DEHYDS
*Digital Electro-Hydraulic Systems*
*The Future of Efficient Motion*
www.dehyds.com
1006 143rd Ave. S.E.
Tenino, WA 98589
360-264-2141 ed@dehyds.com

# Understanding Standby Power Energy Penalties

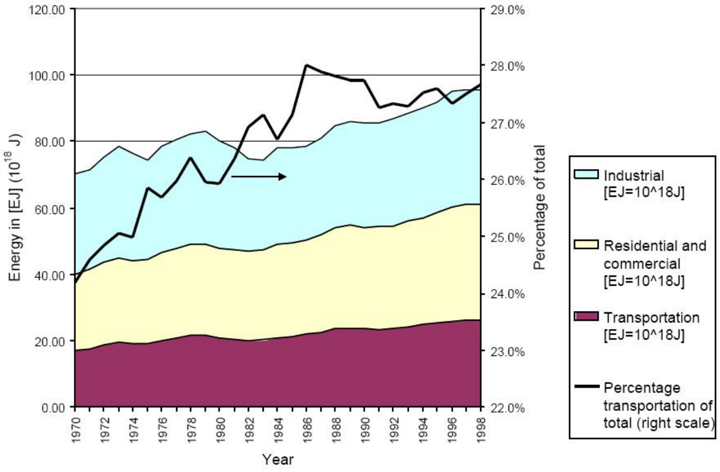
*Prepared by Ed Danzer*

September, 2007

# Introduction

Vehicles and mobile equipment have had a major impact on modern man’s quality of life. Without farming equipment, construction equipment, cars and trucks we could not produce the food, clothing, shelter, and entertainment we take for granted. These daily needs require energy to create and maintain them. Today we use petroleum as the primary energy source to power our equipment and vehicles. Over the past century, the engine, and drive train in our equipment and vehicles has changed very little. Today we are faced with dwindling petroleum reserves, pollution, and a growing population. This creates a demand for a more energy efficient engines and drive train components.

There has been significant work done defining what needs to be done to make our vehicles more efficient. The 21st Century Truck Program and Future Car are just 2 of many programs for vehicles. Transportation energy usage has been nearly constant since 1980, at about 27% (Figure 1)



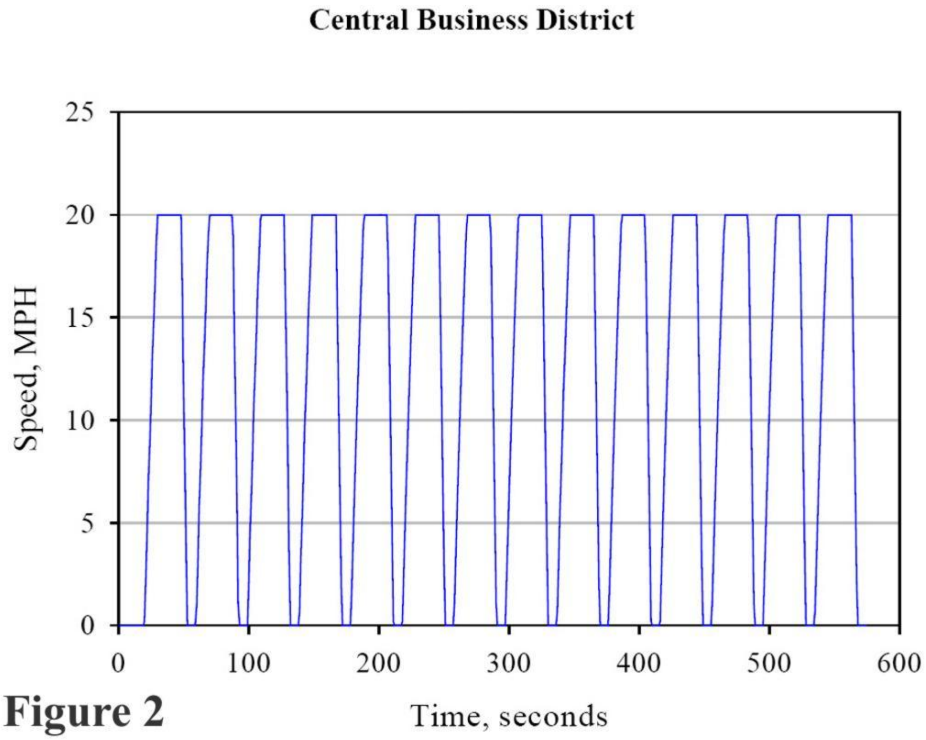
[1] Figure 1: Consumption of Total Energy by End-Use Sector (US), 1970-98.

Reprinted with permission from MIT LFEE

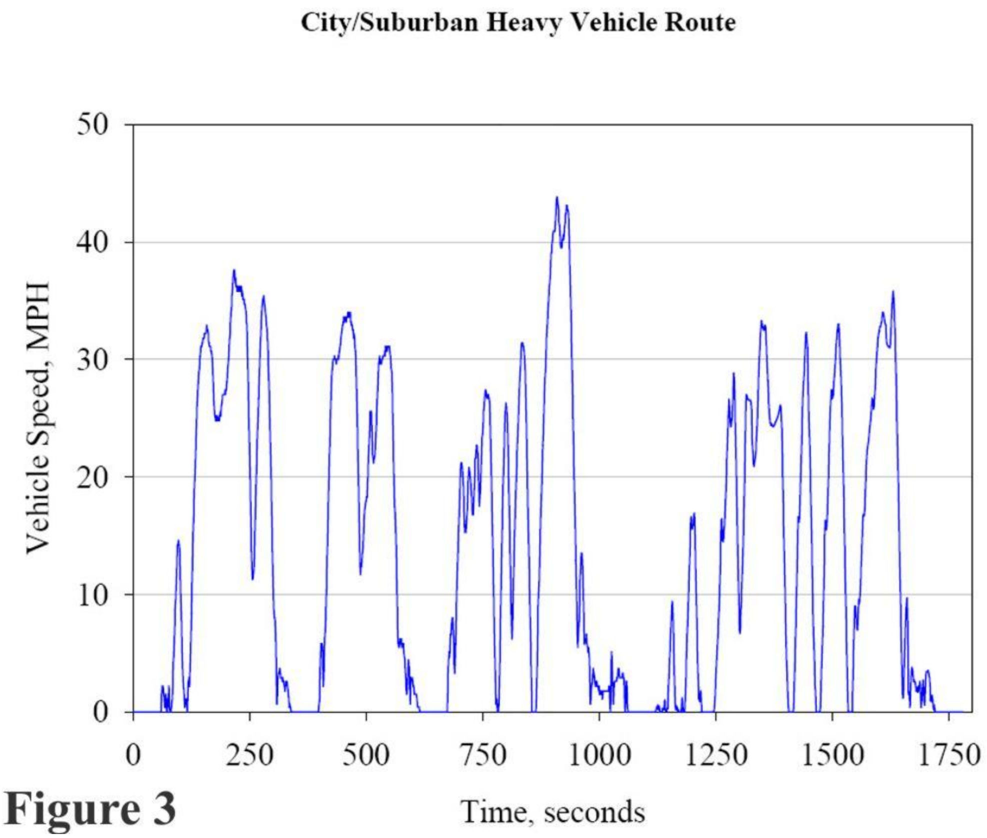
How this energy is used by transportation is currently defined as Idle, or Travel. This paper will explain traveling energy and idling energy into Standby Energy, by using existing drive cycle data, fuel maps, and an engine rpm/load graph. Future papers may show actual drive cycle data. There is little information about how industrial energy usage, but when observing off highway equipment there is idle time, low power usage time, and high power usage time similar to highway vehicles.

# Defining Standby Power

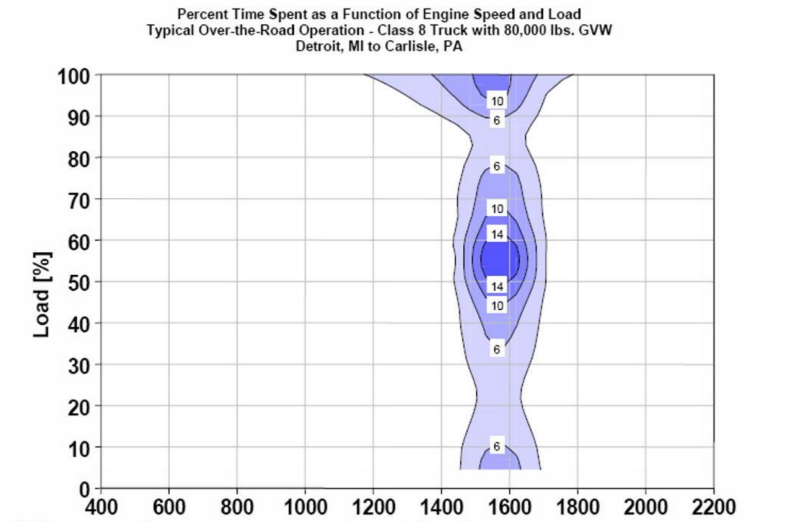
When a vehicle is goes from point A to point B, and back to point A, a drive cycle can be generated. There are many predefined drive cycles used for computer modeling and fuel mileage measuring. Many of these are generated by collecting time, speed, and distance information when someone is driving a route. Of these drive cycles this paper will focus on the Central Business District, or CBD-14 (Figure 2), the City / Suburban heavy vehicle route, or C/S (Figure 3), and the Mountain Drive route, or MD (Figure 4).



[2] **Figure 2**



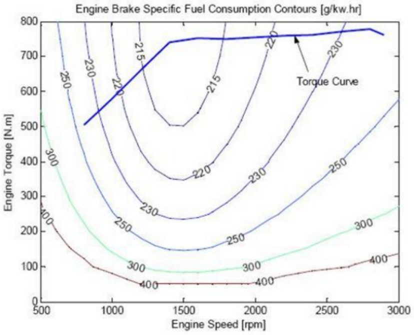
[3] **Figure 3**



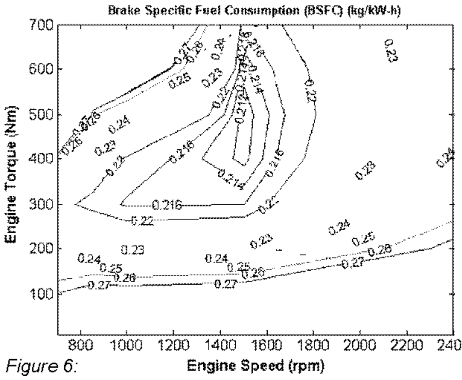
[4] **Figure 4**

Reprinted with permission from Freightliner LLC

The CBD-14 and C/S drive cycles show the vehicle changing speed over time, and MD drive cycle shows engine load and rpm changes during a drive cycle. The CBD-14 drive cycle is defined as a transit bus accelerating from 0 to 20 mph in 10 seconds, traveling 20 mph for 18 seconds, decelerating from 20 to 0 in 4.5 seconds, and idling for 7 seconds. Using standard vehicle drive calculations the minimum power required to accelerate the bus is 200 hp, yet it could take as little as 4 hp to travel the 18 seconds at 20 mph (This is at 100% efficiency). The different fuel maps (figure 5 and 6) show a large difference in fuel used relative to load and rpm. These fuel maps may not represent actual engines, but were taken from other published papers.



[5] *Figure 5: Engine Specific Fuel Consumption Map*



[6] *Figure 6:*

[5]Reprinted with permission from SAE Paper #2005-01-1164 © 2005 SAE International [6] Reprinted with permission from SAE Paper # 2006-01-0442 © 2006 SAE International

The problem with theoretical power calculations is they cannot happen in the real world. 200 hp at 1 mph would spin the tires, so when starting out the torque is high but the actual horsepower is not, and as the speed increases so does the actual horsepower at the tire/road area. The 4 hp to travel at 20 mph should require about 400Nm of engine torque at 900 rpm, or 236Nm at 1500 rpm depending on gear ratio. In either case there is at least a 10% drop in fuel consumption compared to running at the best efficiency. This 10% drop is part of the standby energy penalty. What is not accounted for is the power loss from the engine flywheel to the wheel hub. After searching the internet there does not seem to be publicly viewable data for any transmissions or drive axles showing the input torque verses output torque at different torques and rpm. When manually rotating both a car transmission and drive axle compared to a Class 8 truck transmission and drive axle there is a difference in torque observed. This loss from the transmission and drive axle is another part of the standby energy penalty. Using the Figure 4 engine load graph and Figure 5 or 6 fuel maps, there are areas where the engine is operating in its highest fuel usage range to do very little work. These include high torque at low rpm, and low torque high rpm. Another aspect of standby power even more difficult to obtain data on is the effects of cab heating and cooling (hotel loads), engine cooling loads and lighting. Hot or cold weather increase hotel loads by requiring heating or cooling for the operator. Engine cooling energy needs change with temperature and engine speed. When operating in cold weather the energy used to turn the fan and water pump is wasted and can reduce the efficiency of the engine if not at the correct operating temperature. During hot weather operation, the fan and water pump need to operate at full efficiency at certain times, yet as the power or speed demand changes so do the cooling needs. Additional lighting required for night time operation increases the size of alternator required to keep the batteries charged. Increasing the size of the alternator increased can reduce the efficiency of the alternator when operating at low output levels. The rotating mass of the fan, water pump, alternator, crankshaft, pistons, connecting rods, camshaft, air compressor, clutch, transmission, drive line, and drive axle components must be accelerated at the same time as the load is being accelerated in trucks. This component acceleration requires energy over and above what is required to move the truck. Fuel maps like Figure 5 and 6 do not show fuel usage when accelerating the rotating components of the engine, nor the load created by the drive train components, vehicle weight and cargo.

Standby power is the difference between the maximum engine power available to do all the work possible with the selected components minus the amount of work being done during different portions of an operating cycle. As described above, this is affected by weather, time of day, traffic conditions, and payload, to name a few.

# Completing an Energy Audit

With the lack of credible information required to understand the cost penalty for Standby Energy and the potential for significant energy savings, completing an energy audit is the first step.

DEHydS is setting up to do a portion of this task on 2 axle garbage truck with our EWT011 wheel torque sensor (Figure 7).

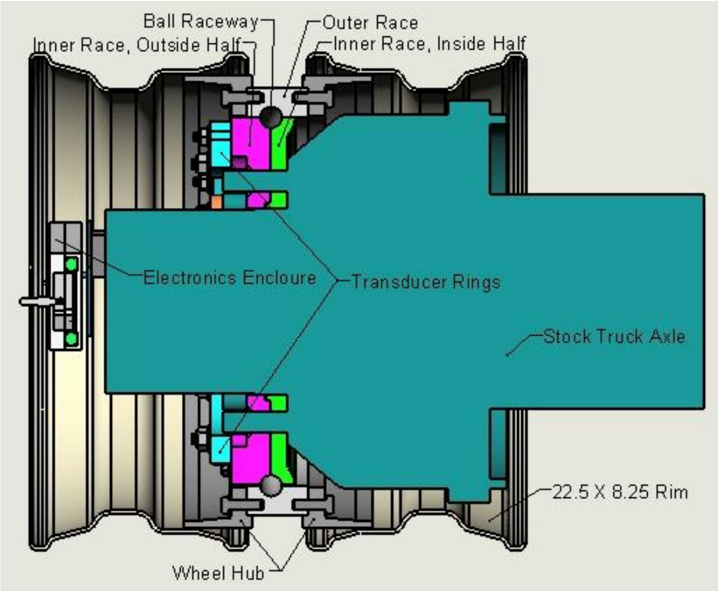


Figure 7

The first data collected will include the actual torque between the wheels and the drive axle, the travel speed using a fifth wheel attached to the truck and the fuel used during a normal pickup drive cycle. This data will provide the actual amount of work done to propel the vehicle and with the fuel used we can determine the thermal efficiency during portions the vehicle drive cycle. The fuel usage will then be compared to the fuel map of the engine to determine the standby energy penalty for the test vehicle at various parts of the drive cycle.

# Conclusion

Determining what components create enough of a standby energy penalty to justify changing by applying different technology is a major task. Our digital electro-hydraulic systems will provide solutions to reduce these standby energy costs.

If you have further interest or questions please visit our web site or contact Ed Danzer.

# References

1. MIT EL 00-001 Fuel Savings Potential and Costs Considerations for US Class 8 Heavy Duty Trucks through Resistance Reductions and improved Propulsion Technologies until 2020
2. National Renewable Energy Laboratory, June, 2001
3. National Renewable Energy Laboratory, June, 2001
4. Craig Savonen, Guangsheng Zhu, Houshun Zhang, Sandeep Singh, Rakesh Aneja, “Heavy-Duty Engine Technology for High Efficiency at EPA 2010 Emissions Regulations.” DEER 2006.
5. S.R. Anderson, D.M. Lamberson, T.J. Blohm and W. Turner, “Hybrid Route Vehicle Fuel Economy.” SAE Technical Paper #2005-01-1164
6. Bin Wu, Chan-Chiao Lin, Zoran Filipi, Huei Peng and Dennis Assanis, “Optimal Power Management for a Hydraulic Hybrid Delivery Truck.” SAE paper # 2006-01-0442