Experimental Evaluation of Aftermarket Air Intake

Andrew Starr
Dr. David Mikesell
Department of Mechanical Engineering
Ohio Northern University
Ada, OH 45810
Email: a-starr@onu.edu
Email: d-mikesell@onu.edu

Abstract

Options to improve engine power and fuel economy abound on the aftermarket, many of which involve reducing flow restrictions. In order to evaluate the claims of one such device, an aftermarket air intake was installed on a 2004 Honda CR-V. The study involved nearly 4600 miles driven, half before and half after the modification, with records and consideration of ambient temperature, type of terrain, wind, urban vs. highway driving, and payload. The new intake resulted in an overall average mileage improvement of 2.3 mpg. No noticeable improvement was seen in acceleration from 5 to 60 mph.

Introduction

In today's car industry, much focus is placed on fuel efficiency. Many steps have been taken to help ease the increasing cost of gasoline. With the current financial pressures on the average car buyer, many are looking to stretch their money by purchasing a more fuel efficient car. For these reasons, fuel economy is an important focal point of the modern automotive industry.

The object of this test was to improve the fuel economy and horsepower of a specific passenger car by replacing the factory air intake with an aftermarket system. Products from various manufacturers were compared, and a decision was made according to a matrix reflecting the priorities of the vehicle owner. In order to obtain statistically significant mileage results, driving data was recorded and analyzed over 4600 miles, roughly half before and half after the new intake was installed. Horsepower was compared anecdotally by measuring acceleration runs pre- and post-modification. Many manufacturers market their intakes as "performance grade" and some, such as K&N, have published in-depth research from dynamometers online. Many times aftermarket intakes are purchased with the intention of improving horsepower, but this goal was secondary to evaluating fuel economy.

There are two main theoretical advantages to an aftermarket intake. The first is that the standard "air box" restricts airflow and increases engine pumping losses, thus reducing its efficiency. The second advantage is lowering the temperature of the air entering the engine. Since cold air is denser, it offers a more efficient combustion than warm air. The plastic surrounding the "air box" can quickly become warm due to heat dissipated from the engine, which warms the air drawn into it. An aftermarket intake draws from open air at a location farther away from the engine, which is potentially cooler.

The above notions are challenged, however, by a 2009 Oak Ridge National Laboratory study showing that air flow restriction, caused in that case by fouled air filters, only impacted fuel economy on older carbureted vehicles[1]. The three modern vehicles tested (with closed-loop feedback control regulating their air-fuel mixture) showed no difference in mileage regardless of filter condition.

The ORNL hypothesis was that a vehicle would exhibit increased power with a clean filter, but any gain in reduced pumping loss across a dirty filter would likely be given up again across the throttle. Thus an operator of a vehicle with a clogged filter would simply open the throttle wider to achieve a given acceleration or maintain a steady-state speed; the net airflow restriction remains unchanged, and the fuel-air mixture remains balanced by the air mass flow sensor and vehicle computer. Despite this evidence, the authors proceeded with the modification of the study vehicle and power and mileage analysis.

Note that there are two standard types of aftermarket air intakes; short ram and cold air. Short ram intakes generally replace the stock filter in the same location in the car, whereas cold air intakes use a longer pipe to draw air from a potentially cooler spot in the car such as the wheel well. Since the car used in the experiment was not a sports car, cold air intakes were not available and a short ram air intake was used.

Method

Vehicle

The vehicle used in the experiment was a 2004 Honda CR-V LX as shown in Figure 1. The car utilizes a naturally-aspirated 2.4L, inline 4 cylinder engine with dual overhead camshafts, 4-speed automatic transmission and all-wheel drive. At the start of the test period, the car had roughly 80,000 miles. The rated horsepower for this model car is 160 hp at 6000 rpm. The EPA estimated MPG is 20/26 (city/highway).

Figure 1: 2004 Honda CR-V, the test study vehicle[2]

Procedure

Mileage and driving data were recorded for 2344 miles before the modification, following the format shown in Table 1. After a statistically significant baseline had been established, the factory standard "air box" was replaced with an aftermarket air intake. The

before and after pictures are shown below in Figures 2 and 3. There are many aftermarket intakes available; the decision criteria for which intake was chosen can be found in the results section. Following the modification ("postmod"), trip and mileage data was collected for another 2217 miles. When the gas gauge reached close to empty the tank was filled. Each fill up was recorded so that the total fuel consumption could be recorded and analyzed.

All test mileage was driven by the same operator. On the "easy-going / average / spirited / aggressive" scale, this driver characterizes himself as "average."

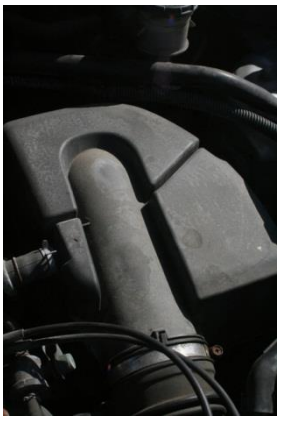

Figure 2: Factory "air box" intake

Figure 3: Intake after modification

The following data were recorded to be analyzed after completion of the experiment. Tank number indicates how many tanks of fuel have been consumed in traveling. Gas Fill Date indicates the date which the gas tank was filled. Miles Driven breaks each trip into segments based on how many miles were traveled during that portion of the entire tank. Temperature indicates temperature at start of trip, from weatherchannel.com. Table 1 shows a small sample of this data; the complete table is in the appendix.

Table 1: Sample of travel data collected

Tank #	Gas Fill	Miles Driven	Temperature (°F)	Avg. Speed (mph)	Wind	Flat/Hilly Terrain	City or Highway	Passengers or Significant Payload
2	5/9/12	92.2	71.0	61.5	No	Flat	Hwy	2 pass.
		5.1	72.0	25.5	No	Flat	City	No
		0.3	74.0	6.0	No	Flat	City	No
		4.4	74.0	29.3	No	Flat	City	No
		29.9	70.0	37.4	No	Flat	City	No
		…	…	…	…	…	…	…
3	5/20/12	2.3	66.0	19.7	No	Hilly	City	1 pass.
		25.0	75.0	40.5	No	Flat	Hwy	No
		15.4	71.0	46.2	No	Flat	Hwy	No

Average Speed was calculated from miles traveled and time taken from start to end of trip. *Wind* indicates magnitude and direction (for or against) of wind during trip. Note: wind less than 5 mph was considered negligible and wind direction was determined by general direction of car travel. *Flat/Hilly terrain* was subjectively determined based on how many hills were encountered during travel. *City/Highway*, another somewhat subjective measure, was determined by how much time was spent traveling at highway speed compared to slower speeds. *Passengers or Significant Payload* indicates the number of passengers or equivalent weight of cargo carried during trip.

Sources of Error

Several limitations were inherent in this study. Many of these errors were controlled by traveling a large number of miles to obtain an accurate average which is more robust to outlying data points. For temperature and average speed readings, a weighted average was taken instead of just an average, meaning that temperature and speed were more heavily-weighted in longer trips. This leads to a more accurate overall interpretation of data. A mixture of short and long distances was traveled also, to allow for a more complete average fuel economy. Finally, tire pressure was periodically measured during testing and was maintained between 35-40 psi.

Some measurement limitations can be attributed to the following causes. Inaccuracies in the gasoline pump gauge, fuel spillage and drips, and the point when the pump automatically shuts off can have small effects on the amount of fuel which actually enters the car and therefore the average fuel economy. There may also be some error in rounding due to inaccuracies in the trip meter of the car. Time was kept via the car clock not via stopwatch, so total time per trip and therefore average velocity contains some error. This is more significant on very short trips. Finally, commercial gasoline was used rather than laboratory-grade fuel, leading to a potential fluctuation in the fuel energy density.

Some precautions were taken to minimize errors in the acceleration runs. Several trials were made to create an average. The same flat terrain was traveled for each run both before and after modification. Tire pressure was equal for all runs, and all were done with a full tank of fuel. The acceleration graphs shown in the results section display 5 to 60 mph instead of 0 to 60 to remove reaction time lag or engine priming inaccuracies. Also, a median filter was applied to the acceleration measurements to remove outlying data points caused by vibration of the sensor mount.

Results

Intake Decision

The decision of which intake to choose was done with the matrix shown in Table 2. Note that this is a scored data sheet with percentages already accounted for, and not a raw data score. The intake selected for this study, the "K&N Typhoon", is shown in green with the highest score. Note that "Lifespan of filter" was a part of the decision; however each intake offered about the same lifespan.

Intakes were judged based on several criteria. *Price* indicates how much the intake would cost. *Proposed HP gain* represents the manufacturers' claimed horsepower increase, if published. *Warranty* indicates whether a warranty was offered and for how long the warranty was valid. *Optional heat protection* represents whether any additional heat protection was offered, such as a heat shield to cover part of the filter, or a pipe cover to minimize ambient heat entering the engine from heating the intake pipe. Finally, *Dyno* represents whether the manufacturer had published figures and results from an engine dynamometer equipped with the intake.

Table 2: Intake Decision Matrix

Intake	Price	Proposed HP Gain	Warranty	Heat Protect	Dyno	TOTAL
Weapon R SRI Secret Wep.	24.4	12.0	7.0	0.0	0.0	43.4
Weapon R SRI Dragon	26.7	12.0	7.0	5.0	0.0	50.7
DC Sports SRI	60.0	0.0	1.0	0.0	0.0	61.0
Fujita SRI	0.0	0.0	0.0	0.0	1.5	1.5
Hurricane Air Intake	37.0	6.0	7.0	0.0	1.5	51.5
K&N Typhoon	54.3	2.8	7.0	0.0	1.5	65.6
HPS SRI	27.5	6.0	0.0	5.0	1.5	40.0

Fuel Economy

Table 3 shows several significant data categories which were measured in the experiment. This table shows the similarities and differences between conditions and driving

types before and after the modification as well as the average MPG. The average miles per tank increased after the modification, as one would expect with the corresponding rise in MPG. The weighted average temperature was slightly colder after the modification, but by only 2.8 degrees. The weighted average speed was only 0.4 MPH faster after the modification. The percentage of flat travel was relatively similar as well, differing by only 0.7%. Highway mileage increased by 9% after the modification, which no doubt affected the change in total MPG. Post-modification fuel economy improved on average by 2.3 MPG (9.8%) compared to the stock vehicle.

Table 3: Summary of key metrics

	Miles per tank	Wtd. Avg. Temp	Wtd. Avg. Speed	%Flat	%Highway	MPG
Premod	256.1	76.2	49.5	88.1	54.3	23.4
Postmod	273.9	73.5	49.9	88.8	63.3	25.7

Figure 4 shows a potential relationship between the amount of mileage spent on the highway compared to the fuel efficiency of the car, both before and after the modification. With a few outlying exceptions, the general trend is higher fuel efficiency with higher highway percentage travel, as expected. It should also be noted that the graph overall shows a higher mileage across the full spectrum for the modified vehicle.

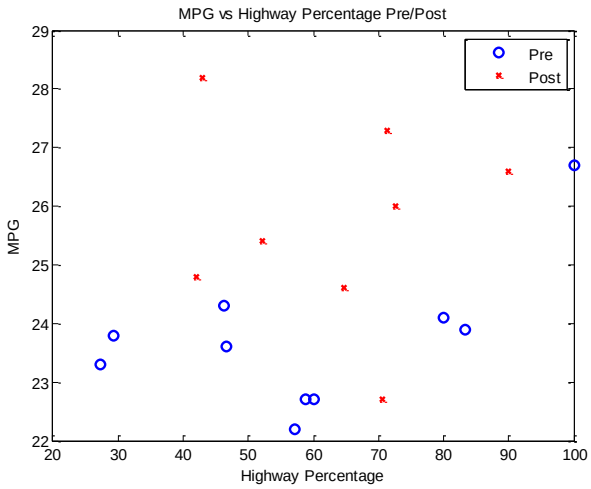

Figure 4: MPG vs. percentage highway travel

Figure 5 shows how the car performed before and after modification with regard to the ambient temperature. According to the graph, the car performed most efficiently in a temperature range of 73 to 76°F. This is slightly unexpected, as air drag and rolling resistance generally decrease as temperature increases. But this plot reflects only temperature, a factor secondary to city/highway mix, driving style, and other factors. Again, the graph shows an increase in mileage after modification regardless of temperature in most cases.

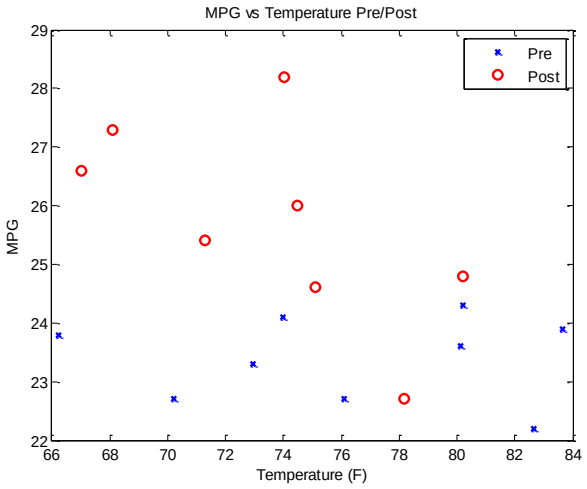

Figure 5: MPG vs. ambient temperature

Acceleration

Acceleration trials for the stock vehicle resulted in times of 9.84, 9.62, and 9.76 seconds for 5 to 60 mph. Four trials for the vehicle after modification took 10.26, 10.29, 10.09 and 10.2 seconds. Complete results are shown in the appendix. A sample comparison of one before and after trial is shown in Figure 6.

The new intake appears to have slowed the mean acceleration time from 9.73 seconds to 10.21 seconds, a 4.9% increase. This is counterintuitive and contradicts the apparent improvement in fuel economy resulting from a freer-breathing engine. Better regulation of the test conditions, such as ambient, tire, and engine temperatures, as well as using laboratory-grade fuel, may better reflect true differences in engine power caused by the new air intake. A back-to-back comparison using a chassis dynamometer would be ideal.

Peak accelerations were measured during each run before and after the modification. The average maximum acceleration for 3 trials premod is 5.11 m/s^2, while the average maximum postmod acceleration was 4.75 m/s^2.

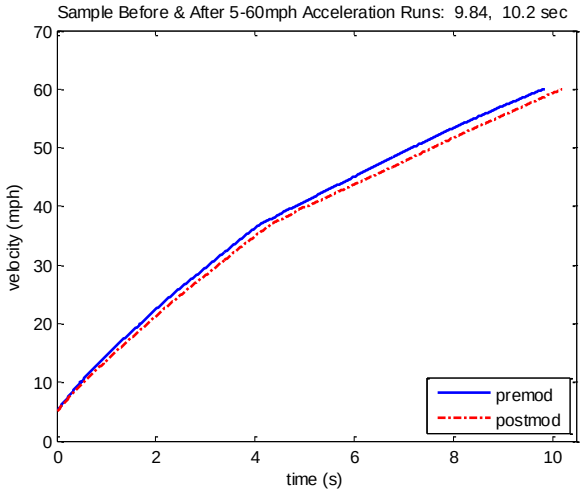

Figure 6: Sample comparison of 5-60mph acceleration

Conclusions

Though contrary to the results published by Oak Ridge National Laboratory, the aftermarket air intake made a statistically significant improvement in fuel economy on the 2004 Honda CR-V. Part – but not all – of the 9.8% increase is likely due to the higher percentage of highway miles driven after the modification. A modest decrease in peak horsepower and 5-60 mph acceleration time was observed, though this portion of the test was not well-regulated.

In order to determine whether the intake was worth the money spent, a simple payback calculation was made. Assuming $3.50 per gallon of gasoline, the reduction in fuel costs will cover the $125 price of the intake after roughly 9300 miles. Depending on how much a car is driven in the course of a year, the payback time could be as little as one year. Because of this return on investment over time, it is believed that the cost of the intake was worth the money for this experiment.

This experiment was not done under laboratory conditions, and thus has several acknowledged limitations. Despite these limitations however, a significant improvement in fuel economy was shown.

References

1. Norman, K., Huff, S., and West, B., "Effect of Intake Air Filter Condition on Vehicle Fuel Economy." ORNL/TM-2009/021, 2009.
2. "New Car Review: 2004 Honda CR-V," http://www.theautochannel.com/news/2004/02/18/181118.html, 10/23/2012.

Biographical Information

Andy Starr (a-starr@onu.edu), owner of the study vehicle, is a junior mechanical engineering student at Ohio Northern University.

David Mikesell (d-mikesell@onu.edu) is an assistant professor of mechanical engineering at Ohio Northern University.

Appendix

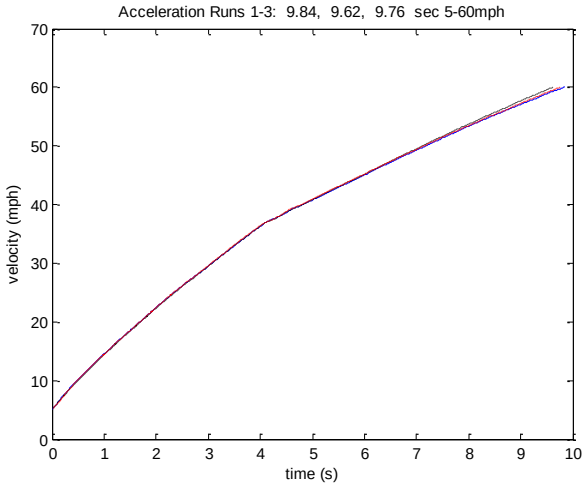

Figure 7: Pre-mod velocity vs. time for runs 1-3

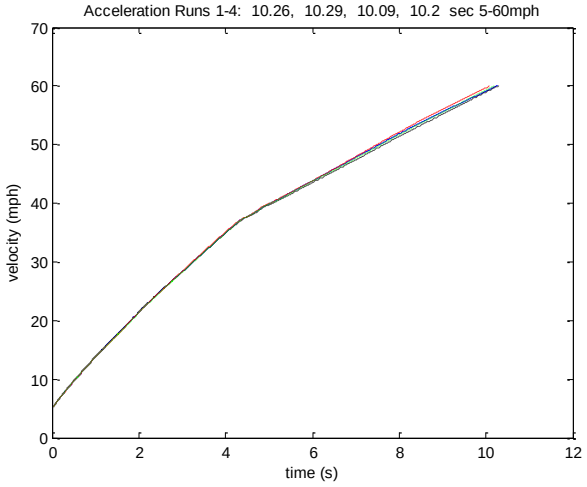

Figure 8: Post-mod velocity vs. time for runs 1-4

Premodification data sheet

Tank #	Gas Fill	Miles	Temperature	Avg. Speed	Wind	Flat/Hilly Terrain	City or Hwy	Passengers/ Significant Payload	% of total miles	
1	5/9/2012	19.8	53.0	44.0	No	Flat	Hwy	No	50.25%	
		19.6	58.0	42.0	No	Flat	Hwy	No	49.75%	1.00
2	5/9/2012	92.2	71.0	61.5	No	Flat	Hwy	2 pass.	36.53%	
		5.1	72.0	25.5	No	Flat	City	No	2.02%	
		0.3	74.0	6.0	No	Flat	City	No	0.12%	
		4.4	74.0	29.3	No	Flat	City	No	1.74%	
		29.9	70.0	37.4	No	Flat	City	No	11.85%	
		5.6	68.0	28.0	No	Flat	City	No	2.22%	
		19.4	65.0	72.0	No	Flat	Hwy	No	7.69%	
		12.2	60.0	27.0	No	Flat	City	No	4.83%	
		5.0	60.0	25.0	No	Flat	City	No	1.98%	
		5.0	60.0	30.0	No	Flat	City	No	1.98%	
		73.3	83.0	47.3	No	Hilly	Hwy	1 pass.	29.04%	1.00
3	5/20/2012	2.3	66.0	19.7	No	Hilly	City	1 pass.	0.90%	
		25.0	75.0	40.5	No	Flat	Hwy	No	9.75%	
		15.4	71.0	46.2	No	Flat	Hwy	No	6.01%	
		15.3	60.0	48.3	10 against	Flat	Hwy	No	5.97%	
		15.6	74.0	52.0	No	Flat	Hwy	No	6.09%	
		15.3	57.0	48.3	No	Flat	Hwy	No	5.97%	
		15.6	76.0	52.0	No	Flat	Hwy	No	6.09%	
		15.3	61.0	54.0	No	Flat	Hwy	No	5.97%	
		15.7	83.0	52.3	No	Flat	Hwy	No	6.13%	
		25.1	67.0	55.7	No	Flat	Hwy	No	9.79%	
		73.5	88.0	53.8	11 with	Hilly	Hwy	No	28.68%	
		4.9	88.0	32.7	No	Hilly	City	No	1.91%	
		1.6	87.0	16.0	No	Flat	City	No	0.62%	
		3.1	87.0	26.6	No	Flat	City	No	1.21%	
		7.8	83.0	26.0	No	Flat	City	No	3.04%	
		1.3	83.0	26.0	No	Flat	City	No	0.51%	
		3.5	79.0	30.0	No	Flat	City	No	1.37%	1.00

4	5/25/2012	2.8	78.0	33.6	No	Flat	City	No	0.97%	
		2.5	90.0	25.0	No	Flat	City	1 pass.	0.86%	
		2.6	87.0	26.0	No	Flat	City	1 pass.	0.90%	
		5.7	90.0	57.0	No	Flat	City	No	1.97%	
		7.7	90.0	33.0	No	Flat	City	No	2.66%	
		72.9	91.0	52.7	No	Hilly	Hwy	No	25.22%	
		15.3	72.0	51.0	No	Flat	Hwy	No	5.29%	
		68.9	81.0	51.0	No	Flat	Hwy	No	23.83%	
		1.1	81.0	16.5	No	Flat	City	No	0.38%	
		0.5	74.0	15.0	No	Flat	City	No	0.17%	
		79.0	74.0	56.4	No	Flat	Hwy	No	27.33%	
		15.0	61.0	47.4	No	Flat	Hwy	No	5.19%	
		15.1	73.0	60.4	14 with	Flat	Hwy	No	5.22%	1.00
5	5/30/2012	1.8	73.0	21.6	No	Flat	City	No	0.74%	
		15.3	57.0	51.0	5 against	Flat	Hwy	No	6.30%	
		16.4	78.0	42.8	No	Flat	Hwy	No	6.75%	
		15.3	61.0	48.3	5 against	Flat	Hwy	No	6.30%	
		66.6	56.0	55.5	13 with	Hilly	Hwy	No	27.42%	
		5.0	57.0	33.3	No	Flat	City	No	2.06%	
		14.6	68.0	32.4	No	Hilly	City	No	6.01%	
		11.5	70.0	43.1	No	Hilly	City	1 pass.	4.73%	
		2.2	70.0	22.0	No	Flat	City	1 pass.	0.91%	
		3.0	68.0	22.5	No	Flat	City	1 pass.	1.24%	
		2.9	66.0	29.0	No	Flat	City	1 pass.	1.19%	
		0.9	64.0	27.0	No	Flat	City	1 pass.	0.37%	
		1.7	63.0	51.0	No	Flat	City	1 pass.	0.70%	
		3.6	57.0	27.0	No	Flat	City	1 pass.	1.48%	
		9.0	57.0	28.4	No	Flat	City	No	3.71%	
		6.2	77.0	37.2	No	Flat	City	No	2.55%	
		66.9	77.0	55.8	No	Hilly	Hwy	No	27.54%	1.00
6	6/3/2012	2.1	66.0	25.2	No	Flat	City	No	0.79%	
		15.3	59.0	48.3	No	Flat	Hwy	No	5.73%	
		15.7	72.0	49.6	10 with	Flat	Hwy	No	5.88%	
		15.3	52.0	51.0	No	Flat	Hwy	No	5.73%	
		15.7	63.0	55.4	10 with	Flat	Hwy	No	5.88%	
		0.8	60.0	16.0	No	Flat	City	1 pass.	0.30%	
		0.8	60.0	16.0	No	Flat	City	1 pass.	0.30%	
		15.3	49.0	48.3	6 against	Flat	Hwy	No	5.73%	
		15.7	75.0	52.3	8 with	Flat	Hwy	No	5.88%	
		15.3	51.0	51.0	No	Flat	Hwy	No	5.73%	
		15.7	71.0	52.3	No	Flat	Hwy	No	5.88%	
		15.3	52.0	51.0	No	Flat	Hwy	No	5.73%	

		66.1	82.0	52.9	8 against	Hilly	Hwy	No	24.75%	
		1.6	82.0	19.2	No	Flat	City	No	0.60%	
		13.0	82.0	37.1	No	Flat	Hwy	1 pass.	4.87%	
		0.2	82.0	6.0	No	Flat	City	1 pass.	0.07%	
		9.0	82.0	33.8	No	Flat	City	1 pass.	3.37%	
		14.7	81.0	34.0	No	Flat	City	1 pass.	5.50%	
		6.3	80.0	29.0	No	Flat	City	1 pass.	2.36%	
		13.2	77.0	52.8	No	Flat	Hwy	No	4.94%	1.00
7	6/9/2022	15.0	80.0	47.4	No	Flat	Hwy	No	5.66%	
		28.3	79.0	54.8	No	Flat	Hwy	No	10.68%	
		78.3	78.0	51.3	No	Hilly	Hwy	No	29.54%	
		15.3	69.0	48.3	No	Flat	Hwy	No	5.77%	
		15.6	74.0	49.3	14 with	Flat	Hwy	No	5.88%	
		15.3	67.0	45.9	5 against	Flat	Hwy	No	5.77%	
		15.7	77.0	49.6	10 with	Flat	Hwy	No	5.92%	
		15.5	57.0	46.5	11 with	Flat	Hwy	No	5.85%	
		15.1	76.0	53.3	11 with	Flat	Hwy	No	5.70%	
		1.1	76.0	16.5	No	Flat	City	No	0.41%	
		15.3	65.0	45.9	No	Flat	Hwy	No	5.77%	
		15.5	82.0	48.9	No	Flat	Hwy	No	5.85%	
		1.7	74.0	14.6	No	Flat	City	No	0.64%	
		2.1	74.0	18.0	No	Flat	City	No	0.79%	
		15.3	63.0	51.0	No	Flat	Hwy	No	5.77%	1.00
8	6/15/2012	66.5	86.0	42.9	No	Hilly	Hwy	No	26.58%	
		7.6	84.0	50.7	No	Flat	City	No	3.04%	
		5.2	84.0	28.4	No	Flat	City	No	2.08%	
		2.6	82.0	39.0	No	Flat	City	No	1.04%	
		5.1	82.0	30.0	No	Flat	City	No	2.04%	
		0.6	82.0	12.0	No	Flat	City	No	0.24%	
		6.6	79.0	33.0	No	Flat	City	No	2.64%	
		6.6	80.0	33.0	No	Flat	City	No	2.64%	
		70.0	78.0	51.9	10 with	Hilly	Hwy	No	27.98%	
		1.5	76.0	18.0	No	Flat	City	No	0.60%	
		15.9	76.0	36.7	No	Flat	Hwy	No	6.35%	
		15.7	86.0	49.6	No	Flat	Hwy	No	6.27%	
		15.3	68.0	48.3	No	Flat	Hwy	No	6.12%	
		15.7	86.0	55.4	10 against	Flat	Hwy	No	6.27%	
		15.3	65.0	51.0	No	Flat	Hwy	No	6.12%	1.00
9	6/20/2012	67.5	91.0	53.3	8 against	Hilly	Hwy	No	24.46%	
		4.9	89.0	29.4	No	Flat	City	No	1.78%	
		13.4	89.0	47.3	No	Flat	City	No	4.86%	
		65.3	89.0	52.9	10 with	Hilly	Hwy	No	23.66%	

		15.3	68.0	57.4	No	Flat	Hwy	No	5.54%	
		15.7	91.0	62.8	No	Flat	Hwy	No	5.69%	
		16.1	85.0	53.7	No	Flat	Hwy	No	5.83%	
		16.0	73.0	48.0	No	Flat	Hwy	No	5.80%	
		15.3	67.0	48.3	No	Flat	Hwy	No	5.54%	
		15.7	84.0	47.1	No	Flat	Hwy	No	5.69%	
		15.3	67.0	48.3	No	Flat	Hwy	No	5.54%	
		15.5	73.0	51.7	10 with	Flat	Hwy	No	5.62%	1.00
10	6/25/2012	2.0	73.0	24.0	No	Flat	City	No	0.97%	
		5.5	60.0	25.0	No	Flat	City	No	2.67%	
		15.3	51.0	51.0	No	Flat	Hwy	No	7.43%	
		15.7	67.0	49.6	3 with	Flat	Hwy	No	7.62%	
		15.3	55.0	51.0	No	Flat	Hwy	No	7.43%	
		15.7	88.0	52.3	No	Flat	Hwy	No	7.62%	
		15.4	65.0	48.6	No	Flat	Hwy	No	7.48%	
		15.2	99.0	53.6	16 against	Flat	Hwy	No	7.38%	
		1.1	99.0	9.4	No	Flat	City	No	0.53%	
		16.3	99.0	46.6	No	Flat	Hwy	No	7.91%	
		75.8	95.0	59.1	No	Hilly	Hwy	No	36.80%	
		4.9	81.0	32.7	No	Flat	City	No	2.38%	
		4.9	81.0	29.4	No	Flat	City	No	2.38%	
		2.9	95.0	21.8	No	Flat	City	No	1.41%	1.00
									Total Miles:	2344.50

Postmodification data sheet

Tank #	Gas Fill	Miles	Temperature	Avg. Speed	Wind	Flat/Hilly Terrain	City or Hwy	Passengers/ Significant Payload	% of total miles	
1	7/7/2012	14.2	95.0	34.1	No	Flat	Hwy	1 pass.	5.59%	
		11.0	91.0	38.8	No	Flat	Hwy	1 pass.	4.33%	
		6.0	83.0	32.7	No	Flat	City	No	2.36%	
		8.8	82.0	31.1	No	Flat	City	No	3.46%	
		72.8	80.0	47.5	No	Hilly	Hwy	No	28.64%	
		15.3	63.0	51.0	No	Flat	Hwy	No	6.02%	
		15.3	83.0	51.0	No	Flat	Hwy	No	6.02%	
		0.4	83.0	8.0	No	Flat	City	No	0.16%	
		1.7	83.0	17.0	No	Flat	City	No	0.67%	
		15.5	63.0	44.3	No	Flat	Hwy	No	6.10%	
		15.6	85.0	52.0	7 with	Flat	Hwy	No	6.14%	
		15.3	65.0	51.0	No	Flat	Hwy	No	6.02%	
		15.7	86.0	52.3	No	Flat	Hwy	No	6.18%	
		15.3	64.0	45.9	No	Flat	Hwy	No	6.02%	
		15.7	88.0	47.1	No	Flat	Hwy	No	6.18%	
		15.3	68.0	51.0	No	Flat	Hwy	No	6.02%	
		0.3	68.0	6.0	No	Flat	City	No	0.12%	1.00
2	7/13/2012	67.1	62.0	52.3	5 with	Hilly	Hwy	No	22.96%	
		5.0	83.0	33.3	No	Flat	City	No	1.71%	
		6.0	83.0	32.7	No	Flat	City	No	2.05%	
		9.3	80.0	34.9	No	Flat	Hwy	No	3.18%	
		5.2	80.0	28.4	No	Flat	City	No	1.78%	
		8.6	78.0	43.0	No	Flat	Hwy	1 pass.	2.94%	
		2.7	78.0	23.1	No	Flat	City	1 pass.	0.92%	
		6.3	72.0	29.1	No	Flat	City	No	2.16%	
		73.5	79.0	53.8	10 with	Hilly	Hwy	No	25.15%	
		15.3	71.0	48.3	6 with	Flat	Hwy	No	5.23%	
		15.6	93.0	49.2	No	Flat	Hwy	No	5.34%	
		15.3	74.0	51.0	6 with	Flat	Hwy	No	5.23%	
		15.7	96.0	49.6	6 against	Flat	Hwy	No	5.37%	
		15.3	72.0	48.3	4 with	Flat	Hwy	No	5.23%	
		15.7	77.0	49.6	No	Flat	Hwy	No	5.37%	

		15.4	69.0	48.6	No	Flat	Hwy	No	5.27%	
		0.3	79.0	6.0	No	Flat	City	No	0.10%	1.00
3	7/19/2012	15.9	79.0	47.7	No	Flat	Hwy	No	5.37%	
		15.3	71.0	43.7	No	Flat	Hwy	No	5.16%	
		15.1	69.0	50.3	5 with	Flat	Hwy	No	5.10%	
		1.1	69.0	18.3	No	Flat	City	No	0.37%	
		78.8	80.0	52.5	No	Hilly	Hwy	No	26.59%	
		6.0	80.0	36.0	No	Flat	City	No	2.02%	
		10.6	80.0	28.9	No	Flat	City	3 pass.	3.58%	
		10.6	84.0	27.7	No	Flat	City	3 pass.	3.58%	
		2.8	84.0	33.6	No	Flat	City	No	0.94%	
		3.8	88.0	28.5	No	Flat	City	No	1.28%	
		6.2	91.0	37.2	No	Flat	City	No	2.09%	
		4.3	91.0	23.5	No	Flat	City	1 pass.	1.45%	
		3.4	87.0	18.5	No	Flat	City	1 pass.	1.15%	
		5.5	84.0	33.0	No	Flat	City	1 pass.	1.86%	
		70.3	82.0	50.8	No	Hilly	Hwy	No	23.73%	
		15.3	72.0	45.9	No	Flat	Hwy	No	5.16%	
		15.7	90.0	49.7	17 against	Flat	Hwy	No	5.30%	
		15.3	78.0	48.3	11 with	Flat	Hwy	No	5.16%	
		0.3	80.0	6.0	10 with	Flat	City	No	0.10%	1.00
4	7/24/2012	15.9	87.0	50.2	No	Flat	Hwy	No	5.64%	
		15.3	63.0	51.0	No	Flat	Hwy	No	5.42%	
		15.3	91.0	48.3	No	Flat	Hwy	No	5.42%	
		75.7	86.0	53.4	No	Hilly	Hwy	1 pass.	26.83%	
		34.8	80.0	58.0	No	Flat	Hwy	No	12.34%	
		4.5	62.0	30.0	No	Flat	City	No	1.60%	
		87.1	62.0	49.7	5 with	Hilly	Hwy	No	30.88%	
		15.7	81.0	47.1	No	Flat	Hwy	No	5.57%	
		2.2	80.0	16.5	No	Flat	City	No	0.78%	
		15.3	54.0	41.7	No	Flat	Hwy	No	5.42%	
		0.3	84.0	9.0	No	Flat	City	No	0.11%	1.00
5	8/7/2012	15.9	84.0	50.2	5 against	Flat	Hwy	No	5.32%	
		15.3	61.0	51.0	No	Flat	Hwy	No	5.12%	
		15.6	85.0	52.0	11 against	Flat	Hwy	No	5.22%	
		21.1	85.0	46.8	11 against	Flat	Hwy	2 pass.	7.06%	
		20.6	70.0	51.5	5 with	Flat	Hwy	2 pass.	6.89%	
		15.3	67.0	48.3	No	Flat	Hwy	No	5.12%	
		15.8	80.0	52.7	No	Flat	Hwy	No	5.29%	
		15.3	65.0	34.0	No	Flat	Hwy	1 pass.	5.12%	
		73.1	68.0	54.1	10 against	Hilly	Hwy	1 pass.	24.46%	
		16.5	63.0	33.0	12 with	Flat	Hwy	No	5.52%	

		17.2	60.0	34.4	No	Flat	Hwy	No	5.75%	
		2.6	68.0	19.5	No	Flat	City	1 pass.	0.87%	
		1.2	69.0	24.0	No	Flat	City	1 pass.	0.40%	
		1.5	71.0	22.5	No	Flat	City	1 pass.	0.50%	
		5.2	71.0	31.2	No	Flat	City	1 pass.	1.74%	
		9.0	72.0	27.0	No	Flat	City	No	3.01%	
		5.0	74.0	15.0	No	Flat	City	No	1.67%	
		3.8	77.0	45.6	No	Flat	City	No	1.27%	
		4.2	77.0	28.0	No	Flat	City	No	1.41%	
		2.1	77.0	15.7	No	Flat	City	No	0.70%	
		5.9	77.0	29.5	No	Flat	City	No	1.97%	
		6.0	74.0	36.0	No	Flat	City	No	2.01%	
		10.7	68.0	45.9	No	Flat	Hwy	No	3.58%	1.00
6	8/12/2012	60.3	67.0	53.2	No	Hilly	Hwy	No	35.28%	
		15.3	60.0	48.3	No	Flat	Hwy	No	8.95%	
		15.7	74.0	49.6	No	Flat	Hwy	No	9.19%	
		15.3	64.0	48.3	No	Flat	Hwy	No	8.95%	
		15.7	74.0	52.3	No	Flat	Hwy	No	9.19%	
		15.3	54.0	54.0	No	Flat	Hwy	No	8.95%	
		15.6	81.0	49.2	No	Flat	Hwy	No	9.13%	
		2.1	78.0	25.2	No	Flat	Hwy	No	1.23%	
		15.3	60.0	51.0	No	Flat	Hwy	No	8.95%	
		0.3	80.0	9.0	No	Flat	City	No	0.18%	1.00
7	8/16/2012	92.5	80.0	56.6	No	Flat	Hwy	No	31.08%	
		5.6	77.0	18.7	No	Flat	City	No	1.88%	
		1.4	74.0	12.0	No	Flat	City	No	0.47%	
		115.0	68.0	58.0	No	Flat	Hwy	No	38.64%	
		2.4	75.0	14.4	No	Flat	City	No	0.81%	
		77.9	76.0	55.6	No	Hilly	Hwy	1 pass.	26.18%	
		2.8	61.0	24.0	No	Flat	City	4 pass.	0.94%	1.00
8	8/18/2012	74.7	62.0	61.4	5 with	Hilly	Hwy	4 pass.	25.00%	
		15.0	69.0	39.1	No	Flat	Hwy	4 pass.	5.02%	
		89.9	75.0	56.8	4 against	Flat	Hwy	1 pass.	30.09%	
		3.0	78.0	25.7	No	Flat	City	1 pass.	1.00%	
		9.9	63.0	34.9	No	Flat	City	3 pass.	3.31%	
		80.7	63.0	59.0	4 with	Flat	Hwy	3 pass.	27.01%	
		25.6	78.0	49.5	No	Flat	Hwy	No	8.57%	1.00
									Total Miles:	2191.10