

Results of a Trial of Nitrogen Tire Inflation in a Long-Haul Trucking Fleet

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Abstract

Drexan Corporation conducted an experimental trial in 2006 to determine the fuel economy and tread life benefits of Nitrogen tire inflation to the long haul trucking industry. In 2005, Drexan received a Contribution Agreement for this trial from Transport Canada in Round 7 of the Freight Sustainability Demonstration Program. The trial was conducted in a fleet comprising 70 long haul tractors and 117 trailers of different configuration (Super B, tridems, tandems). Data was collected for 1,988 wheel positions. The trial comprised over 9.8 million tractor km (6.1 million tractor miles) and 177 million tread km (110 million tread miles) over a 9-month period.

Two independent methods were used to determine fuel savings to this fleet: comparison of trial results against two historical baselines, and comparison of electronically monitored engine performance data with a control within the trial itself. Tread wear was monitored by wheel position by equipment using an electronic data collection system called Snapshot¹. The experiment was designed to control for all variables impacting tread wear and fuel economy. Results of the trial were evaluated using statistical analysis software, and were determined to be statistically significant.

The results are as follows.

- When compared against historical data, Nitrogen tire inflation provides 6.1% better fuel efficiency than a fleet with air inflation and no tire pressure maintenance program.
- When compared against both historical data and the in-trial control, Nitrogen tire inflation provides 3.3% better fuel economy than a fleet with air inflation and a tire pressure maintenance program.
- When compared to the in-trial air control, Nitrogen tire inflation provides an average of 86% longer tread life over air inflated tires with a tire pressure maintenance program. No historical data was available to compare historical tread wear with tread wear during the trial.

The study proves that Nitrogen improves fuel efficiency and tread life for long haul fleets. The study infers that Nitrogen extends casing life and reduces failures.

¹ Snapshot is a product of International Marketing Inc., Professional Arts Building, Suite C, P.O. Box B, Chambersburg, PA 17201 (p) 1-800-233-7086 (f) 1-717-264-5483

Background

Lawrence Sperberg wrote a paper in 1985 titled *Million Mile Truck Tires – Available Today*. Sperberg's paper analyzes and re-presents data from a trial that was conducted in the early 1970's. In his trial, the data set comprised 98 tires: 54 new and 44 retreaded drive tires. The construction of these tires was bias ply construction. The total tread miles of this study was approximately 12.07 million km (7.5 million miles).

The key focus of Sperberg's study was the effect of Nitrogen on tire casing life and tread wear. Sperberg concluded that new tires inflated with Nitrogen had 26% longer tread life on average than air inflated tires. Further, Sperberg showed that retreaded tires had 54% longer tread life on average than air inflated tires. Sperberg noted that the retreaded casings were in fact oxygen-aged, i.e., they had not been inflated with Nitrogen prior to being retreaded.

Sperberg also discussed the results of chemical analysis of the tire rubber using electron beam microscopy. He determined that oxidation of the tire casing rubber and tread rubber was the cause of accelerated tread wear in the air inflated tires, and that it was the elimination of Oxygen (by using Nitrogen) that arrested or eliminated this aging.

Oxidation of tire rubber has been previously addressed by others, notably John Baldwin of Ford in his paper *Effects of Nitrogen Inflation on Tire Aging and Performance* presented to the Rubber Division, American Chemical Society in May, 2004, and Guy Walenga of Bridgestone Firestone in his presentation *Nitrogen Inflation for Truck Tires*, presented at the Clemson University Tire Industry Conference in March, 2004.

While Sperberg's findings are very promising for the trucking industry, fleet owners and fleet maintenance managers fail to see the relevance of his findings to today's realities. Their reasons are:

- Tire construction has changed
- Tire compounds have changed
- Sperberg's experiment had a very small sample size.
- Sperberg's experiment only tested one tire position: drive tires.
- Sperberg's experiment did not provide any data on potential fuel savings.

Yet, fleet owners and managers face economic challenges due to rising fuel costs and tire prices. A list of impacts on fleet operating costs and the underlying cost driver would include:

- Fuel costs (underinflation)
- Tread wear (underinflation and oxidation)
- Sidewall damage (oxidation)
- Retreadability (oxidation)

When proposing Nitrogen tire inflation to this segment, we found that fleet owners and maintenance managers consistently asked us these questions:

1. Where is the hard data on the benefits of Nitrogen, in the context of how I operate my fleet?
2. What will Nitrogen cost me to deploy?
3. What is the cost to maintain Nitrogen inflation in my fleet operations – not only in my own facilities, but on the road along my routes – even across the continent?
4. What is the tangible benefit, net of capital investment, subcontract costs, and direct and indirect labour? What will Nitrogen inflation actually do for my fleet?

We realized that fleets needed these answers with a hard return on investment before they would commit capital and resources to adopt this technology.

The Experimental Trial and Transport Canada's Freight Sustainability Demonstration Program

We realized that we had to update Sperberg's trial for today's factors. Perhaps it was possible that other factors would negate his results. We also realized that we had to address particular needs of fleet operators. For instance, fleet operators do not generally wish to scrap their complete tire asset base in a wholesale upgrade to a new tire technology. They generally wish to get the full service life out of existing assets. So our methodology had to respect this significant need.

Luckily, Sperberg's and Baldwin's work led us to conclude that for a fleet, converting to Nitrogen provides benefits to fleet managers and operators regardless of where a tire is in its life cycle. Sperberg's data on retreaded casings indicate significant benefits to retread life on oxygen-aged casings.

Realizing that as a small company we required assistance to produce this data, we approached Transport Canada under a program called the Freight Sustainability Demonstration Program. The mandate of this program is²:

- to reduce greenhouse gas emissions from the freight transportation sector
- to stimulate the development of innovative tools, technologies and efficient best practices for increasing the sustainability of Canada's transportation system
- to realize measurable environmental benefits

Based on our assessment of the needs of fleet operators, we submitted our proposal, including methodology, to Transport Canada. After rigorous examination and significant due diligence by their in-house technical team, our

² <http://www.tc.gc.ca/programs/environment/Freight/FETI/FSDP/menu.htm>

submittal was funded on the merits of the proposal and Drexan received a Contribution Agreement from the Crown in 2006.

The objectives of our study were the following:

- Quantify the mean increase in fuel efficiency by using Nitrogen as the tire inflation gas instead of compressed air.
- Quantify the mean increase in tire tread wear by using Nitrogen as the tire inflation gas instead of compressed air.
- Monitor failure rates of tires during the study.
- Conduct the study over a statistically significant sample size and over a long enough period to reduce or eliminate experimental noise due to variance.
- Finally, and most critically for the target audience for this study: conduct this study with the minimum impact possible on fleet operations, while gathering real-world data on the costs of fleet conversion and fleet maintenance

When we submitted our proposal to Transport Canada, we told them that based on existing data, we expected to see fuel savings in the range of 2% obtained through optimized rolling resistance, and we expected to see increases in tread life of between 25% and 55% based on Sperberg's results.

Description of the Participants

The trial fleet was Harris Transport based in Winnipeg, Manitoba. The trial fleet had excellent characteristics that met the requirements of our experimental design.

- The fleet has a very stable history with virtually no fluctuation in tractor or trailer numbers. This means that we could compare current performance to past history.
- The fleet gave us 1,988 wheel positions. This gives us a statistically significant sample size with high confidence level as compared to Sperberg's sample of 98 tires.
- The fleet uses owner operators, so the same driver runs the same rig. Also, in this fleet tractors are generally mated with trailers.
- The fleet hauls on consistent long haul routes, running from Manitoba west to BC, and from Manitoba south to San Diego. This means that our data incorporates seasonal effects of ambient temperature change and altitude change over the route.

35% of the fleet was run as an air inflation control. Air inflated tractors were paired with air inflated trailers, and Nitrogen tractors with nitrogen trailers. Any potential blend of air tractors with Nitrogen trailers or vice versa would serve to make the results more conservative (i.e. shorter tread wear, lower fuel economy).

The fleet has excellent historical records used for filing for fuel tax credits. In addition to these paper records, the fleet also incorporated SensorTracs³ into each tractor, so we were able to capture data electronically for each tractor in the trial. Hubometers were installed on each piece of equipment and served to verify the Sensortracs data.

To make the study even more interesting, in 2004 and prior, the fleet did not have a good tire pressure maintenance program. But in 2005, Harris Transport incorporated a tire pressure maintenance program using a 3rd party tire service company. The results therefore compare three fleet maintenance scenarios: lax tire pressure monitoring, aggressive tire pressure monitoring, and Nitrogen tire inflation with aggressive tire pressure monitoring.

The 3rd party tire service company, West End Tire, was well suited to perform the labour for the experiment. West End Tire was the Canadian beta test partner for Parker Hannifin's cold weather trials of Mobile Tire\$aver⁴ Nitrogen tire inflation systems, so we had a good working relationship and therefore could confirm proper conduct of the experiment using this customer and proven service provider.

In addition, West End Tire entered into a service contract with Harris in 2005 and was already fully immersed in Harris' fleet maintenance protocols. Not only were the results of West End's work already incorporated into Harris' historical results for 2005, but we could be assured that West End's presence on site would not taint the experiment. The only changes to the maintenance work flow would be the tire inflation gas and the tread wear measurements. West End Tire is also Harris' retreaded tire supplier, supplying Hawkinson and Marangoni Ringtread products.

Andre Mech, P.Eng., MBA, a principal of Mech and Associates, managed the research project and conducted the analysis of the trial results. Mech's experience as Field Installation Manager, Air Traffic Control Systems for Raytheon Aerospace and his domain expertise of the United Nations Protocol on Climate Change (also known as 'Kyoto') provided valuable insights to the design of experiment and data analysis.

Design of Experiments

Equipment was converted to Nitrogen on a random, FIFO system – what was in the yard got converted – on a stagger start basis from February to April 2006. West End Tire converted tractors and trailers from air inflation to Nitrogen inflation using a Parker Hannifin MTS12 or MTS06 Mobile Nitrogen Tire Inflation System. Tires were purged to atmospheric pressure, and then the tires were

³ SensorTracs is a product of QUALCOMM Wireless Business Solutions, 5775 Morehouse Drive, San Diego, CA 92121-1714

⁴ Tire\$aver is a trademark of Parker Hannifin Corporation.

inflated to setpoint pressure using the Mobile Nitrogen Tire Inflation System. Purity of the gas in the casing was verified using a hand held Oxygen analyzer, and purity in the casing was at least 95%. Four tread depth readings were taken per tire using a hand-held data collection system called Snapshot. This tread wear data was tracked by tire by equipment. Tread wear was recorded by West End Tire during the course of the trial as equipment cycled through the work yard. Equipment had final readings taken after a minimum of 6 months elapsed time for each piece of equipment between September and November 2006.

The drivers did not know which vehicles had Nitrogen and which had air in the tires. The conversion was done by West End Tire as part of normal tire maintenance at Harris' Winnipeg depot. Because the fleet conducted maintenance in a business-as-usual mode, we controlled for any maintenance impact. The fact that West End was taking the tread wear readings meant that Harris employees would not taint the experiment through changed behaviour due to knowledge of experimental results during the trial period.

Because drivers always drove the same equipment, we eliminated driving behaviour as a factor.

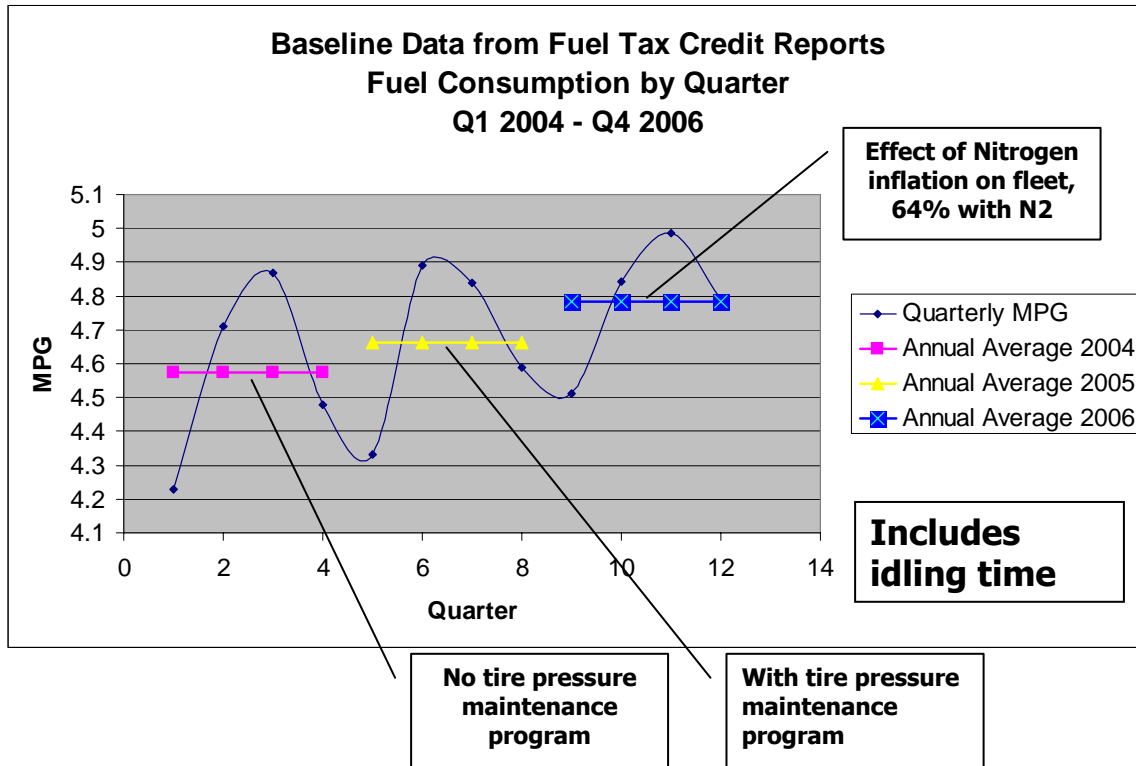
Because the routes were consistent, we eliminated route variances as a factor.

The trial started in February, statistically the coldest month of the year in Canada, and incorporated July, statistically the hottest month of the year in Canada, so the data set incorporates climactic changes during the course of the trial as well as during the course of individual hauls. We captured a minimum of 6 months data per piece of equipment. Because we ran the trials over 9 months spanning winter through fall, we accounted for climactic events.

Because we converted over equipment at random without regard to tire age, new or retread, tread depth, tire brand, or retread technology, we were able to assure ourselves that any change in the mean could be due only to the inflation gas, and nothing else.

Results: Fuel Efficiency

Fig. 1: Comparison against Historical Data



Our data set of 2 years history and 9 months of fleet usage during the trial period comprises over 35.4 million tractor km (22 million tractor miles). Figure 1 is produced from three years of fuel tax credit reports. It shows the classical seasonal variation in fuel efficiency that all trucking firms experience, where winter fuel efficiency is lower and summer fuel efficiency is higher. It is important to note that this data includes idling, which is why the y-axis mileage is lower than expected. The sinusoidal shape shows the period from winter (high idling, therefore higher fuel consumption) to summer (less idling, therefore lower fuel consumption) and back to winter.

The first sine wave shows 2004 data, prior to incorporation of a tire pressure maintenance program. The average for this period is shown in the purple line – about 4.58 mpg.

The second sine wave shows 2005 data. It shows the positive impact of the tire pressure maintenance program on the fleet. The average fuel efficiency increases to 4.67 mpg.

The third sine wave is very interesting. This shows the impact of Nitrogen tire inflation on the fleet average fuel economy, which becomes almost 4.8%. But

Nitrogen was only used in 64% of the tractors in the fleet. So if the entire fleet had been converted, the positive impact would have been greater still.

Overall, while seasonality is consistently evident year on year, the trend for efficiency is up and to the right based on the introduction of each measure – first tire pressure maintenance in 2005, then Nitrogen inflation in 2006.

Fig. 2: Comparison of Test vs. Control within the Experimental Trial

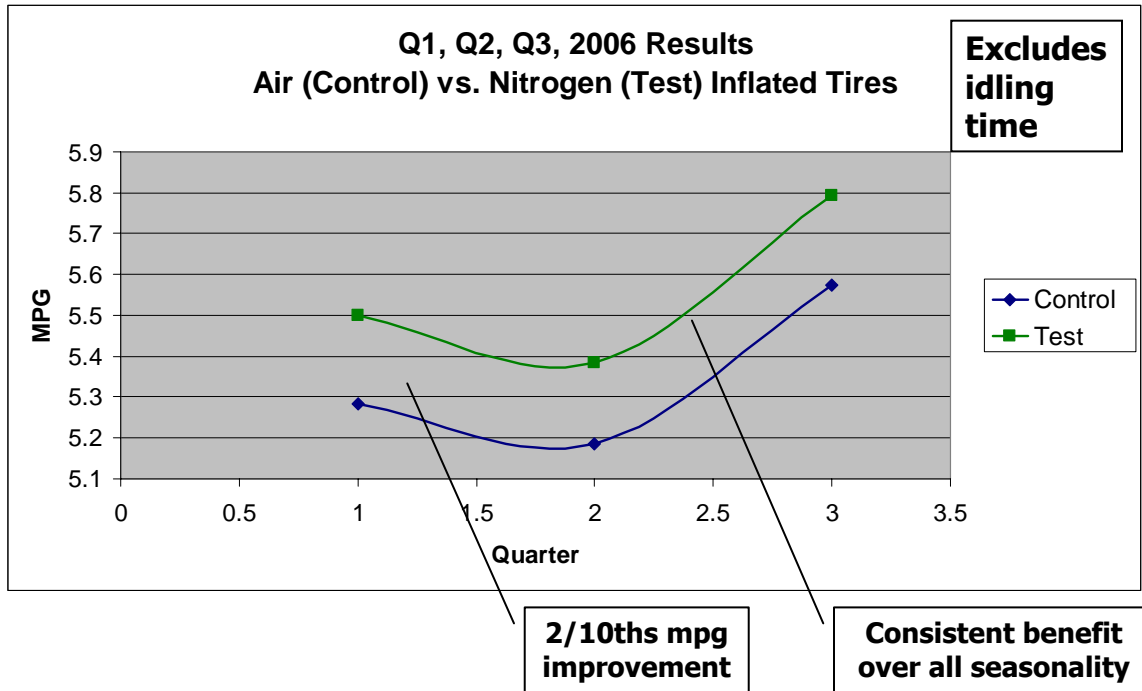


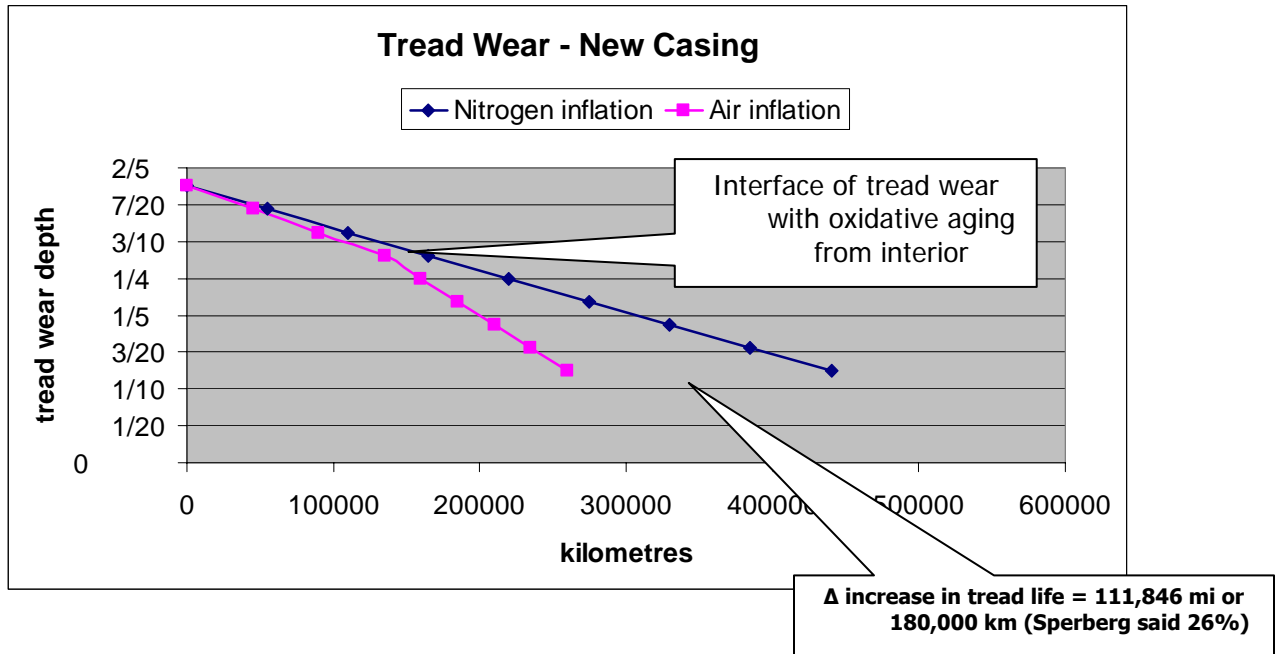
Figure 2 uses a second, totally independent methodology to demonstrate significant fuel savings obtained from Nitrogen tire inflation.

While Figure 1 compares fleet fuel efficiency year-on-year, Figure 2 compares fuel efficiency of Nitrogen inflation with air inflation within the experiment itself. This data is derived from electronic data capture using Sensortracs, and it excludes idling. It is important to note that this trial covers over 9.8 million tractor km (6.1 million tractor miles), and that it represents fuel usage during actual driving (long-term idling is excluded).

The lower curve shows fuel consumption for the air inflated control. The upper curve shows the fuel consumption for the Nitrogen inflated test group. We see clearly that the Nitrogen inflated vehicles were 2/10ths of a mile per gallon more efficient than the air inflated control. We also see that the lines are essentially parallel over the entire test period. This is important – if the lines were to diverge or converge, we would strongly suspect another factor. In the absence of convergence or divergence, our confidence is high that increased fuel efficiency is solely due to Nitrogen tire inflation.

Results: Tread Wear

Figure 3: Expected tread wear – new casings



Prior to this trial, we had very promising anecdotal evidence of increased tread life from existing TireSaver customers. Customers told us about obtaining tread wear of between 45,000 to 60,000 km (28,000 miles to 37,280 miles) per 32nd of tread wear on small trials.

Figure 3 is a graph prepared from this anecdotal evidence. While the data used to prepare this graph is statistically insignificant due to small sample size, it explains why a Nitrogen inflated tire gets more tread miles than an air inflated tire. The lower line shows a new trailer tire with approximately 250,000 km (155,350 miles) of tread wear. Our customer base says this is typical tread wear for new, air-inflated trailer tires. However, these same customers said that they were seeing 45,000 to 60,000 km (28,000 to 37,280 miles) tread wear per 32nd with Nitrogen inflated tires. Extrapolating this as a straight line yields the upper line.

Harkening back to Sperberg, he explains the mechanism for increased tread endurance over the entire available tread depth shown in Figure 3. Sperberg's experiment showed that that for new tire casings, Nitrogen provided 26% longer tread life. He concluded that the increase was due to the elimination of oxidative aging of the tire rubber that occurs in air inflated tires right through to the tread face itself. The interface between the tire road surface and the oxidized tread rubber is represented at the inflection point of the lower line in this graph, where it curves downward. At this point, the oxygen-aged tire rubber has shorter polymers. Oxygen has broken down unsaturated bonds in the tire rubber. Shorter polymers are weaker, resulting in softening of the tread rubber and

accelerated wear of the tread rubber due to road contact. And this is indeed what fleet owners and operators report as their experience in the field.

Figure 4: Expected tread wear – retreaded casings

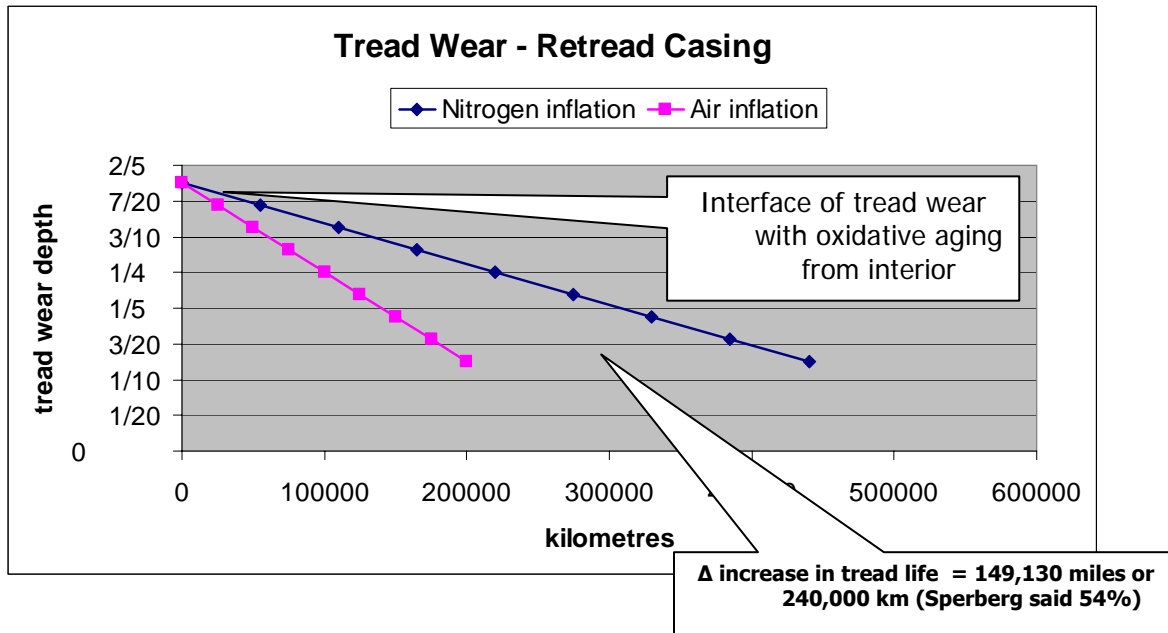


Figure 4 shows a similar treatment for retreads, but with even shorter life for the retreaded tire. Recall that Sperberg said Nitrogen-inflated retreads lasted 54% longer than air-inflated retreads. This occurs not because the Nitrogen tires last any longer – that would be impossible. This occurs because the air-inflated tire rubber breaks down faster, since the oxygen in air has no more bonds to attack in the casing. So these Oxygen molecules start to break down the tread rubber faster than in a new casing.

On the basis of prior research and anecdotal evidence, we told Transport Canada in our proposal that we expected to see an increase in tread life due to the elimination of oxidative aging in the casings.

Please note that during the trial, since we were doing Business-As-Usual maintenance, if a tire had to be replaced, it was. The replacement tire was inflated with the same gas as before – air with air, Nitrogen with Nitrogen. So during the trial, old oxygen-aged casings were replaced with new rubber – either new casings, or newly retreaded tires.

We obtained over 177 million km (110 million miles) of tread wear data from the actual trial, and our sample size included 1,988 tire positions. We have extremely high confidence in the results.

Figure 5: Observed Tread Wear

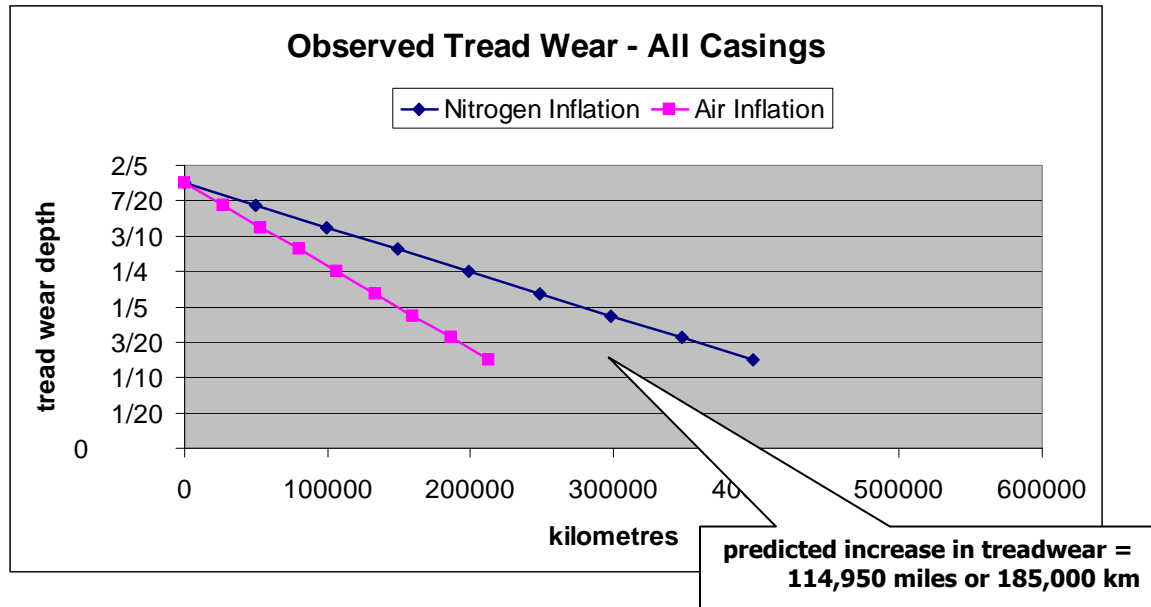


Figure 5 shows the actual results from over 110 million miles of tread wear data during the trial. It only comprises trailer tires, since the data set for tractor tires was statistically insufficient to report.

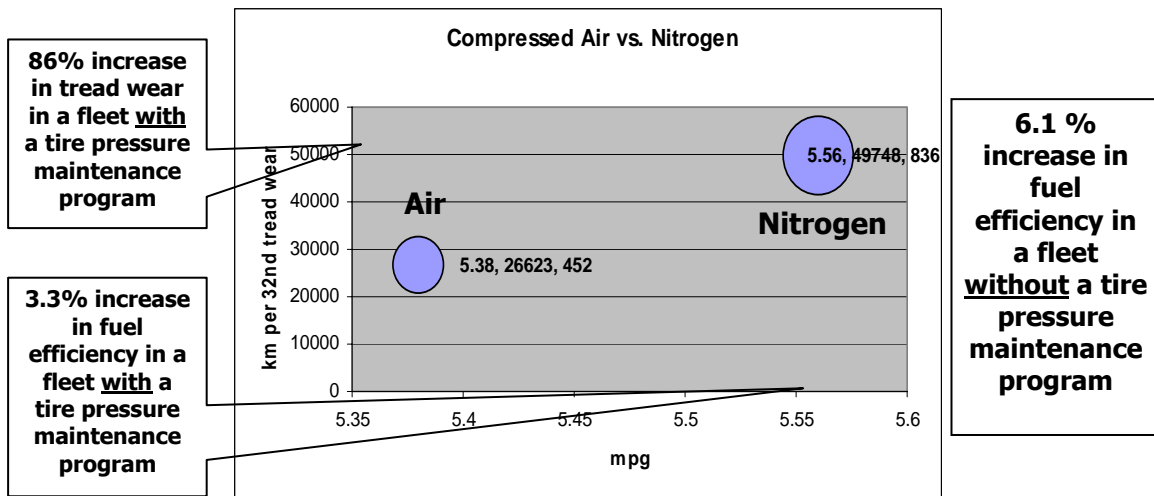
The lower line shows the actual average tread wear of 16,543 miles, or 26,623 km, per 32nd for the air inflated control comprising a set of 452 tire positions, trended for the tread life of the tire.

The upper line shows the actual average tread wear of 30,912 miles, or 49,748 km, per 32nd tread wear for the Nitrogen test group with 836 tire positions, trended for the tread life of the tire.

Extrapolating these findings for the entire tread depth (12/32 to 4/32) yields a predicted 86% mean increase in trailer tire tread life for Nitrogen inflated tires over compressed air, which translates to approximately 115,000 miles, or 185,000 km.

It is important to recall that this tread life was obtained in a fleet that already has a tire pressure maintenance program in place. Tread life is likely longer for a fleet without a tire pressure maintenance program.

Figure 6: Tread Wear and Fuel Efficiency – Air vs. Nitrogen Inflation



Sperberg study (1985): 12.07 million tread km (7.5 million tread miles), 98 bias ply drive tires
Mech and Mech study (2006): over 177 million tread km (110 million tread miles), 1,988 steel belt radial drive & trailer tires

Figure 6 compares the air inflated control to the Nitrogen inflated test group.

Lawrence Sperberg's study was conducted over 12.07 million tread km (7.5 million tread miles) with only 98 tire positions, all on drive tires, with an obsolete tire construction. Our study comprises over 177 million tread km (110 million tread miles) of data for 1,988 tire positions, using today's widely-used steel belt radial construction. We also have over 35.4 million km (22 million tractor miles) of fuel efficiency data.

The left balloon shows the air inflated control with 452 tire positions. This control obtained 5.38 mpg average fuel consumption, and average tread wear of 26,623 km (16,543 miles) per 32nd of tread wear.

The right balloon shows the Nitrogen test group with 836 tire positions. The Nitrogen group achieved average fuel consumption of 5.56 mpg, and average tread wear of 49,748 km (30,912 miles) per 32nd of tread wear.

These results show a 3.3% increase in mean fuel efficiency for Nitrogen inflated tires over compressed air. These results show an 86% increase in mean tread life for Nitrogen inflated tires over compressed air. However, both these metrics are obtained in a fleet that already has a tire pressure maintenance program in place. The increase in fuel efficiency for this fleet when compared to historical data prior to a tire pressure maintenance program is truly impressive – it is 6.1%.

7 Nitrogen inflated casings failed early in the trial. The failed tires were all extremely high mileage multiple retread casings that were near the end of their operational lives. Nitrogen cannot repair damaged rubber – it can only arrest further oxidation. One air inflated casing failed later in the program.

Discussion of Economic and Public Policy Implications

Guy Walenga is Engineering Manager, North American Commercial Products, Bridgestone/Firestone North American Tire LLC. During his presentation *Nitrogen Inflation for Truck Tires* At Clemson University's Tire Industry Conference in 2004, he stated: "So far, we have verified many advantages of Nitrogen inflation, with no negative performance attributes. The only negative we see is the added cost. Can the added cost be justified by improved performance such as:

- Fewer road failures and less downtime
- Additional retreads
- Better wear life and fuel economy from better inflation retention?"

In reply to Mr. Walenga's question "Can the added cost be justified?" our answer is a resounding yes. The economics are compelling. In fact, fleet maintenance managers and fleet operators ignore these findings at their economic peril⁵.

It cost Harris \$8,500 CAD to convert 65% of their fleet to Nitrogen. They saved over 500,000 litres (110,000 gallons) of diesel during the trial period. That is roughly \$285,000 USD or \$425,000 CAD in fuel cost savings alone⁶. But the average increase in tread life not only decreases the cost per km dramatically, it also defers actual cash flow for fleets. In a tight margin business, a dollar saved is better than 10 dollars earned in the top line, because there are no cost of sales associated with the savings. Most fleets are able to calculate their cost per km for tires, and so would be able to calculate the value of this extended tread life.

Further, because the fuel efficiency can be quantified so tightly, the reduction in Greenhouse Gases can be calculated, claimed through the appropriate program, and sold for incremental revenue on carbon trading sites. This incremental revenue alone may be enough to cover the cost of a fleet's entire Nitrogen program.

Assuming that at some stage the owners would like to sell their company, the true value of Nitrogen tire inflation is not just the cost savings. The true value is the savings that drop to the bottom line of the business as earnings, multiplied by the appropriate business multiplier.

For this particular business, the enterprise value of converting to Nitrogen tire inflation is worth over \$1,060,000 CAD (\$710,000 USD) for the period of the trial, excluding tire savings⁷. Annualized savings would be greater, since Nitrogen inflation maintenance is less expensive than fleet conversion.

⁵ The corollary is: what a great way to get a bonus.

⁶ Fuel costs vary by jurisdiction – these are estimates of fuel costs in Canada and the US.

⁷ Refer to point 6 for the swing in values – fuel is a significant cost driver.

For a very large fleet that is publicly traded, the shareholder value is determined by taking the earnings per share from the latest stock tables. For instance, EPS for FedEx and UPS are around 3.

There are also public policy implications to this technology. In the last State of the Union address given to the American people on January 23rd 2007, President Bush set a target of 20% fuel reductions by 2017 in order to reduce dependence on foreign oil. Our data shows that Nitrogen tire inflation has the potential to deliver nearly one quarter of these savings immediately.

Further, the United States and Canada have both stated they will support carbon trading. This technology directly benefits the long haul trucking industry by enabling the quantification of fuel savings and therefore the monetization of carbon credits⁸. Extended tire life and extended casing life also mitigate waste disposal issues that are of concern to municipalities, provinces and states. Lastly, this would be perceived by the general public as the right thing to do in terms of environmental stewardship.

Conclusion

Nitrogen tire inflation significantly improves fuel efficiency over air inflation – even in fleets with tire pressure maintenance programs. Nitrogen tire inflation therefore reduces green house gases. Nitrogen tire inflation also significantly increases tread life. The return on investment for fleets is substantial.

Based on the results of this study, and based on other related research, this study also infers more retreads per casing (since the casing would appear to retain its mechanical and elastomeric properties); fewer failures for the same reason; and the resultant secondary effects:

- Fewer roadside service calls
- Less lost service hours due to breakdown
- Less liability for accident or tread damage
- Safer highways
- Fewer tire disposal issues

Acknowledgements

I would like to thank Dave Connaughton from Parker, Harvey Brodsky from TRIB, Transport Canada, Andre Mech of Mech and Associates, and the good people from Harris Transport and from West End Tire, for their assistance in research and development of this paper.

⁸ This is why we consider the details of our study to be intellectual property. Drexan Corporation is open to licensing this material to interested parties.

About the Author

Konrad Mech, a Professional Engineer, is registered in the provinces of Ontario and British Columbia. Konrad obtained his Bachelors of Mechanical Engineering from the Royal Military College of Canada and his MBA from The European Business Institute (INSEAD) in France. He is Vice President and a Principal of Drexan Corporation. Konrad and his company have been selling Nitrogen tire inflation systems for three years. Konrad's marketing efforts have been directed to meeting the needs of long haul trucking fleets as well as major tire banners.

About Drexan Corporation

Drexan was founded in 1928. It is a privately-held incorporation doing business globally. The company's focus is technical in nature, and employs a number of engineers and technologists. Drexan is a manufacturer, and Drexan also distributes a number of products including Parker Hannifin's Tire\$aver Nitrogen tire inflation systems.

Drexan has locations across Canada, and has a representative and distributor network throughout North America. Drexan is currently expanding into South America and Europe.

Drexan has been a distributor of Parker Hannifin since January 1997, and has been selling Nitrogen generation equipment since that time. Drexan is Parker's largest seller of Nitrogen tire inflation systems in Canada.

Drexan is a world leader in Green House Gas Reduction and is registered on the Canadian Standards Association CleanProjects Registry for GHG reduction using Nitrogen tire inflation.

About Parker Hannifin Corporation

Parker Hannifin is one of America's powerhouses. It is a publicly traded company with over \$8.2 billion in sales last year. It has global operations. The company employs a number of industrial gas specialists.

Parker has been delivering Nitrogen generating equipment since 1980, and has sold over 10,000 tire inflation systems world wide. These systems are manufactured in Holland, and in Haverhill, Massachusetts.

David Connaughton (M.Eng.) of Parker presented a paper on Nitrogen tire inflation to the 22nd Annual Tire Industry Conference in 2006, sponsored by Clemson University, titled *Recent Trends in Nitrogen Inflation*.