, etc.

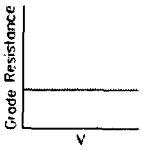


3) Air resistance depends upon cross section area, shape, length, etc. of vehicle,varies with the square of speed.



Note curve can drop when vehicle reaches a more drag-free regime, i.e., break sound barrier, hydrofoil.

4) Grade resistance, from going up or down grade can be positive or negative; doesn't vary with speed.



Grade resistance is equal to the component of vehicle weight which is parallel to the grade line.

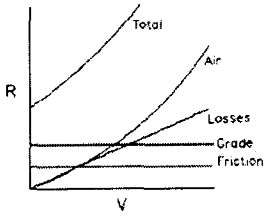
$$\text{Grade resistance} = \frac{W * G}{100}$$

W = weight of vehicle

G = percent grade

5) Curve Resistance: From friction of rail flanges against rails as a train goes around a cure, etc.. Railroad cure resistance is 0.8 lb. per ton of car per degree of curvature. I.e., a 100 ton car on a 2 degree curve has a resistance of 160 lb..

Total resistance



or $R = K_1 + K_2 * V + K_3 * V^2 + W * G/100$

Resistance equations for various types of vehicles.

Davis formula--Railway

$R_{\text{flat ground}} = (1.3wn+29n) + bwnV + CAV^2$

$R_t = (1.3wn+29n) + bwnV + CAV^2 + 20wn*G$

R_t = total resistance in lb. including grade resistance

V = speed - mph.

w = weight per axle (tons)

n = number of axles;

Note, $w_v = w*n$ = gross vehicle weight

b = coefficient of moving friction: .03 locomotives; .045 freight cars

C = drag coefficient of air .0017 streamlined locomotives, .0025 other locomotives, .0005 for trailing freight cars and .00034 for trailing passenger cars.

A = cross sectional area of vehicle, 120 sq. ft. for locomotives, 90 sq. ft. for freight cars and 120 sq. ft. for passenger cars.

G = % grade (upgrade +, downgrade -)

. . for Davis formula

$K_1 = 1.3wn + 29n$

$K_2 = bwn$

$K_3 = CA$

Modified Davis Equation (FE booklet)

$$R = 0.6 + \frac{20}{W} + .01 * V + \frac{KV^2}{WN}$$

N = number of axles
W = load per axle
K = air resistance coefficient

Road vehicle resistance

for Trucks on a gradient

$R = 7.6T + .09TV + .002AV^2 + 10*T*G$

K = air resistance coefficient

0.0935 = container on flat car
0.16 = trailer on flatcar
0.07 = other rail cars

T = weight of vehicle in 1000 lb.

V = velocity = mph.

A = cross sectional area - $ft.^2$

R = resistance in lb.

G = percent grade

for Autos on a gradient

$R = 10T + .1TV + .0026CAV^2 + 10*T*G$

C = air resistance parameter

Auto C = .4 to .5, new autos C = .35

Convertible C = .6 to .65

Bus C = .6 to .7

Comparison of equations

These equations are all similar in form, but show different effects from the various components of motion.

	Truck	Auto	Bus	Four Axle Locomotive
K_1	7.6T	10T	10T	2.6T+116
K_2	.09TV	.1TV	.1TV	.06TV
K_3	$.0020AV^2$	$.0013AV^2$	$.0016AV^2$	$.0025AV^2$

(T is weight in kips in all of the above.)

Propulsion Systems:

Need propulsive force to overcome resistance, accelerate vehicle. We are interested in the force needed to accelerate a given mass of vehicle at a given rate. Again, simple physics used:

$F = ma$

The rate at which work is done is power.

P = $\underline{dw}$ from work equation dw = F(x)dx/dt

P = F(x)$\underline{dx/dt}$; units in the English system are ft. - lb/sec.

Horsepower

$$1HP = \frac{550 \text{ ft.lb.}}{\text{sec.}} = \frac{375 \text{ lb.mi.}}{\text{hr.}}$$

$$P = \frac{F * V}{550}$$

Note that force is needed to accelerate vehicle and to overcome resistance to motion.

$$F_{max} = \frac{550P}{V} = \frac{375 * P(\text{Horsepower})}{V(\text{mph.})}$$

If you include drive train efficiency, e,

$$F_{max} = \frac{375 * HP * e}{V(\text{mph.})}$$

when the propulsive force exceeds the resistance, the vehicle accelerates;

when F is less than R, the vehicle decelerates.

$$F_{net} = \frac{W}{g} * a = F - R$$

$$a = \frac{g(F-R)}{W}$$

Fuel Consumption

Force applied over a distance, x, is work:

$$W = F * x, \text{ or } \frac{W * a * x}{g}$$

or in general, $W = F(x)dx$

Fuel consumption is directly related to the amount of work done.

Fuel = consumption rate * work done

The fuel consumption rate could be given in gallons of fuel per ft.-lb. For example, 1 gallon of gasoline contains 120,000 BTU and 1 BTU is equivalent to 778 ft.-lb. of work. Therefore 1 gallon of gasoline has the energy equivalent of $9.33 * 10^7$ ft.-lb. of work.

Propulsion/Resistance Examples:

1) A 200 ton, 4 axle locomotive has the following characteristics:

$b = .03$, $C = .0025$, $A = 120 \text{ ft.}^2$

What is the resistance at 12 mph? 50 mph? 70 mph? 100 mph?

Weight/axle = 50 tons

at 12 mph:

$R = 1.3 * 200 + 29 * 4 + .03 * V * 200 + .0025 * 120 * V^2$

$R = 376 + 6V + .3V^2$

$R = 376 + 72 + 43.2 = 491.2$ lb.

at 50 mph:

$R = 260 + 116 + .03 * 200 * 50 + .0025 * 120 * 50 * 50$

$R = 376 + 300 + 750 = 1426$ lb.

at 70 mph:

$R = 376 + 6 * 70 + .3 * 70^2$

$R = 376 + 420 + 1470 = 2266$ lb.

at 100 mph:

$R = 376 + 600 + 3000 = 3976$ lb.

2) What is the maximum traction force of a 2500-HP locomotive with an efficiency of .83 at 12 mph? 50 mph? 70 mph? 100 mph?

at 12 mph:

1 HP = 550 ft.-lb./sec = 550 * 3600/5280 = 375 lb.-mi./hr.

$F = 375 * P(HP) * E/V(mph) = 375 * 2{,}500 * .83/12$

$F = 64{,}800$ lb.

at 50 mph: $F = 15{,}600$ lb.

at 70 mph: $F = 11{,}100$ lb.

at 100 mph: $F = 7{,}800$ lb.

3) At what speed does the resistance of the locomotive equal its maximum propulsive force? (i.e., what is the maximum speed assuming proper gearing and suitable track?)

$F = R$

$778{,}100/V = 376 + 6V + .3V^2$

Solving the above (by trial and error),

$V_{max} = 128$ mph.

4) At what gradient will the locomotive coast downhill at a constant 50 mph?

$R_{50 \text{ mph}} = R_{grade}$

$1426 = 20 * wn * g$

$g = 1426/(20 * 200) = 0.356$

$g = -0.36\%$

5) The locomotive moving alone travels 10 miles at a constant 50 mph, on level track. If the energy conversion rate is 30%, what is the fuel consumption rate?

At a constant speed a force equal to the resistance must be applied: (zero acceleration)

$F = R = 1426$ lb. (from Davis equation)

Work = $1426 * 5280 * 10$ ft. lb.

Fuel used = $1426 * 5280 * 10/(.3 * 9.33 * 10^7) = 2.69$ gallons

Rate = .269 gal./mile = 3.72 mpg

6) Very small automobile

Engine power = 12 hp.

Weight = 1200 lb.

Cross sectional area = 20 ft.^2

Standard suspension, aerodynamic characteristics

Wind resistance parameter: $C = 0.4$

Engine efficiency = 0.3

Flat road, no curves

Question: How fast is the maximum steady state speed and what is the fuel economy at that speed?

$R = R_a + R_r$

$R = 0.01T + 0.0001TV + 0.0026CAV^2$

$= 0.01(1200) + 0.0001(1200)V + 0.0026 * 20 * .4 * V^2$

$R = 12.0 + 0.12V + 0.0208V^2$

At steady state speed

$F = R$ Propulsive force = R

so substituting F for M in the horsepower relationship

$$R = \frac{375 * HP}{V} * E$$

Assume for simplicity, there are no losses in the drive line, so $E = 1.00$

Then:

$R * V = 375HP = 4500$

Substituting for R

$12V + 0.12V^2 + 0.0208V^3 = 4500$

Which can be solved for V (trial and error)

$V \simeq 55.1$ mph

$R = 81.7$ lb.

Is this car fuel efficient?

Let's use these relationships.

1 btu = 778 ft.-lb.

1 gallon of gas = 120,000 btu

Fuel conversion efficiency = 0.3

Drive the car for one mile:

$$\text{Gallons of gas} = \frac{81.7 * 5280 \text{ feet/mile}}{0.3 * 778 \text{ ft.-lb./BTU} * 120{,}000 \text{ BTU/gal.}}$$

$$\text{Fuel economy} = \frac{55 \text{ miles}}{\quad} = \frac{1}{\quad} = 64.9 \text{ mpg BTU/gal.}$$

0.84 gallons 0.0154 gal./mile

7) What is the maximum acceleration from a speed of 30 mph of a 250 hp truck operating up a 5% grade? The truck weighs 20,000 lbs., is 85% efficient and has a cross-sectional area of 100 sq. ft.. (15)

$$F_{max} - R = m \ast a$$

$$R = 7.6 \ast T + .09T + V + .002 \ast A \ast V^2 + 10 \ast T \ast g$$

$$R = 7.6 \ast 20 + .09 \ast 20 \ast 30 + .002 \ast 100 \ast 30^2 + 10 \ast 20 \ast 5$$

$$R = 152 + 54 + 180 + 1000 = 1386 \text{ lb.}$$

$$F_{max} = \frac{375 \ast 250 \ast .85}{30} = 2656 \text{ lb.}$$

$$F_{net} = F_{max} - R = 2656 - 1386 = 1270 \text{ lb.}$$

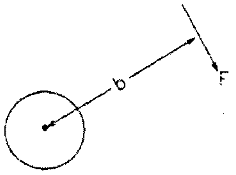
$$F_{net} = m \ast a$$

$$M = \frac{w}{g} = \frac{20{,}000}{32.2} = 621$$

$$1270 = 621 \ast a$$

$$a = 2.04 \text{ ft./sec.}$$

Torque: twisting moment applied to a wheel



Torque = F * b, units are ft.-lb.

Torque/Horsepower Relationship

Horsepower = 0.00019*t*N

t = torque of engine

N = rpm of engine

For a fixed gearing, torque is directly proportional to tractive effort.

Tractive effort = tGE/r

t = torque at output shaft of engine

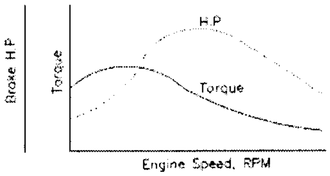
G = total gear ratio between output shaft and axle

E = drive line efficiency

r = radius of wheel under loaded conditions

concern with propulsion system which has two elements: prime mover and transmission.

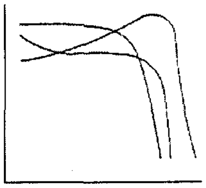
For prime mover we can look at horsepower and torque curves



The above curve is typical of a diesel engine; for a gasoline engine, maximum torque is reached at a higher RPM.

This difference is why diesel engines are good for weight hauling, since they can apply high torque at low speeds, as used in locomotives. Gasoline engines are good for rapid acceleration, as used in automobiles.

Electric motors, Horsepower v. Engine Speed



Curves can have a number of different shapes depending upon requirements; i.e., need high starting torque--you can get practically any shape you want depending on the design of the engine and transmission.

Advantages of straight electric locomotive: you can temporarily overload the locomotive when starting out and start up a heavy train.

Same idea used in diesel-electric locomotive (and also heavy off-road trucks).

Steam locomotive did not have nearly the same starting torque as a diesel. Diesel can pull more than a steam locomotive with the same horsepower. This and lower maintenance and operating costs led to the replacement of steam locomotives by diesel-electrics.

Transmissions. Want to get torque and power of engine transmitted to the wheels.

Purpose of transmissions

transfer power from engine to drive wheels while producing a reduction in engine speed and providing flexible control.

Types

electric

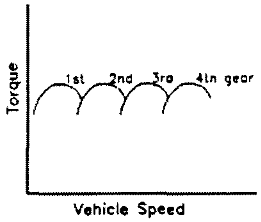
mechanical

different gearings

caterpillar, etc.

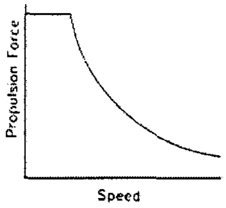
hydraulic-fluid

action-reaction-rocket



Vehicle movement is concerned is the variation of net propulsive force with speed (unfortunately, this is not a constant).

Also, net force = propulsive force - resistance.



Maximum propulsive force limited by: characteristics of the propulsion system, i.e., for above at low speeds motors and generators heat up. To maintain high torque and prevent stalling.

Also adhesion of wheels to ground limits maximum pull.

$F = \mu N$

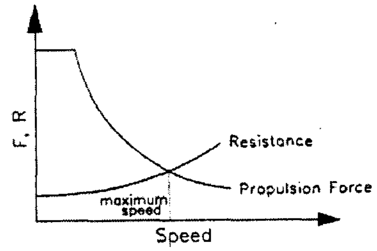
μ = coefficient of friction between wheel and rail, roughly .30

N = weight on one wheel

Minimum tractive effort is determined by maximum safe operating speed of motor, i.e., red line, above that engine tears apart from centrifugal force.

Look at propulsive force of vehicle as it varies with speed and also resistance.

Note when $F = R$ the vehicle is at maximum speed (i.e. net force = 0) and there is no force available to accelerate the vehicle.



Use curves such as this to describe motion of vehicle.

Note: It is analytically impossible to predict speed, distance, acceleration of most vehicles because:

$$\begin{tikzcd} & F = f(v) \arrow[dr] & \\ a = f(F) \arrow[ur] & & v = f(a) \arrow[ll] \end{tikzcd}$$

You can, however, solve for maximum speed, maximum grade, maximum weight, etc. This has to be analyzed by simulation.

Use small increments of time, Dt. Using t, beginning--find v, then F, then solve for new a, find v, . . ., etc.

Go to speed limit.

Two types of limits on speed.

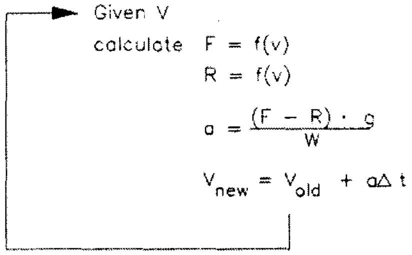
- Artificial (i.e. speed limit)

- Curvature (i.e. maximum safe speed around a curve)

V curve = 429.53 * (F+e)/degree curvature

Deceleration of vehicles usually occurs at constant rate.

Vehicle motion then simulated for a short period of time t.



Given V

calculate $F = f(v)$

$R = f(v)$

$$a = \frac{(F - R) \cdot g}{W}$$

$$V_{new} = V_{old} + a\Delta t$$

Vehicle Characteristics

Force-velocity curve

K_1, K_2, K_3

Weight

Side friction factor

Deceleration rate

Route Characteristics

Grade

Curvature

Superelevation

Speed limits

Distance

Vehicle Data		**SI Units**
Vehicle		
Vehicle Mass (tons)	0.6	545
Vehicle Frontal Area (sq ft)	20	1.9
Number of Axles	2	2
Mass per Axle (tons)	0.30	272
Engine efficiency	32.0%	32.0%
Drive train efficiency	95.0%	95.0%
Misc Resistances		
Journal constant 1 (lbsf/ton)	20.000	
Journal constant 2 (lbsf/ton)	0	
Flange constant (lbs/ton/mph)	0.200	
Drag Coefficient	0.0010	
Journal constant (lbsf)	12.00	53.4
Journal per W (lbsf)	0	0
Flange constant (lbsf/mph)	0.120	1.194
Wind (lbsf per mph sq)	0.02080	0.46297
Distance (miles)	1.00	1,609
Speed (mph)	40.00	17.8816
Journal resistive force (lbsf)	12.00	53.38
Flange resistive force (lbsf)	4.8	21.35
Wind resistive force (lbsf)	33.28	148.04
Journal energy		85,904
Flange energy		34,362
Wind energy		238,241
Total energy losses		358,507
Energy to Reach Speed		
Energy to reach speed		87,100
Total energy to reach speed		445,607
Fuel		
Specific energy (BTU/lb)	18,800	43,728,800
Density (gms/cc)	0.72	720
Mass fuel per gallon		2.748
Energy per gallon (BTU/gal)	113,899	120,170,748
Mecahnical energy per gallon		36,531,907
Gallons to reach speed		0.012
MPG		81.982
Percentage journal to total energy		24%
Total energy to reach speed if journal energy is zero		359,703
Gallons to reach speed		0.010
MPG		101.561
Percent savings in mpg		23.9%
Vehicle		
Small Car		
Fuel		
Gasoline		

Vehicle Data		SI Units
Vehicle		
Vehicle Mass (tons)	2.5	2,270
Vehicle Frontal Area (sq ft)	31	2.9
Number of Axles	2	2
Mass per Axle (tons)	1.25	1,135
Engine efficiency	32.0%	32.0%
Drive train efficiency	95.0%	95.0%
Misc Resistances		
Journal constant 1 (lbsf/ton)	20.000	
Journal constant 2 (lbsf/ton)	0	
Flange constant (lbs/ton/mph)	0.200	
Drag Coefficient	0.0013	
Journal constant (lbsf)	50.00	222.4
Journal per W (lbsf)	0	0
Flange constant (lbsf/mph)	0.500	4.975
Wind (lbsf per mph sq)	0.04030	0.89701
Distance (miles)	1.00	1,609
Speed (mph)	40.00	17.8816
Journal resistive force (lbsf)	50.00	222.41
Flange resistive force (lbsf)	20	88.96
Wind resistive force (lbsf)	64.48	286.82
Journal energy		357,934
Flange energy		143,174
Wind energy		461,592
Total energy losses		962,700
Energy to Reach Speed		
Energy to reach speed		362,918
Total energy to reach speed		1,325,618
Fuel		
Specific energy (BTU/lb)	18,800	43,728,800
Density (gms/cc)	0.72	720
Mass fuel per gallon		2.748
Energy per gallon (BTU/gal)	113,899	120,170,748
Mecahnical energy per gallon		36,531,907
Gallons to reach speed		0.036
MPG		27.558
Percentage journal to total energy		37%
Total energy to reach speed if journal energy is zero		967,684
Gallons to reach speed		0.026
MPG		37.752
Percent savings in mpg		37.0%
Vehicle		
SUV		
Fuel		
Gasoline		

Vehicle Data		SI Units
Vehicle		
Vehicle Mass (tons)	15	13,620
Vehicle Frontal Area (sq ft)	100	9.3
Number of Axles	2	2
Mass per Axle (tons)	7.50	6,810
Engine efficiency	42.0%	42.0%
Drive train efficiency	90.0%	90.0%
Misc Resistances		
Journal constant 1 (lbsf/ton)	20.000	
Journal constant 2 (lbsf/ton)	0	
Flange constant (lbs/ton/mph)	0.200	
Drag Coefficient	0.0016	
Journal constant (lbsf)	300.00	1334.5
Journal per W (lbsf)	0	0
Flange constant (lbsf/mph)	3.000	29.851
Wind (lbsf per mph sq)	0.16000	3.56132
Distance (miles)	1.00	1,609
Speed (mph)	40.00	17.8816
Journal resistive force (lbsf)	300.00	1334.46
Flange resistive force (lbsf)	120	533.78
Wind resistive force (lbsf)	256	1138.74
Journal energy		2,147,605
Flange energy		859,042
Wind energy		1,832,623
Total energy losses		4,839,270
Energy to Reach Speed		
Energy to reach speed		2,177,509
Total energy to reach speed		7,016,779
Fuel		
Specific energy (BTU/lb)	18,200	42,333,200
Density (gms/cc)	0.84	840
Mass fuel per gallon		3.206
Energy per gallon (BTU/gal)	128,642	135,724,763
Mecahnical energy per gallon		51,303,961
Gallons to reach speed		0.137
MPG		7.312
Percentage journal to total energy		44%
Total energy to reach speed if journal energy is zero		4,869,174
Gallons to reach speed		0.095
MPG		10.536
Percent savings in mpg		44.1%
Vehicle		
Bus		
Fuel		
Diesel		

Vehicle Data		**SI Units**
Vehicle		
Vehicle Mass (tons)	10	9,080
Vehicle Frontal Area (sq ft)	100	9.3
Number of Axles	2	2
Mass per Axle (tons)	5.00	4,540
Engine efficiency	42.0%	42.0%
Drive train efficiency	90.0%	90.0%
Misc Resistances		
Journal constant 1 (lbsf/ton)	15.200	
Journal constant 2 (lbsf/ton)	0	
Flange constant (lbs/ton/mph)	0.180	
Drag Coefficient	0.0020	
Journal constant (lbsf)	152.00	676.1
Journal per W (lbsf)	0	0
Flange constant (lbsf/mph)	1.800	17.911
Wind (lbsf per mph sq)	0.20000	4.45166
Distance (miles)	1.00	1,609
Speed (mph)	40.00	17.8816
Journal resistive force (lbsf)	152.00	676.13
Flange resistive force (lbsf)	72	320.27
Wind resistive force (lbsf)	320	1423.42
Journal energy		1,088,120
Flange energy		515,425
Wind energy		2,290,779
Total energy losses		3,894,324
Energy to Reach Speed		
Energy to reach speed		1,451,672
Total energy to reach speed		5,345,996
Fuel		
Specific energy (BTU/lb)	18,200	42,333,200
Density (gms/cc)	0.84	840
Mass fuel per gallon		3.206
Energy per gallon (BTU/gal)	128,642	135,724,763
Mecahnical energy per gallon		51,303,961
Gallons to reach speed		0.104
MPG		9.597
Percentage journal to total energy		28%
Total energy to reach speed if journal energy is zero		4,257,876
Gallons to reach speed		0.083
MPG		12.049
Percent savings in mpg		25.6%
Vehicle		
Truck		
Fuel		
Diesel		