ExxonMobil PROPRIETARY

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

ExxonMobil Chemical

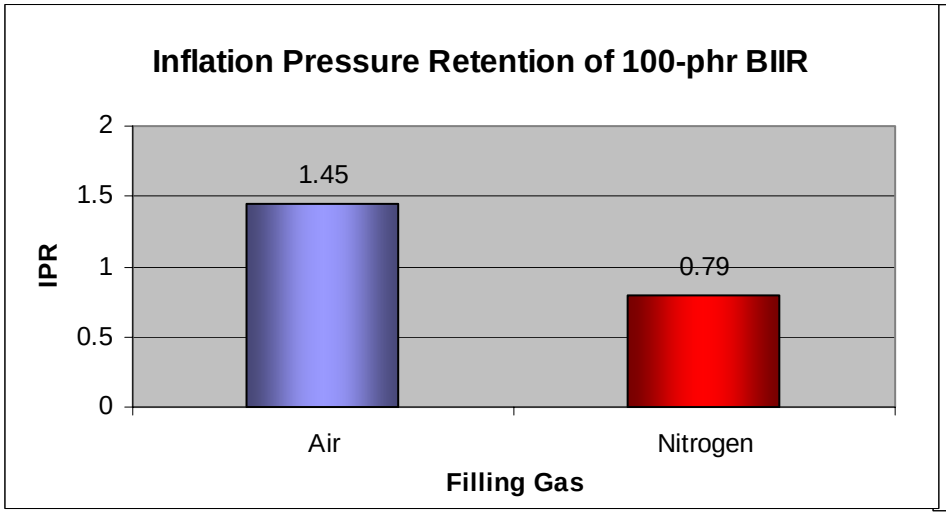
Filling Gas Effects: Tire IPR

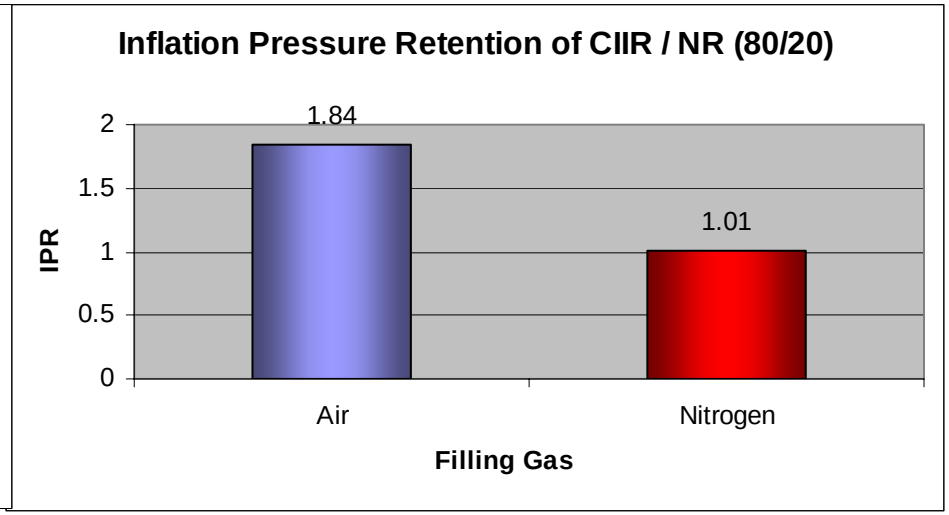
Walenga (Bridgestone/Firestone) reported on 11R22.5 truck tires

(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 SR15 tires with different innerliners





IPR Loss Rates Reduced 45% using Nitrogen Inflation

ExxonMobil Chemical

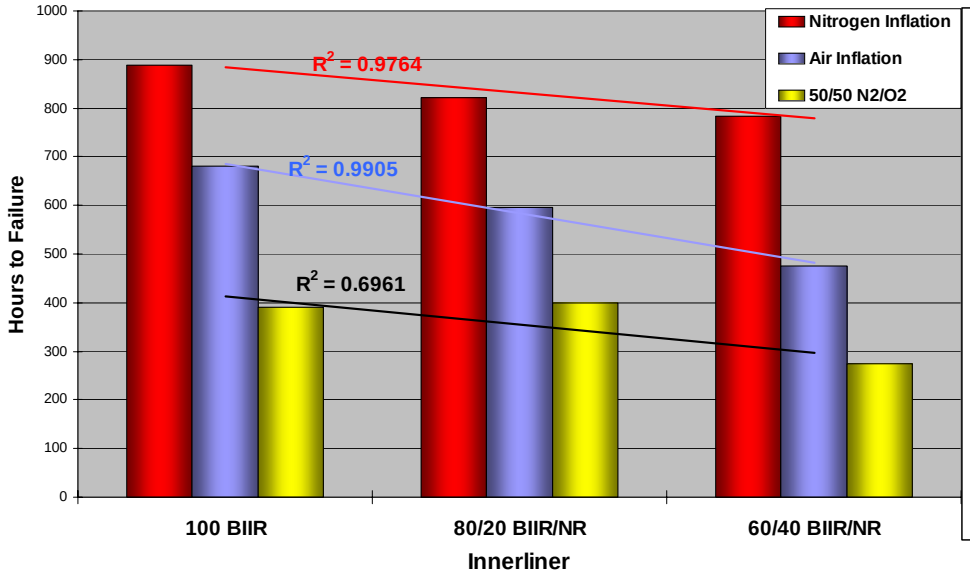
Filling Gas Effects: Roadwheel Durability

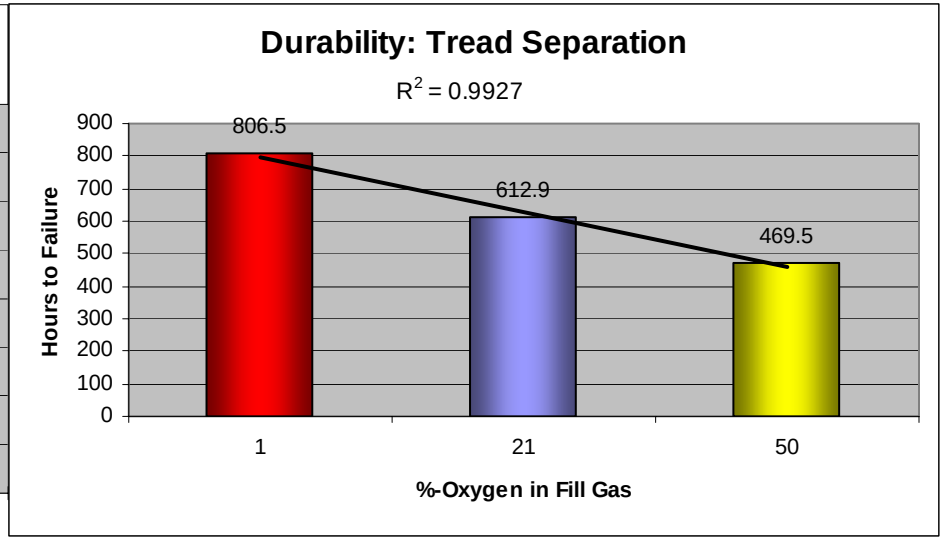
Tokita et. al. (Uniroyal) studied passenger tires with different liners and different oxygen contents by testing on a lab test wheel

(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



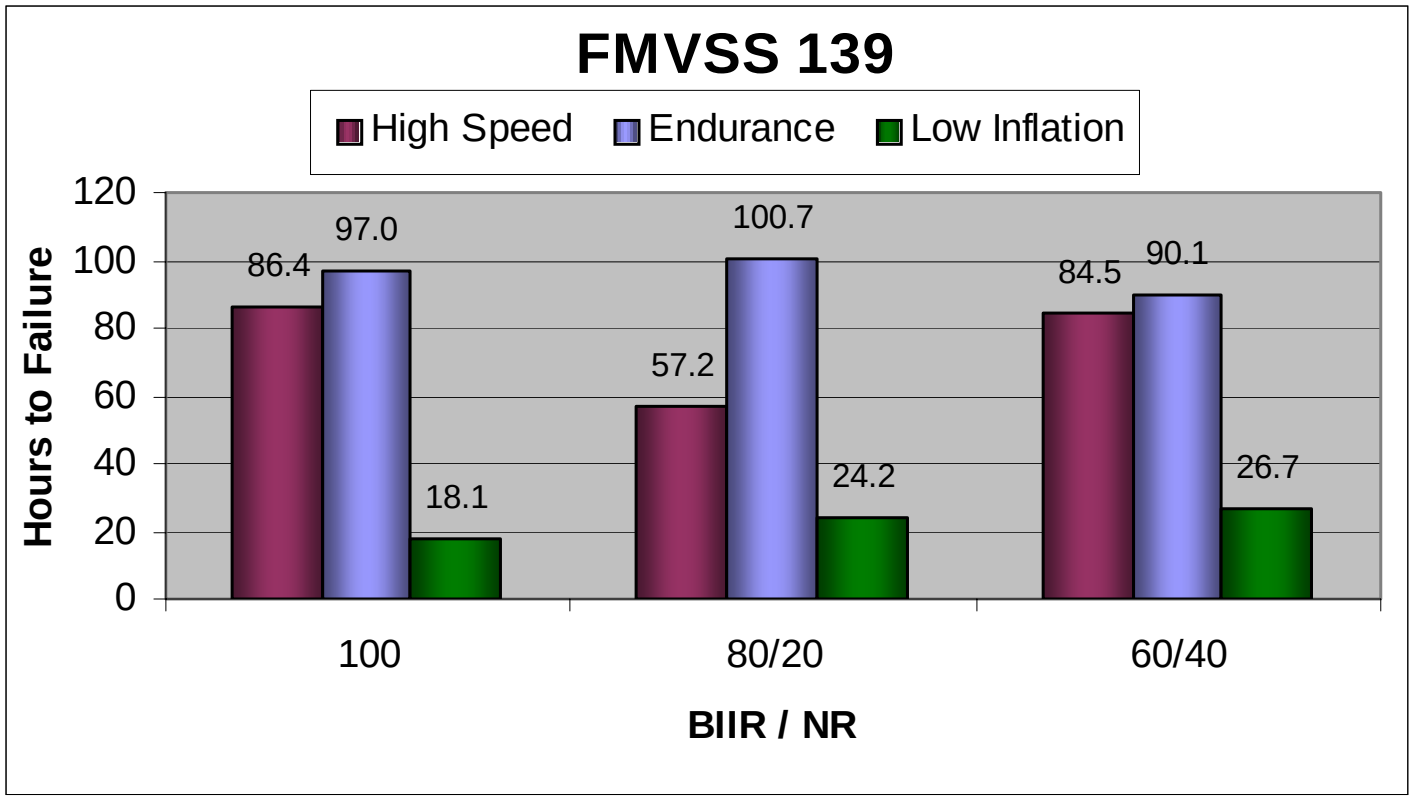


New Tire Results Improved by Reducing Oxygen

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

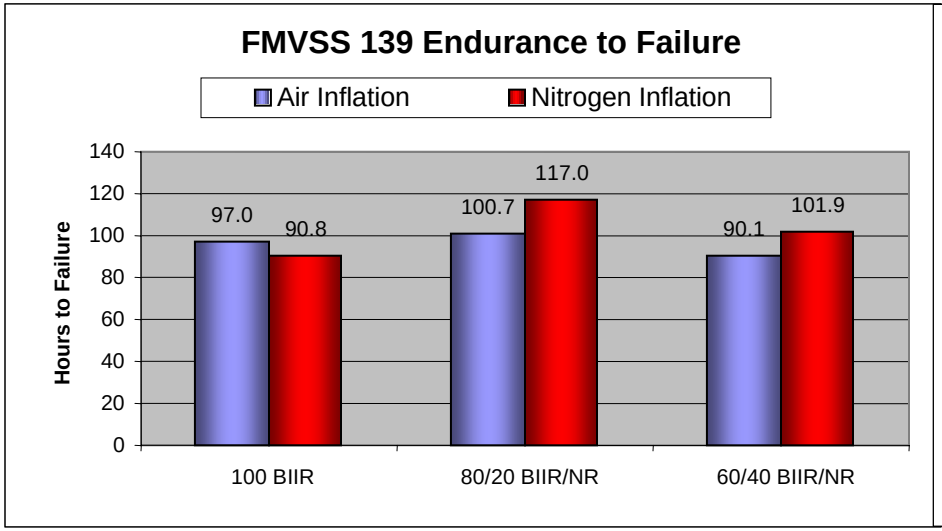
All New Tires Pass Tests, and Performance is Comparable

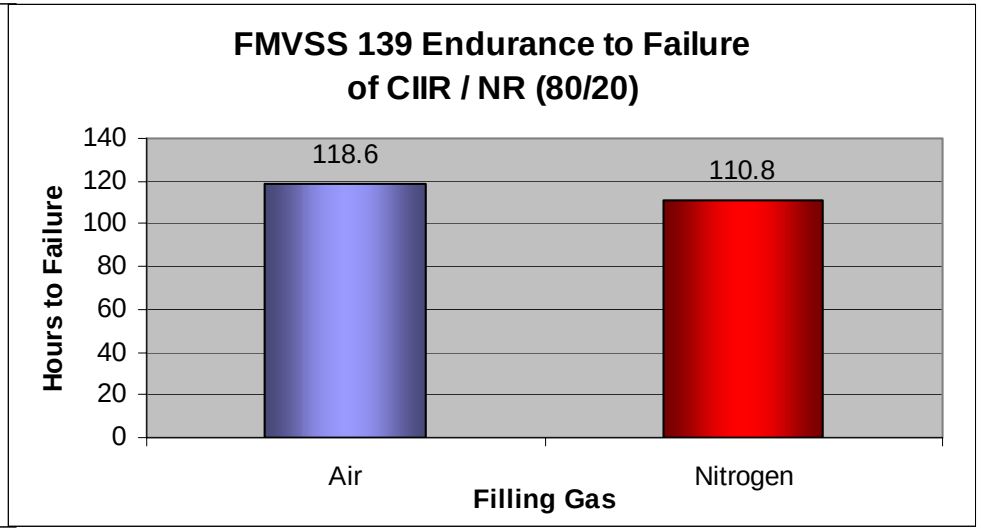
ExxonMobil Chemical

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**



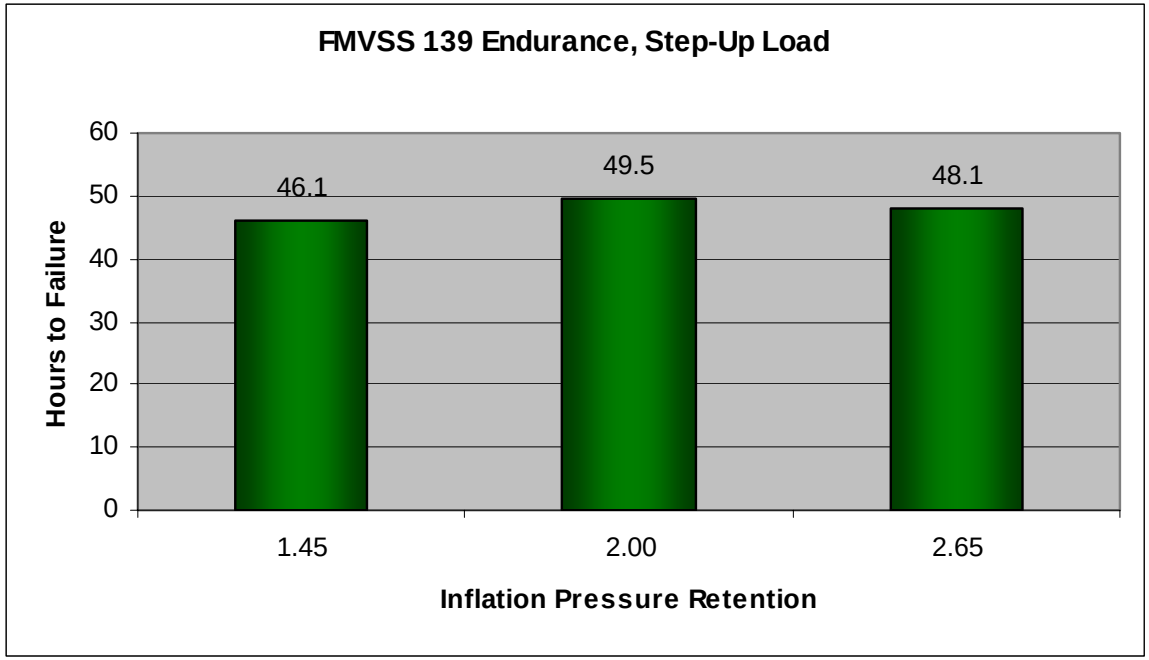


Performance of New Tires Comparable

New Tire Performance: FMVSS 139E / SUL

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

- Temperature: 38°C
- 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

ExxonMobil Chemical

Agenda

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

ExxonMobil Chemical

Oven Aging Studies

P205/60 SR15 tires aged in air-circulating oven for 4 weeks @ 70°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

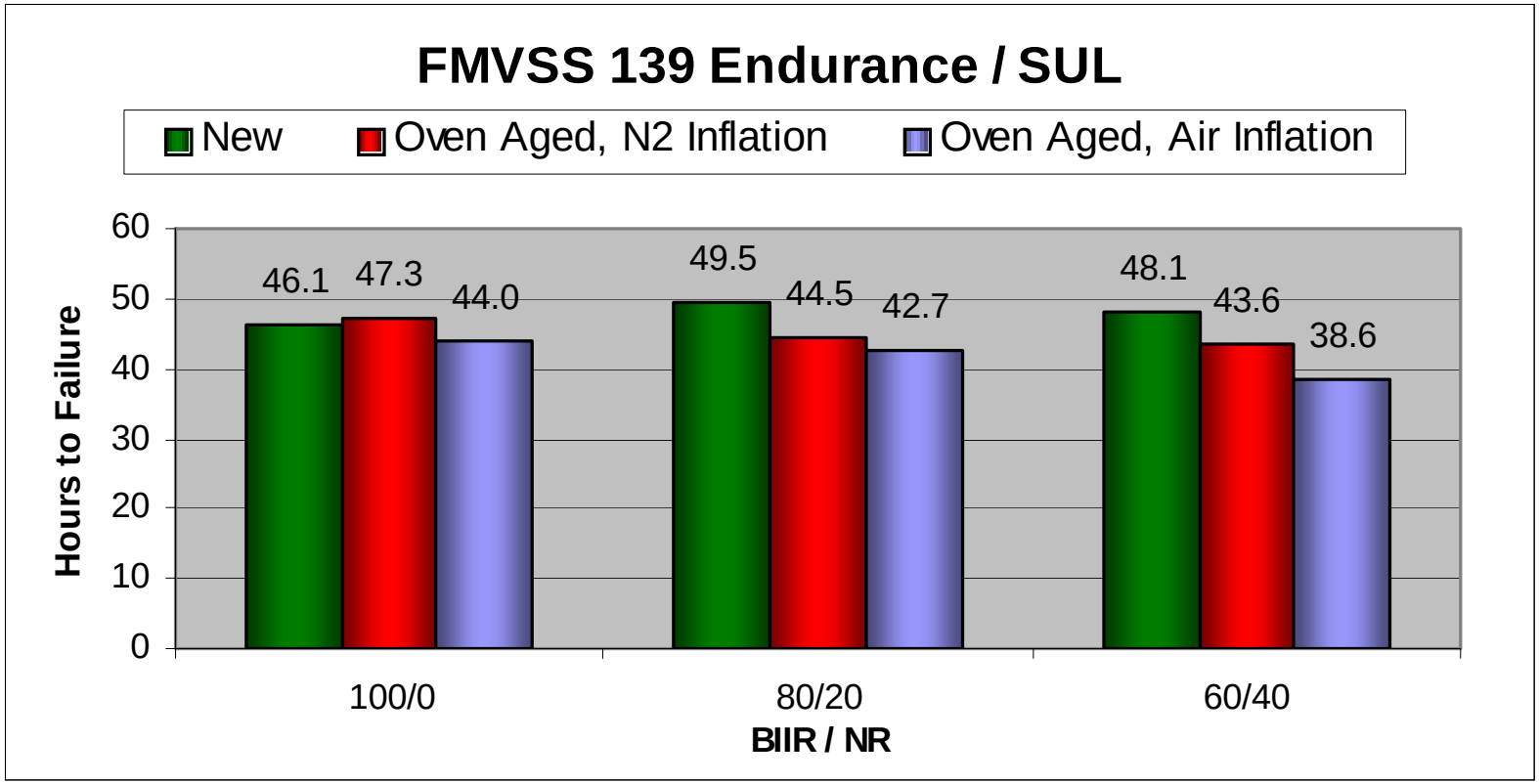
- FMVSS 139 Endurance / Stepped-Up Load to failure completed

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

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

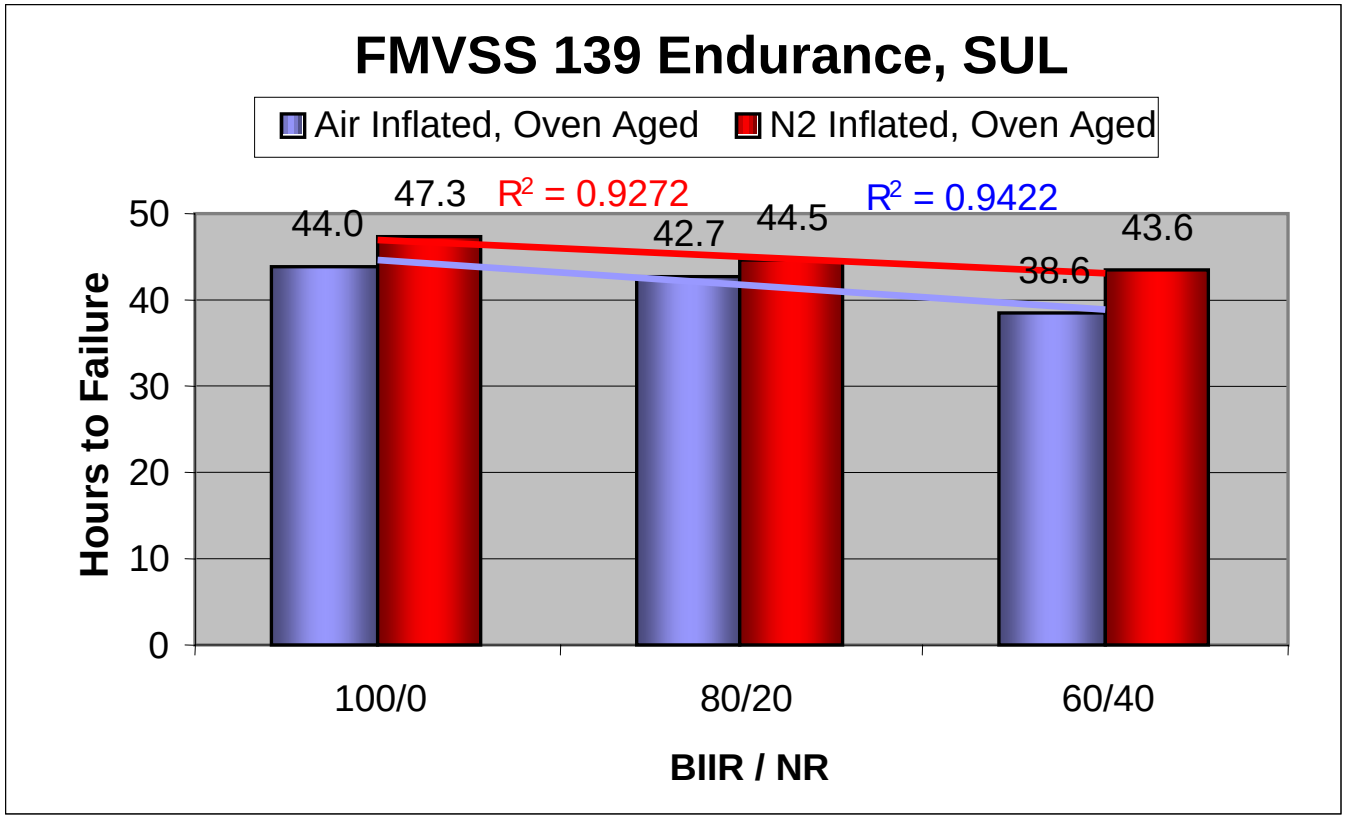
ExxonMobil Chemical

Filling Gas Effects: FMVSS 139 Endurance/ SUL



Endurance of Aged Tires Improved using Nitrogen Inflation

Filling Gas Effects: FMVSS 139 Endurance/ SUL

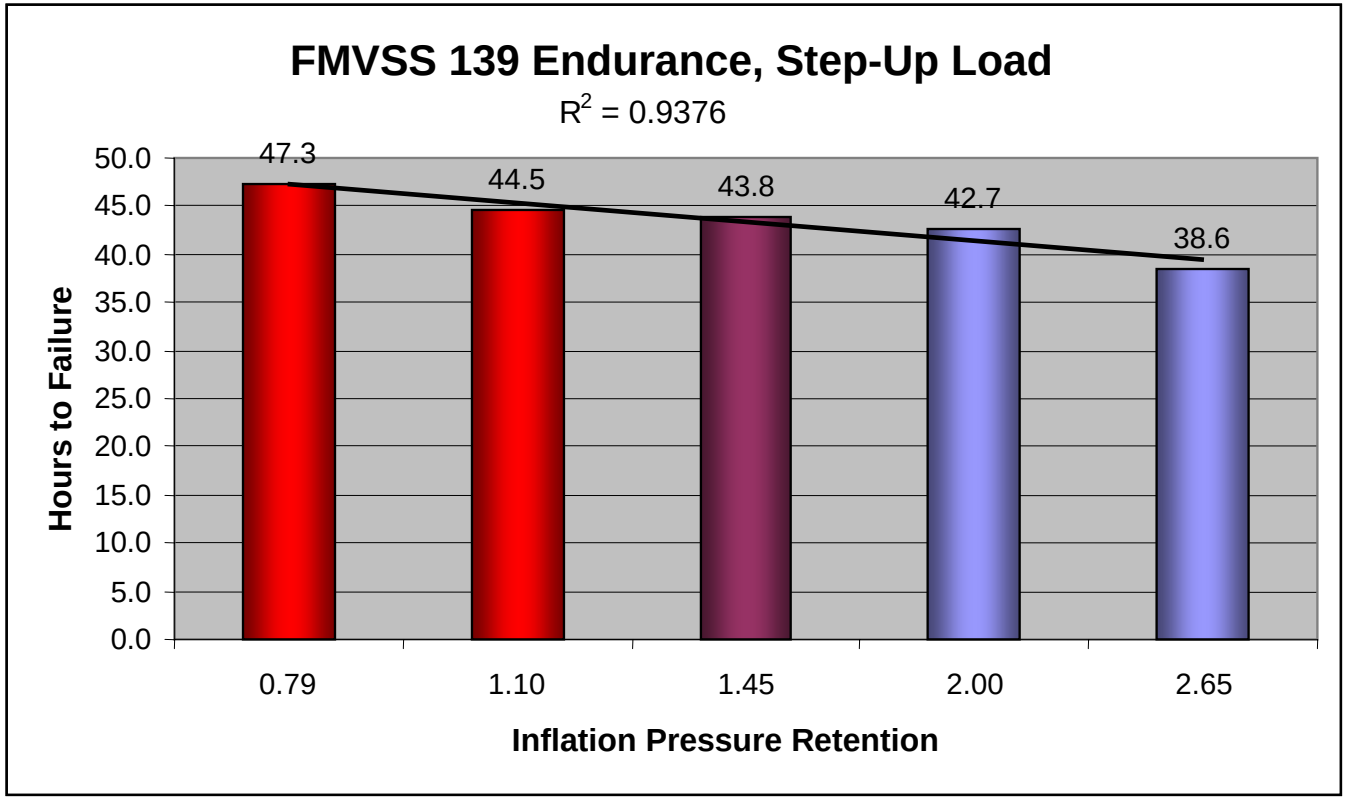


Roadwheel Results Improved by Reducing Oxygen

Benefits Largest for Highest IPR Innerliner

ExxonMobil Chemical

Tire IPR Effects: FMVSS 139 Endurance/ SUL

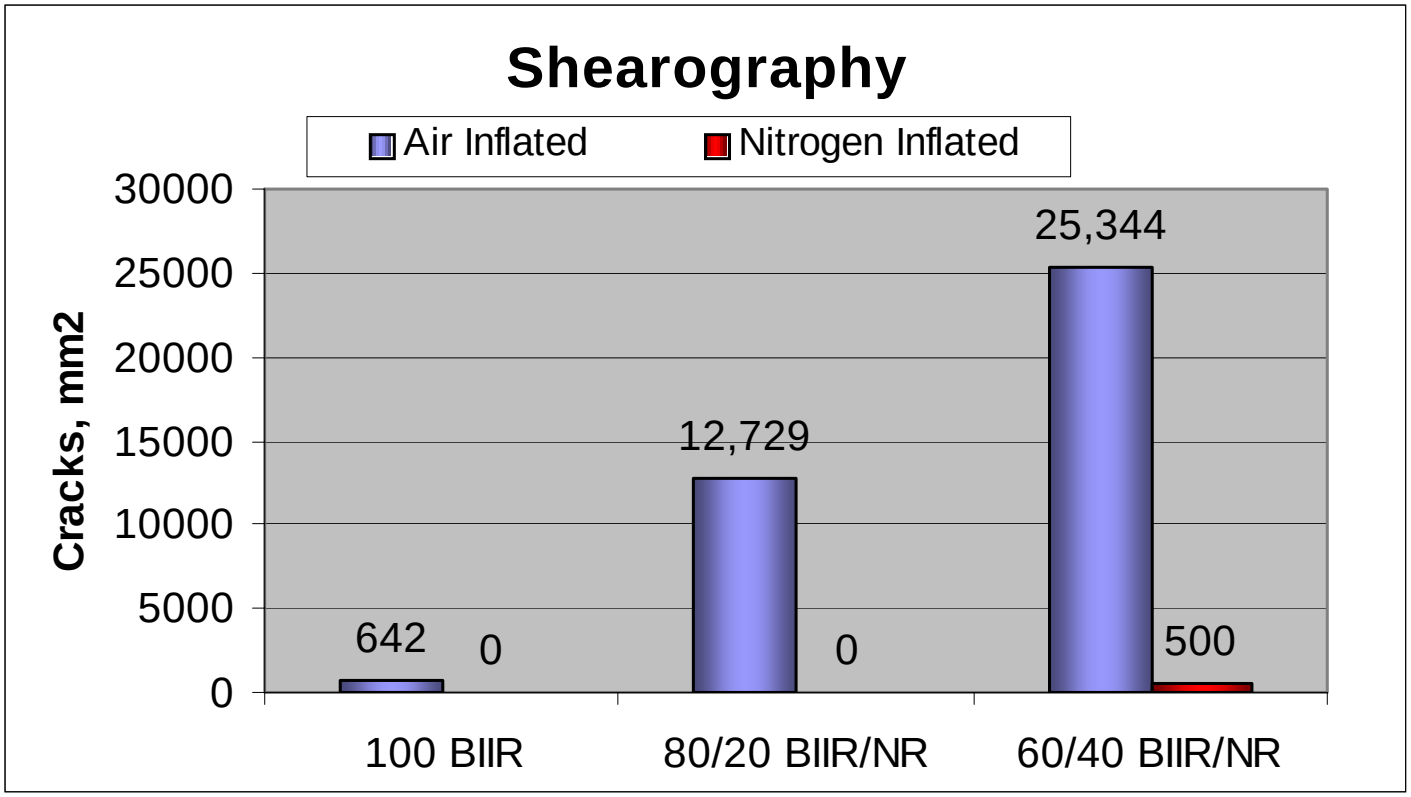


Red = Nitrogen Purple = 1 Nitrogen and 1 Air-filled Tire Blue = Air

Lab Roadwheel Endurance Quantitatively Correlates to Tire Inflation Pressure Retention

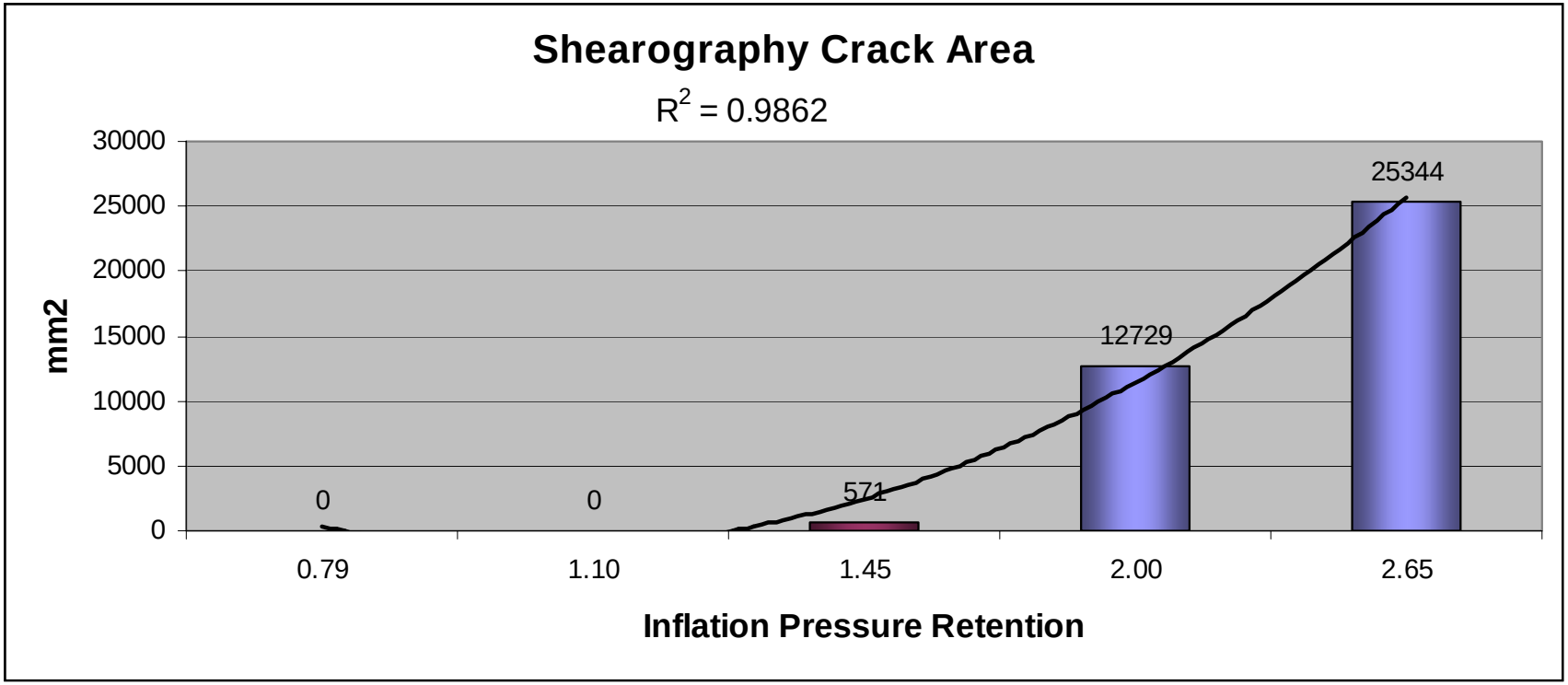
ExxonMobil Chemical

Filling Gas Effects: Shearography



Cracking of Aged Tires Significantly Reduced by Reducing Oxygen

Tire IPR Effects: Shearography



Shearography Cracking Quantitatively Correlates to Tire Inflation Pressure Retention

Agenda

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

ExxonMobil Chemical

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**

ExxonMobil Chemical

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.**

ExxonMobil Chemical

Nitrogen Inflation of Tires

Disclaimer

©2006 ExxonMobil Corporation. To the extent the user is entitled to disclose and distribute this document, the user may forward, distribute, and/or photocopy this copyrighted document only if unaltered and complete, including all of its headers, footers, disclaimers, and other information. You may not copy this document to a Web site. The information in this document relates only to the named product or materials when not in combination with any other product or materials. We based the information on data believed to be reliable on the date compiled, but we do not represent, warrant, or otherwise guarantee, expressly or impliedly, the merchantability, fitness for a particular purpose, suitability, accuracy, reliability, or completeness of this information or the products, materials, or processes described. The user is solely responsible for all determinations regarding any use of material or product and any process in its territories of interest. We expressly disclaim liability for any loss, damage, or injury directly or indirectly suffered or incurred as a result of or related to anyone using or relying on any of the information in this document. There is no endorsement of any product or process, and we expressly disclaim any contrary implication. The terms, “we”, “our”, "ExxonMobil Chemical", or "ExxonMobil" are used for convenience, and may include any one or more of ExxonMobil Chemical Company, Exxon Mobil Corporation, or any affiliates they directly or indirectly steward.

ExxonMobil Chemical