What NHTSA Applied Research Has Learned From Industry About Tire Aging

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Statistics on Tires in the Field

- **Number of tires on the road in America in 1999 -non-commercial vehicles (cars, LT, SUVs, etc.)**
  - 822 million
- **Number of passenger & LT tires shipped in 2002:**
  - 291 million (797,000/day)
- **Average use 2002:**
  - 44,700 miles / 3.7 years
    - – Note: large distributions in average use

Data Source: Rubber Manufacturer's Association - www.rma.org

Meetings With Industry to Discuss Tire Aging

- **From October 2002 through April 2003, NHTSA Applied Research had meetings to discuss tire aging with:**

Manufacturers

- Bridgestone Firestone
- Continental General
- Ford
- General Motors
- Goodyear
- Michelin

Standards and Testing Organizations

- Akron Rubber Development Lab
- ASTM F9 Committee
- SAE Highway Tire Committee
- Smithers Scientific Services
- Standards Testing Laboratory

- Also, numerous informal contacts with industry

Industry Comments on Tire Failures In the Field

Tire Failures In the Field

- **Industry has told NHTSA that common tire failure modes seen in the field are:**
  - Belt edge cracking
    - May lead to tread separation
    - Known safety problem!
  - Bead failure
    - Results in more rapid air loss
    - Not generally a safety problem!

Tire Failures In the Field

- **Infrequently seen tire failure modes:**
  - Sidewall failure (blowout)
    - Occurs after tire sidewall damaged or tire operation while underinflated
    - Known safety problem!
  - Tread chunking
    - Usually due to manufacturing/quality control problems
    - Not generally a safety problem!

General Agreement: Older Tires Are More Likely to Suffer One of These Failures Than Are New Tires

→ **Tire Aging Matters**

Types of Tire Aging

- **Industry has told NHTSA that while there are many aging mechanisms acting on a tire, only two really matter:**
  - Chemical aging
    - Changes in tire rubber due to heat and oxygen interactions
    - In regards to tread separations, it is the oxygen permeation into area around end of top belt (belt #2) that really matters
  - Mechanical aging
    - Changes in rubber due to mechanical stress/strain
    - Area around end of belt #2 has highest strain energy density
      - Mechanical aging effects are greatest in this area

What We've Learned From Firestone Tire Recall

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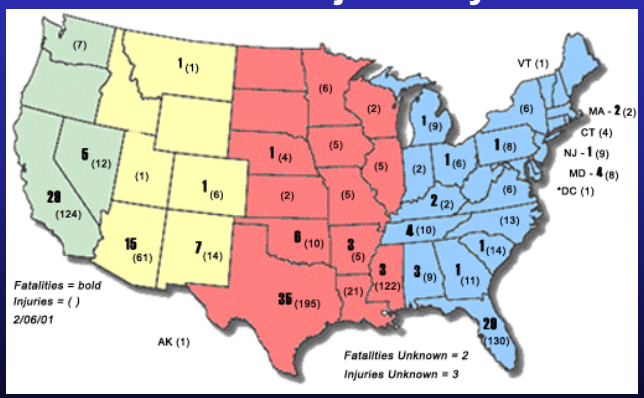
What We've Learned From Firestone Tire Recall

Fatalities and Injuries by State



Most tread separations occurred in warm climates: CA, AZ, TX, MS, FL

Source: Public Citizen, Firestone Tire Resource Center, Slide 6 (2-6-2001)

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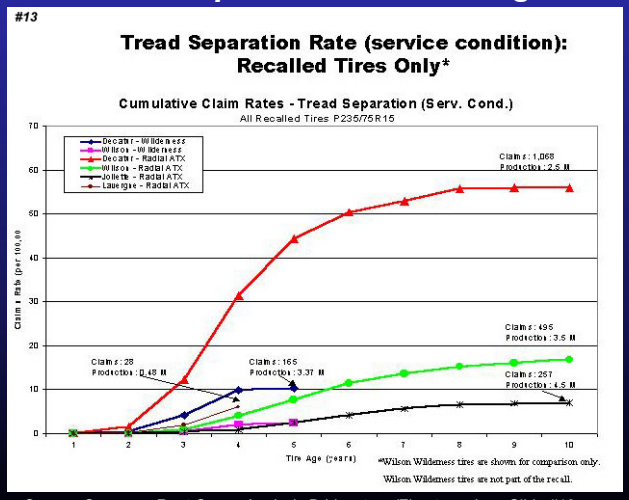
What We Learned From the Firestone Tire Recall

Tread Separations vs. Tire Age



Source: Summary Root Cause Analysis Bridgestone/Firestone, Inc., Slide #13

Summary Firestone Data

- High ambient temperatures result in an increase in tire failures (southern states)
- High ambient temperatures accelerate the rate of chemical aging in tires
- Tire failures don't begin to manifest until about 2-3 years of use
- Most importantly: testing new tires from the factory may not identify defective designs

Possible Tire Aging Tests

Possible Tire Aging Tests

- **Six possible aging test protocols were advanced during NHTSA's discussions with industry:**
  - Air permeability test (ASTM F1112-00)
  - Continental General P-END test
  - General Motors Accelerated Tire Endurance (ATE) test
  - Michelin Long Term Durability Endurance (LTDE) test
  - Roadwheel conditioning followed by peel force test (NPRM FMVSS 139)
  - Hybrid oven/mechanical aging endurance test

Air Permeability Test (ASTM F1112-00)

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31-July-03, slide 15

Air Permeability - Test Philosophy

- **Chemical aging is due to oxygen diffusing through the tire composite and reacting with the internal components**
- **If the rate at which air diffuses through the tire is slowed, the rate of chemical aging will be similarly slowed**
- **Other tests in the proposed FMVSS 139 will hopefully ensure that mechanical aging effects are reasonably handled**

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Air Permeability - Test Philosophy

- **According to tire manufacturers**
  - Tires with more expensive, 100% halogenated-butyl inner liners lose air at a rate of 2.0 - 2.5 percent per month
  - Tires with cheaper, blended butyl inner liners lose air at a rate 4.0 - 5.0 percent per month
  - For the same inner liner compound, a thicker inner liner will lower the air loss rate
  - A reduction in air loss rate, by a factor of 2, may be achievable for some tires

Air Permeability Test

- **Test procedure:**
  - Place inflated tire in climate controlled room
    - Inflated with air
    - Maximum permitted inflation pressure
  - No data taken for first month
  - Measure percent air lost per month for next five months
  - Industry standard procedure for doing this - ASTM F1112-00 “standard test method for static testing of tubeless pneumatic tires for rate of loss of inflation pressure”

Continental General P-END Test

Continental General P-END Test

- **Test procedure**
  - Test performed on 67-inch roadwheel
  - Inflation mixture: Normal air (21% oxygen, 78% nitrogen)
  - Test conditions proprietary

General Motors Accelerated Tire Endurance (ATE) Test

General Motors Accelerated Tire Endurance (ATE) Test

- **Test procedure:**
  - Test tires on an actual vehicle
  - Drive vehicle 45,000 miles on public roads in Texas and Mexico
    - Speeds range from 70 to 25 mph
    - Paved and gravel surfaces
  - Test takes approximately 11 weeks to perform

Michelin Long Term Durability Endurance (LTDE) Test

Michelin Long Term Durability Endurance (LTDE) Test

- **Test procedure (Michelin submission, not NPRM version):**
  - Test performed on 67-inch roadwheel
  - P-metric standard load tires tested at 111% of maximum T&RA load, 40 psi pressure
    - Different load/pressure combinations used for extra load and LT tires
  - Inflation mixture of 50% oxygen, 50% nitrogen used

Michelin LTDE Test

- **Test procedure:**
  - Ambient temperature of 38° C (100° F)
  - 60 mph speed
  - Michelin believes that 100 hours of LTDE testing simulates one year of actual tire service

Roadwheel Conditioning Followed by Peel Force Test (NPRM FMVSS 139)

Conditioning Followed by Peel Force Test

- **Test procedure (from draft FMVSS 139 final rule)**
  - Condition tire for 24 hours on 67-inch roadwheel
    - 75 mph
    - 40°C ambient temperature
    - 26 psi air inflation
    - 90%/100%/110% of maximum load rating labeled on tire with 8 hours at each load step
  - After conditioning, a test specimen is cut out of the tire
  - The force required to separate adjacent belts is measured using the ASTM D413-98 test procedure

Hybrid Oven/Mechanical Aging Endurance Test

Oven/Mechanical Aging Endurance Test

- **Test procedure:**
  - Heat tires aging in oven interspersed with mechanical stressing on 67-inch roadwheel
  - Inflation mixture of 50% oxygen, 50% nitrogen used
  - Oven temperature of 70° C (158° F)
    - Industry has presented data that higher temperatures may cause rubber reversion problems
    - Two ASTM procedures use this temperature
  - Time in oven needs to be determined
  - Roadwheel testing parameters need to be determined

NHTSA Applied Research

Design of Experiment - Tire Aging

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Primary Objective

- **NHTSA wants reasonable assurance that all tires covered by the FMVSS 139 will wear out (have less than 3/32nds tread left) before they suffer a safety related failure:**
  - Tread separation
  - Sidewall failure (blowout)
  - Bead failure

Tire Aging Test Background

- **The agency reserved the right to revise tests or incorporate additional tests in the proposed FMVSS 139**
- **The agency has identified the need to test tires that have been subjected to the equivalent of many years of use**
- **Currently, there exist no industry accepted accelerated tire aging method**

Tire Aging Project Basics

Quantify How Tires Age in the Field

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Evaluate Proposed Tire Aging Methods

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Develop an Aged Tire Endurance Test

Tire Collection from the Field

- **Collection area: Phoenix, Arizona**
  - Average annual temperature 72.9°F (22.7°C)
  - The state of Arizona had the highest per capita Firestone tire tread separation rate in the U.S.
  - Population: 1,210,420 (7th largest U.S. City – large pool of vehicles)

Tire Collection – 8 Different Categories

- **Original Equipment**
  - P-metric tires
    - –Compact car
    - –Mid-size car
    - –Mid-size SUV
    - –Large SUV
- **Replacement Brand**
  - P-metric tires
    - –Mid-size car
    - –Full-size car
    - –Large SUV
  - Light Truck
    - – Load Range E

Tire Selection Requirements

- **Production availability**
  - In production 1998 to current
- **Popularity**
  - OE: must have been OE on at least one US vehicle
  - Replacement: must be available at a large tire retailer
- **Design legacy**
  - No ‘major’ design changes from 1998 – current

Tires Collected from the Field

- **Field collection**
  - Collect 720 tires off of Phoenix area vehicles
    - 60 of each tire (12 different models)
    - 20 in each age group 1: 97-98, 2: 99-00, 3: 01-03
  - Assume 192 / 720 tires fail inspection (repairs, abuse…)
  - Laboratory analysis (over 20 tests) – 144 tires*
  - FMVSS 139 endurance test – 144 tires*
  - Remainder of the tires used for tire aging test development
  - Data to be released after analysis by NHTSA

*(48 of each age / 4 each model)

Phase I Test Tires

Type	Size	Load Index	Speed Rating	Brand	Model
P-metric	P195/65R15	89	S	BFGoodrich	Touring T/A
P-metric	P205/65R15	92	V	Goodyear	Eagle GA
P-metric	P235/75R15	**108***	S	Michelin	LTX M/S
Metric	255/65R16	109	H	General	Grabber ST A/S
P-metric	P265/75R16	114	S	Firestone	Wilderness AT
LT	LT245/75R16/E	**120****	Q	Pathfinder	ATR A/S OWL

***Extra Load / **Load Range E**

- **12 Tire Models Collected From The Field (Phoenix)**
- **6 Tire Models Will Be Tested In Phase I**

Evaluate the Effectiveness of Proposed Tire Aging Methods

Aging Tests Selected for Evaluation

- **Aging tests selected for evaluation:**
  - Air permeability test (ASTM F1112-00)
  - Continental General P-END test
  - Michelin Long Term Durability Endurance (LTDE) test
  - Hybrid oven/mechanical aging endurance test
- **Aging tests not selected for evaluation:**
  - General Motors Accelerated Tire Endurance (ATE) test
  - Roadwheel conditioning followed by peel force test (NPRM FMVSS 139)

Tentative Tire Aging Project Schedule

Meet with Industry / Project Planning	10/02 - 1/03
Tire Collection in Phoenix, Arizona	2/03 - 3/03
Analysis & Testing of Field Tires	3/03 - 10/03
Evaluation of Tire Aging Methods	3/03 - 10/03
Aged Tire Endurance Test Development	10/03 - 3/04

Website

NHTSA Tire Aging Program Public Documents & Presentations are Available on the Following Website:

http://www-nrd.nhtsa.dot.gov/vrtc/ca/tires.htm