Nitrogen Fleet Information

Fleet Savings Examples with Nitrogen Tire Inflation

Tire manufacturers and industry studies conducted on Nitrogen for tire filling agree that under-inflated tires waste between 2% and 4% of fuel due to increased rolling resistance. Tires inflated with Nitrogen maintain correct pressure longer than air-inflated tires – up to 5 times longer, which reduces rolling resistance and lowers fuel consumption. Studies also conclude that approximately 25% longer tire tread wear can be achieved by removing the Oxygen (oxidation) from inside the tire casing, as well as keeping them properly inflated. Under-inflated tires wear faster. Additionally, 20 lbs of CO2 emissions are saved for each gallon of fuel not consumed.

These excess costs may be now be recouped. The following examples illustrate the annual savings potential for fuel and tires by switching to high-purity Nitrogen for your fleet.

Fuel Cost Assumptions

- 20,000 average miles per year per vehicle
- 15 miles per gallon
- $2.25 average fuel cost per gallon
- 1,333 average gallons per vehicle per year (20,000 miles ÷ 15 mpg)
- **$3,000 average fuel cost per vehicle per year** (1,333 gallons x $2.25)

Tire Cost Assumptions

- $90 average cost per tire
- 20,000 average road miles per tire
- 1 average tires per vehicle per year – single tire (20,000 miles ÷ 20,000 road miles per tire = 1)
- 4 average tires per vehicle per year – total vehicle (1 average tires per vehicle – single tire x 4 tires = 4)
- **$360 average tire cost per vehicle per year** (4 tires per vehicle x $90 per tire)

Current Annual Cost Summary

- Current annual fuel cost per vehicle per year $3,000
- Current annual tire cost per vehicle per year $360
- **Current average annual cost per vehicle $3,360**

Projected Fleet Savings	Savings Range		
	Minimum	Average	Maximum
FUEL SAVINGS PER VEHICLE	2%	3%	4%
Projected Savings per Vehicle	$60	$90	$120
TIRE SAVINGS PER VEHICLE	15%	25%	35%
Projected Savings per Vehicle	$54	$90	$126
OVERALL SAVINGS PER VEHICLE	3.4%	5.4%	7.3%
Projected Savings per Vehicle	$114	$180	246
PROJECTED FLEET SAVINGS:			
300 Vehicles	$34,200	$54,000	$73,800
500 Vehicles	$57,000	$90,000	$123,000
1,000 Vehicles	$114,000	$180,000	$246,000
2,000 Vehicles	$228,000	$360,000	$492,000
3,000 Vehicles	$342,000	$540,000	$738,000
4,000 Vehicles	$456,000	$720,000	$984,000
5,000 Vehicles	$570,000	$900,000	$1,230,000
8,000 Vehicles	$912,000	$1,440,000	$1,968,000
10,000 Vehicles	$1,140,000	$1,800,000	$2,460,000

Following is a partial list of fleets which are working with Nitrogen Tire Inflation:

REPRESENTATIVE MUNICIPAL FLEETS

- **West Palm Beach Transit**
- **Westchester County Police Department**
- **Westchester Dept. of Public Works**
- **Oahu Transit Services Inc.**
- **City of Allentown, PA**
- **Lehigh County, NY**
- **NYC Transit**
- **USPS**
- **Broward County, FL Sheriff's Office**
- **Citrus County, FL**
- **Pearland School District, TX**
- **Coconut Creek, FL**
- **Jefferson County, FL**
- **Canyon County, ID**
- **City of Milwaukee, WI**
- **Fairfax County Police Department, VA**
- **Richardson, TX**
- **Euless, TX**
- **US Air Force**
- **Colorado State Penal System**

REPRESENTATIVE PRIVATE FLEETS

- **Brothers Auto Transport**
- **Adams Motor Express**
- **Wood County Bandag**
- **Winnipeg Motor Express**
- **Harris Transport**
- **Air Products & Chemicals**
- **Kraft Foods**
- **Larsen Trucking Inc.**
- **Ajax Paving**
- **Aberdare Cables**
- **Drexan Corporation**
- **LCT Transportation Services**
- **PJAX Freight System, Gibsonia, PA**
- **Pete Larsen Trucking, Greenville, Mi**

Board of County Commissioners

Office of Fleet & Transportation Management

1300 S. Lecanto Hwy., P.O. Box 215
Lecanto, Florida 34460

(352) 527-7626 ● FAX (352) 527-7625

July 28, 2009

Re: Purigen98 Nitrogen Tire Inflation

To Whom It May Concern:

Citrus County Fleet Management participated in a controlled test with Florida Atlantic University utilizing the Purigen98 Nitrogen Tire inflation system. The test lasted approximately 10 months and involved our ½ ton pick-up trucks. We compared 28 trucks filled with Nitrogen with an equal number of the same class of truck that was filled with ambient air.

I have seen many articles touting the advantages of filling tires with Nitrogen. Unfortunately all of the tests were done with long haul trucking companies. I was skeptical of the benefit for the every day, local driving. I was eager to participate in this test to determine if there was any advantage of Nitrogen on your standard work truck.

After 10 months of test data, the results were surprising. We documented an increase in mpg of 5.1% over the control group filled with ambient air. We had an increase in mpg of 4.6% in the test group compared to the same period last year. The only negligible change made to the two groups was the tire fill.

Citrus County used the Purigen98 Mobiflator M6324 unit. This system was easy to operate and had four hoses to inflate quickly. The technicians appreciated the ease of operation. We are now looking forward to filling the rest of our fleet with Nitrogen to maximize our fuel savings.

Regards,

Michael R. Webster
Director
Office of Fleet & Transportation Management

Nitrogen Tire Filling

Field Data Analysis

NY City Transit, Flatbush Depot

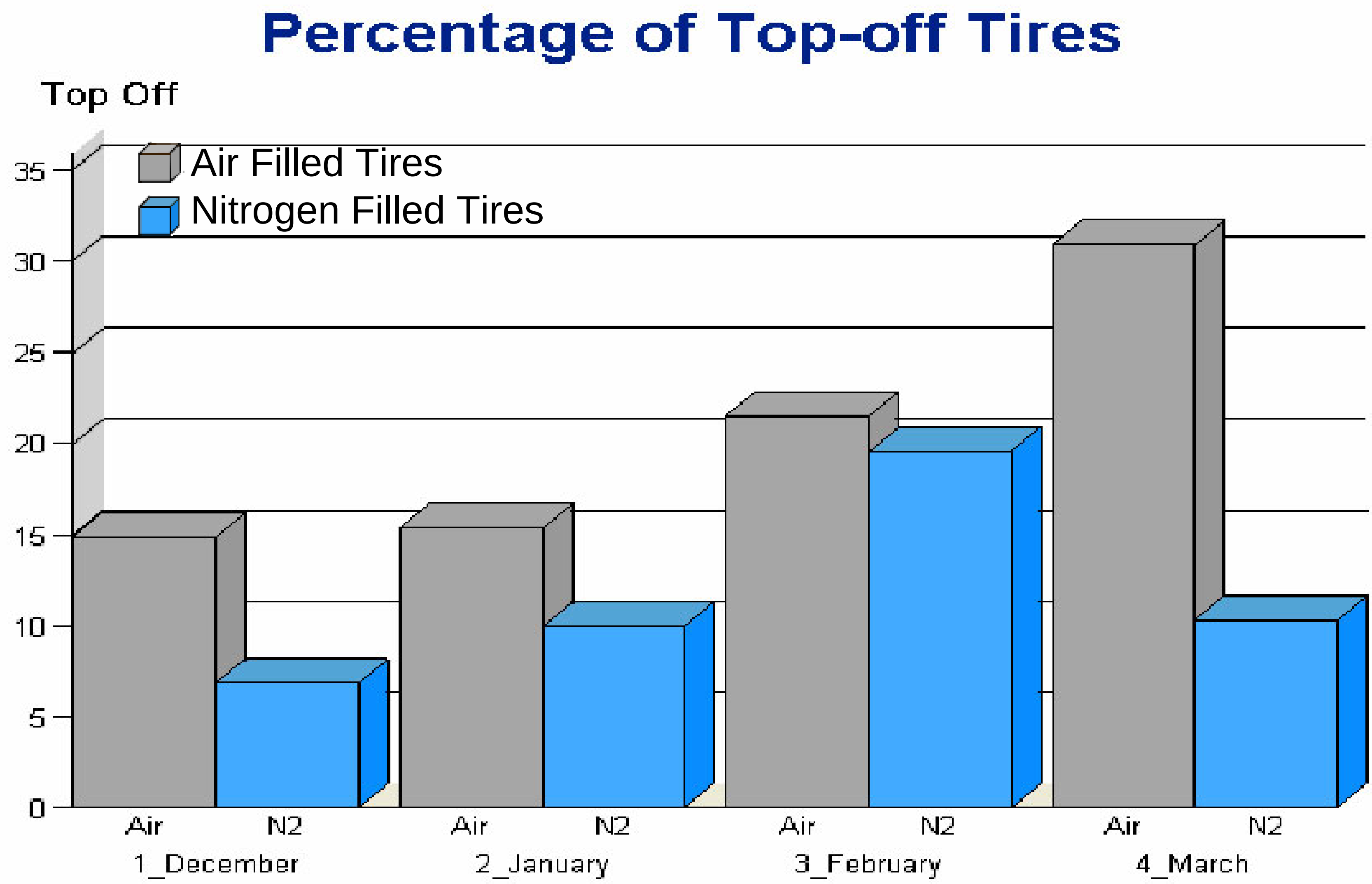
NYC Transit Bus Fleet Base Data

A trial was conducted by NYC Transit, NY Power Authority to evaluate the benefits of using Nitrogen in bus tires at NYCT's Flatbush Avenue bus depot in Brooklyn, NY in December 2007. This rigorously collected data formed the basis for further conversion of other depots to nitrogen. Since then, 4 more depots have been converted to Nitrogen.

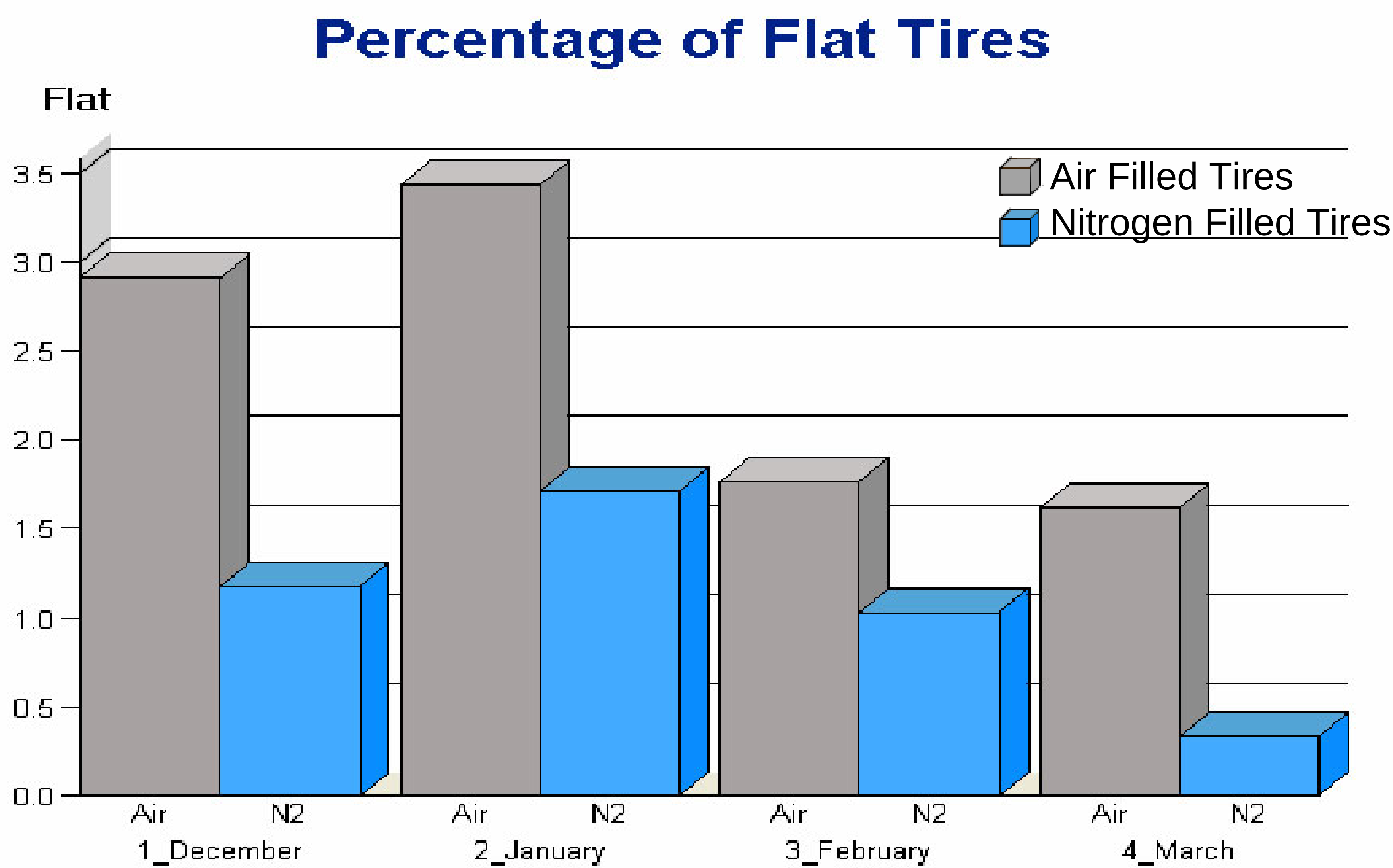
Fleet Size	285
Miles/yr (per vehicle)	~25000
Fuel Cost ($)/gallon (corrected for current cost)	~2
Tire Life (years)	~3
Test Period (months)	>3
Dates	Dec '07 – Mar '08
Average Miles/gallon	2.5

Analysis done in this report is based only on field data collected in the trial.

Tires Requiring Top-off in 30 days

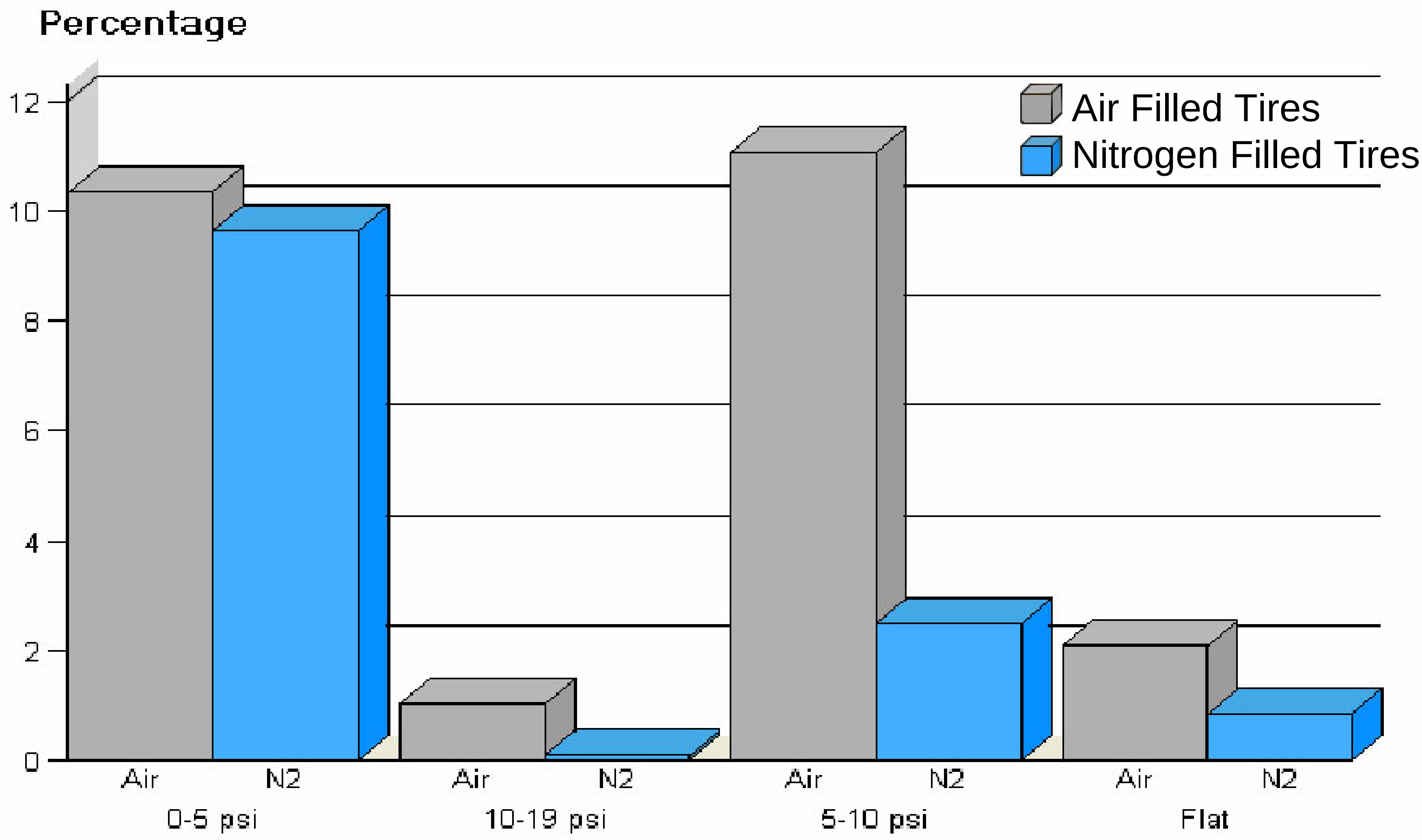


Number of Flat Tires Every Month



Pressure Loss Data

3 month average



Impact of Under-Inflation

Data from various Tire Companies

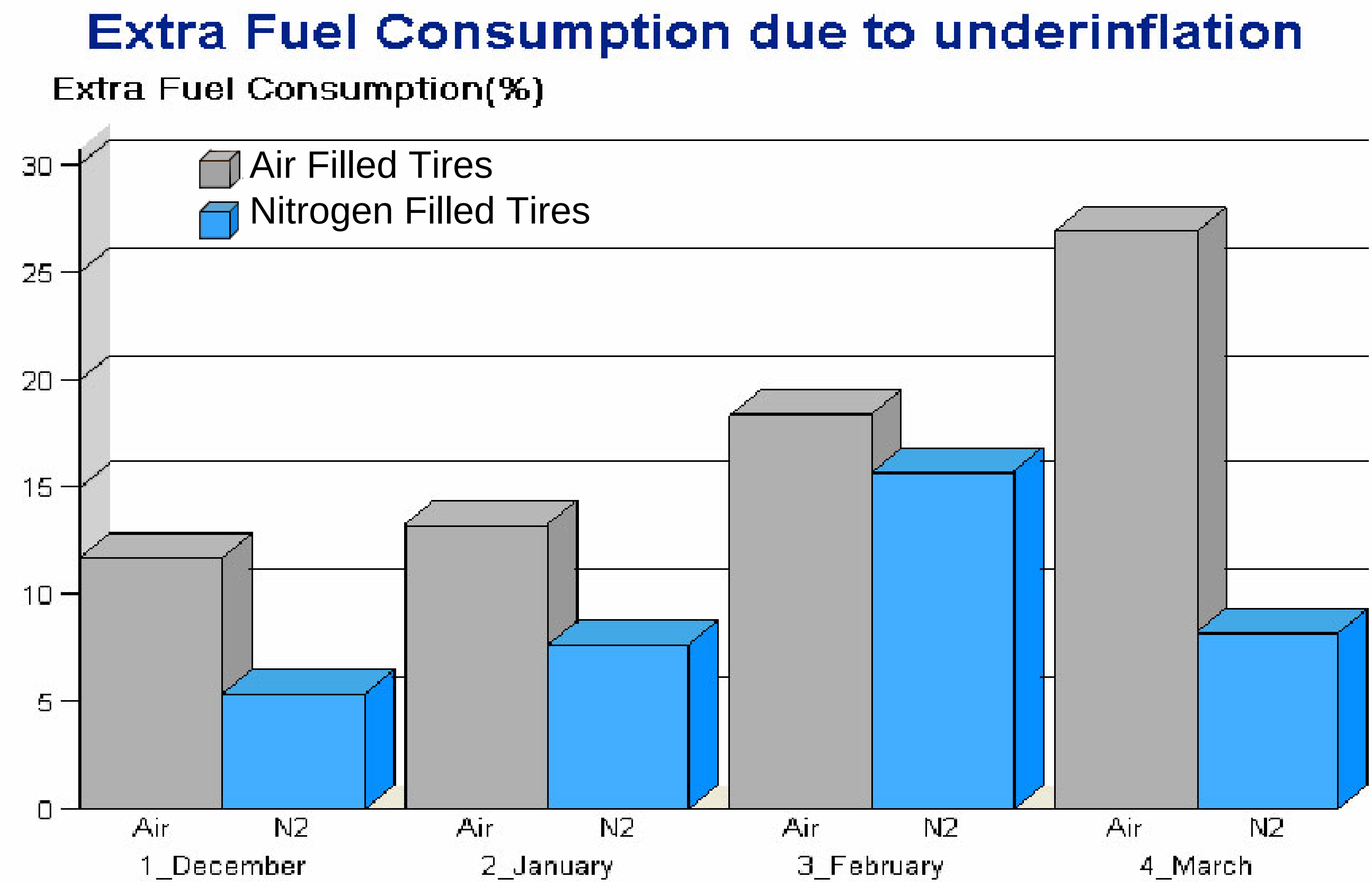
Extra Fuel Consumption (%)			
Under Inflation (%)	Michelin	Continental	Goodyear
5	0.75	1	2
10	1	2.5	4
20	2.25	7.5	12

Shortening of Tire Life (%)		
Under Inflation (%)	Michelin	Continental
5	1	2
10	2	5
20	20	28

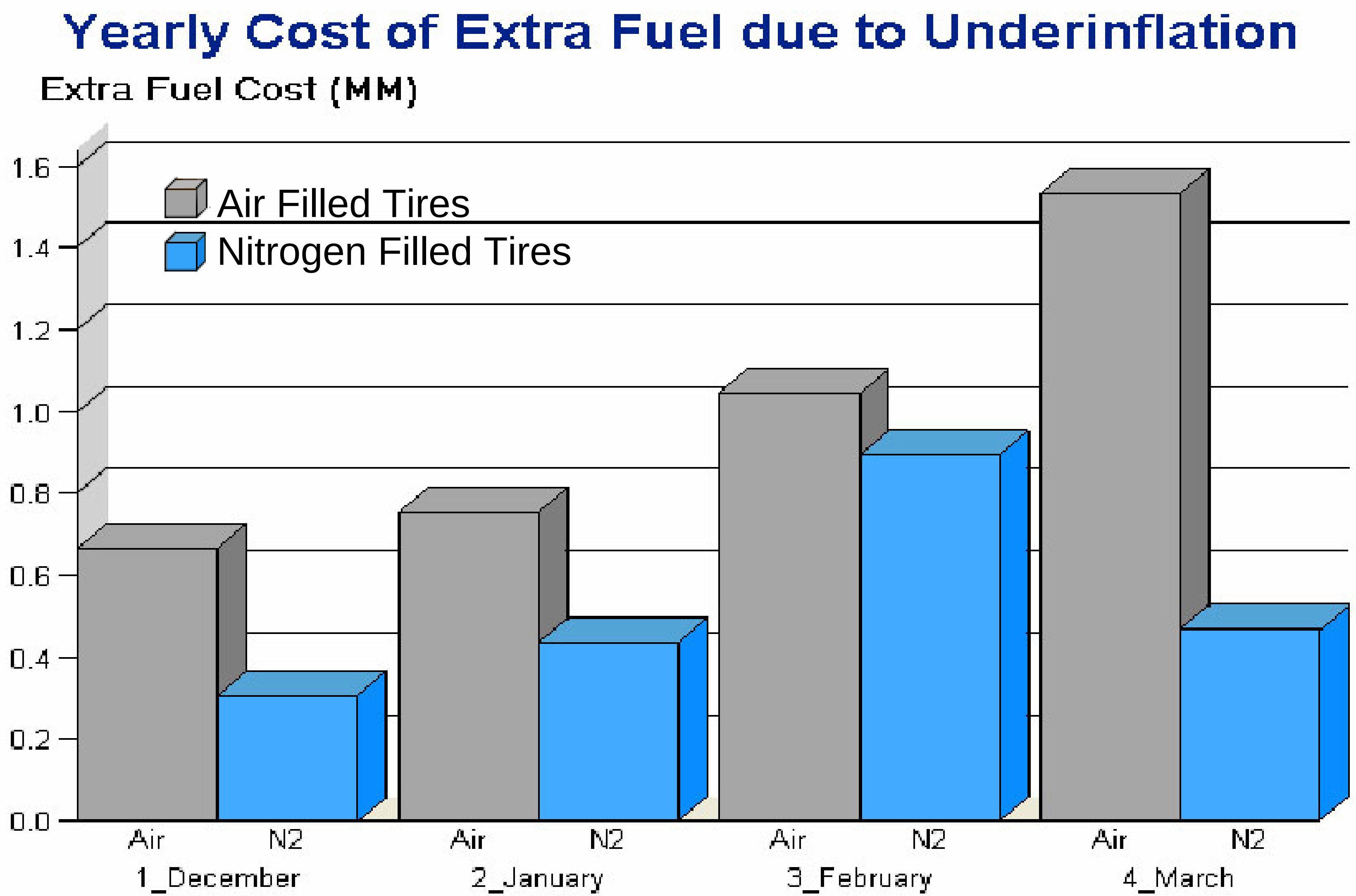
Most Conservative estimates from Michelin are used for cost savings

Fuel Consumption Impact

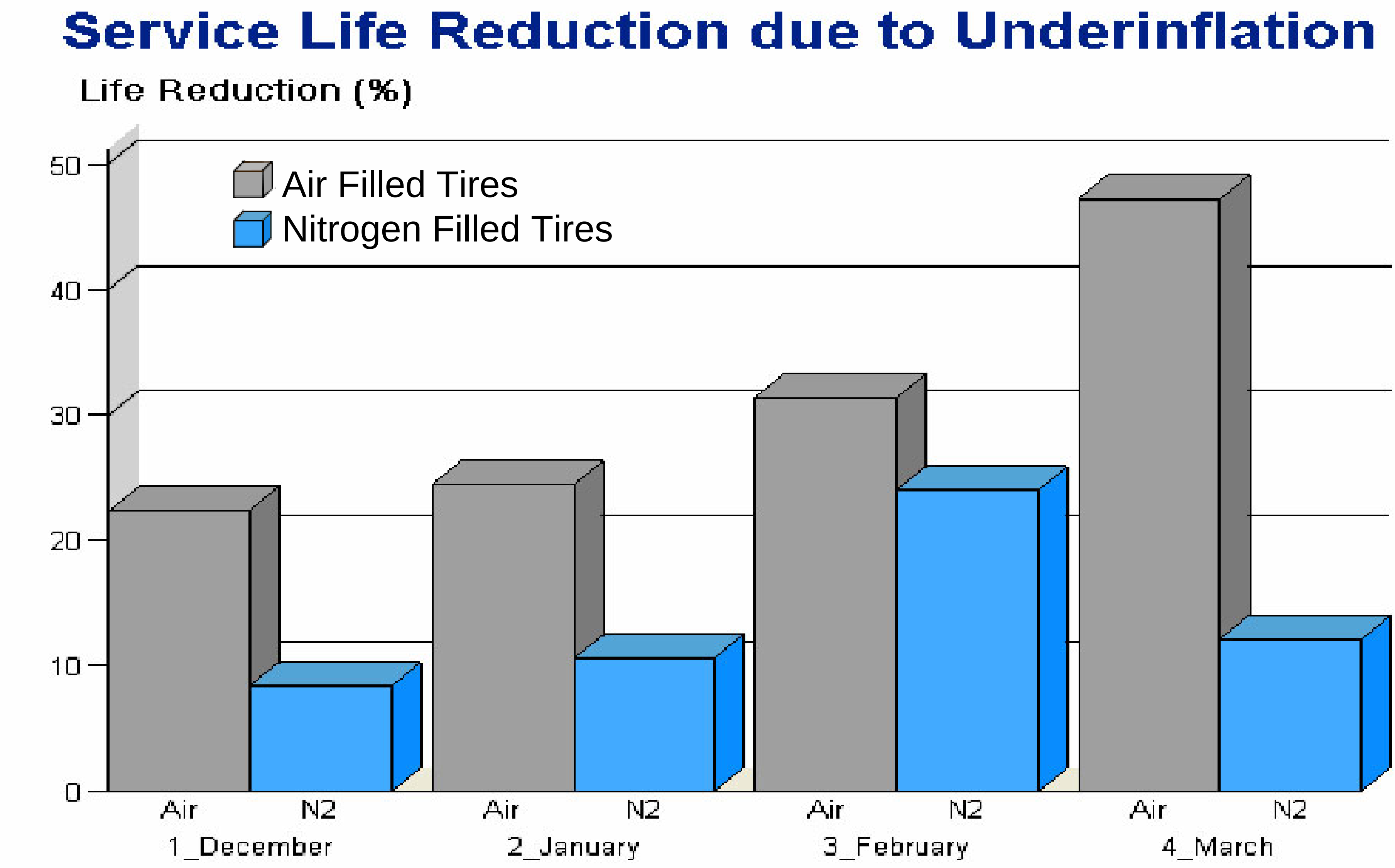
Based on Michelin Data



Fuel Cost Impact



Tire Life Impact



Conclusions

Nitrogen tire filling showed clear & demonstrated benefits over air filled tires as listed below:

1. **Tires retained correct pressure for longer time**
    - **Less tire top offs would result in lower labor cost**
    - **Lower number of flat tires (by ~3/month) would help reduce expensive downtime and tire cost**
2. **Tire rolling resistance was reduced**
    - **Lowered fuel consumption is projected to be $0.5 MM/year based on Michelin's conservative basis**
3. **Tire friction and tire wear was reduced**
    - **Tire life improvement is extrapolated to be about 20% based on the most conservative data**

NITROGEN INFLATION OF TIRES

presented to

National Highway Traffic Safety Administration
Washington, DC

Walter H. Waddell
Butyl Product Technology
August, 2006
2006PYBXA 12

ExxonMobil Chemical

Agenda

- **Introduction**
- **Filling Gas Studies**
  - **New Tires**
  - **Oven-Aged Tires**
- **Summary**

ExxonMobil Chemical

Introduction: Gas Permeability

- **Nitrogen inflation utilized for tires used in severe service conditions**
  - NASA, race cars, truck fleets, military applications, agricultural machinery
  - FAA requires nitrogen inflation of tires on braked wheels of all aircraft over 75,000 lbs takeoff weight

- **Nitrogen (0.10975 nm) is smaller molecule than Oxygen (0.1208 nm), but is 50% less soluble in Natural Rubber than is Oxygen gas**

  (ref: van Amerongen, Rubber Reviews 37, 1065 (1964))

- **Nitrogen is less permeable in rubber than is Oxygen gas**
  - Natural Rubber @25°C $N_2 = 6.12$ $O_2 = 17.7$ ($10^{-8}cm^2.sec^{-1}.atm^{-1}$)
    - For Natural Rubber $Q_{Air} \sim 1.4\ Q_{Nitrogen}$ ➔ *70%* of Air
  - Butyl Rubber @25°C $N_2 = 0.247$ $O_2 = 0.99$
    - For Butyl Rubber $Q_{Air} \sim 1.63\ Q_{Nitrogen}$ ➔ *60%* of Air

Nitrogen Less Permeable and Less Soluble than Oxygen

ExxonMobil Chemical

Agenda

- Introduction
- **Filling Gas Studies**
  - New Tires
    - Inflation Pressure Retention
    - Roadwheel Durability
    - FMVSS 139 Testing
  - Oven-Aged Tires
- Summary

ExxonMobil Chemical

Production of Experimental Tires

- **Compounds prepared in 2-step factory mix**
  - GK400 sheeted out on extruder with roller die
  - GK160 sheeted out on two-roll mill
- **Experimental summer tires made on full automatic building machines**
  - P205/60 SR15 (no nylon cap ply)
  - Cured innerliner gauges of 1.0 mm

Ingredient	1	2	3
Exxon™ Bromobutyl 2222	100	80	60
Natural Rubber, SMR 20		20	40
Processing Aid, 40MS	7	7	7
Carbon Black, N660	60	60	60
Processing Aid, SP1068	4	4	4
Processing Oil, TDAE	8	8	8
Stearic Acid	1	1	1
Zinc Oxide	1	1	1
Sulfur	0.5	0.5	0.5
Accelerator, MBTS	1.25	1.25	1.25

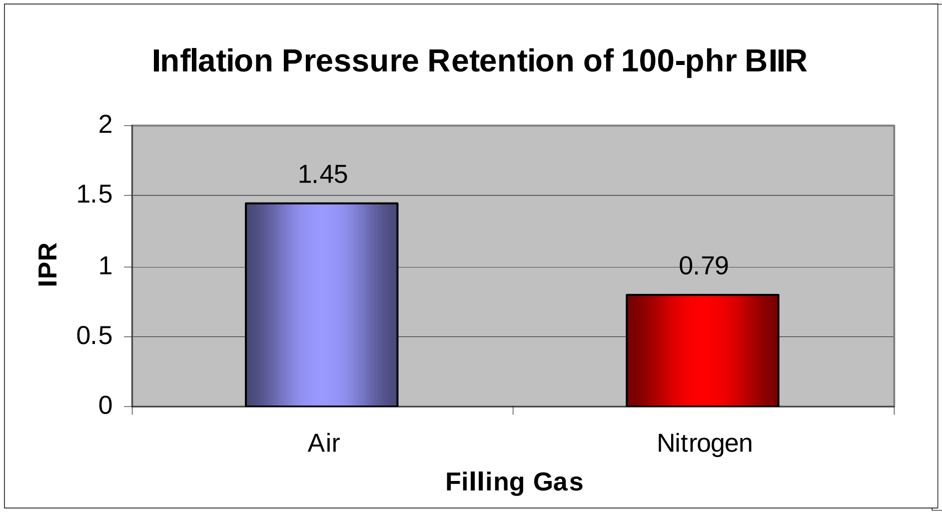
Filling Gas Effects: Tire IPR

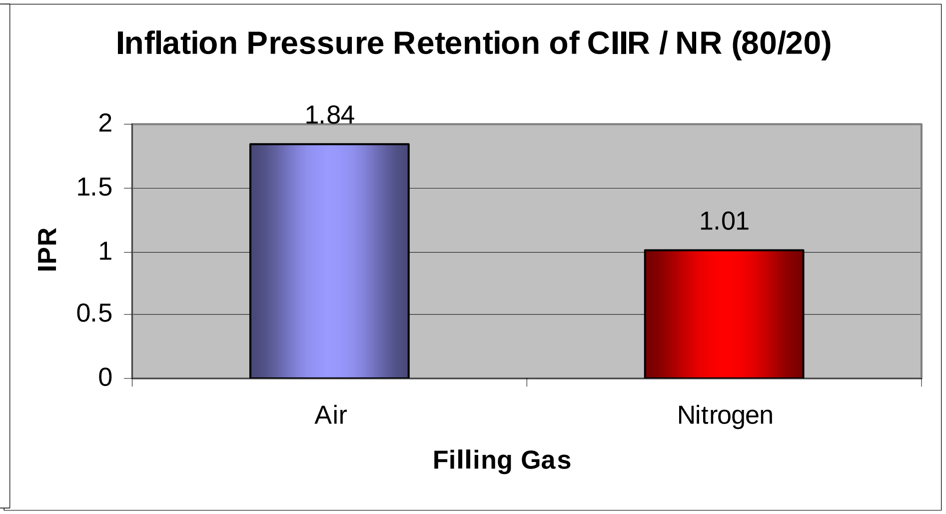
Walenga (Bridgestone/Firestone) reported on 11R22.5 truck tires

(ref: Guy Walenga, Clemson Tire Conference, Mar 11, 2004)

- Air-inflated tires lost 2.7%/month; dry nitrogen inflated tires lost 0.7%/month
- 'Nitrogen Inflation does reduce the oxidation degradation of rubber components in Truck Tires'

Used ASTM F-1112-00 to study IPR of P205/60 S R15 tires with different innerliners





IPR Loss Rates Reduced 45% using Nitrogen Inflation

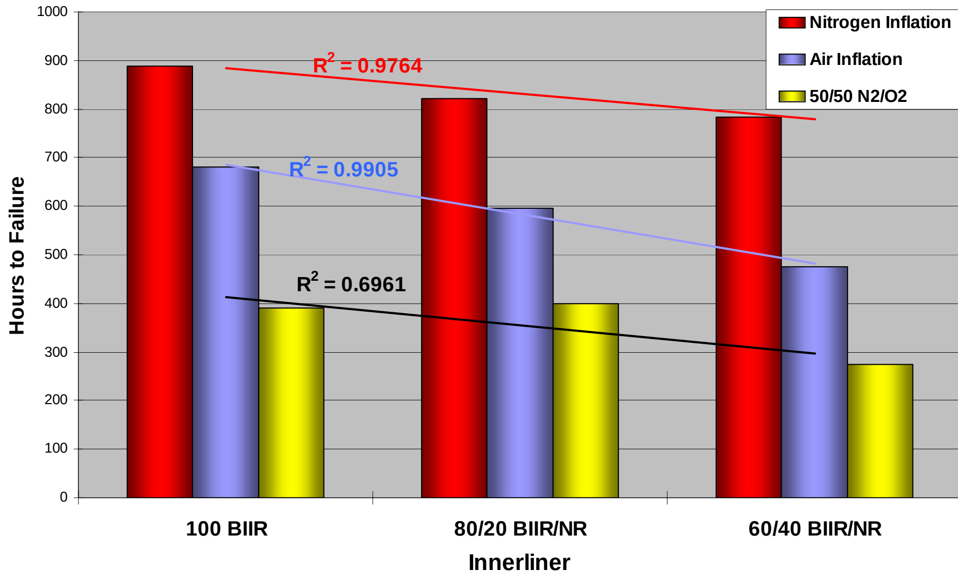
Filling Gas Effects: Roadwheel Durability

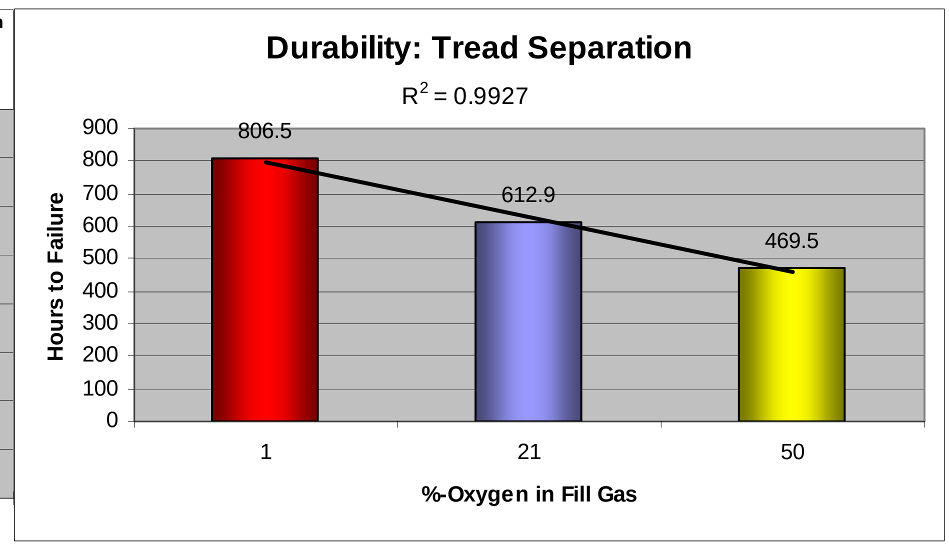
Tokita et. al. (Uniroyal) studied passenger tires with different liners and different oxygen contents by testing on a lab test wheel

(ref: N. Tokita, W. D. Sigworth, G. H. Nybakken, G. B. Ouyang, International Rubber Conference, Kyoto, Oct 15-18, 1985)

- Air-inflated tires failed at 215 and 240 hours, nitrogen-inflated tires did not fail at 600 hours
- 'Liner permeability and its gauge are the most influential for BES'

Studied Tread Separation of P205/60 SR15 tires with different liners



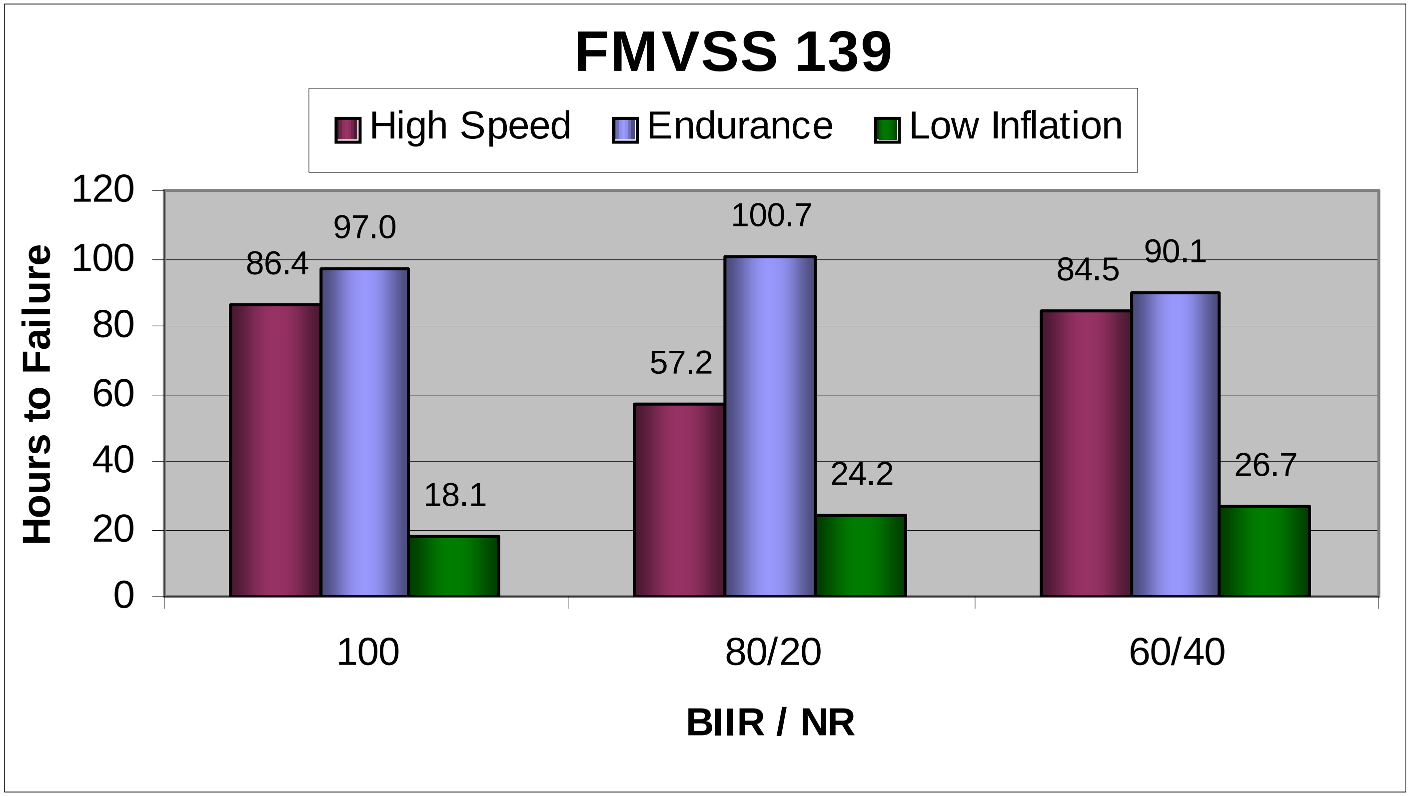


New Tire Results Improved by Reducing Oxygen

ExxonMobil Chemical

New Tire Performance: FMVSS 139

205/60 SR15 tires made with different innerliner compositions tested according to three FMVSS 139 test standards, then until tire failure



90 minutes

34 hours

+90 minutes

<u>All New Tires Pass Tests, and Performance is Comparable</u>

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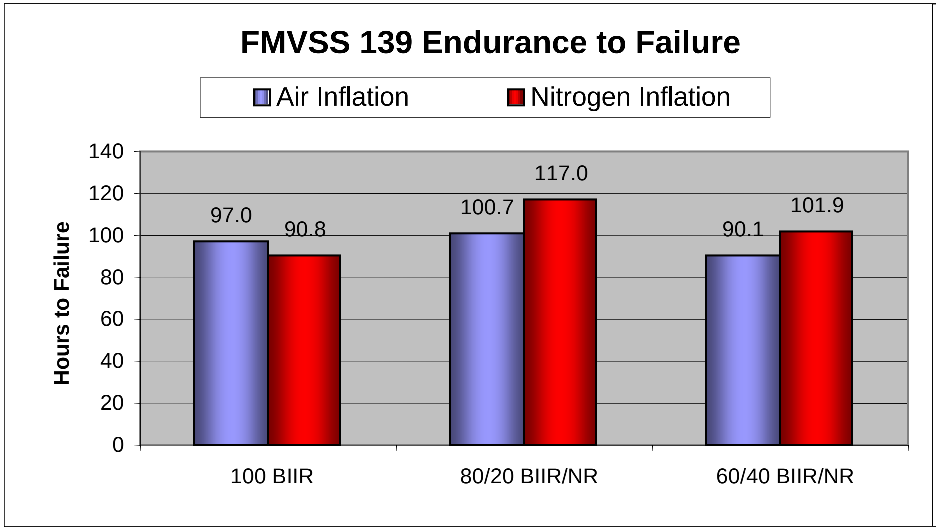
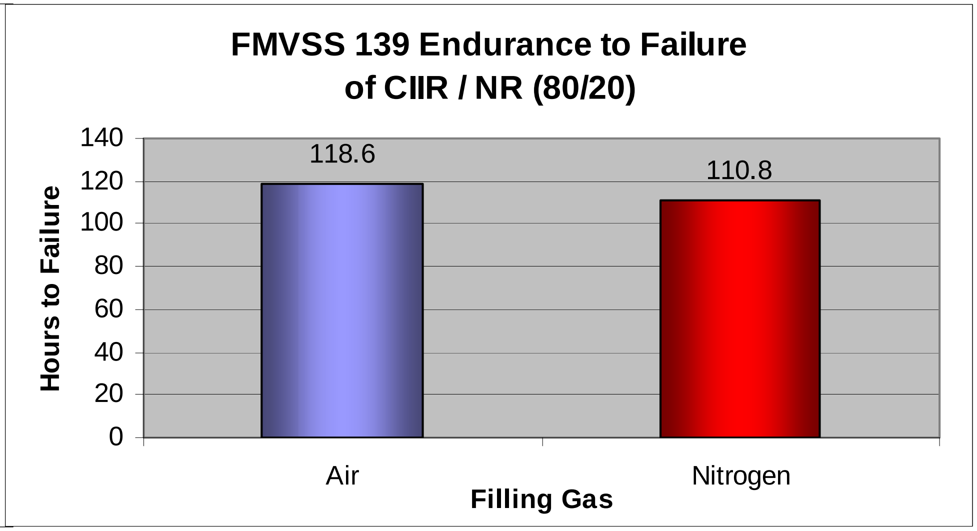
Filling Gas Effects: FMVSS 139 Endurance

FMVSS 139 Endurance test modified by
- **running until tire failure**
- **using dry, 99.9% Nitrogen as the fill gas**





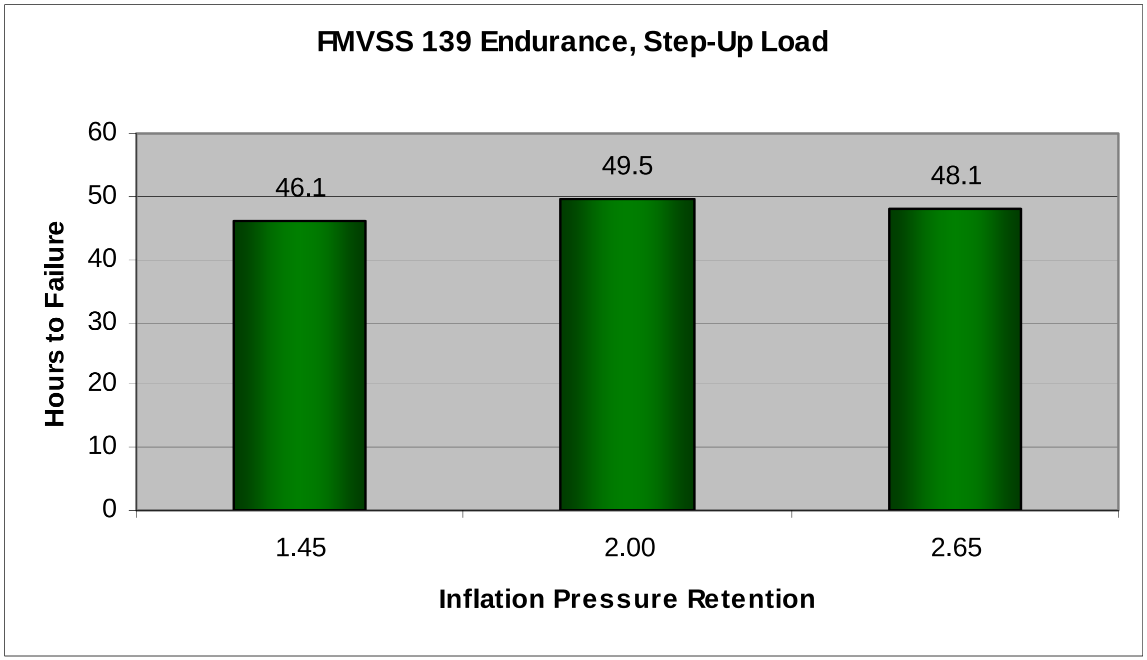
Performance of New Tires Comparable

ExxonMobil Chemical

New Tire Performance: FMVSS 139E / SUL

FMVSS 139 Endurance test modified by following-up with a Stepped-Up Load test until failure

- Temperature: 38ºC
- Speed: 120 km/h (75 mph), Pressure: 180 kPa (26 psi) air
- Load: 4 hr @85% / 6 hr @90% / 24 hr @100% of rating
- Stepped-Up Load: 10% @ 4-hour intervals until tire failure



Performance of New Tires Comparable

Agenda

- Introduction
- **Filling Gas Studies**
  - New Tires
  - Oven-Aged Tires
    - FMVSS 139 Endurance / SUL Testing
    - Shearography
- Summary

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Oven Aging Studies

P205/60 SR15 tires aged in air-circulating oven for 4 weeks @ 70^{o}C

- 100-phr Bromobutyl rubber, and 80/20 and 60/40 BIIR / NR innerliners
- Tires inflated with dry nitrogen (99.9%) or dry air

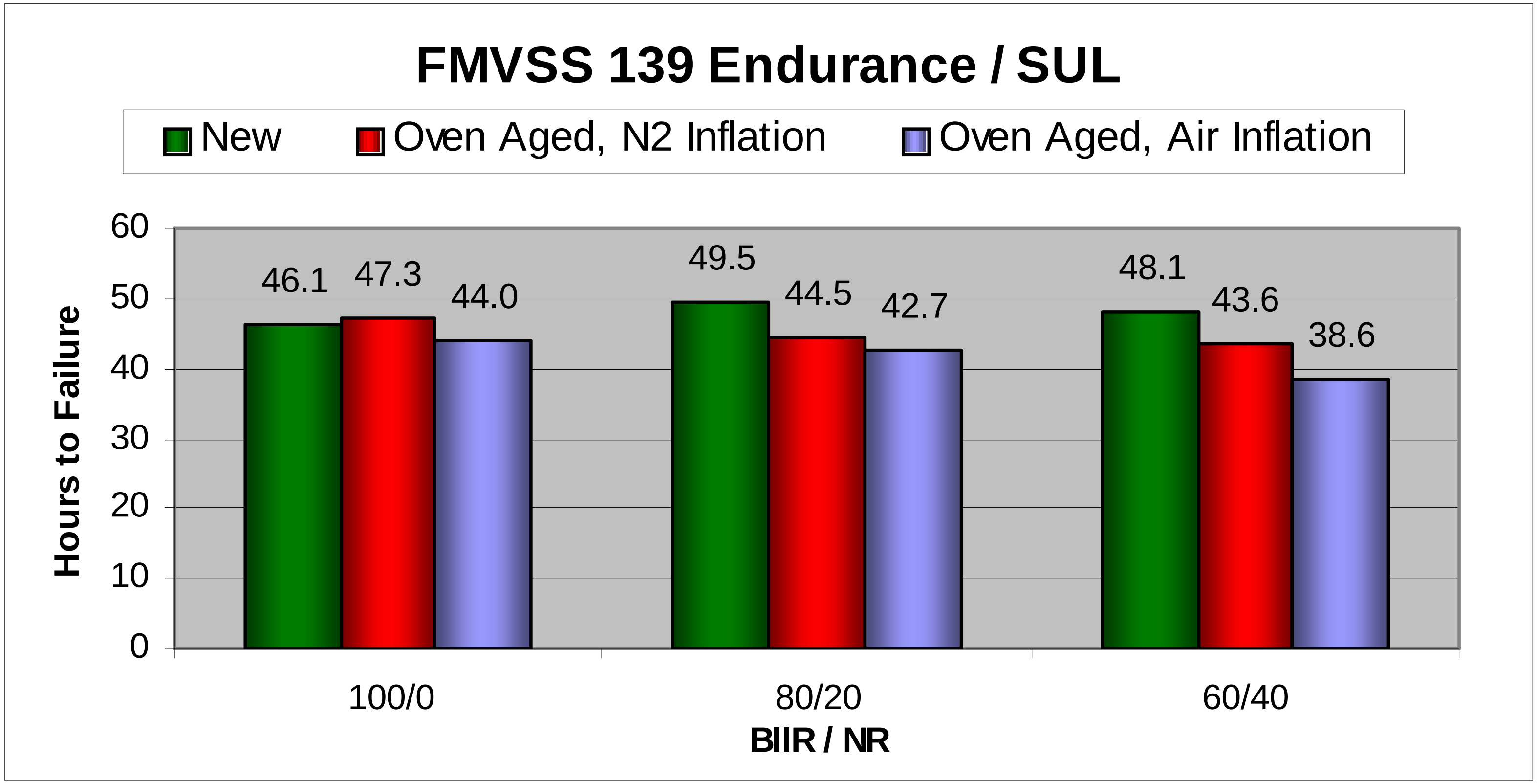
Oven-aged tires were then tested on a 1.7-m laboratory road wheel at the Bangalore Research & Development Technology Center according to the new FMVSS 139 standards

- FMVSS 139 Endurance / Stepped-Up Load to failure completed

New and oven-aged / road wheel tested tires analyzed by Akron Rubber Development Laboratory

- 100% Modulus, Elongation at break, Peel Strength, Crosslink Density
- Shearography

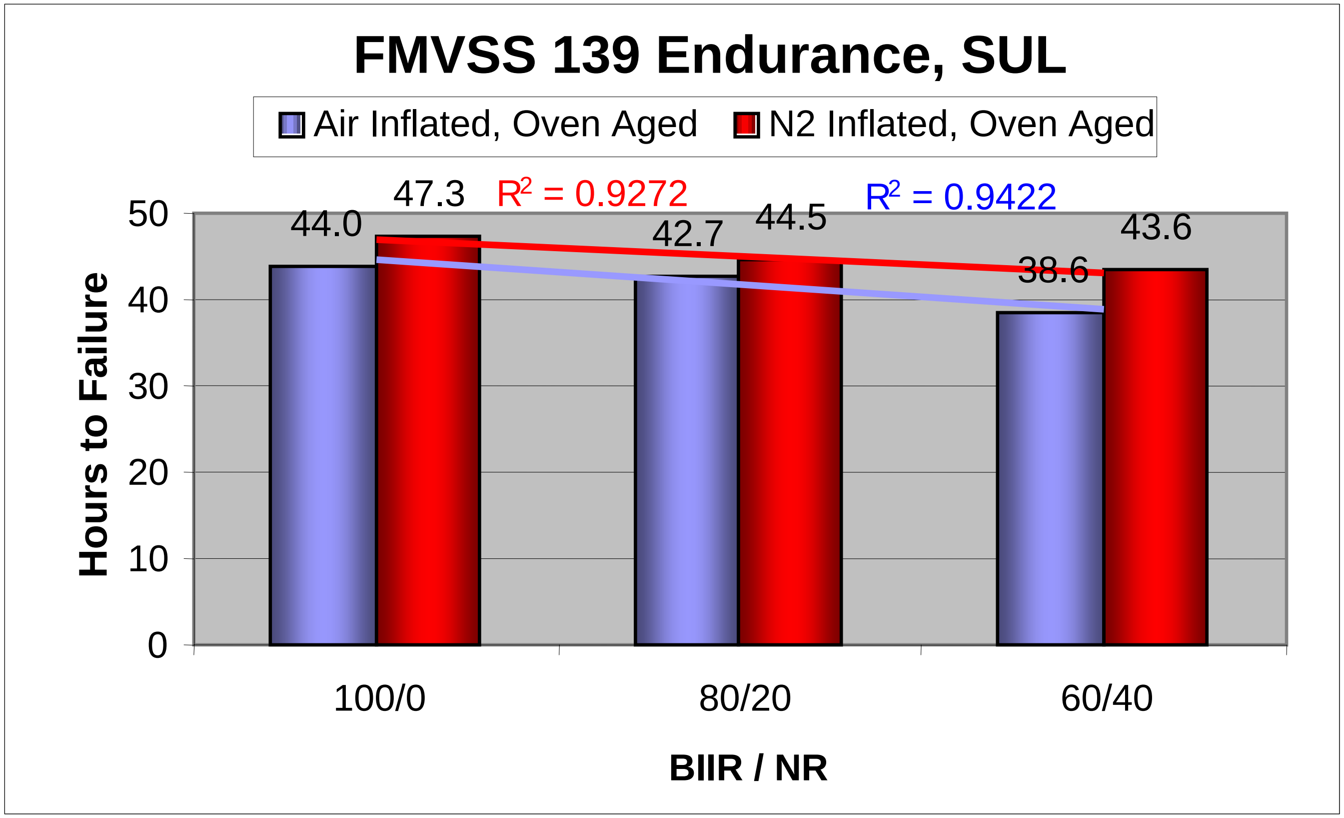
Filling Gas Effects: FMVSS 139 Endurance/ SUL



<u>Endurance of Aged Tires Improved using Nitrogen Inflation</u>

ExxonMobil Chemical

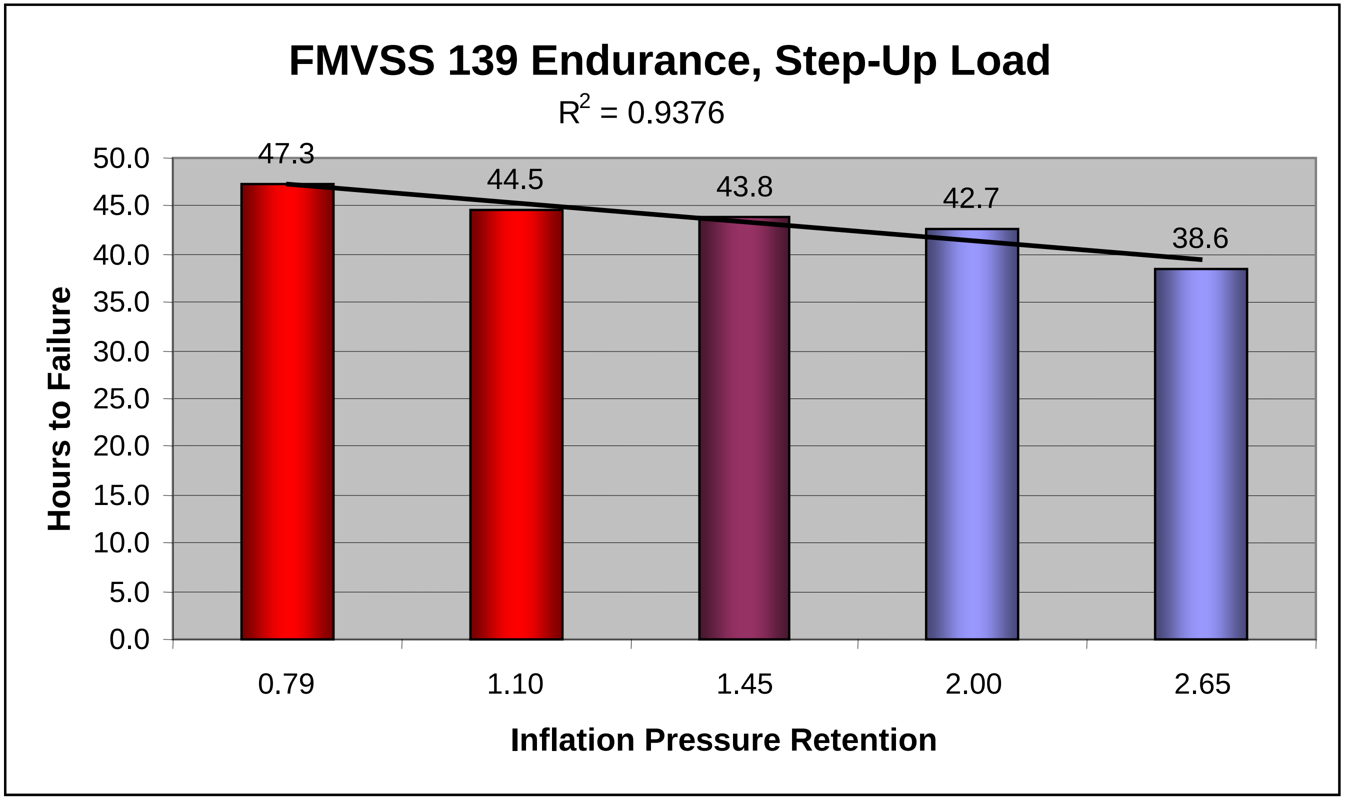
Filling Gas Effects: FMVSS 139 Endurance/ SUL



Roadwheel Results Improved by Reducing Oxygen

Benefits Largest for Highest IPR Innerliner

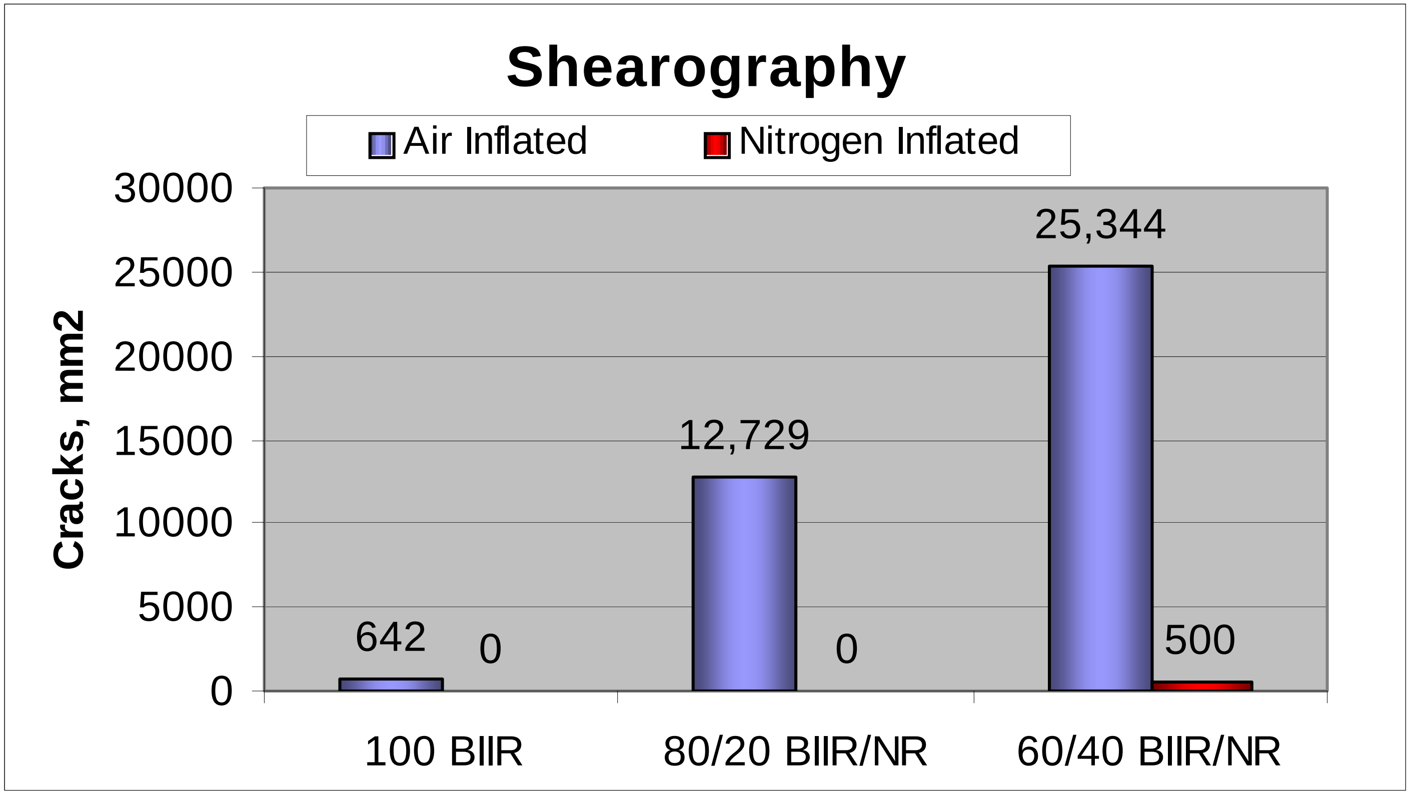
Tire IPR Effects: FMVSS 139 Endurance/ SUL



Red = Nitrogen **Purple = 1 Nitrogen and 1 Air-filled Tire** **Blue = Air**

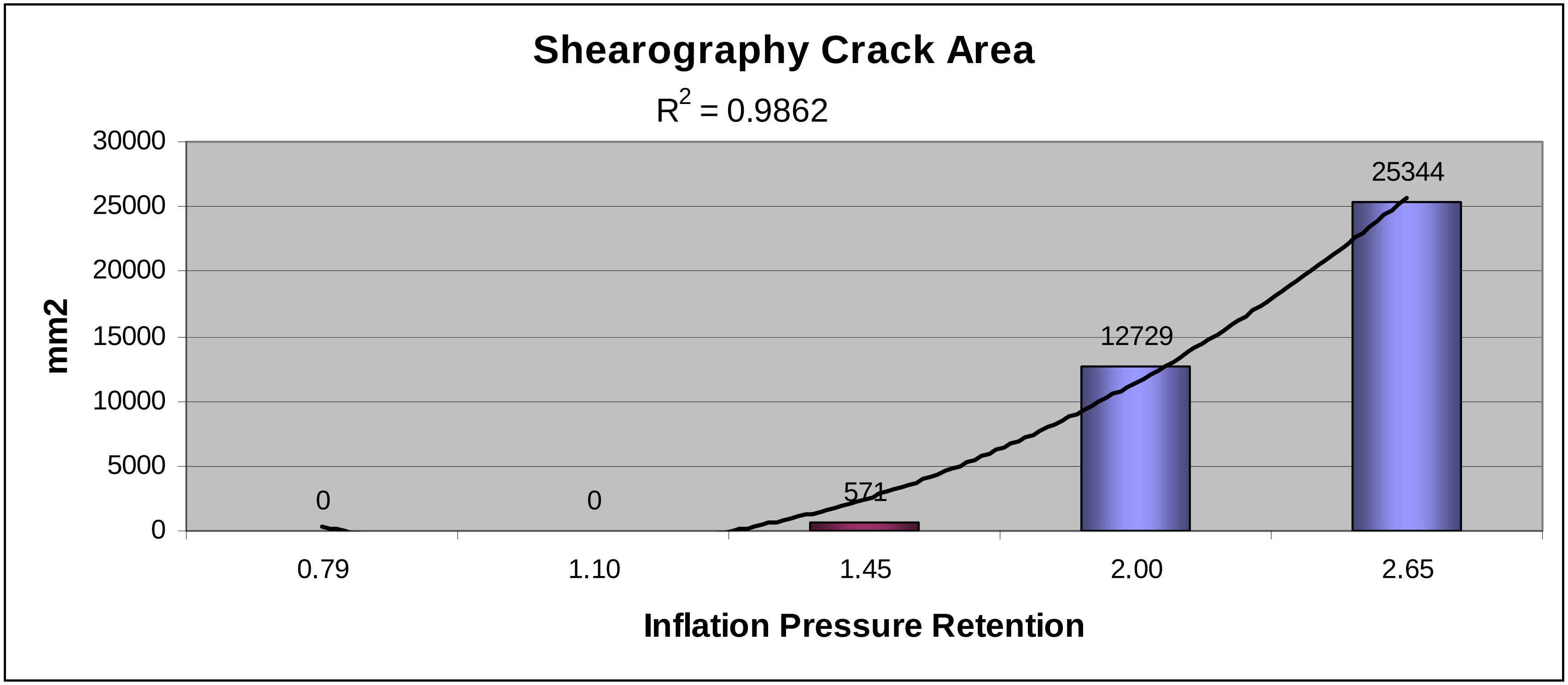
Lab Roadwheel Endurance Quantitatively Correlates to Tire Inflation Pressure Retention

Filling Gas Effects: Shearography



Cracking of Aged Tires Significantly
Reduced by Reducing Oxygen

Tire IPR Effects: Shearography



Shearography Cracking Quantitatively Correlates to
<u>Tire Inflation Pressure Retention</u>

ExxonMobil Chemical

Agenda

- Introduction
- Filling Gas Studies
  - New Tires
  - Oven-Aged Tires
- Summary

Summary

- Nitrogen gas permeates slower than Oxygen through rubber
  - Tire IPR is reduced 45% using dry, 99.9%-nitrogen inflation
- Laboratory roadwheel durability of new tires increased quantitatively with decreasing %-Oxygen in the filling gas
- FMVSS 139 Endurance testing of new tires is insensitive to %-Oxygen in the filling gas
- FMVSS 139 Endurance/Stepped-Up Load testing of new tires is insensitive to Tire IPR
- FMVSS 139 Endurance/SUL testing of oven-aged tires can be quantitatively correlated to Tire Inflation Pressure Retention
- Shearography cracking of oven-aged tires reduced using Nitrogen as fill gas
- Shearography cracking of oven-aged tires can be quantitatively correlated to Tire Inflation Pressure Retention

Summary

- All passenger tires that were tested in our laboratory under carefully controlled conditions were aged either in an oven and/or on a roadwheel.
- We have quantitatively shown that use of materials that afford the lowest IPR loss values per month retard this aging process.
- Use of dry, 99.9% Nitrogen to inflate tires can also be beneficial under these idealized laboratory conditions.
- Use of materials that afford the lowest IPR loss values per month with dry, 99.9% Nitrogen inflation further retard this laboratory aging process.
- Results that could potentially be obtained by the average consumer have not been studied.

Nitrogen Inflation of Tires

Disclaimer

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

Konrad Mech, P.Eng., MBA
Vice President, Drexan Corporation
Burnaby, BC
1-(800)-663-6873

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 Snapshot[1]. 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.

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[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 is[2]:

- 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 SensorTracs[3] 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$aver[4] 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

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[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.

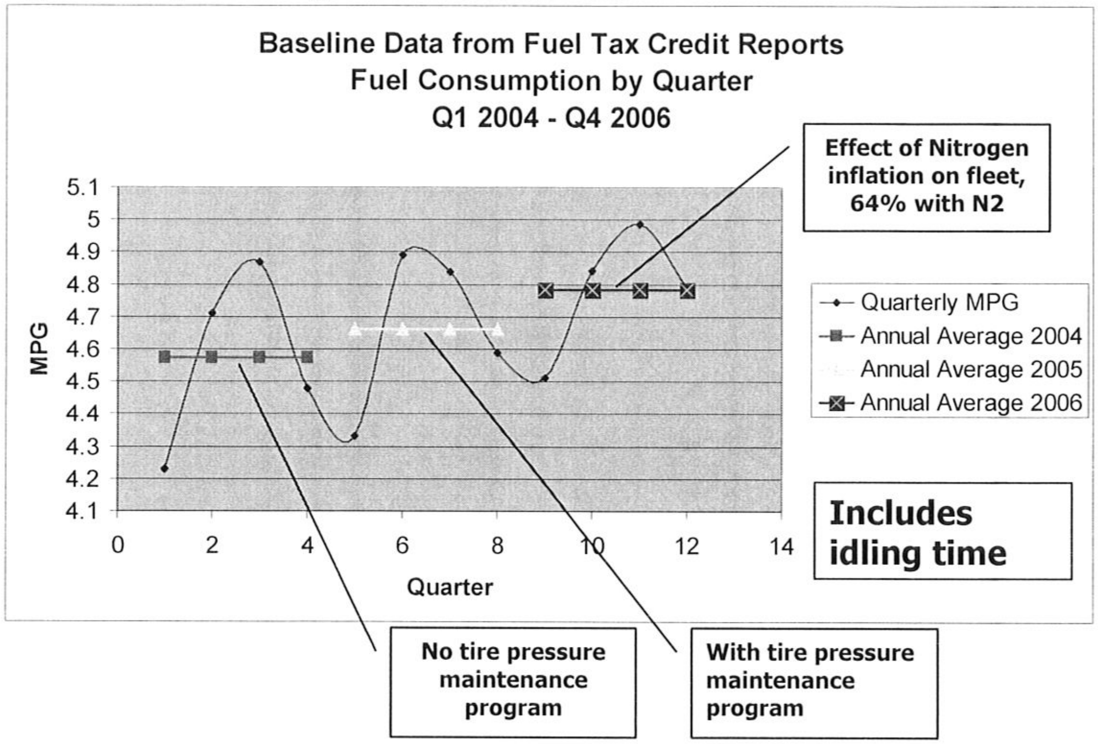
Because the routes were consistent, we eliminated route variances as a factor.

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