

A Manual for Increasing Your Miles per Gallon

We were driving through western Kansas one winter, about a week before Christmas. The weather could not have been worse. Temperatures were in the single digits, there was a strong northwest wind and the snow was starting to come down heavy. It was a frozen, barren landscape with not a sign of civilization anywhere on the horizon. Not the kind of place you want to get stranded.

We knew the truck was running low on gas but we figured there was plenty to get us to the next town about 10 miles away. It was hard to tell exactly how much we had left in the tank since the gas gauge went out several months earlier. Replacing the gauge was more work than we had time or motivation for so we started using the odometer as a substitute gas gauge. In other words we knew about how many miles per gallon the truck got so we knew how far we could drive on a tank of gas. Or so we thought.

By our calculation there should have been at least 50 miles worth of gas left in the tank. Plenty to make it to the next town. You can imagine our surprise then when all of a sudden the truck began to hesitate and run sporadically, telltale signs of a vehicle running out of gas. The next thing you know we were stopped, motionless, stranded. This was not good. What went wrong? Where was the flaw in the logic?

What we did not realize at the time was that the extreme cold and the winter driving conditions had drastically reduced the gas mileage. The mileage that we thought we could get on a tank of gas was based on more or less ideal, summertime driving conditions. Gas mileage, it turns out, can vary a great deal. Our ignorance of this fact is what got us stranded.

Luckily this bit of ignorance was not as costly as ignorance sometimes is. Shortly after we started walking to the next town, before we had lost any fingers or toes to frostbite, a car stopped to give us a ride. In town a Kansas State Trooper stopped to talk to us, no doubt wondering what kind of nuts were walking around in this kind of weather. We told him what happened and he offered to take us to the gas station and then back to our truck. He could not have been a nicer guy.

After this incident we became curious (one of those traits engineers have that sometimes seems to annoy people) about exactly what affects gas mileage and how. Some of what we have learned is contained in this document. We will look at how environmental factors and the condition of the vehicle can influence gas mileage. We will also look at how driving behavior and in general how the vehicle is operated, influences gas mileage.

Why should you care about saving gas? A typical driver puts over 11,000 miles on their vehicle odometer every year, while the average mpg in America (cars, SUV's and light trucks) is 24.5. This translates into 448 gallons of gas,

which, at \$3.00 per gallon costs \$1,344 every year. The good news is that there are a lot of easy things you can do to reduce this yearly bill. Of the energy in your fuel tank, roughly 15% actually moves your car and runs your car accessories, so there's a lot of room for improvement.

FUEL, OIL, AND THE ENGINE

The following is a table of the energy content of common fuels in units of megaJoules per Liter.

FUEL TYPE	ENERGY CONTENT [MJ/L]
Gasoline	29.0
LPG	22.16
Ethanol	19.59
Methanol	14.57
Gasohol(10% ethanol+90% gasoline)	28.06
Diesel	40.9

As you can see, diesel fuel contains the most punch per volume, with 41% more energy content than gasoline. This accounts for the fact that diesel engines are 30-35% more fuel efficient than gasoline engines. Something you might want to consider the next time your looking for a new car. Also note that gasohol, which is sold at some gas stations in the place of gasoline, is 3.2% lower in energy content than gasoline.

A key part in the process of extracting energy from the fuel in your tank, occurs when a fuel/air mixture is injected into an engine cylinder, and the piston begins to compress this mixture. When the compression has reached a maximum, the mixture is ignited, causing the mixture to explode and converting it into heat, which forces the piston back, and moves the car.

The octane rating of gasoline is a measure of how explosive the gas is. The higher the octane, the lower the explosiveness of the gas. If you use gas whose octane is too low for your engine, the gas will explode prematurely in the cylinders, and will produce knocking. Engine knocking lowers your mpg, the energy in the gas is not as fully used, and can also damage the engine. You should use the lowest possible octane that does not produce knocking. Your owners manual should indicate the proper octane, although most new cars can use the lowest octane (and lowest price) gas. The compression ratio, which is the ratio of the maximum volume to minimum volume, in the cylinder, is the biggest factor in determining the appropriate octane fuel for your car. The higher the compression ratio the higher the octane (and less explosive) fuel required. Note that if you have lots of carbon buildup in your cylinders, this will increase your compression ratio and can cause knocking, in spite of the fact that you may be using the correct octane for your engine.

Engine oil reduces the friction that the engine needs to overcome in order to run. The type of oil you need may depend on the seasons, since as it gets colder, oil becomes more viscous which makes the engine harder to turn. Always

use a multigrade oil, identified by a number followed by a "W" then another number, like 10W-40 since its viscosity changes less with temperature than a single grade oil. For cold winters, some engines can use a lighter oil like 5W-30. For every season, use the lightest oil that your owner's manual recommends, in order to increase your mpg. In recent years auto manufacturers have been reducing the weight of the recommended engine oils, probably due to a combination of three reasons: the quality of the engine oils have been improving over the years, the tolerances of the engine parts are tighter, requiring lighter oils to flow between the engine components, and mpg is increased with lighter oils.

You should check your oil level at least every time you gas up, since a low oil level can reduce your gas mileage and damage your engine. Dirty oil also reduces your mpg by increasing engine friction, so change it at the recommended intervals.

If you use improved friction oil, you can boost your mpg by about 5%. There are two types of improved friction oil, both of which perform about the same, synthetic oil and conventional oil with additives. Conventional oil with additives is about half the price of the synthetic oil, because synthetic oil is created from scratch and not derived from petroleum. You'll know that the oil is improved friction oil, if the API performance symbol has the words "energy conserving" on it.

If spark plugs are significantly covered with combustion deposits, are no longer gapped correctly due to corrosion, or were not gapped correctly when put in, then the fuel/air combustion will not occur efficiently, and the result will be a lower mpg. So if they're badly crudded up or corroded, replace them, if not so bad, you can get by with cleaning them off with a wire brush and regapping them. The prices of spark plugs vary widely, from about \$1 to \$10. They increase in price from standard, to platinum, to multiprong. Standard should work fine in any case. Platinum should be used when you want to extend the life of the spark plugs, since the platinum reduces the rate of corrosion. Manufacturers of multiprong spark plugs claim that you can increase your mpg by using them, but we have found no evidence that this is the case. The Federal Trade Commission has taken to court, one spark plug manufacturer that made specific claims of this type, saying their claims were unsubstantiated. The consent order prohibits the company from making such claims.

Increasingly auto manufacturers are replacing carburetors with fuel injectors. If you don't have a carburetor, skip this paragraph. The carburetor is where the fuel is mixed with air to create the proper fuel/air mixture for combustion. If the fuel/air mixture is not correct, combustion will not be as efficient as it could be, thereby reducing your mileage. Carburetors need to occasionally be cleaned with some carburetor cleaner, to ensure that the ports are not gummed up. Fuel additives that can be purchased in an auto parts store can also help for this. Also make sure that you replace your air filter as often as your owner's manual specifies. If your air filter is dirty, the carburetor may not get as much air flow as it needs, which can reduce your mpg by up to 10%.

As discussed in the introduction, temperature can have a big effect on your mpg. A cold engine results in more fuel in the fuel/air mixture, making the combustion less efficient, and reducing your mileage. In the winter, make sure the preheater hose is not missing or ruptured, which ensures the carburetor creates a proper fuel/air mixture. When an engine is cold, the oil is more viscous, increasing the friction in the engine, and reducing your gas mileage. But there is no need to idle your car for long before driving. Idling gives you no miles per gallon, and modern microprocessor equipped cars can be driven about 30 seconds after starting, although they should be driven slowly until the engine has a chance to warm up, reducing wear on the engine. A block heater can be used along with a timer, to begin warming your engine a few hours before you are ready to drive off. This can increase your mileage up to 10% in the winter. Block heaters are even more valuable for diesel engines, since they tend to be more difficult to start in cold weather.

Giving your car a tune-up, as describe by the owner's manual, can result in a 4% improvement, on the average, of your mpg. The spark plugs, distributor, timing, and PCV valve, should at least be checked. A tune-up is especially necessary if you have failed an emission test. Replacing a bad oxygen sensor can improve your mileage by 40%.

TIRES

The first thing to say about tires, is that if you don't have radials, get them. Switching from non-radials to radials at the same psi, you'll increase your mpg by 3% in city driving, and by 10% in highway driving. Keep your tires properly inflated, and check them once a week, and especially after a sharp change in temperature. The pressure in your tires changes by 1 psi for every 18 degrees Fahrenheit temperature change. Tires also naturally leak, without any holes in the tires, they can leak as much as 2 psi per month. At low speeds, such as in city driving, tires are the major component of rolling resistance. For every 2 psi that your tires are underinflated, your mpg decreases by 1%. Keep in mind that the recommended tire pressures that are posted on the side of your drivers door, or on the door of your glove compartment, tend to be specified as low as practical, in order to provide a smoother ride. The maximum pressure for your tire is written on the tire itself. Some people recommend that you fill your tire to the maximum pressure specified on the tire. This is unwise, since an increase in temperature can easily take it over the maximum. You should at least have your tires at the pressure recommended by your car manufacturer. Note that one exception is when the roads are icy and slick, then you want a lower tire pressure to improve your tire's grip on the road.

AIR FRICTION

The speed at which your car gets the best mpg is between 35 and 45 miles per hour. While at speeds lower than this, tires are responsible for most of the rolling resistance, at speeds higher than this, wind drag becomes the major factor in rolling resistance. Of course auto manufacturers know this, and that is why Klick and Klack of Car Talk say that all modern cars look like jellybeans. At speeds of about 50 mph and up, the extra horsepower needed to increase your speed is a function of the cube of the velocity. For example increasing your speed from 55 to 70 mph, assuming your engine requires 10

horsepower at 55, it would require 20 horsepower at 70.

At highway speeds, keeping your windows open, significantly increases your car's rolling resistance. You can save gas on the highway by rolling your windows up, and using flow-through ventilation. Or if it's too hot for that, you can roll your windows up, and turn on your air conditioner, with roughly no change in your mpg. But note that in the city, using your air conditioner will significantly reduce your gas mileage.

A roof rack, loaded with stuff, can decrease your mpg by 5%. If you can put things in the trunk instead, you can cut out this air resistance.

Several years ago, everyone with a pickup truck removed their tailgate and replaced it with a plastic net. The claim was that it reduced wind resistance and maybe it also looked cool. But does it really reduce wind resistance? Klick and Klack have a nice explanation of it. When driving at highway speeds, there is a large slowly rotating bubble of air just above the bed of the truck. The air rushing by, sees this bubble as part of the truck. The result is that the profile of the truck is more like a minivan, and the tailgate has no effect on the gas mileage.

Some claim that a clean car gets better gas mileage. Of course if it's true, it would only be the case at highway speeds. A little dust on the car would not have any measurable effect on the mpg, but if there are sizable clumps of dirt on your car that significantly alters the air flow along its surface, then it would reduce your gas mileage. In any case, a clean car doesn't hurt, and it sure looks nice.

TRANSMISSIONS

Manual transmissions, being more efficient than automatic, can save you money on gas. But if you're stuck with an automatic there are things you can do to improve your gas mileage. When stopped at a traffic light, put the transmission into neutral or park. When in drive, the automatic transmission is constantly applying force to the wheels by way of a fluid in the transmission, thereby wasting fuel. Also, you are wasting fuel when you use the accelerator to remain stationary on an uphill slope. Use the brake instead, or better yet, put it in park. If you have an overdrive mode on your automatic transmission, it can save you gas when traveling at highway speeds, since it makes the engine run slower.

SPEED, ACCELERATION, STOPS, TRAFFIC LIGHTS AND EXTRA WEIGHT

As mentioned above, your car gets the best gas mileage while going at a speed of 35 to 45 mph. The mpg drops dramatically, below and above this range. It requires 20% more fuel to drive at 70 mph than at 55. So the most efficient way to get from point A to point B is to drive at a steady 35-45 mph. Of course doing this is often unrealistic, since on the highway you need to drive a little faster to avoid being a hazard, and in the city there are lots of traffic lights to deal with. But you can still save quite a bit of gas with some good driving habits.

Every time you step on the brake you are wasting gas, because you'll just have to step on the accelerator to get up to the speed you were. In fact 5.8% of the energy in your gas tank is wasted by braking. So a good policy is to use

the brakes as little as possible, of course without hitting pedestrians or other cars. When you're approaching a red light, you can take your foot off the accelerator as early as possible, so that you don't have to come to a complete stop when the light turns green. You can also do the same for traffic jams that you see up ahead. Keep a good distance from the car ahead of you so it won't be necessary to slam on the brake at the same second he does. Rapid acceleration, slamming on brakes, and excessive speed, are all unnecessary and can reduce your mpg by 33% on the highway and 5% in the city. When you accelerate, do so smoothly and you can save half the gas as jackrabbit starts.

The typical driver loses 17.2% of the gas in his tank due to idling. If you anticipate more than a minute of being stopped, then turn off your engine; stopping for one minute with your engine idling, takes double the amount of gas as restarting it. Also keep in mind that big engines consume more gas when idling, than small engines. You can reduce your idling by taking a route that has fewer stops, has right turns on red, or has synchronized lights.

Extra weight in your car burns more gas. Removing 100 pounds from your car can boost your mpg by 2%. This provides yet another reason to lose some weight.

DUBIOUS DEVICES AND PROVEN DEVICES

There are many things you can buy that claim to save you gas: magnets, gas tablets, and other fuel additives. As far as we know, gas tablets are only good for eliminating flatulence. As for the others, the EPA has tested at least 100 of these so called "gas savers" and of the few that increase your mpg, they do so only marginally. The EPA test results can be found at <http://www.epa.gov/otaq/consumer/reports.htm>

There are three devices proven to save you gas when you use them appropriately: cruise control, a vacuum gauge, and a miles per gallon meter.

For those long boring stretches of highway, cruise control can increase your mpg by about 5% because it helps you maintain a constant speed. It may also prevent you from getting a speeding ticket. To get the most out of it though, you need to turn it off when climbing a hill, because you save the most gas, when hill climbing, by keeping steady pressure on the accelerator, so that you naturally slow down, and you can engage it again once you reach the top.

The vacuum gauge is another proven gas saver. In one test, mpg was boosted from 8.5 to 13.6%, while others have shown as much as a 24% improvement, though keep in mind that some drivers actually lowered their mpg, possibly due to more attention being paid to the gauge than to traffic. The business end of the gauge is connected to the intake manifold, and drivers save gas by accelerating in a way that keeps the gauge pressure as high and as steady as possible. Evidently this works, by ensuring a constant and steady supply of the fuel/air mixture into the cylinders.

The miles per gallon meter actually gives you a constantly updated mpg value for your car as you are driving. On the highway it reminds you that you are, for example consuming a lot more gas at 70 mph than at 55. Because of a slight delay required for computation, the meter doesn't help much in the city where conditions change abruptly.

COMBINING TRIPS AND COMMUTING

As discussed above, a warm engine gets you more mpg than a cold engine. You can use this fact to save you money when doing necessary errands around town, by combining several trips into one. If you choose to do your errands when traffic is lightest, you save even more gas, by spending less time in traffic and burning less fuel. Likewise, you can spend less time in traffic while driving to work, if you are able to avoid rush hour times.

CONCLUSION

We hope with the above information you will start increasing your mpg. Not only does it save you money, but it keeps the air cleaner, and reduces the amount of money going to countries that may be hostile to the United States. You might want to start keeping score by writing down the miles shown on your odometer, and the gallons, each time you gas up.

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