Oregon Department of Transportation

"Green Light" Emission Testing Project

Conducted by the
Oregon Department of Environmental Quality
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Summary

Emission measurements were taken from a Class 8 diesel powered truck traveling at interstate highway speeds and also when it was proceeding through a weigh station checkpoint. The over the road operational mode resulted in a 57% improvement in fuel economy. A reduction in each of the pollutants monitored, particulate matter, carbon dioxide, nitrogen oxides, carbon monoxide and hydrocarbons, ranging from 67 to 36 percent was recorded compared to traveling through the weigh station. Overall annual benefits from the Green Light Program can be substantial.

Background

The Green Light Program was initiated in 1995 as a weigh station preclearance program through the creation of an automated and intelligent truck transportation system. The intention is to improve the safety and efficiency of the commercial trucking industry while at the same time increasing the performance of roadside weigh station facilities without physically expanding them, and protecting the public investment in the infrastructure.

Oregon has installed systems at 21 weigh stations to electronically screen trucks as they approach at highway speeds. The deployment at all 21 sites was completed and fully operational by March 2001. Weigh-in-motion (WIM) systems check the vehicle's weight and height, and automatic vehicle identification (AVI) systems check records for registration, tax status, and safety status. The driver is signaled with an in-cab device to either Report to the station or to Bypass.

The Oregon Department of Transportation (ODOT) has commissioned various studies to evaluate the operation and functionality of the system. In 2003 ODOT made a request to the Department of Environmental Quality to evaluate the emission impact from the Green Light program. At the time, the DEQ ran the EPA Mobile Model assuming a heavy duty truck traveling at various speeds, 60, 17, 10.2 and 7.3 mph. This was, at best, an imperfect application of the model to this circumstance. The result suggested that particulate emissions were unchanged, nitrogen oxide emissions increased, and volatile organic and carbon monoxide emissions decreased for vehicles traveling at highway speeds compared to those operating at the slower speeds through the weigh stations.

In the spring of 2008 the DEQ obtained a Portable Emission Measurement System (PEMS). The PEMS used was the Montana system manufactured by Clean Air Technologies, Inc. This system is capable of real-time, continuous mass measurement of fuel consumption and nitrogen oxides (NO_x), carbon monoxide (CO), carbon dioxide (CO_2) and particulate matter measured aerodynamically at 10 microns or less (PM_{10}). PM measurement is facilitated using a light-scattering device with an undiluted, conditioned exhaust sample. Mass exhaust flow necessary for the calculation of mass emissions is determined from the engine operating data, in lieu of a direct measurement. Several studies have indicated a strong correlation between data obtained from this system and measurements conducted in more controlled laboratory settings. Use of this instrument will allow for a more precise characterization of emissions benefits, if any, from the Green Light program.

Procedure

ODOT supplied and operated the vehicle, a Volvo D12 2004 model year tractor. The truck was configured with a lowboy trailer carrying steel plate with a gross weight of 51,700 pounds. The fuel used was ultra low sulfur diesel blended with 20% biodiesel.

The test area was a section of Interstate 5 in Oregon from the Aurora/Donald interchange at milepost 278 to the Woodburn interchange at milepost 271. The Woodburn Port of Entry southbound on I-5 at milepost 274 and the Woodburn weigh station northbound on I-5 at milepost 274.5 are located within the test area.

The test was conducted on June 17, 2008. The test equipment was warmed up for at least 45 minutes prior to the test run and was installed on the vehicle according to the manufacturer's directions and protocols for conducting emission testing. The unit was calibrated on June 16, 2008.

The truck started from the southbound Woodburn Port of Entry and proceeded to the Woodburn interchange (Segment 1). The truck then returned to the freeway northbound (Segment 2) and went through the Woodburn northbound weigh station as if it were being weighed, although the station on this day was closed. The truck then returned to the highway (Segment 3), exiting at the Aurora interchange, getting back on the freeway southbound (Segment 4). The Woodburn port of entry weigh station was open and the truck entered and was weighed on each pass. The cycle was repeated for 5 weigh station trips. The highway segments measured emissions when the truck reached 55 mph and until it began decelerating upon approaching the ramp or the weigh station. Valid data were obtained for ten of the twelve highway segments and the five weigh station segments that were run.

Results

There were distinct differences between the two conditions for each of the pollutants measured as well as in fuel economy whether traveling at highway speed or entering and exiting the weigh stations. Table 1 displays the data for each mode and run. Table 2 shows the means of the valid samples and the percentage change between the modes. The greatest pollution reduction is for particulate matter followed by carbon monoxide, hydrocarbons, nitrogen oxides and carbon dioxide. Fuel economy was 57.1% improved in the highway mode as compared to the acceleration and deceleration pattern that was typical of a weigh station interaction. Each of the differences is significant although less so for hydrocarbon emissions. A two-tailed t-test gave a p-value < 0.01 for fuel economy and emissions of NO_x, CO, CO_2 and PM_{10}, so the difference in these sample means is significant at the 1% level. The difference in sample means for HC is significant only at the 5% level (p-value < 0.05) (see Table 3). Figure 1 displays the results on a logarithmic scale, which was done given the range in detected mass emissions depending upon the pollutant monitored. In the graphic the results for PM_{10} are reported in grams per mile as compared to mg/mi in the data set.

Discussion

With trucks accelerating under load in leaving a weigh station, it should not be surprising that there is a decrement in fuel economy as well as an increase in emissions produced as compared to the truck operating in a steady state mode on the highway. This report is able to provide a better characterization of the differences between the two operating states than the previous attempt.

ODOT anticipates 1.5 million Green Light bypasses to occur in 2008. Based on the results from this investigation, this translates in fuel savings alone to be worth over $600, 000. There is also a time savings of 1.47 minutes for each bypass resulting in increased distance traveled. Factored over the year's projection for bypasses, the Green Light program would result in a savings of about 2.2 million minutes of driver time or, to put it another way, freight having moved by over 2 million miles by securing a Bypass rather than a Report command. In a just-on-time distribution system, that many businesses today rely on and in which trucks play a key role, this also has economic benefit.

The resulting annual emission reductions include NOx by 8 tons, hydrocarbons by 1 ton, carbon monoxide by 2.4 tons and particulate matter by 0.5 tons. PM and NOx emissions have significant potential for harm to human health and the environment and reductions of these pollutants are important in protecting public health. Each pollutant has differing health and environmental impacts and has consequently differing value in terms of public health and environmental benefits gained. According to at least one study (McCubbin and Delucchi 1999) reductions in PM and NOx emissions achieve the highest value for ton of pollutant reduced.

Climate change is an emerging area of concern with serious global implications. Many strategies to mitigate global warming are being discussed and evaluated but implementation is not widespread. Carbon dioxide, a dominant climate change forcing agent, is projected to be reduced by 1300 metric tons annually with this program. While this is relatively small in relation to the annual total emitted in the U.S., it is a readily deployable action that has proven effective since its start in 1995.

Each bypass results in fuel savings and emission reductions, which can be very significant cumulatively. A million bypasses can result in over $400,000 in fuel savings, 1.5 million additional miles traveled as well as pollution reduced on the order of 5.5 tons for NOx, 0.6 tons for hydrocarbons, 1.6 tons for CO, 0.3 tons for PM and 875 metric tons for CO_2. Since 1998 there have been over 9.8 million preclearance bypasses from this program.

Approximately 500,000 trucks operating in Oregon each year are unable to be weighed in motion in the Green Light Program because they have a transponder issued by HELP Inc., which has prohibited their use in the state. This lost opportunity results in avoidable impacts of around $135,000 in fuel costs and results in a significant amount of pollution: more than 2.66 tons of nitrogen oxide, hydrocarbon, carbon monoxide and particulate matter emissions and more than 291 metric tons of carbon dioxide emissions. Green Light will realize its full potential to save fuel and reduce emissions when barriers to the use of compatible transponders are removed.

To the extent that ODOT program goals to ensure safe and legal operation of trucks on the state's highways are still met, further efforts to encourage use of the Green Light program will have positive benefits in improved fuel economy, increased operational efficiency along with reduced emissions affecting human health and climate change.

Figure 1 Test Plan Layout

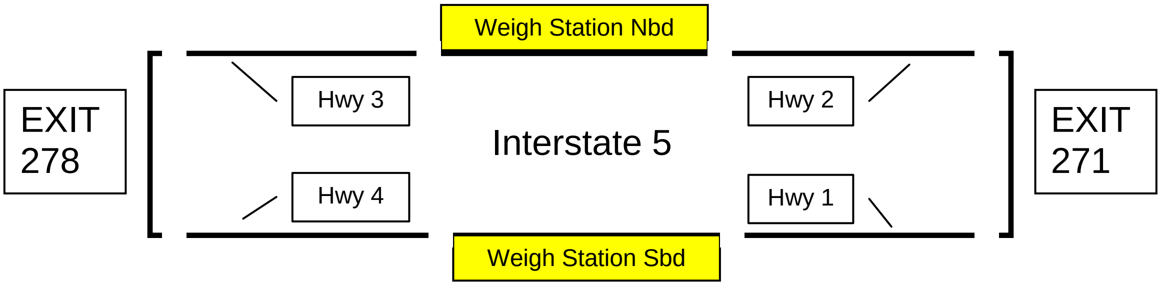

Table 1 Test Data

Mode	Distance [mi]	fuel[mpg]	NO_x[g/mi]	HC[g/mi]	CO[g/mi]	CO_2 [g/mi]	PM[mg/mi]
Weigh Nbd	0.9	4.4	12.05	0.7	2.6	2257	431.32
Weigh Sbd	1.15	3.9	15.76	1.54	3.45	2543	459.454
Weigh Nbd	0.83	4	13.81	1.35	2.94	2506	398.979
Weigh Sbd	1.01	4.3	13.52	1.2	2.93	2306	317.314
Weigh Nbd	0.98	3.9	13.61	1.08	2.83	2518	435.36
Highway 2	1.15	5.5	11.21	0.51	1.48	1816	137.712
Highway 4	3.41	6.3	8.92	0.66	1.64	1583	155.545
Highway 1	1.67	7	8.46	0.77	1.47	1415	98.681
Highway 2	1.31	6.3	9.45	0.89	1.77	1568	180.179
Highway 3	4.12	5.9	7.89	0.91	1.61	1692	87.67
Highway 4	3.15	7	7.56	0.54	1.17	1417	132.32
Highway 1	1.8	7	7.84	0.64	1.66	1422	139.412
Highway 2	1.18	6.2	9.11	0.42	1.45	1603	122.038
Highway 3	3.84	6.6	8.49	0.51	1.44	1491	143.991
Highway 4	3.27	6.6	8.48	0.45	1.49	1508	146.903

Table 2 Compiled data results

	fuel [mpg]	NO_x [g/mi]	HC[g/mi]	CO[g/mi]	CO_2 [g/mi]	PM[g/mi]
Highway Mode	6.44	8.74	0.63	1.52	1551.50	0.13
Weigh Station	4.1	13.75	1.17	2.95	2426.00	0.41
Fuel Economy Improvement	57.1%					
Emission Reduction		36.4%	46.3%	48.5%	36.0%	67.1%

Figure 2 Emission Results

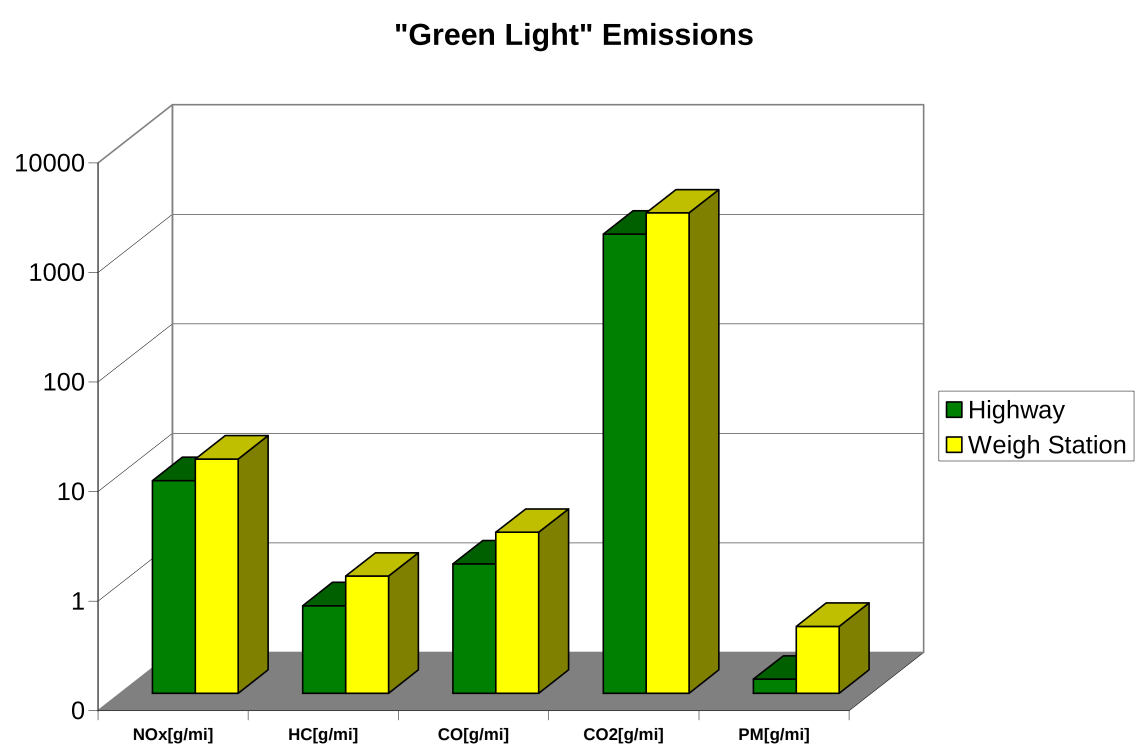

Table 3 t-Test: Two-Sample Assuming Unequal Variances

	Fuel[mpg]	NO_x *[g/mi]*	*HC[g/mi]*	*CO[g/mi]*	*CO_2[g/mi]*	*PM[mg/mi]*
t Stat	12.31	7.38	3.58	9.64	12.04	10.48
P(T<=t) two-tail	0.00000002	0.000152	0.015845	0.000204	0.000002	0.000136
t Critical two-tail (a = 0.05)	2.16	2.36	2.57	2.57	2.31	2.57
t Critical two-tail (a = 0.01)	3.01	3.5	4.03	4.03	3.36	4.03

Table 4 Sources and Health Effects of Pollutants

Pollutant	Source	Harmful Effects	Relative value in reducing one ton of pollutant in avoided human health impact (CO as baseline)[1]
Nitrogen oxides (NOx)	Combustion byproduct	One of the main ingredients involved in the formation of ground-level ozone, which can trigger serious respiratory problems. Reacts to form nitrate particles, acid aerosols, as well as NO_2, which also cause respiratory problems. Contributes to formation of acid rain. Contributes to nutrient overload that deteriorates water quality. Contributes to atmospheric particles, that cause visibility impairment most noticeable in national parks. Reacts to form toxic chemicals. Contributes to global warming.	226X
Hydrocarbons (HC)	Combustion byproduct, fuel production and storage	Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system. Some organics can cause cancer in animals; some are suspected or known to cause cancer in humans	14X
Carbon Monoxide (CO)	Combustion byproduct	Inhibits the blood's capacity to carry oxygen to organs and tissues. Persons with heart disease are especially sensitive to carbon monoxide poisoning and may experience chest pain if they breathe the gas while exercising. Infants, elderly persons, and individuals with respiratory diseases are also particularly sensitive. Carbon monoxide can affect healthy individuals, impairing exercise capacity, visual perception, manual dexterity, learning functions, and ability to perform complex tasks.	1X
Carbon Dioxide (CO_2)	Fuel combustion	Primary anthropogenic contributor to climate change impacts	NA

[1] McCubbin, Donald and Mark Delucchi (1999), The Health Costs of Motor-Vehicle-Related Air Pollution, *Journal of Transport Economics and Policy*, September, Vol. 33, Part 3, pp. 253-86.

Particulate matter (PM)	A variety of sources that emit dust and other fine particles but the smallest particles most responsible for the majority of health effects are typically combustion related	Particle pollution - especially fine particles - contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including: • increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, for example; • decreased lung function; • aggravated asthma; • development of chronic bronchitis; • irregular heartbeat; • nonfatal heart attacks; and • premature death in people with heart or lung disease.	2180X