

SUMMARY: INFLATION PRESSURE RETENTION EFFECTS ON TIRE ROLLING RESISTANCE, VEHICLE FUEL ECONOMY AND CO₂ EMISSIONS

presented to

California Air Resources Board
Sacramento, CA

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Global Specialty Polymers Technology

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Objectives

Establish that low Tire Inflation Pressure Retention loss rates significantly contribute to maintaining tire rolling resistance, increasing vehicle fuel economy

Approach

- Measure tire rolling resistance as a function of inflation pressure
- Calculate rolling resistance increases based upon Tire IPR loss rates
- Estimate potential fuel savings by using tires with low IPR loss rates
- Estimate annual potential fuel savings and CO₂ emission reductions for the State of California

Analysis Based Upon 25% Loss in Tire Pressure When TPMS Activates

Agenda

- **Tire Rolling Resistance Measurements**
 - Testing Methods
 - Tire Footprint
 - Cavity Air Temperature
 - Rolling Resistance Coefficient
- **Tire IPR Loss Rates**
- **Tire Reinflation**
- **Tire IPR, Fuel Economy and CO₂ Emissions**
- **Summary**

Tire Rolling Resistance Characterization

- **Rolling resistance measured at Smithers Scientific Services on 1.708-m indoor roadwheel at 24°C by three test procedures**
 - Six inflation pressures requested: 32, 31, 30, 28, 26, 24 psi
- **Single Point Inflation**
 - Measured at 50 mph, 70% load and one inflation pressure
 - Tire Footprints obtained and areas determined
- **SAE J1269**
 - Current recommended practice used to evaluate tires by tire industry
 - Measured at constant 50 mph speed at 50% and 90% of maximum load and two inflation pressures
- **SAE J2452**
 - Current recommended practice used to evaluate tires and effect on vehicle fuel economy
 - Many vehicle manufacturers use this technique to generate CAFE predictions
 - Measured at speed of 71 mph coasting down to 9 mph at two loads and two inflation pressures
 - Rolling resistance values calculated from regression curve

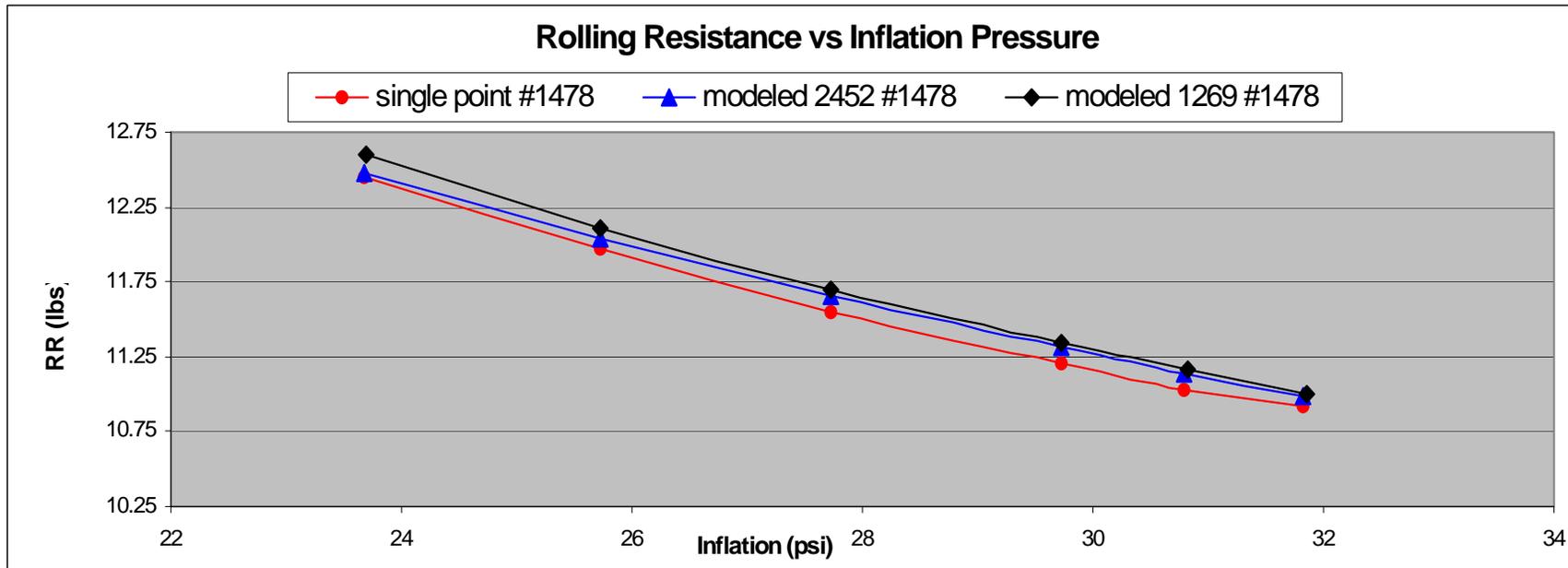
Measurements Made Until 25% Loss in Tire Pressure
When TPMS Activates to Alert Driver

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Tire Rolling Resistance Characterization

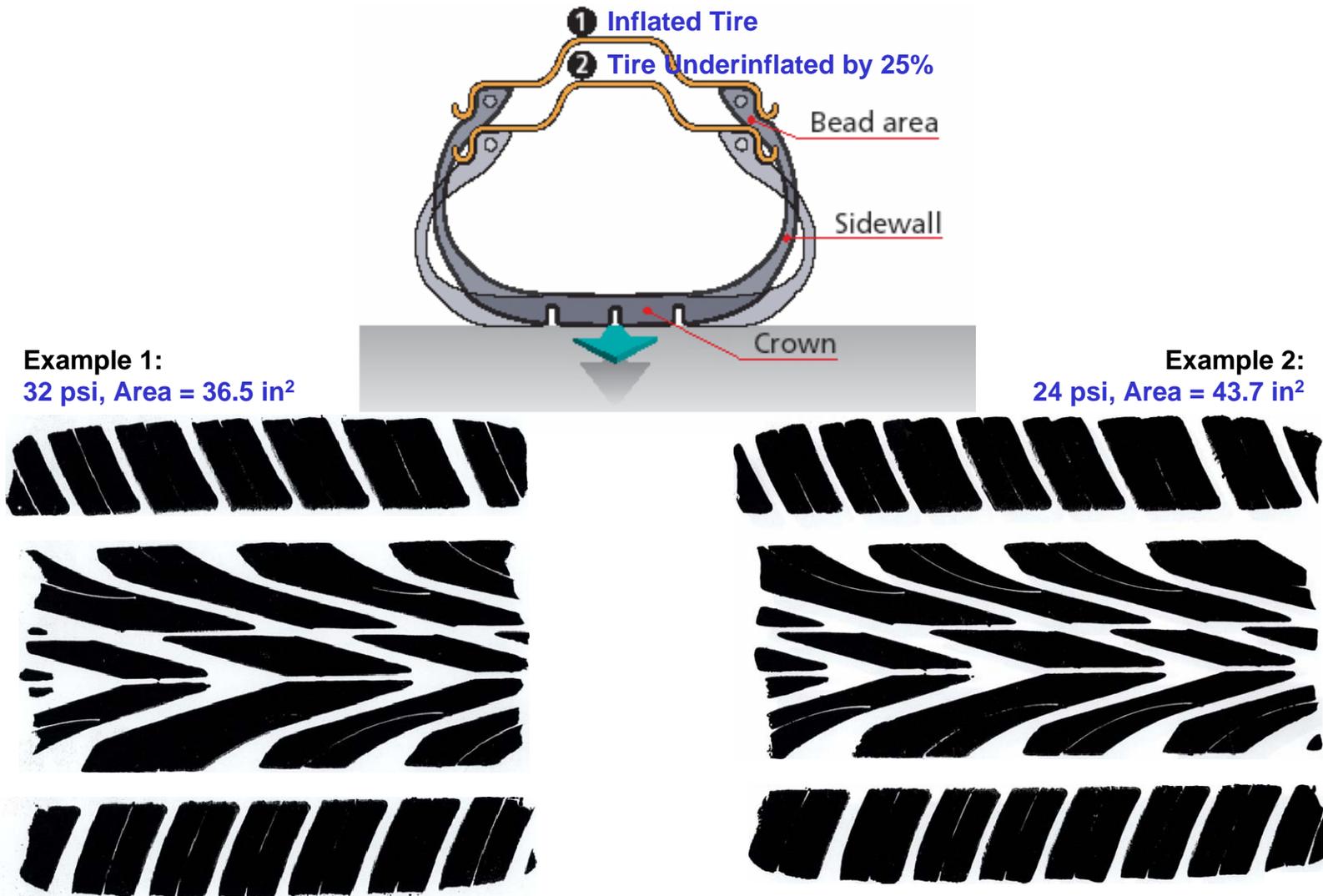
- **Three tests run: Single-point inflation, SAE J1269 and SAE J2452**
 - Tests on experimental tires: P205/60 SR15, 1-mm, 100-phr BIIR

Test Methods Comparison



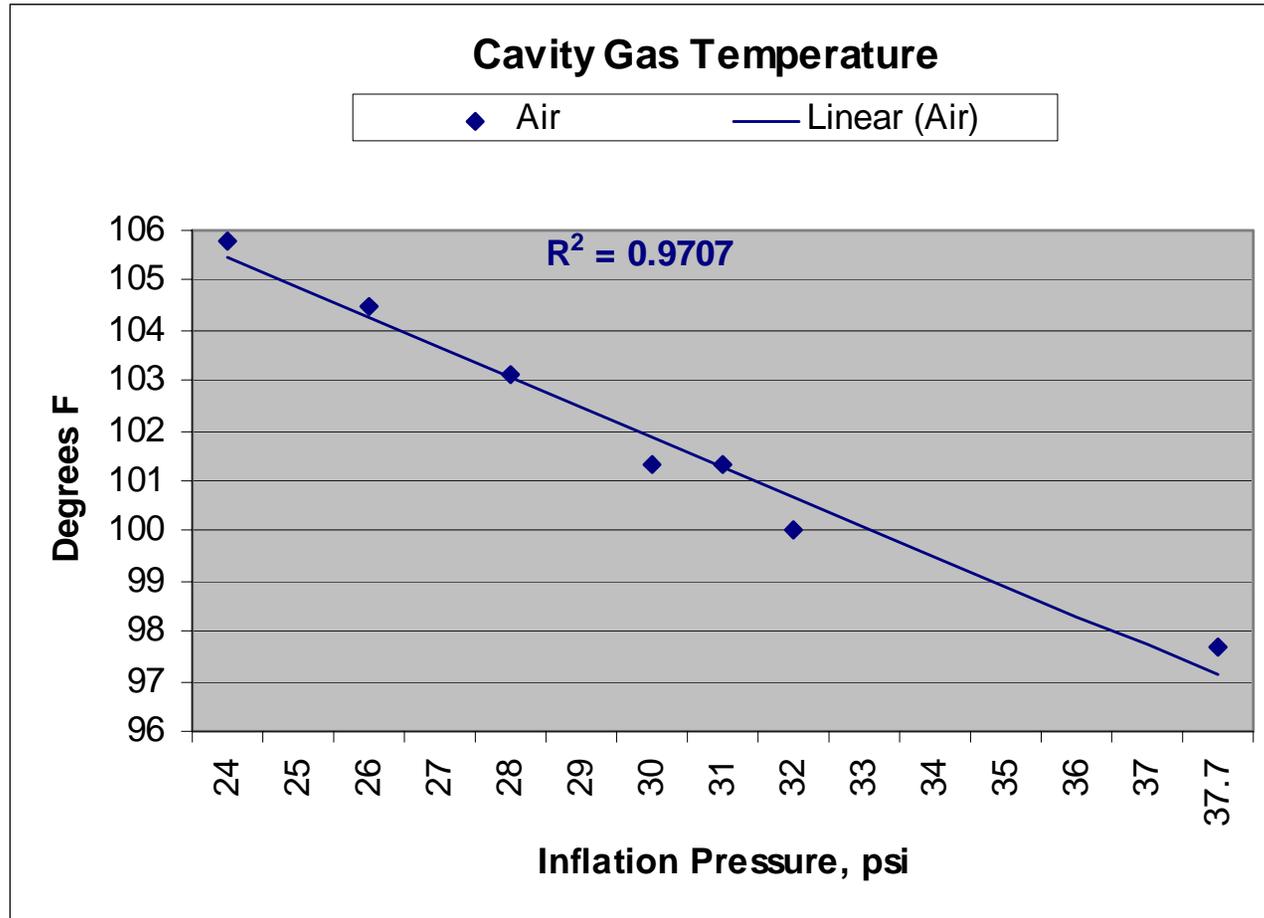
- **Rolling resistance (RR) measured experimentally**
 - Excellent reproducibility between three methods: Mean = 10.754, SD = 0.045

Tire Inflation Pressure Effects



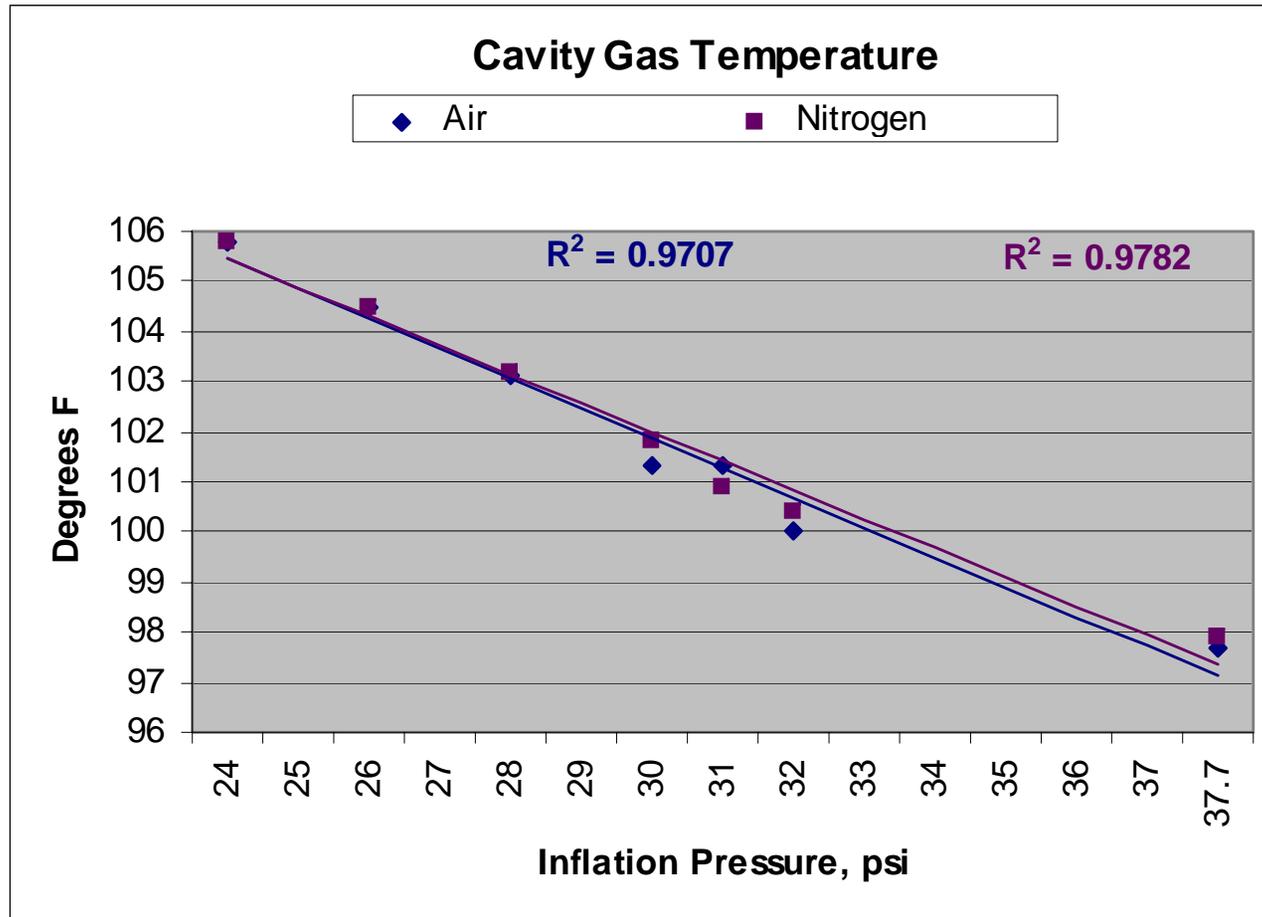
25% Pressure Loss Increases Footprint by 20% ExxonMobil Chemical

Filling Gas Effects: Cavity Air Temperature



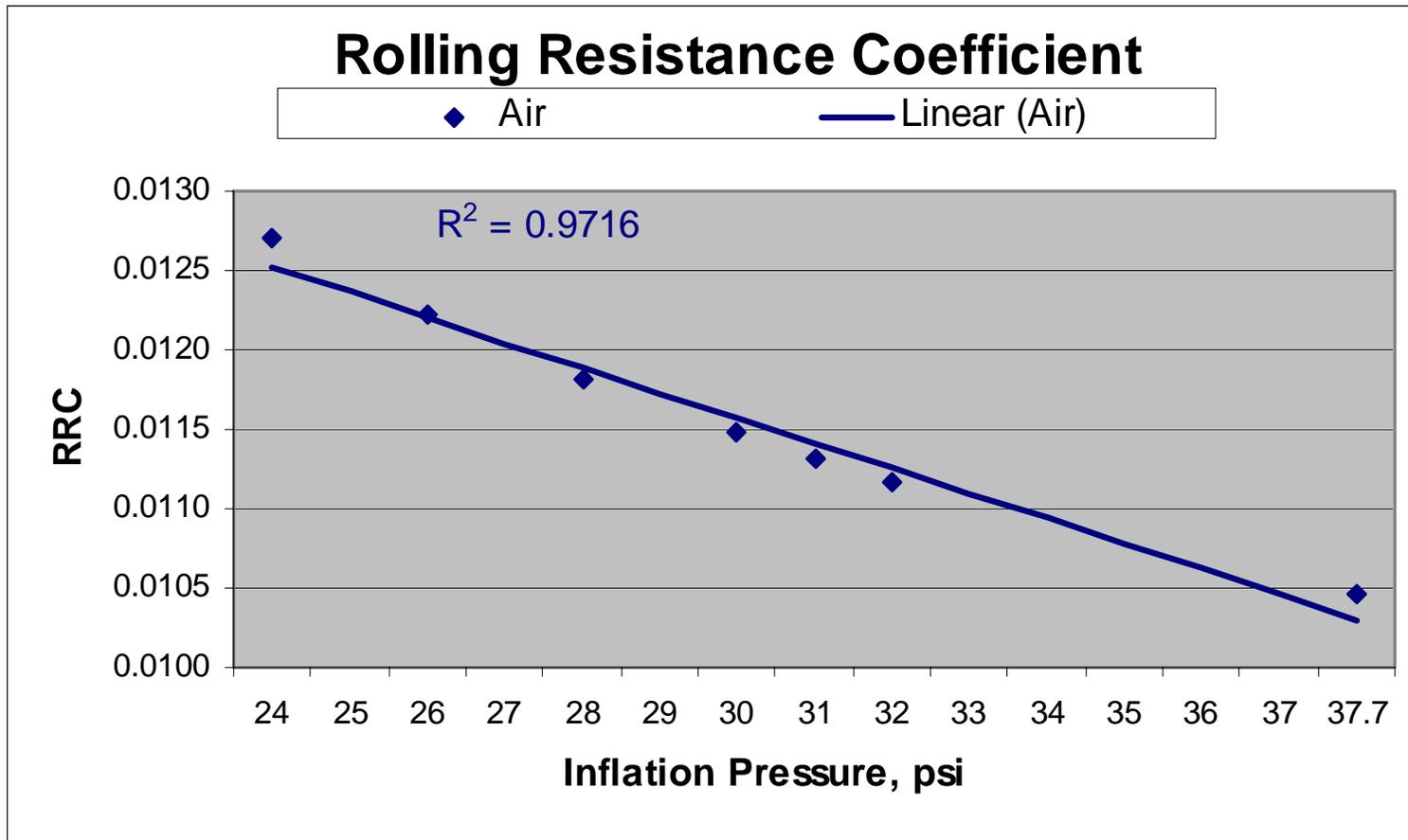
Cavity Air Temperature Dependent Upon Inflation Pressure

Filling Gas Effects: Cavity Gas Temperature



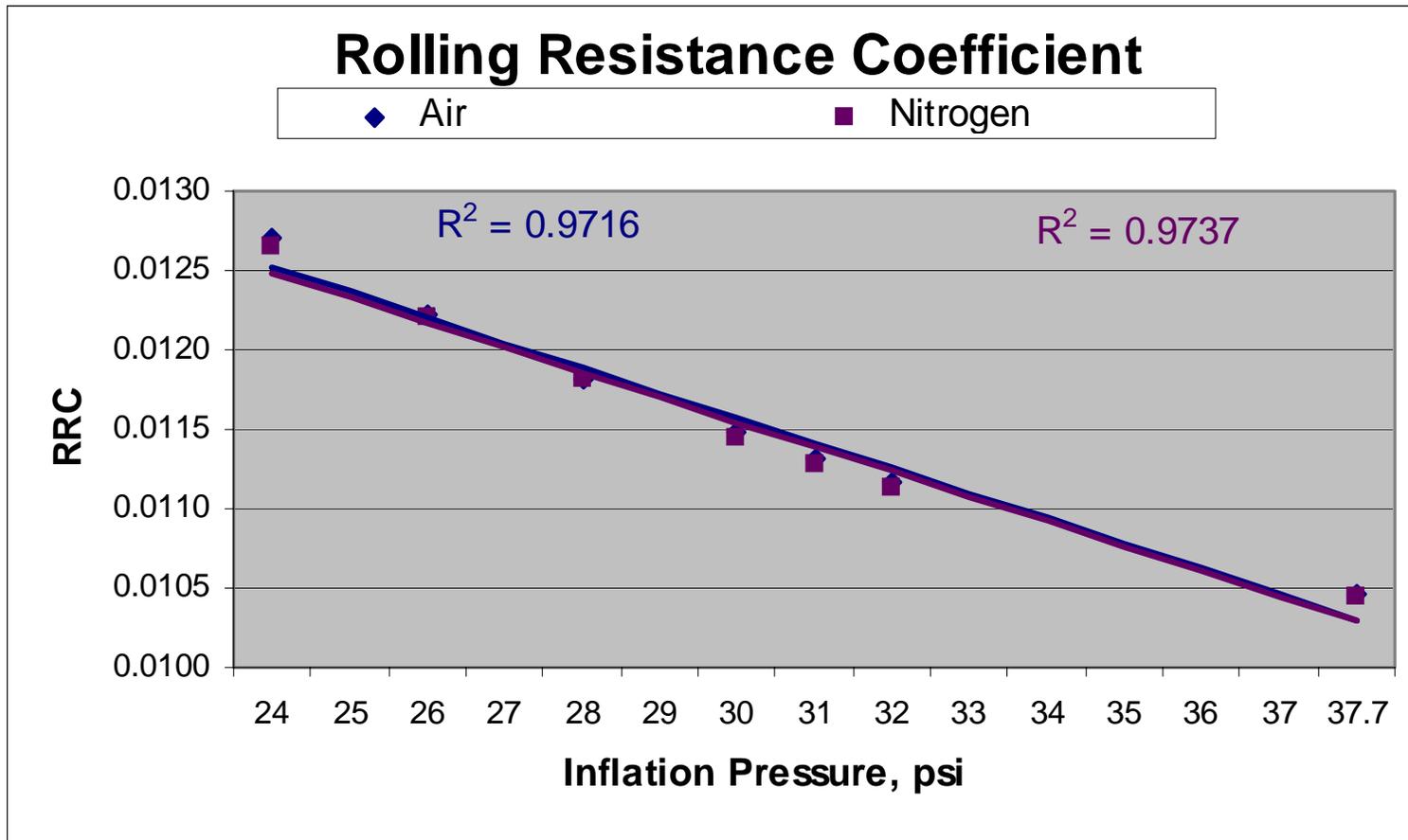
Cavity Air Temperature Does Not Change using Nitrogen Gas

Filling Gas Effects: Tire Rolling Resistance



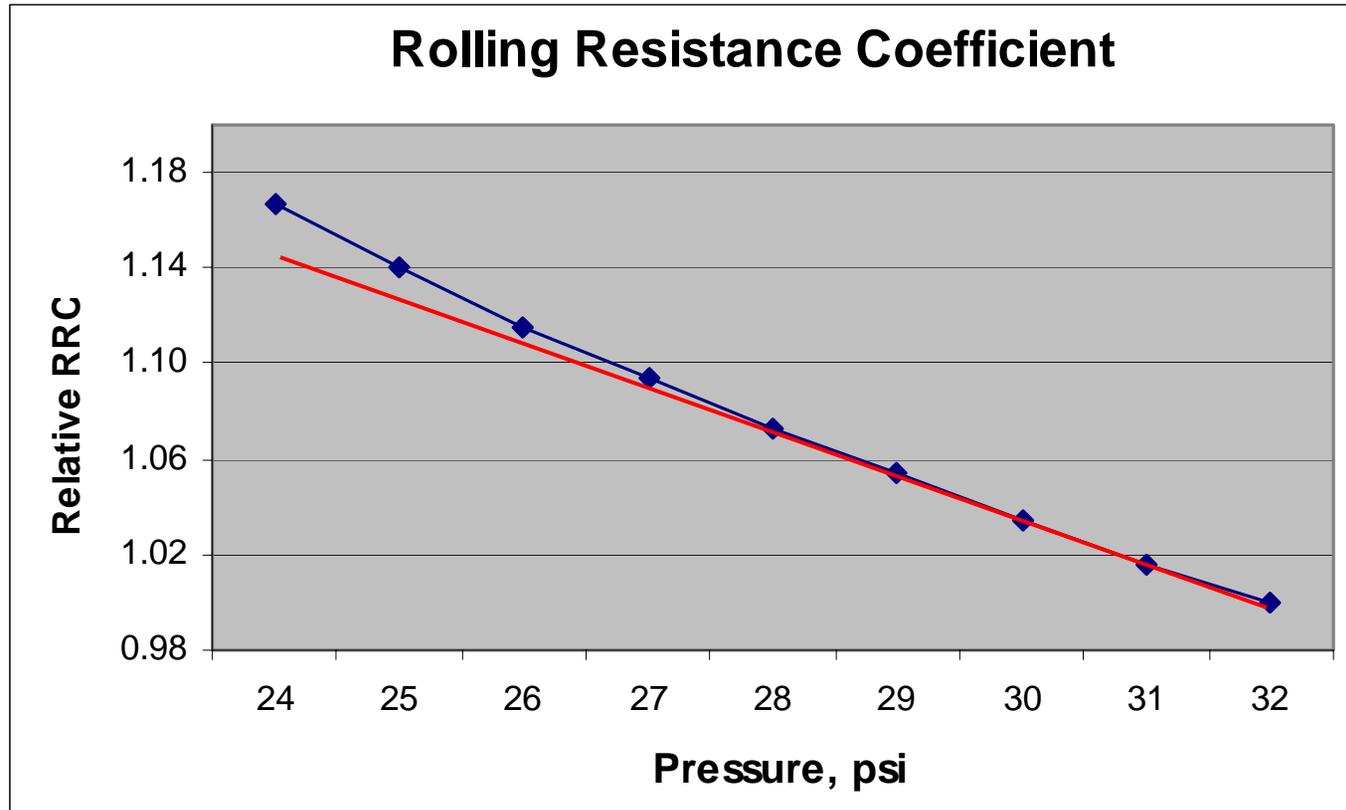
Tire Rolling Resistance Dependent Upon Inflation Pressure

Filling Gas Effects: Tire Rolling Resistance



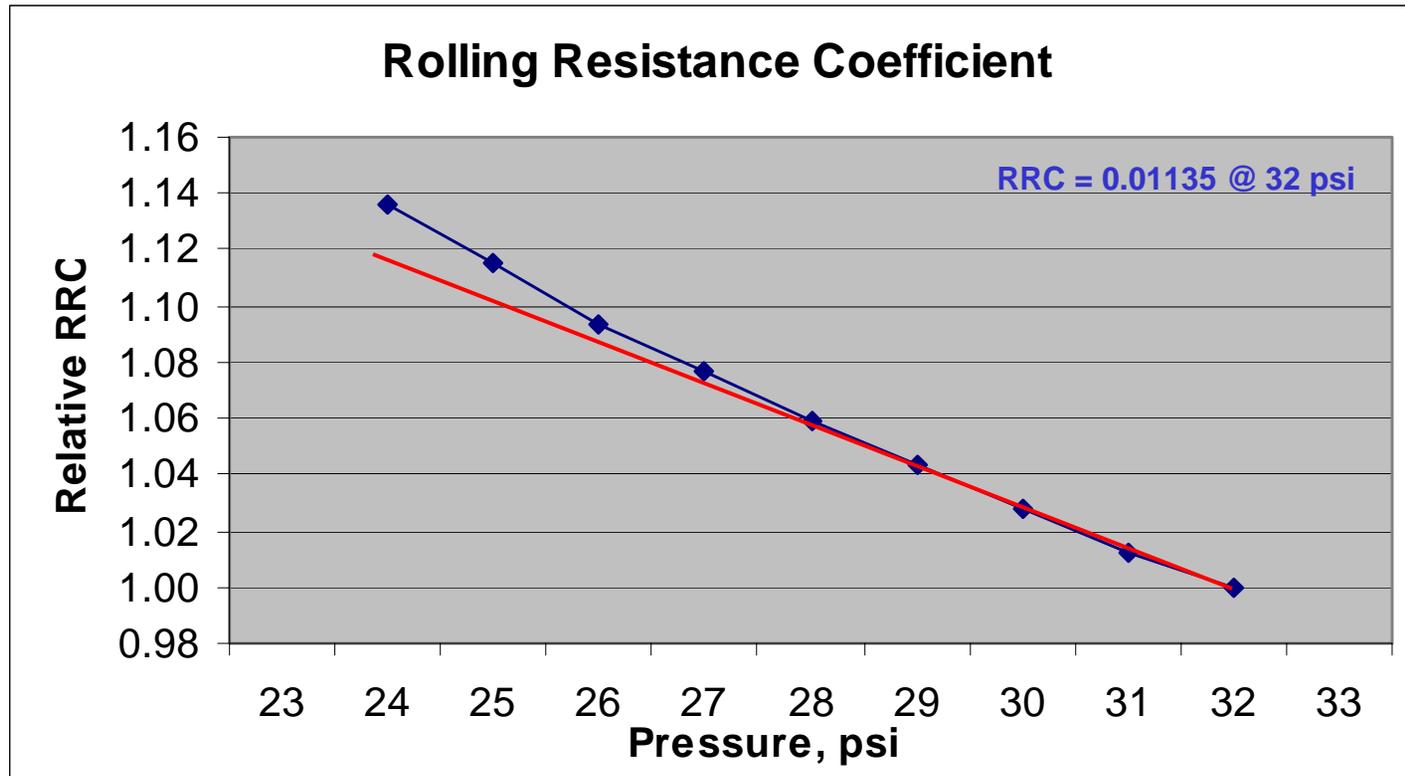
Tire Rolling Resistance Does Not Change Using Nitrogen Gas

Tire Inflation Pressure and Rolling Resistance - 1



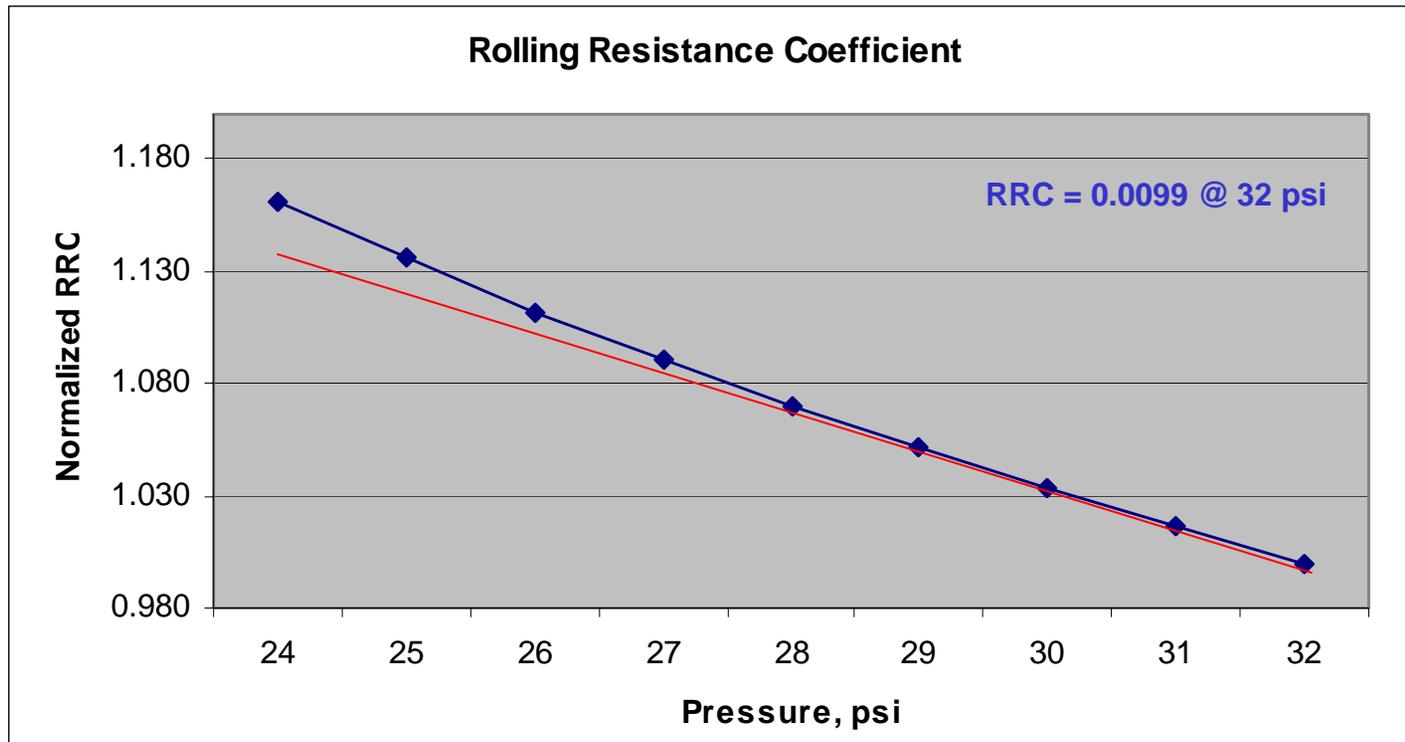
***Example 1. Tire Rolling Resistance Coefficient Increases
16.6% as Inflation Pressure Decreases by 25%***

Tire Inflation Pressure and Rolling Resistance - 2



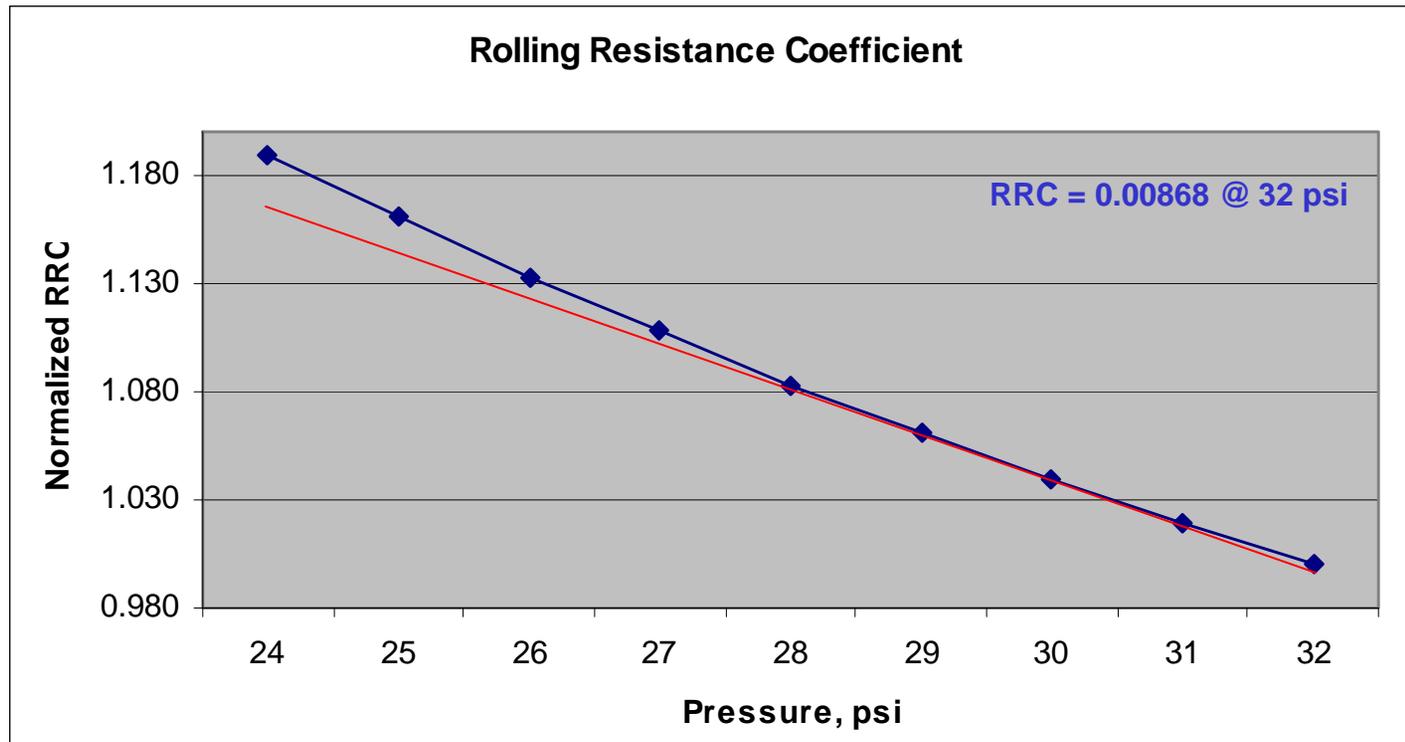
Example 2: Tire Rolling Resistance Coefficient Increases 13.7% as Inflation Pressure Decreases by 25%

Tire Inflation Pressure and Rolling Resistance - 3



Example 3. Tire Rolling Resistance Coefficient Increases 16.2% as Inflation Pressure Decreases by 25%

Tire Inflation Pressure and Rolling Resistance - 4

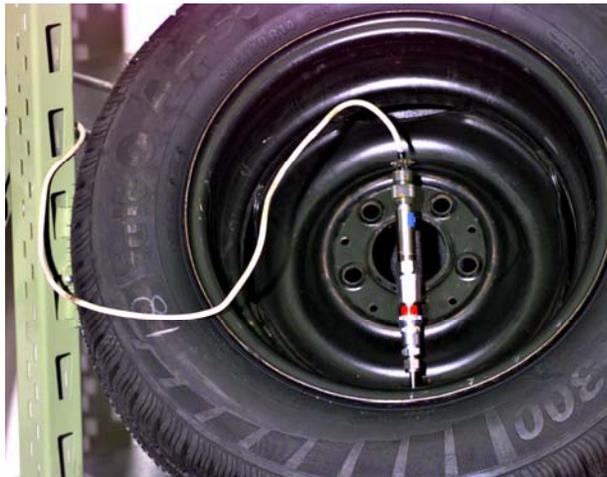


***Example 4. Tire Rolling Resistance Coefficient Increases
19% as Inflation Pressure Decreases by 25%***

Agenda

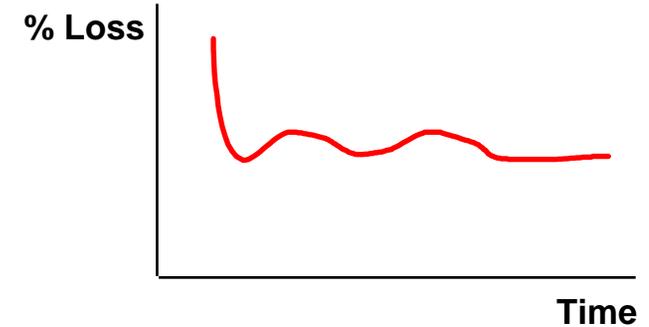
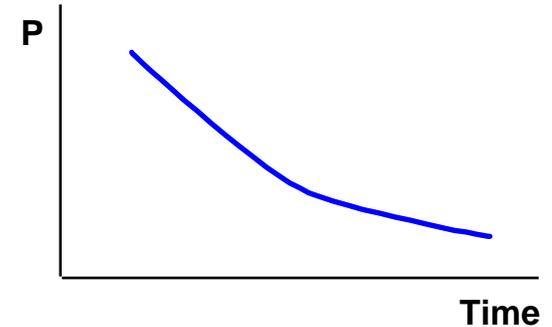
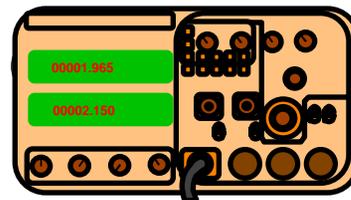
- Rolling Resistance Measurements
- Tire IPR
 - Monthly Loss Rates
 - Increases in Rolling Resistance with Pressure Loss
 - Temperature Effects on Tire IPR
 - Operating Effects on Tire IPR
- Tire Reinflation
- Tire IPR, Fuel Economy and CO₂ Emissions
- Summary

Inflation Pressure Retention Test



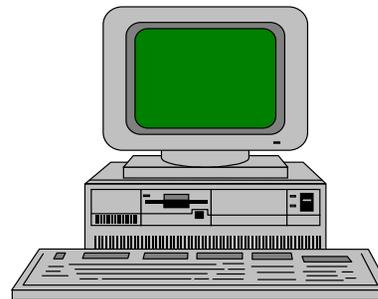
Digital Monitor

Atmospheric pressure



Modified ASTM F-1112

- Two weeks equilibration at 21°C before starting the test
- Tire start pressure = 2.2 bar (220 kPa or 32 psi)
- Automatic measurement every minute averaged over 24 hours
- Testing duration is 28+ days

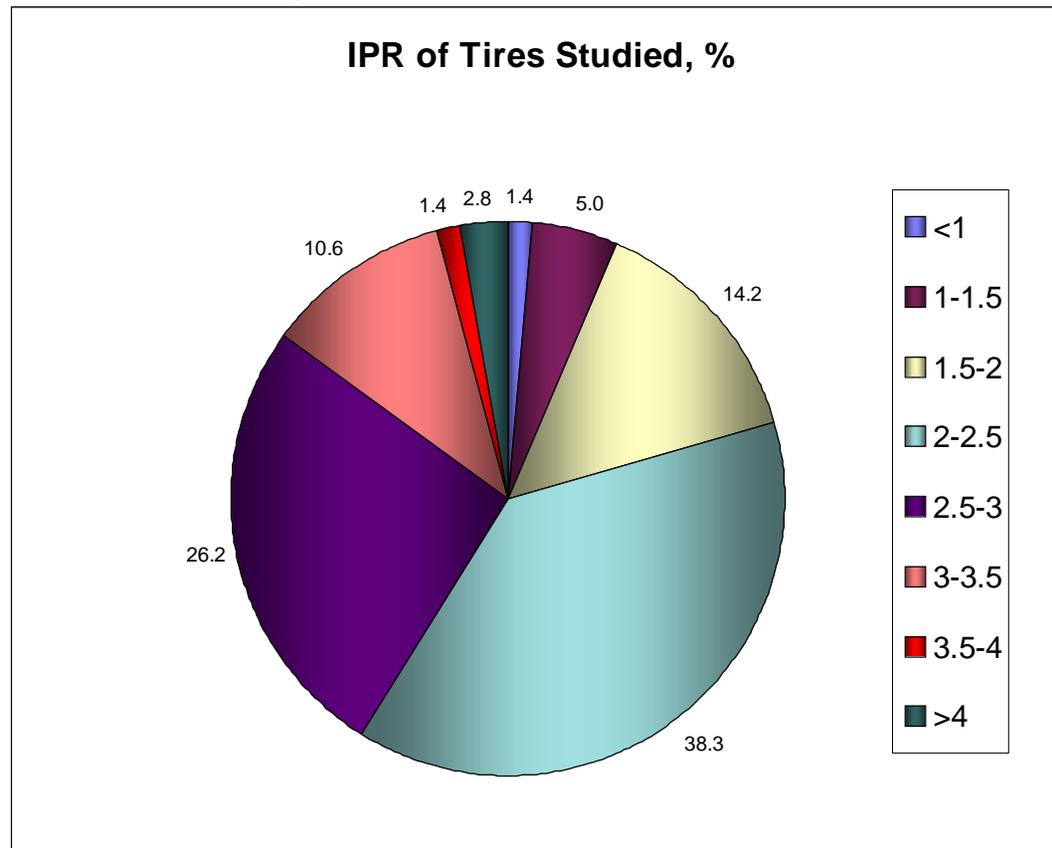


Computer

Tire Inflation Pressure Monthly Loss Rates

Tire Surveys performed during last decade with >140 tire types studied

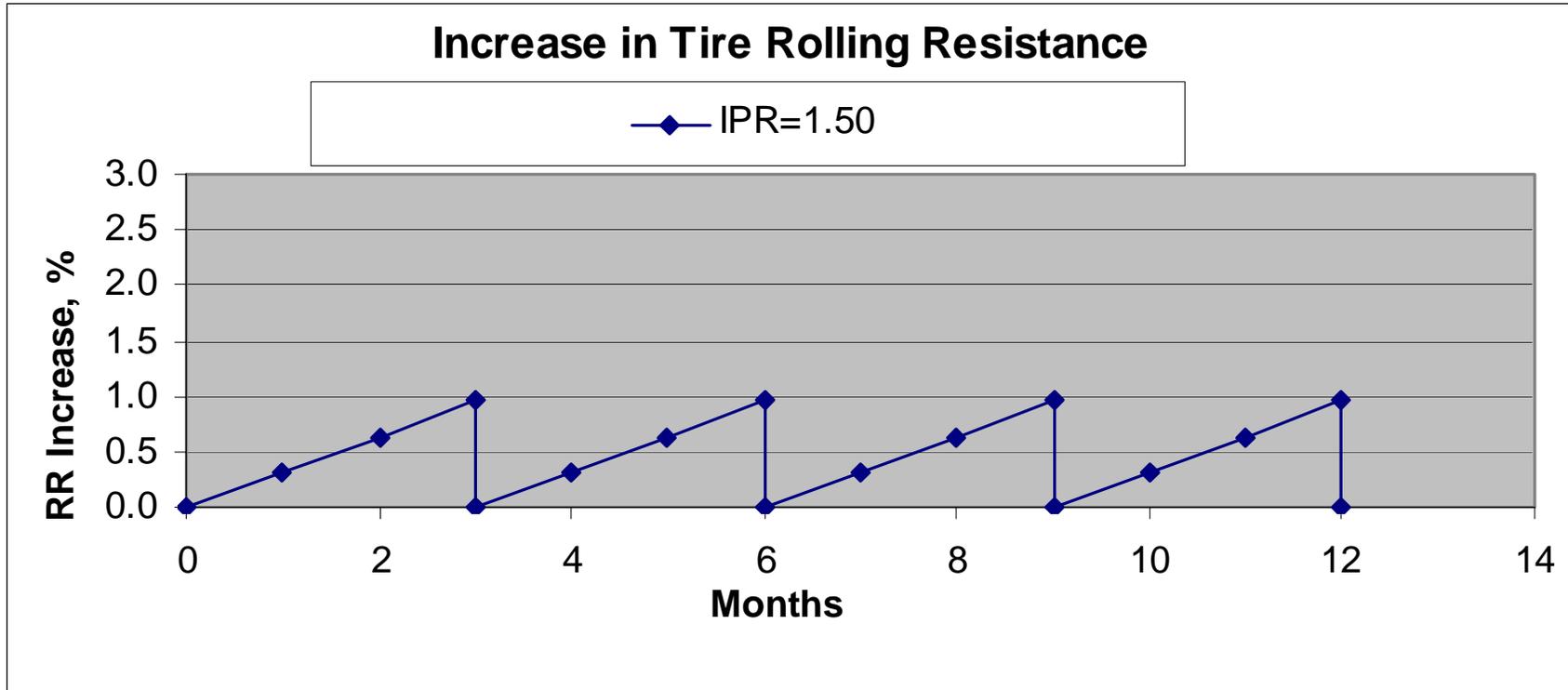
- 9th Tyre Survey, China/India Tyre Survey, 10th Tyre Survey, other surveys
 - Majority of tires are H-rated; some Q, S, T, V, Y, and W-rated tires also included
- Tire IPR loss rate values important parameter measured: ASTM F1112 modified
 - Tire IPR loss rates ranges from 0.86 – 4.6 %-loss/month



41% of Tire Types have IPR Loss Rates > 2.5%

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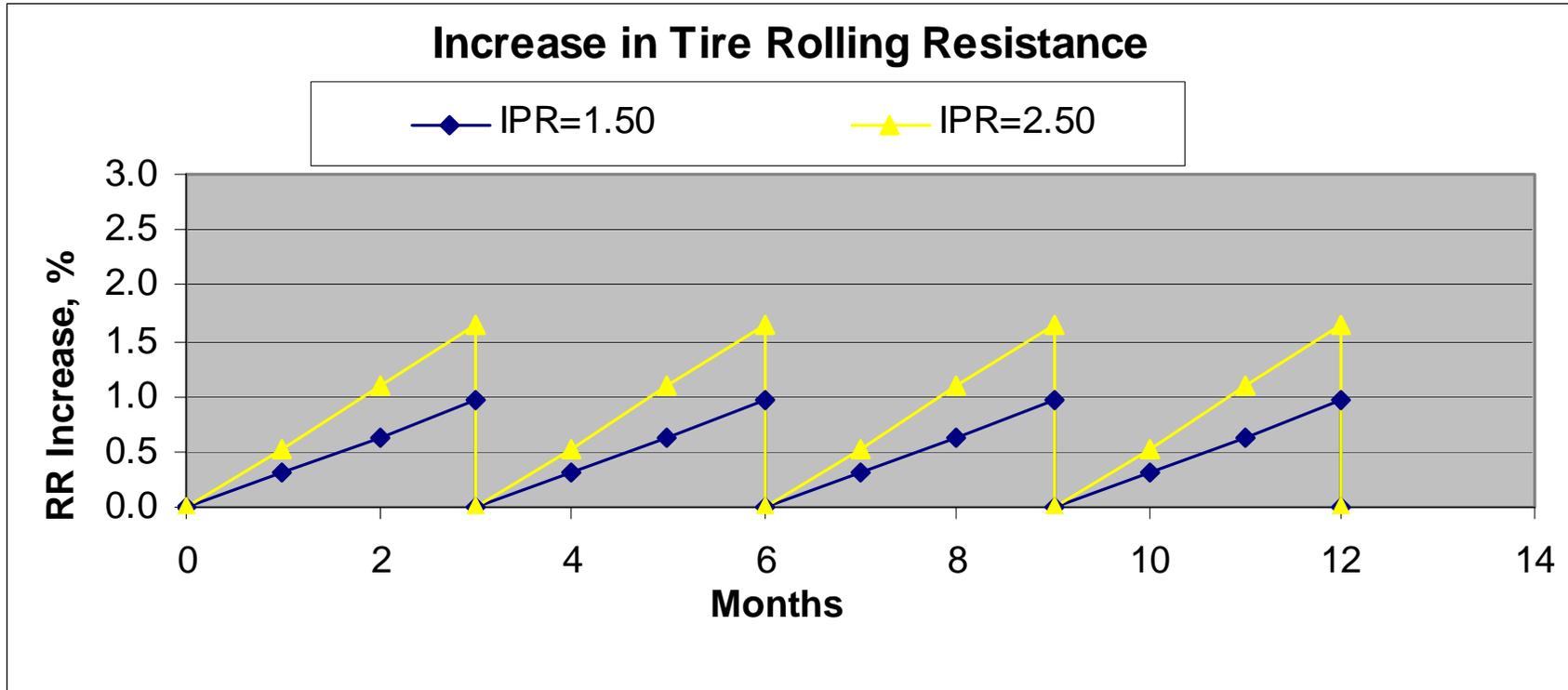
Rolling Resistance and Tire IPR



Rolling Resistance Loss Reinflating Tire Pressure Quarterly

Tire with IPR = 1.5% will have RR Increase of 1%

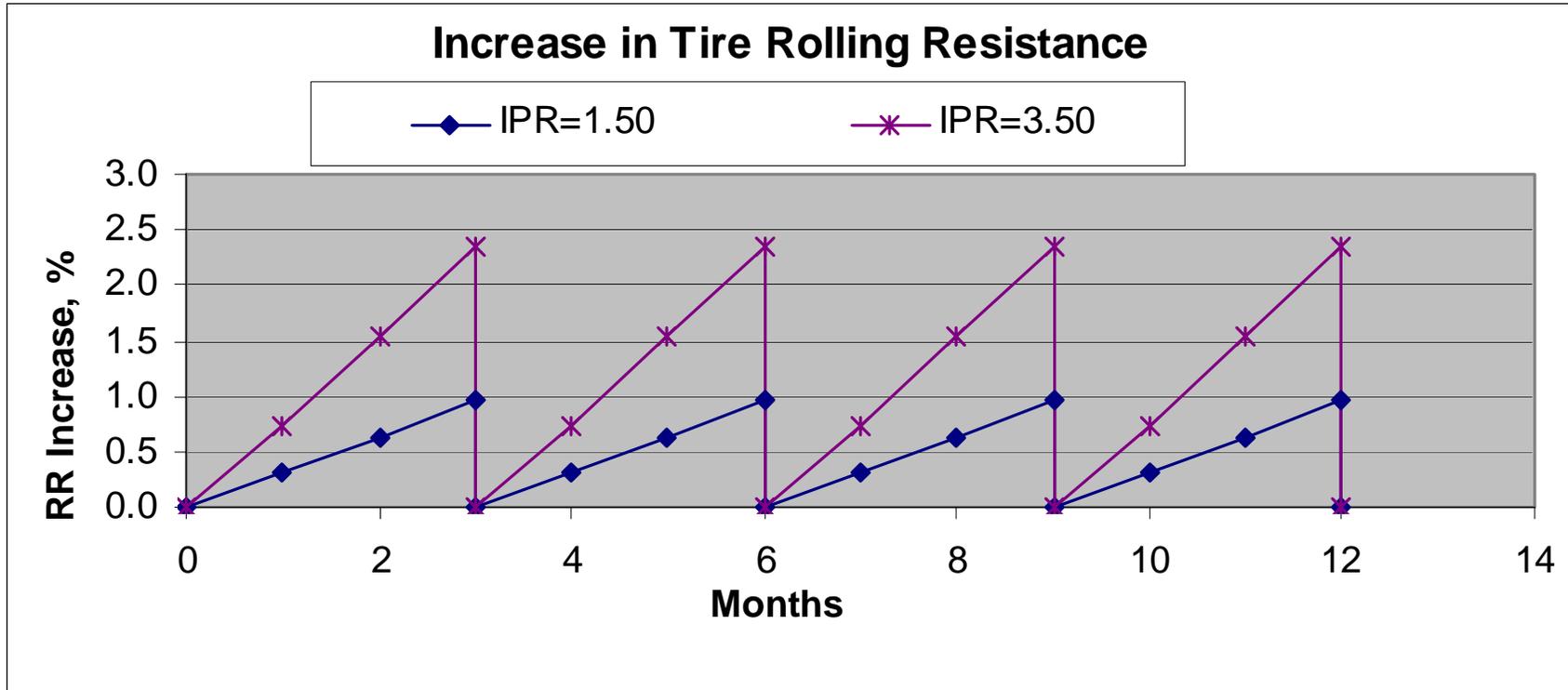
Rolling Resistance and Tire IPR



Rolling Resistance Loss Reinflating Tire Pressure Quarterly

Tire with IPR = 2.5% will have RR Increase of 1.66%

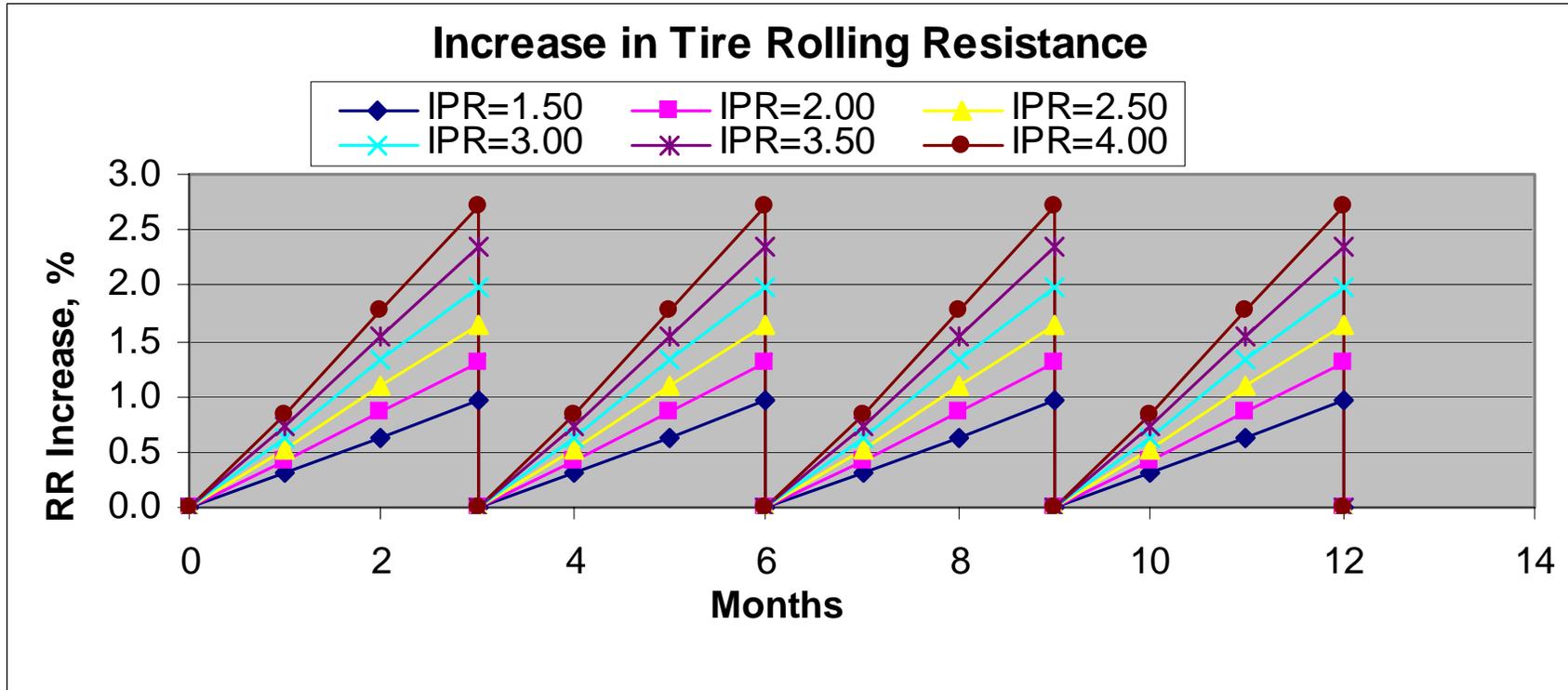
Rolling Resistance and Tire IPR



Rolling Resistance Loss Reinflating Tire Pressure Quarterly

Tire with IPR = 3.5% will have RR Increase of 2.34%

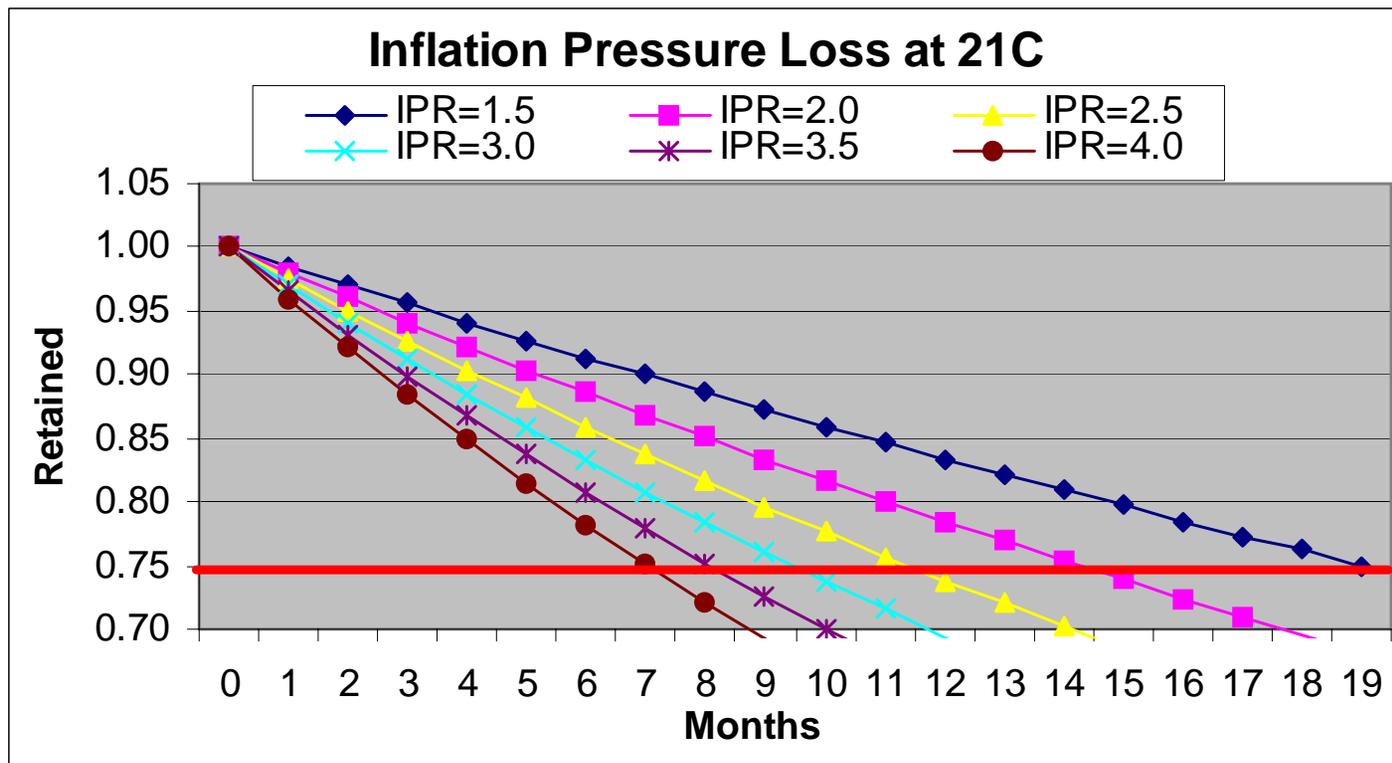
Rolling Resistance and Tire IPR



Rolling Resistance Increases More for Tires with Higher IPR Values

Tire Inflation Pressure Monthly Loss Rates

Can theoretically calculate how long it will take to lose 25% of tire inflation pressure when Tire Pressure Monitoring System activates (**Red Line**) as Function of **Tire IPR Loss Rates at 21°C per ASTM F1112**

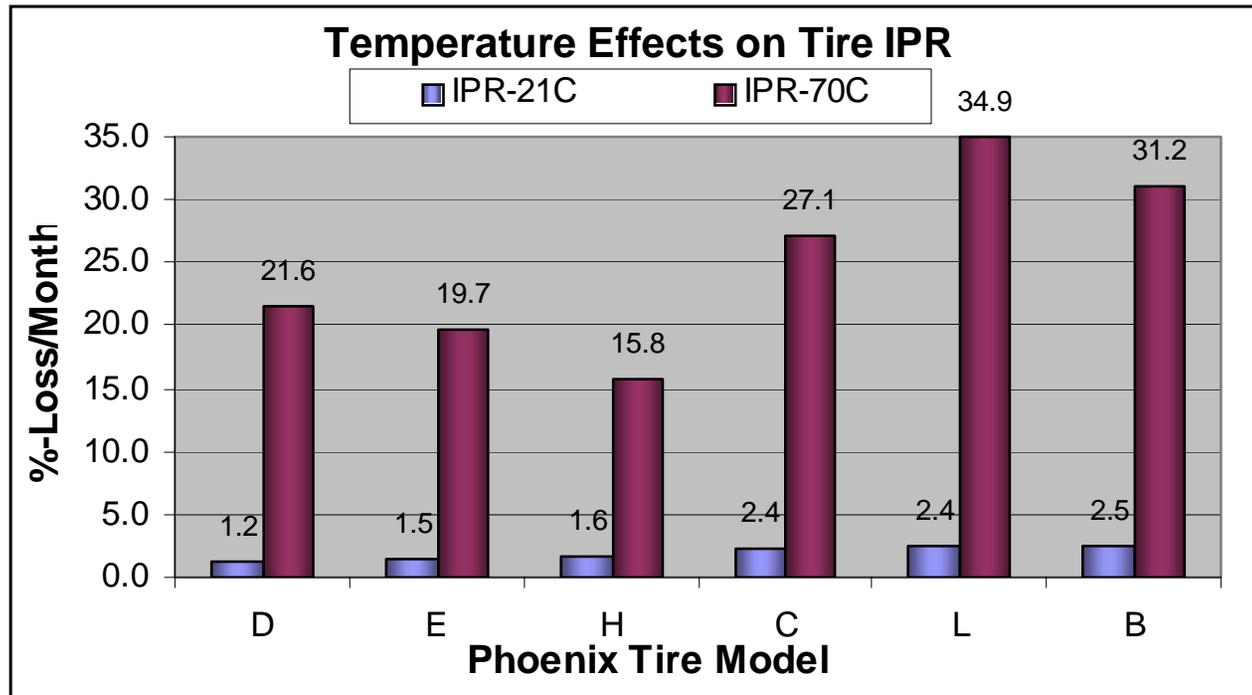


Time to Lose 25% Pressure Depends Upon Tire IPR Loss Rates

Temperature Effects on Tire IPR Loss Rates

(ref: Harris and Maclsaac, Paper #18, Rubber Division, ACS, October, 2006)

- **Tires lose air faster at the higher operating temperatures**
- **ASTM F-1112 measures static loss rates at 21°C, but tires in-service continually deform and operate at temperatures near 60°C - 70°C**

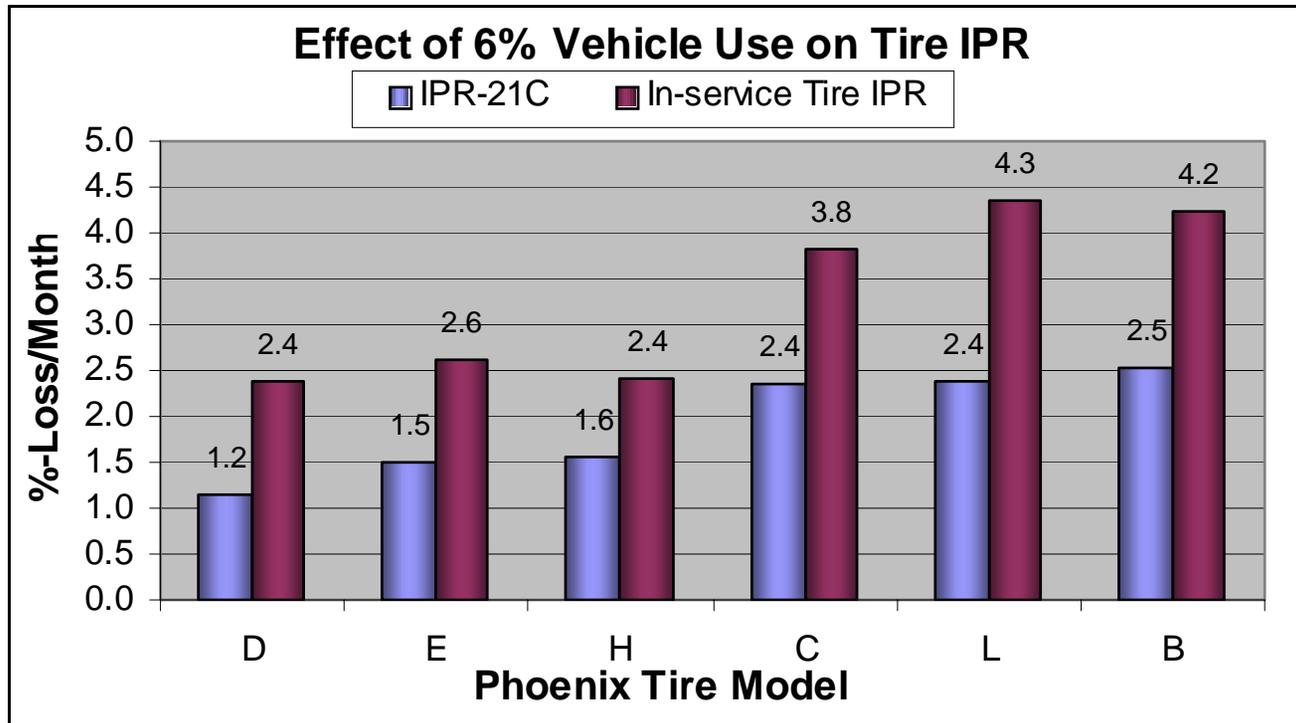


- **Measured air loss rates increase greatly at higher temperatures**
 - Dependent upon tire manufacturer/type: 10X - 19X higher loss rate at 70°C

Tire with IPR = 2.4% at 21°C → IPR = 30% at 70°C ExxonMobil Chemical

Operating Effects on Tire IPR Loss Rates

- IPR loss rates increase 10X - 19X at 70°C dependent upon tire type
- If vehicle is operated only 6% of time, IPR Loss Rates increased 40–100%

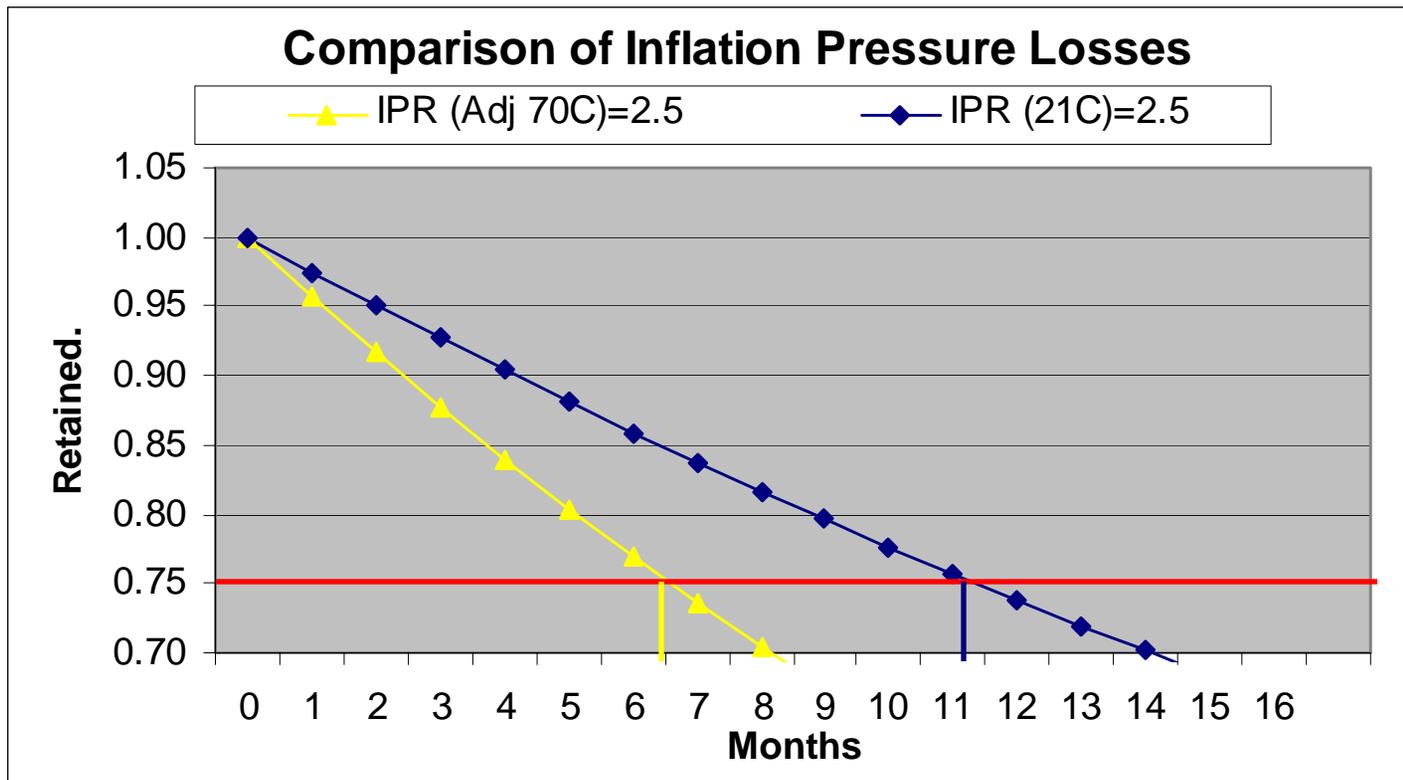


- Tire with IPR = 2.4% at 21°C → IPR ~4% when Car Operated 6% of Time

70% Increase in Tire IPR Loss Rates

Tire Inflation Pressure Monthly Loss Rates

Comparing how long it will take to lose 25% of tire inflation pressure when Tire Pressure Monitoring System activates (**Red Line**) as a Function of **Tire IPR Loss Rates at 21°C and at 70°C**



Time to Lose 25% Pressure Decreased Using Hot Tire IPR Loss Rates

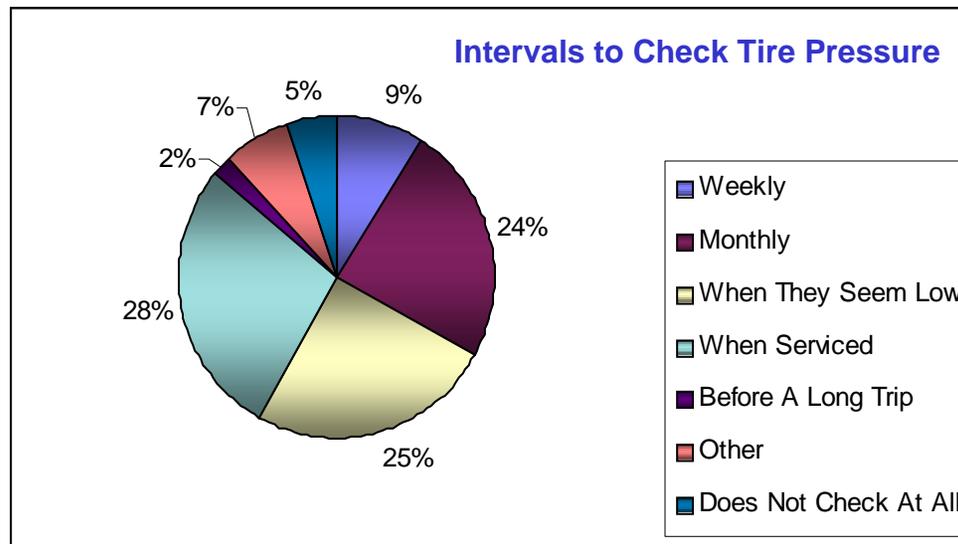
Agenda

- Rolling Resistance Measurements
- Tire IPR Loss Rates
- **Tire Reinflation**
 - NCSA Study
 - Visual Inspection of Tire Pressure
- Tire IPR, Fuel Economy and CO₂ Emissions
- Summary

Tire Pressure Maintenance Studies

(ref: NHTSA Research Notes DOT 809 316, August 2001)

- In February 2001, NHTSA's **National Center for Statistics & Analysis** conducted 'Tire Pressure Special Study'
 - 11,530 vehicles inspected at 24 locations over a 14-day time period
 - 6,442 Passenger Cars, 1,874 SUV's, 1,376 Vans and 1,838 Pick-up Trucks
- Overall, 85% of drivers concerned with proper tire inflation, but...



- Only 1 in 3 Drivers Check Tire Pressure on Regular Basis
- 1 in 4 Drivers Check Tire Pressure 'When They Seem Low'
- ~1 in 4 Drivers have Pressure Checked When Serviced

Visual Check of Tire Inflation Pressure



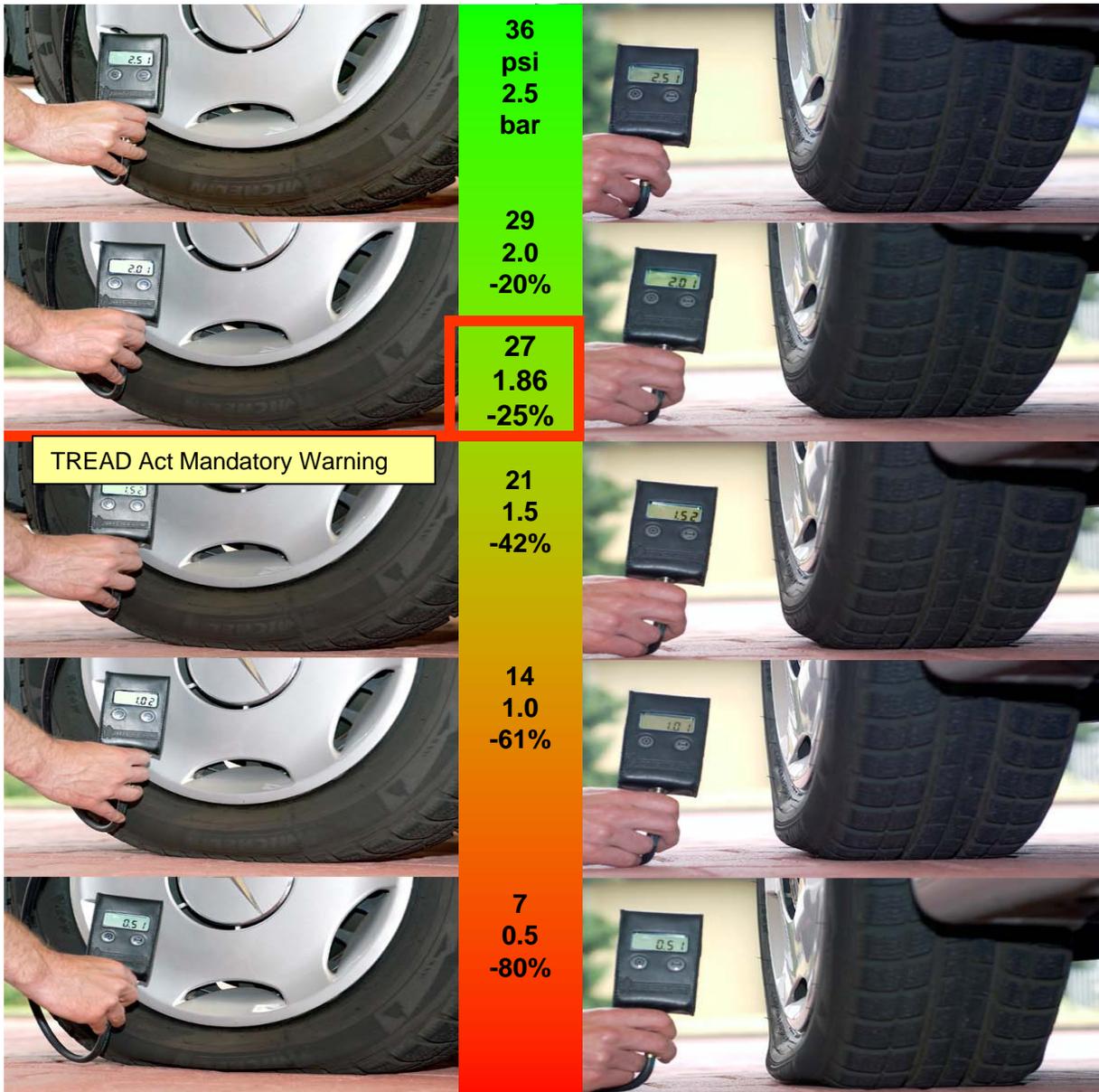
It is important to check your vehicle's tire pressure at least once a month for the following reasons:

- Most tires may naturally lose air over time.
- Tires can lose air suddenly if you drive over a pothole or other object or if you strike the curb when parking.
- With radial tires, it is **usually not possible to determine under inflation by visual inspection.**

(ref:<http://www.safercar.gov/Tires/pages/TPandLoadingCheck.htm>)

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Visual Check of Tire Inflation Pressure



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Agenda

- Rolling Resistance Measurements
- Tire IPR Loss Rates
- Tire Reinflation
- **Tire IPR, Fuel Economy and CO₂ Emissions**
 - United States
 - State of California
- Summary

Estimates of Potential Annual Fuel Savings: U.S.

National Research Council estimates reducing tire rolling resistance 10% promises 1-2% fuel savings for ~220 million light vehicles in U.S.

- Annual national fuel savings estimated at up to 2 billion gallons of gasoline
- Equivalent to taking about 4 million cars and light trucks off the road
- Average individual car annual savings estimated at about 10 gallons/year
- Average savings of 1 gallon for each 1% decrease in tire rolling resistance

Using **quarterly reinflation** time periods, annual fuel losses due to tire pressure is affected by maximum **hot Tire IPR %-loss/month** values

Tire IPR, Loss/Month	Estimate of Tires Affected	Rolling Resistance Increase at Three Months	Potential Annual Gasoline Savings	Potential Annual Reduction in CO2 Emissions
1.5%	94%	2.1%	731 Mgal	8.1 MMtons
2.0%	79%	3.6%	633 Mgal	7.0 MMtons
2.5%	41%	4.4%	393 Mgal	4.4 MMtons
3.0%	15%	5.1%	164 Mgal	1.8 MMtons
3.5%	4%	5.9%	55 Mgal	0.6 MMtons

Tire IPR_{MAX} = 2.5% Specification Potentially Saves 390 Million Gallons of Gasoline Annually in U.S.

Estimates of Potential Annual Fuel Savings: State of California

- **State of California has 20,914,500 light vehicles registered in 2007**
 - 12,900 miles/year driven on average
 - 20.1 miles/gallon on average
 - 59.3% automobiles
- **Using quarterly reinflation time periods, annual fuel losses due to tire pressure is affected by maximum hot Tire IPR %-loss/month values**

Tire IPR, Loss/Month	Estimate of Tires Affected	Rolling Resistance Increase at Three Months	Potential Annual Gasoline Savings	Potential Annual Reduction in CO ₂ Emissions
1.5%	94%	2.1%	74.6 Mgal	0.83 MMtons
2.0%	79%	3.6%	64.7 Mgal	0.72 MMtons
2.5%	41%	4.4%	40.2 Mgal	0.45 MMtons
3.0%	15%	5.1%	16.8 Mgal	0.19 MMtons
3.5%	4%	5.9%	5.6 Mgal	0.062 MMtons

Tire IPR_{MAX} = 2.5% Specification Potentially Saves California 40 Million Gallons of Gas and 0.45 million metric tons of CO₂ Emissions

Summary: Effects of Tire IPR Specification in U.S.

390 million gallons of gas yearly in U.S. is equivalent to

- **Not shipping 3 Ultra Large Crude Carriers**

- 1 million tons of crude oil



- **Not refining 20 million barrels of crude**

- U.S. imports 12 million barrels of crude oil daily (ref: Monthly Energy Review, July 2007)

- Average mix: 19.5 gallons of gas/barrel (ref: www.newton.dep.anl.gov/askasci/eng99/eng99288.htm)

- **Not sending 65,000 tanker trucks to deliver gas to service stations**

- 5,000 – 7,000 gallon tanks



- **Taking 650,000 light vehicles off the roads**

- Average of 12,000 miles @ 20 mpg = 600 gallons/year

- (ref: <http://onlinepubs.trb.org/onlinepubs/sr/sr286.pdf>)



- **Emitting 4.4 million fewer metric tons of CO₂**

- 22.2 lbs of CO₂ / gallon of gasoline consumed (2.28 kg / liter)

- (ref: www.epa.gov/otaq/greenhousegases.htm)

***390 Million Gallons Saved Annually is 4.6% of NHTSA
8.5 Billion Gallons Goal for “Twenty in Ten” Gasoline Program***

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Summary: Effects of Tire IPR Specification in the State of California

40 million gallons of gas yearly in California is equivalent to

- **Not refining 2 million barrels of crude**

- U.S. imports 12 million barrels of crude oil daily (ref: Monthly Energy Review, July 2007)
- Average mix: 19.5 gallons of gas/barrel (ref: www.newton.dep.anl.gov/askasci/eng99/eng99288.htm)

- **Not sending 6,500 tanker trucks to deliver gas to service stations**

- 5,000 – 7,000 gallon tanks



- **Taking 65,000 light vehicles off the roads**

- Average of 12,900 miles @ 20.1 mpg = 640 gallons/year



- **Emitting 0.45 million fewer metric tons of CO₂**

- 22.2 lbs of CO₂ / gallon of gasoline consumed (2.28 kg / liter)
(ref: www.epa.gov/otaq/greenhousegases.htm)

Summary: Inflation Pressure Retention Effects on Tire Rolling Resistance and Vehicle Fuel Economy and CO₂ Emissions

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