The Past, Present and Future of Nitrogen Tire Inflation

Real World Application and Acceptance of Nitrogen
Commercial Success from Passenger to Commercial Markets

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Objective – Executive Overview

This paper summarizes the conclusions made by commercial businesses to justify the investment in a nitrogen tire inflation program. While there are many benefits to nitrogen, the return on investment is the key to any capital expenditure decision. Many are measurable, some non-measurable and some were not discovered until a year after the application. This paper will also provide a framework to help an organization determine what benefits are applicable to their organization, their customers and help determine all the factors to consider before making an investment.

Proof

The readers of this paper should be convinced on the actual measurable benefits of nitrogen. If this is not the case, we recommend researching the eleven independent studies and tests on the benefits of nitrogen found on the Get Nitrogen Institute website at http://www.getnitrogen.org/savebillions/index.php.

Revenue and Benefits

The most important factor before making an investment is the revenue it will generate or cost savings it will create. Some companies want a return in one fiscal quarter and some are patient enough to wait two to three years. There are many benefits to nitrogen tire inflation and not all are applicable to all industries. Measurable benefits are based on combining independent test results with an organizations current data to calculate a hard return. Other elements are somewhat difficult to measure and are often left out of an ROI but can have a huge impact to the investing organization, their customers and the environment.

Table 1 provides a quick look at the benefits and their applicable industries.

Benefit	Consumer	Tire Shop	Fleet Owner / Operator	Sustainability / Environmental
Tire Life	✓		✓	✓
Reduced Warranty Claims		✓		
Fuel Savings	✓		✓	✓
Safety	✓	✓	✓	
Down Time			✓	
Retreadability			✓	✓

A Day in the Life of an Air Filled Tire

Compressed air may be the most widely used inflation medium but is it the best? All tires lose pressure. As a tire becomes underinflated it has a larger contact patch with the road surface and causes flexing of the crown and sidewall. The increased contact with the road and increased flexing of the sidewall generate heat (think of repeatedly bending a paper clip). A hot tire is more permeable and therefore loses pressure more rapidly causing greater flexing and an even larger contact patch…you see where this is leading.

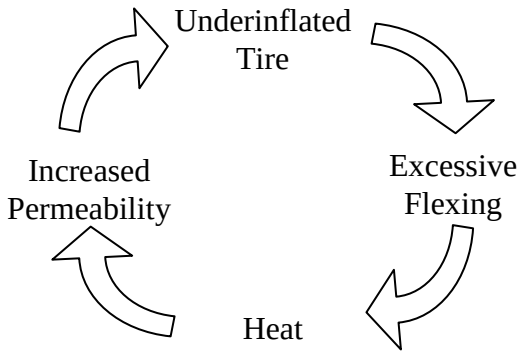

Figure 1. A Day in the Life of an Air Filled Tire. The self perpetuating cycle of increasing under inflation.

Any solution to this destructive cycle must be economically viable, readily available and easily implementable. We will show that nitrogen fits all these criteria and will decrease operational costs while increasing safety and service.

Tire Life

The effective life of both the original tire and the use of the casing to produce retreaded tires have been greatly extended through the use of nitrogen as an inflation medium. The primary factors affecting a tire's life span are tire aging and tread wear.

In a study performed by Lawrence Sperberg in 1985 the effect of nitrogen inflation for long-haul trucking was shown to greatly increase tire life. With over 7 million miles of testing, using both new and retreaded tires, the study found that the nitrogen inflated tires provided 26% longer tread life than those inflated with compressed air.[4]

In a study entitled Nitrogen Tire Filling System performed by Clemson University's Department of Mechanical Engineering, nitrogen was proven to help reduce the impact of both retreadability and tread life.[1]

Tread Wear

Tread wear occurs through contact with the road surface. Heat generated by friction softens the tread material making it more easily worn away during operation. As tires

lose pressure through permeation of the inflation gas through the tire material, a larger portion of the tire makes contact with the road surface. This has two effects; it increases the surface area of the tire that is subjected to the abrasive effects of contact with the road; and more heat is generated as a greater portion of the tire is subjected to friction.

Clemson's study found that nitrogen's lower permeability allowed the tire to maintain correct pressure much longer, thereby decreasing the surface area of the tire subjected to friction. Rolling resistance of tires inflated with nitrogen was found to be 70% lower than those filled with compressed air. Table 2, taken from the Clemson study, shows a comparison of wear per mile for front and rear tires inflated with nitrogen and compressed air.[1]

	Front Tires				Rear Tires			
	Nitrogen Inflation	Air Inflation			Nitrogen Inflation	Air Inflation		
Location	Wear/mile (mm)	Wear/mile (mm)	Increment (mm)	Percentage (%)	Wear/mile (mm)	Wear/mile (mm)	Increment (mm)	Percentage (%)
DC 1	0.00005082	0.0001	0.000049	49	0.000071	0.00015	0.000079	53
DC 2	0.000068	0.00013	0.000062	48	0.000081	0.00016	0.000079	49
DC 3	0.000052	0.0001	0.000048	48	0.00006	0.00012	0.00006	50

Table 2. Comparison of tire wear per mile for nitrogen and compressed air inflated tires. (Tire Nitrogen Filling System, Dept of Mechanical Engineering, Clemson University, Clemson, South Carolina)

The net effect is to decrease tread wear thereby extending the useful life of the tire. This effect is more dramatic when looking at fleet vehicles due to the larger number of miles and longer operation times. Based on the results of four independent studies, tire life in fleet vehicles was extended by an average of 57.5%.[1,3,4,5] Passenger vehicle tires have been shown to last 31% longer when using nitrogen inflation.[1]

Tire Aging

Tire aging affects the tire's components, the steel belts and rubber that make up the tire. Many factors can contribute to aging the tire including exposure to the elements, repeated flexing of the sidewalls while in operation and heat generated during operation. Tire aging causes the rubber in the tire to become brittle, increasing blowout potential and rendering the casing unusable for retreading, and can cause belt packages to rust, creating a risk of belt separation. According to a study done by the NHTSA, "Operation of the tire while underinflated is known to increase rolling resistance and wear, and with increasing amounts of under inflation can lead to thermal flex-fatigue damage or destruction of the tire."[7]

As mentioned previously, tires that have the correct inflation pressure produce less heat from friction and sidewall flexing. This allows the tire to run significantly cooler. Amalgamated Bulk, a South African trucking firm, found that with nitrogen, their tires averaged a 13 – 15% lower operating temperature than those inflated with compressed air.[6] Two trucks were run over the same route on the same day, one with nitrogen and one with compressed air. Starting tire temperatures were the same and temperatures were taken at two times during operation. Table 3 shows the compiled data from Amalgamated Bulk.

Location of Tire	11:50 AM temp	12:45 AM temp	Inflation Medium	Temp Difference N2 vs. Air
Drive	127.22	147.02	Air	-19.8
Drive	120.74	127.22	Nitrogen	
Steer	132.44	138.2	Air	-17.46
Steer	114.8	120.74	Nitrogen	
Trailer	140.36	147.02	Air	
Trailer	147.02	153.68	Air	
Trailer	140.36	147.02	Air	
Trailer	150.26	153.86	Air	-24.8 Average
Trailer	120.74	127.22	Nitrogen	
Trailer	127.22	133.88	Nitrogen	
Trailer	127.22	130.46	Nitrogen	
Trailer	127.22	133.88	Nitrogen	

Table 3. Operational tire temperature with nitrogen and compressed air. Starting temperatures were the same. (Compiled from data supplied by Amalgamated Bulk, Springs, South Africa)

Fuel Savings

Inflation pressure has a significant impact on a vehicle's fuel economy. In a study done for Oak Ridge National Laboratory by Energy and Environmental Analysis, Inc., it is stated that "Most drivers do not pay much attention to the impact of their tires on their car's fuel economy. This is unfortunate, as tires are a significant factor in a car's fuel efficiency. Tires are directly responsible for about 15 to 27 percent of typical fuel consumption."[21] For every 1 psi drop in inflation pressure, fuel economy decreases by 0.3%. In a field survey conducted by the NHTSA, it was found that 85% of all vehicles had at least one tire underinflated and 29% had at least one tire seriously underinflated (by >8 psi).[8] The overall impact of this is the loss of as much as 13 billion gallons of fuel a year due to underinflated tires.[9]

One of the most beneficial aspects of nitrogen for tire inflation is its low permeability rate, the rate at which it is able to escape through the tire rubber. Nitrogen, while being a lighter molecule than oxygen, has a larger diameter. As a result, nitrogen permeates through the tire 3 – 4 times more slowly than oxygen.[5] The result is that the tire stays at, or near, the correct inflation pressure between maintenance periods.

For over the road and inner-city trucking, this can have a very large impact. Several studies have been performed that evaluated the use of nitrogen inflation for Semi tractor/trailers. All studies showed a significant fuel savings when using nitrogen, even for companies that had a rigorous tire pressure maintenance program in place. Table 4 outlines the results of each study.

		Clemson	Transport Canada	Computerized Austrian Test
Fuel Savings Using N2	vs. Air filled (checked regularly)		2.80%	
	vs. Air filled (not checked regularly)	23%	6.10%	13%

Table 4. Fuel savings for semi tractor/trailers using nitrogen inflation. (Get Nitrogen Institute website, research section)

Using average miles traveled by a semi tractor of 25,590 per year[9], this equates to 116 gallons or about $350 saved per tractor per year for those with a rigorous tire pressure maintenance program.[10] For those without a maintenance program, using the average of the three studies above, this jumps to 246 gallons or about $740 per year.[10] This savings does not take into consideration the extension of tire life that has been demonstrated in many studies. This will be addressed later in this document.

Larsen Trucking of Greenville, MI was able to improve their fleet's average mpg from 5.57 to 7.05. He attributed a significant portion of this increase to the use of nitrogen inflation.[13]

Passenger vehicles also gain the fuel savings benefit from nitrogen inflation. Although less dramatic than those for fleets, studies have shown an average of 2.25% for those who check their pressure regularly and an average of 5.75% for those who do not check their pressure regularly.[1,11] Since, as was stated earlier, 85% of Americans do not check their tire pressure regularly, most will see the larger savings. Using average miles traveled and fuel economy for passenger vehicles, most consumers can expect to save about $119 per year on fuel.

Down Time

Down time incurred due to a tire blow out is more than just inconvenient and dangerous. There are significant costs in the form of delayed deliveries, damage to the vehicle, replacement tires, on-site repair or towing and unproductive driver time. The NHTSA has stated that under inflation is a leading cause of tire blowouts.[12] Nitrogen's ability to maintain correct tire pressure can significantly reduce the risk of a catastrophic tire failure.

Aberdare Cable of South Africa stated that "no blowouts have been experienced since the change to Nitrogen. Before Nitrogen was installed, we were losing one tire per 1030km (640 mile) trip"[2]

Larsen Trucking, Inc of Greenville, MI converted their fleet to nitrogen in 2007. The President, Peter Larsen, stated that "In the first 4 months of 2006, our on-road tire repair expenses calculated by tire failure were $5,126.72 per month…for the first 6 months of 2007 [after nitrogen conversion]; the on-road tire repair expenses were $929.95 per month – an 82% reduction!"[13]

Safety

"As important as tires are to the handling and performance of your vehicle, they remain one of the most neglected components."[14] This statement from the Tire Industry Association is evidenced by the number of underinflated tires found on America's roads. Tires are the only component of the car that maintains contact with the road and therefore are responsible for control of the vehicle.

Between 1995 and 1997, 62 people were killed and 663 were injured due to truck crashes caused by tire blowouts in the US.[15] The NHTSA has stated that 95% of blowouts are caused by underinflated tires. These deaths can be prevented by maintaining proper tire pressure which, as we've shown earlier, can be done by using nitrogen inflation.

Retreading

"Nearly half of all truck tire replacements are retreads. It takes approximately 22 gallons of oil to manufacture one new truck tire…it takes only approximately 7 gallons of oil to produce a retread."[16] These statements from the Tire Retread & Repair Information Bureau demonstrate that not only is retreading commonly done by most trucking companies, it is also the environmental option.

In order for a tire to be retreaded, there is one basic requirement; a sound casing on which the new tread material can be bonded. Minor casing imperfections, such as nail holes, can be repaired but if the rubber itself is cracking or the belts are separating, the casing becomes another piece of trash in a landfill.

As was discussed earlier, the largest enemies of the tire are heat and under inflation. Nitrogen mitigates both of these concerns, thereby improving not only the longevity of the original tread but also the casing, allowing more retreads from the same casing.

In his article "Million Mile Truck Tires – Available Today", Lawrence Sperberg, using electron beam microscopy, showed that oxidation due to migration of oxygen through the tire rubber, especially in combination with water vapor often present in compressed air, was a major factor in the breakdown of the rubber.[4]

But what does nitrogen do in the real world? We can find out by looking at the results of a test by Amalgamated Bulk of South Africa. Running 1,100 mile turn-around trips 95% under load with ambient temperatures of 77 – 104^{o}F they are able to retread each casing up to 5 times and were told by their retreader that the "casings are like new tyres."[6]

Aberdare Cable, also of South Africa, stated that their "*very best* before nitrogen was 3 recaps per casing." They are now consistently getting 4 per casing.[2]

Environmental

In the current environmental climate, it is important to consider not just the additional revenue available but also the benefits to the world in which we live. With greenhouse gases in our atmosphere on the rise and mountains of tires being held in landfills, what impact can each of us have? Fortunately, with nitrogen inflation, the answer to this is "a significant impact".

It is to America's credit that there has been a concerted effort to increase recycling of scrap tires. In 1990 only 17% were recycled, in 2003 that number had jumped to 80%. Based on 2003 scrap tire data[17]:

- 130 million are used as fuel
- 56 million are recycled or used in civil engineering projects
- 18 million are converted into ground rubber and recycled into products
- 12 million are converted into ground rubber and used in rubber-modified asphalt
- 9 million are exported
- 6.5 million are recycled into cut/stamped/punched products
- 3 million are used in agricultural and miscellaneous uses
- 16.5 million scrap tires are retreaded
- 27 million scrap tires are estimated to be disposed of in landfills or monofills

Approximately 15%, or 42 million, of these tires are truck tires.[18] Each of these 42 million tires requires about 22 gallons of oil to produce, approximately 924 million gallons of oil in total. By extending the life of each tire by the proven 57.5%[1,3,4,5] 24.15 million truck tires would have been prevented from entering landfills and 531 million gallons of oil would have been saved on tire production.

The average passenger tire requires about 7 gallons of oil to produce.[19] Therefore, after removing the truck tires above; the remaining 236 million tires represent 1.652 billion gallons of oil.

Through nitrogen inflation tire life can be extended by 57.5%[1,3,4,5] for truck tires and 31%[1] for passenger tires. This equates to 97.31 million tires not entering landfills and 1.043 billion gallons of oil that could be saved in tire manufacturing alone every year simply by inflating with nitrogen.

Additionally, as discussed earlier, nitrogen inflation improves fuel economy, saving as much as 13 billion gallons of fuel from being burned each year. Since each gallon of diesel burned creates 22.2 lbs[20] of CO_2 and each gallon of gasoline burned creates 19.4 lbs[20] of CO_2, a total of 138.7 million tons of CO_2 would not enter the atmosphere.

Cost of Converting to Nitrogen

There are a number of methods available to help maintain pressure; tire additives, automatic tire pressure maintenance systems, TPMS systems…but all involve a large initial investment per vehicle and none have the proven performance record of nitrogen. A simple TPMS system for a tractor/trailer will cost about $1000, an automatic pressure maintenance system even more. None of these can alleviate the inherent problems with compressed air; oxidation, permeation, and contaminants.

When you add the savings from improved fuel economy, increased tire life, greater retreadability, decreased maintenance costs, and decreased downtime the cost of using nitrogen becomes increasingly easy to bear.

Return on Investment

One of the most important questions that will be asked before someone makes an investment in nitrogen is "What is the benefit to me?" While it is noble to look at how this will help the environment, most companies do not have the revenue to invest in technology that does not provide an immediate return.

Nitrogen inflation provides a means to promote a sustainable environmental focus as well as providing a return through multiple channels. In this section we will explore some of the ways you can not only pay for your equipment costs but gain additional revenue as well.

Carbon Credits

If you have a verifiable reduction in the output of greenhouse gases (GHG) as a result of methods you have put in place to do so, you have carbon credits. Carbon credits can be bought and sold, much like a commodity, and are a means to gain extra return on your investment in nitrogen inflation.

To participate, the only requirement is to implement a verifiable means of tracking your GHG output and have a means of bringing them to market. This can be extremely simple to do and there are existing companies that can assist with setup and act as an agent for the trade or sale of credits. Nitrogen carbon credits are currently being sold in Canada and are viable in the US.

Nitrogen as Part of Your Business

There are various ways to incorporate nitrogen into your available services and various indirect benefits in doing so. This section will examine in more detail what the options are and how they benefit both the customer and the nitrogen provider.

As a fleet owner, the obvious benefits are the fuel and tire savings which, based on the Get Nitrogen Institute's Savings Calculator are shown in Figure 1. The following figures

were used: $275 average tire cost, $3.00 average fuel cost, 10 tires on the vehicle, 5.7 mpg, with a tire pressure monitoring program and 25,000 miles driven per year.

Figure 1. Semi tractor / trailer savings when using nitrogen tire inflation from the Get Nitrogen Institute website.

What is not so obvious are the cost savings from decreased downtime and maintenance or the increased ability to deliver product on time. One blown tire can cost $500 or more to replace and means that the load is now sitting on the side of the road rather than on its way to a customer. What is the effect of a late delivery on your company's reputation?

Nitrogen, through better pressure retention and cooler running tires, can greatly decrease blowout potential. Adam's Motor Express of Georgia stated "We're running a five-to-one trailer-to-tractor ratio, and lots of those are dropped trailers. Some are away from the shop three months at a time, but we've seen little if any pressure loss on those tires. We've got 2,800 tires on nitrogen now, and we haven't had a soft-tire blowout in four years. The year before we started we had 63 pressure-related failures."[22].

The cost of maintaining tire pressure on a semi tractor/trailer can be high…the cost of not maintaining pressure can be much higher. As shown above, nitrogen inflation is a cost effective method to maximize your return.

Nitrogen Now

Modern Tire Dealer has been conducting reader surveys on various aspects of the tire industry for many years. In recent years a section on nitrogen has been added to this survey that looks at adoption, pricing models and trends in equipment.

In 2007 the survey showed that 21% of respondents said that they offered nitrogen with another 10% stating that they planned to add it in the future. In 2008 33% of survey respondents stated that that they offered nitrogen, more than expected based on the 2007 survey, and another 8% stated that they planned to add it.[23]

With only 4.4% of respondents having had nitrogen for 5 years or more, it is easy to see that this is a new technology…a rapidly expanding new technology.

The growth rate has been fueled by demand from consumers as awareness of the service has spread through the efforts of manufacturers, dealers and other organizations. While nitrogen still must be "sold" to many consumers, it is increasingly becoming an expected offering. Consumers are aware of the benefits to both them and the environment and feel that it should be available.

Manufacturers have done their part to make this growth possible by offering more innovative designs including a handheld "wand", lower cost systems, and auto-inflators that decrease labor time and increase accuracy.

Early nitrogen systems were large and immobile, requiring the shop to be plumbed with multiple outlet points for servicing. Now most nitrogen systems that are produced are smaller and mobile, able to be moved from bay to bay, eliminating the need to plumb the shop. Most require only an input line from the compressor. This reduces installation costs to near zero and provides the flexibility for one system to service multiple bays.

Many large retailers such as Costco Tire Centers, Tire Discounters Inc., Belle Tire and Discount Tire, after reviewing existing research and performing their own tests to confirm, have made nitrogen an integral part of their service centers. Costco, Belle Tire and Tire Discounters Inc. use nitrogen exclusively in every tire they sell.

Initially intent on selling the environmental aspects of nitrogen, they discovered that they were also able to reduce costs. Nitrogen caused warranty claims to decrease as fewer tires experienced early wear or damage often caused by oxidation and under inflation.

Large trucking fleets such as Walmart[22] and Safeway[24] have also made the change to nitrogen. They performed initial trials, converting part of their fleet to nitrogen, and compared this to other available options to reduce tire costs, including TPMS and automatic pressure maintenance systems. Nitrogen, with a lower implementation rate (per truck cost) and greater benefits, was the clear choice. The savings from extended tire life alone justified the cost of the system and installation. With the addition of fuel savings and retreadability, the decision to make the conversion was fairly easy.

The Future

We have seen that nitrogen has had a relatively high rate of adoption; but what about the future? Will nitrogen continue to grow in the coming years?

Let's take another look at the information from the Modern Tire Dealer survey. The survey showed a rapid increase from less than 4.4% prior to 2003 to 33% in 2008. If looked at from another perspective, this leaves 67% of respondents still without nitrogen.

Consumer demand has spurred much of the increase in dealers offering nitrogen. The growth in consumer sales has showed no sign of slowing and is, in fact on the increase. The consumer expectation that they should have access to nitrogen at any shop will further spur the need for those shops without nitrogen to make the investment.

Additionally, as the "newness" of nitrogen decreases, the expectation will be that it should be a free service. Early adopters were able to charge a premium for nitrogen inflation. In many cases they were able to pay off their equipment in months, if not days. The later someone enters the market, the less opportunity they will have to charge and therefore the less chance to see a return.

Cost of Ownership and Rate of Return

Retail Tire Location

Costs:	System	$ 6500
	Auto-Inflator	$ 2000
	Tank	$ 1000
	Plumbing	$ 500
	Shipping	Included
	5 yrs Filters	Included
	Total Fixed Cost	$10,500

Assuming 800 tires converted per month (80%) charging $29.95 per conversion (4 tires):

800 x 60 months = 48,000 tires (cost per tire of $0.22)
800/4 = 200 conversions per month x $29.95 = $5,990 revenue per month
Full return in 1.75 months. Additionally warranty claims have been reduced from 7% of bottom line to 2.6%.

Oil Lube Chain

Costs:	Unit	$8500
	Tank	Included
	Shipping	Included
	5 yrs Filters	Included
	Total Fixed Cost	$8500

Assuming 120 customers per month at 35% conversion rate and $29.95 per conversion:

120 x 35% = 42 conversion per month
42 x $29.95 = $1,258 revenue per month
Full return in 6.76 months.

Regional Fleet

Costs: Variable depending on fleet size

Justification method for one major fleet operation
Used 51% average tire life increase from studies
Divided by 4 as worst case scenario to get 12.75% tire life increase
Tire cost of $2400 per year x 12.75% = $250 per tractor per year
Equivalent to 8 month payback.

Originally planned to use Meritor Tire Inflation system but found that nitrogen inflation has similar benefits, no maintenance problems and a lower cost per tractor.

Fleet Travel Stops

Costs: Variable depending on service model

Assuming 10 customers per day at $150.00 per conversion (10 tires):
10 tires x 30 days x 60 months = 18,000 tires
30 conversion per month x $150 = $4,500 revenue per month
Full return in 2-5 months.

Other benefits include increased traffic, customer retention, higher tire sales, and the ability to bundle with other green solutions. Can also charge for top-offs from customers who purchased nitrogen at another location.

References:

1. Jalili, N., Prakash, V. Clemson University, Department of Mechanical Engineering, 2000. *Tire Nitrogen Filling System*. Clemson, South Carolina, USA: Clemson University.
2. Wybrow, M. (1999) *RE – Nitrogen in Tyres*, Letter to Mr. Sowry, Retrieved from http://www.getnitrogen.org/savebillions/index.php
3. Mech, A., Mech, K. (2007). Effects of Nitrogen Tire Inflation on Canadian Long Haul Trucking. Drexan Corporation, Burnaby, BC, Canada.
4. Sperberg, L.R. (1985). Million Mile Truck Tires – Available Today "Oxygen and Moisture – the Killer of Tires"
5. Sabino, L. (2000). Degree thesis, University of Bologna, Mechanical Engineering Department, 2000. *Abstract: Chapters III and IV*. Tyres Inflation with De-Oxigenated [sic] Air. Bologna, Italy: University of Bologna.
6. Lavos, F. F. (1998) *RE: Nitrogen Plant*, Letter to Mr. Sowry, Retrieved from http://www.getnitrogen.org/savebillions/index.php
7. NHTSA. (March, 2010). *NHTSA Tire Aging Test Development Project – Tire Innerliner Analysis*. Washington, DC: National Highway Traffic Safety Administration. Retrieved from http://www.nhtsa.gov/DOT/NHTSA/NVS/Vehicle%20Research%20&%20Test%20Center%20(VRTC)/ca/Tires/811296rev.pdf
8. NHTSA. (July 26, 2001). *National Automotive Sampling System, Tire Pressure Special Study*. Washington, DC: National Center for Statistics and Analysis, National Highway Traffic Safety Administration.
9. Energy Information Administration. (2007). Annual Energy Review 2007. Retrieved from http://www.eia.doe.gov/aer/petro.html
10. Get Nitrogen Institute. (2010). Fleet Savings Calculator. Retrieved from http://www.getnitrogen.org/fleet_trucks
11. Bob Jane T-marts. (2006). Nitrogen inflation test. Retrieved from http://www.getnitrogen.org/savebillions/index.php
12. NHTSA. (Aug 9, 2007). Research Report to Congress on Tire Aging. Washington, DC: National Highway Traffic Safety Administration. Retrieved from