Working Paper No : TYREgtr-07-05e
ASTM F9.30
Light Vehicle Equivalent Severity Roadwheel Task Group

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Summary and Status

02/02/09

Agenda:

- Background
- Objective & Scope
- Procedure
- Results
- Summary
- Next Steps

Background: Laboratory Drum Curvature Effects

RMA OMB Presentation 4-7-03

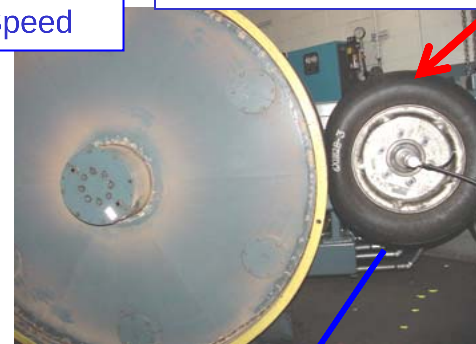
Tire operating temperatures are significantly higher in the laboratory due to a more severe loading surface and no cooling airflow.

On Highway

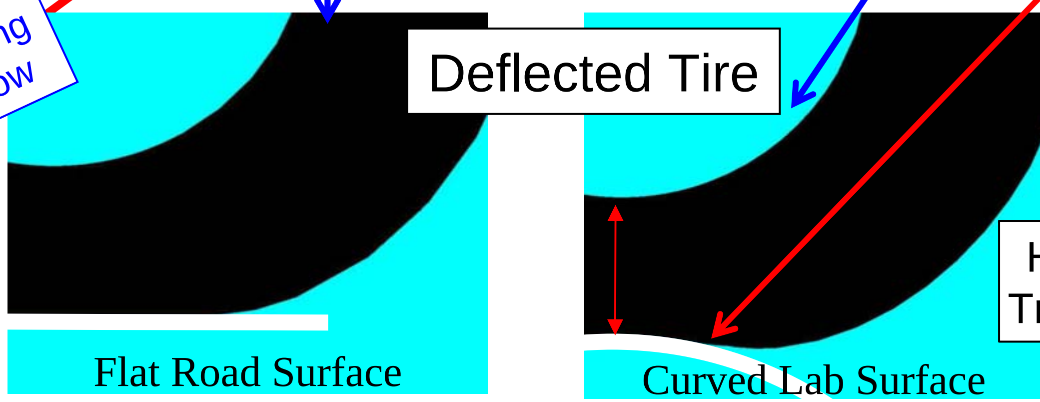
Same Vertical Load
Same Inflation Pressure
Same Forward Speed

In Laboratory

No Cooling Airflow



Cooling Airflow



Greater deflection
Increased stress/strain
Higher footprint pressures

↓

More energy into the tire

↓

More heat generation

↓

Higher Tire Temperatures

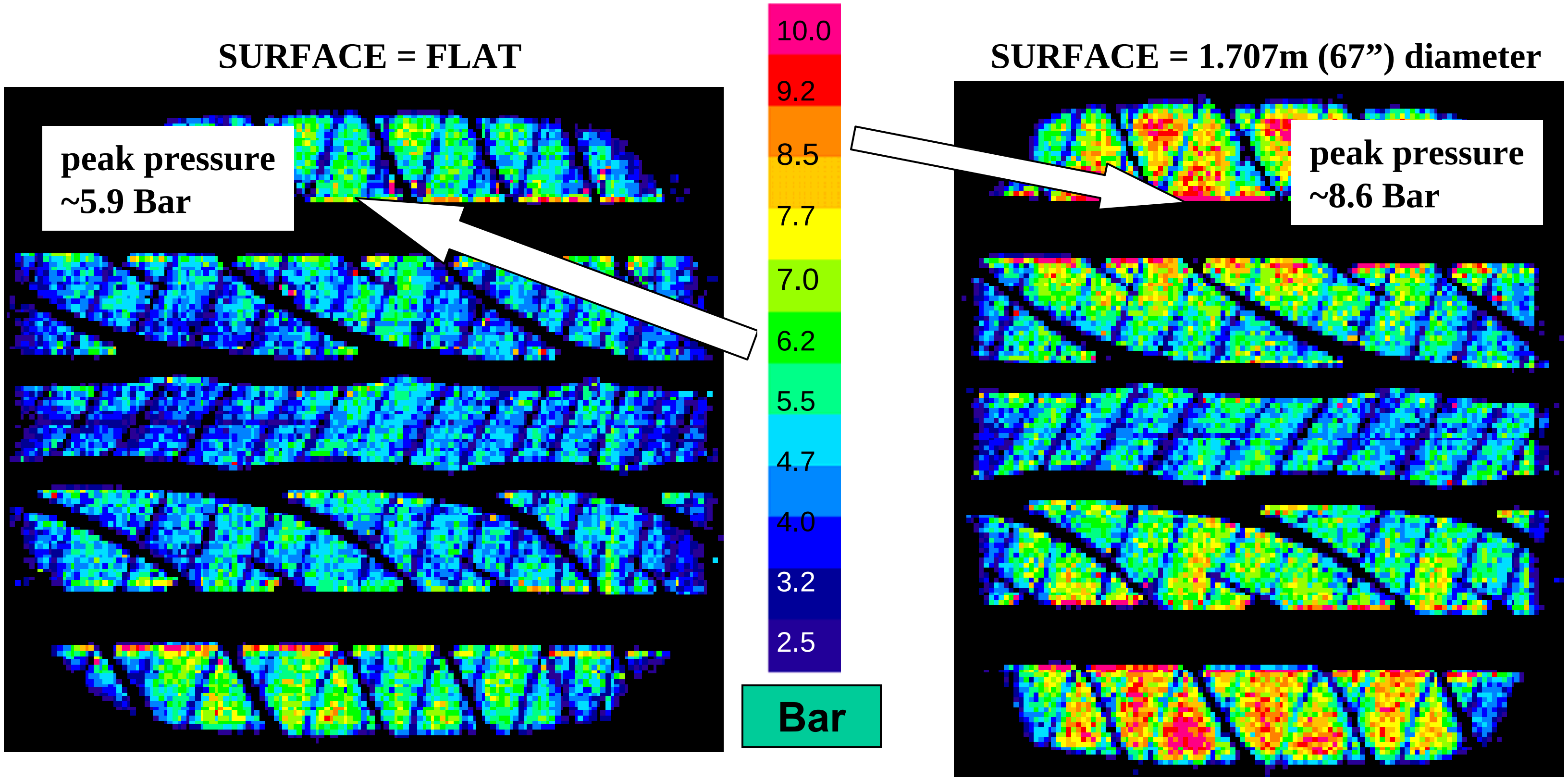
↓

Heat Induced Tread Chunking

- Laboratory Roadwheel produces higher test severity vs. highway
- Higher test severity can produce removal conditions that are not representative of field.

Background: Curvature Effect Upon Footprint

265/60R18 @ 2 Bar & 1056 Kg



-21% Footprint length
+21% Mean shoulder footprint pressure
+40% Maximum shoulder footprint pressure

- Drum curvature results in higher pressure due to smaller contact area
- Higher test severity can produce removal conditions that are not representative of field.

Objective & Scope:

-Develop a technical standard for Light Vehicle Tires which provides equivalent test severity on a curved surface vs. a flat (Real World) surface.

- Light Vehicle Tires: Tires for application to vehicles ≤ 4545 Kg (10,000 lb GVW)
- Test Severity: Determined by stress-strain amplitude as measured by tire internal temperatures (Belt edge, tread lugs, bead, etc.)
- Curved Surface: 1.707m (67”) diameter roadwheel (Laboratory)
- Flat surface: Real world operating temperatures (Highway and Flat Track)

Procedure:

Action Plan:

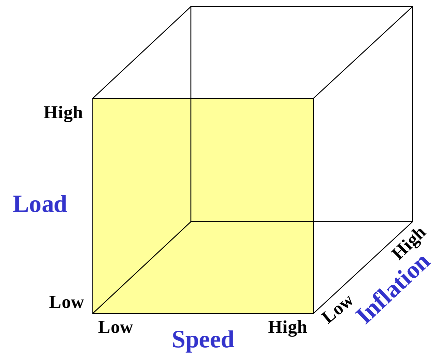
- Determine Real World Operating Temperatures
    - via a flat surface **D**esign **O**f **E**xperiment
- Determine Curved Surface Operating Temperatures
    - via a lab **D**esign **O**f **E**xperiment
- Develop resultant response surface models that will facilitate matching real world tire operating temperatures with roadwheel tire temperatures.
- Develop a technical standard for Light Vehicle Tires which provides equivalent test severity on a curved surface vs. a flat (real world) surface.

Action Plan: Design Of Experiments (DOE)

Phase 1, 2 & 3 Design Of Experiment (DOE) Overview:

Tire Line-up

Brand:	Size:	LI:	ASTM Phase:	Sample Size:	Tread Depth: (Mean IN)	Sect Width (Mean IN)	Sect Height (Mean IN)	T&RA Ref PSI (Max)	T&RA Ref lbs (Max)
G	P225/60R16	97	1, 2, & 3	36	0.34	8.90	5.32	35	1609
H	P225/60R16	97	1 & 2	38	0.37	9.00	5.31	35	1609
D	LT265/75R16	123 LRE	1 & 2	31	0.65	10.50	7.83	80	3415
C	LT265/75R16	123 LRE	1, 2, & 3	32	0.71	10.10	7.83	80	3415
L	P215/35R18	80W	3	20	0.32	8.60	2.95	35	805
M	LT325/65R18	127 LRE	3	20	0.70	13.00	8.38	65	3860
C	LT265/75R16	123 LRE	3	21	0.71	10.10	7.83	80	3415
N	P225/60R16	97	3	20	0.38	8.70	5.31	35	1609
P	LT315/70R16	120 LRD	3	20	0.56	12.72	8.70	50	3085
G	P225/60R16	97	3	20	0.34	8.90	5.31	35	1609



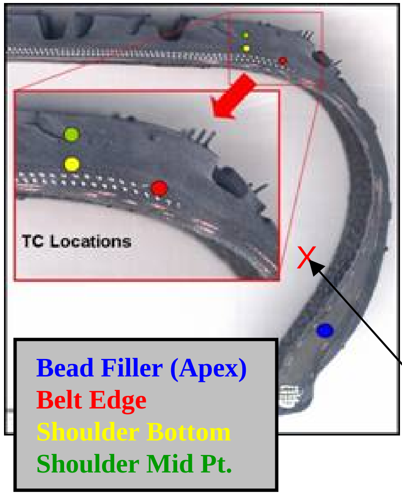
DOE Variable Range:	
Load:	85% to 115% of TRA SW Max
Pressure:	50 to 110% of TRA SW Max
Speed:	80 to 136 kph

FMVSS139 test conditions

Speed MPH (KPH)	Load % of SW Max	Type	T&RA Max Infla. PSI (Kpa)	DOT139 End Press PSI (Kpa)	Infla % of T&RA Max	DOT139 End + Low Pressure PSI (Kpa)	Infla % of T&RA Max
75 (120)	85 to 100	SL	35 (240)	26 (180)	74	20 (138)	57
75 (120)	85 to 100	XL	41 (280)	32 (220)	78	23 (159)	56
75 (120)	85 to 100	LRC	50 (350)	38 (260)	76	29 (200)	58
75 (120)	85 to 100	LRD	65 (450)	49 (338)	75	38 (262)	58
75 (120)	85 to 100	LRE	80 (550)	59 (407)	74	46 (317)	58

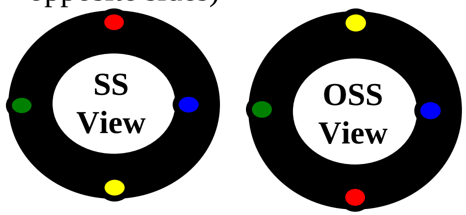
- **DOE consists of three variables at two or three levels**
- **FMVSS139 Endurance + Low Pressure conditions included within the range for tires selected**

Action Plan:
Overview of Data Acquired



Internal Tire Temps.

- **Thermocouple Locations:** (2 in each location 180 deg. apart. & opposite sides)



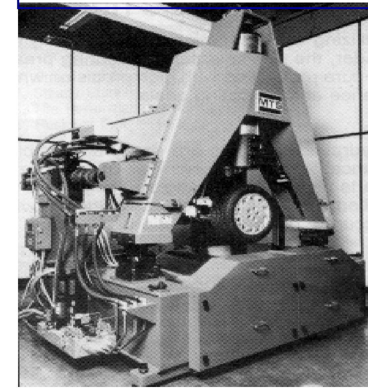
- **Contained Air Temperature and Pressure via wireless sensors mounted inside the tire**

Surface Temps.

- **Tire Surface, Track, Flat-trac and Roadwheel Temperatures via an infrared thermometer.**

Phase 1: Outdoor Test Apparatus:

Phase 3: Indoor Flat-trac:



Phase 2 & 3: Indoor 1.707m Drum:

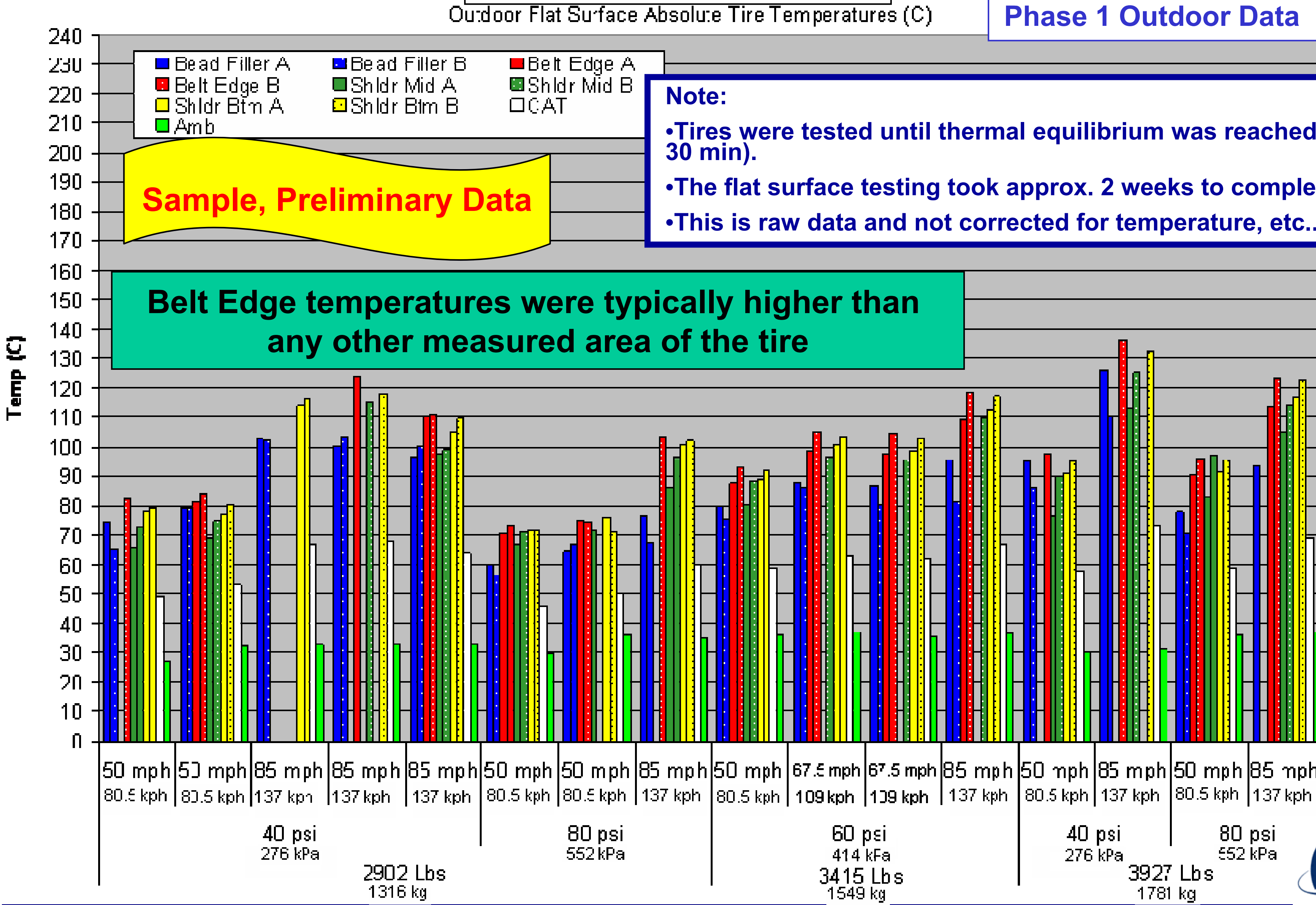
	Phase 1 Outdoor	Phase 2 Indoor	Phase 3 Indoor	Phase 3 Indoor
Location	Texas	Ohio	Ohio	Ohio
Timeframe	Jul-Aug 05'	Nov 05'	Sep 06'	Sep 06'
Ambient	75-99 deg-F (24-37 deg-C)	100 deg-F +/-5 (38 deg-C)	100 deg-F +/-5 (38 deg-C)	80-105 deg-F (25-39 deg-C)
Data Acquired				
- Belt Edge	X	X	X	X
- Shldr Lug Bottom	X	X		
- Shldr Lug Middle	X	X		
- Bead Filler	X	X		
- Tread Center			X	X
Contained Air Temp	X	X	X	X
Contained Air Pressure	X	X	X	X
Tire Surface Temps				
- Tread Cntr	X	X	X	X
- Shldr Surface	X	X	X	X
- Shldr Bottom Groove	X	X	X	X
Ambient Temps	X	X	X	X
Surface Temps	X-- Track	X-- Drum	X-- Drum	X-- Flat-trac
Wind Speed/Direction	X			

Extensive resources were contributed by many companies and individuals

Sample Results: Phase 1 Flat Surface Data

LT265/75R16 LRE All-Season

Phase 1 Outdoor Data



Note:

- **Tires were tested until thermal equilibrium was reached (≈ 30 min).**
- **The flat surface testing took approx. 2 weeks to complete.**
- **This is raw data and not corrected for temperature, etc..**

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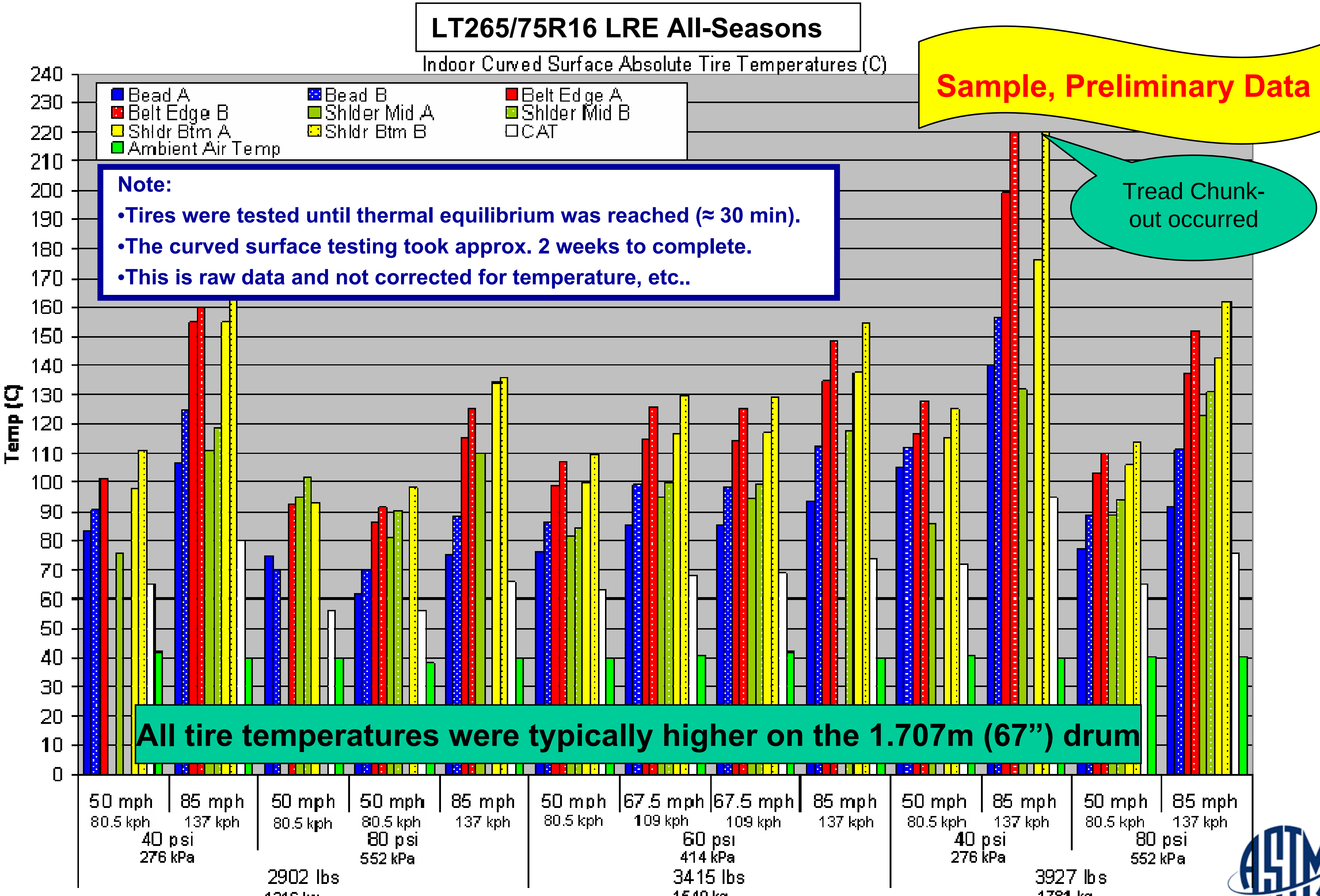
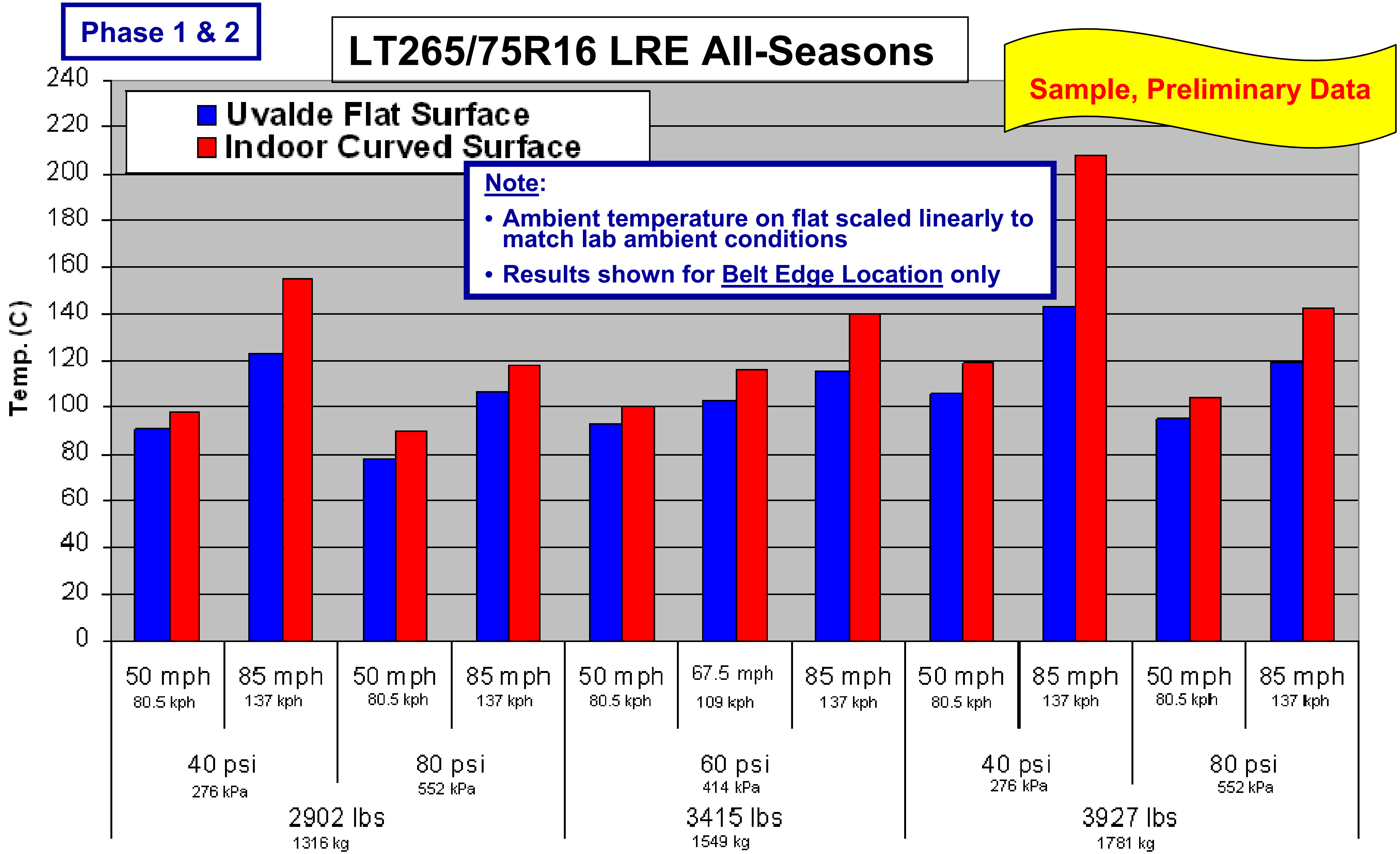
Sample Results : Phase 2 Curved 1.707m (67”) Surface Data



Sample Results: Phase 1 & 2 Flat vs. Curved Surface Data



All ambient adjusted belt edge temperatures were higher on the 1.707m (67") drum
Average Temperature Difference ≈ 20 deg-C: Highest Difference ≈ 63 deg-C

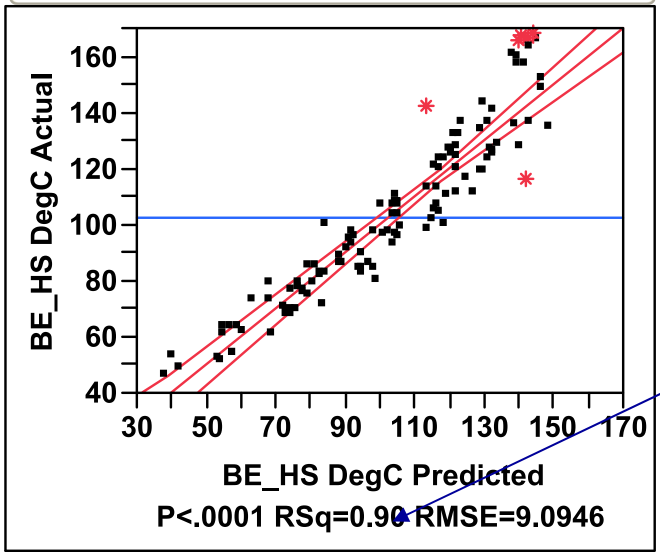
Modeling Results: Objective

- Develop surface response models with the highest R^2 values by adding pertinent engineering terms

- Substitute terms to make the models practical to use without sacrificing the quality of the fit.

Modeling Results: Latest Model (LT-metric only)

Actual by Predicted Plot

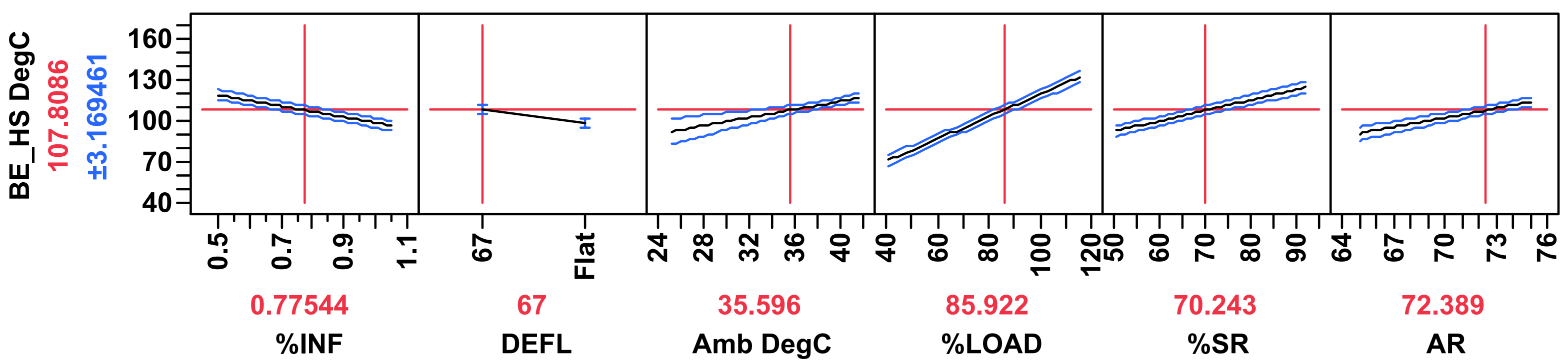


BE Model	Size	Fit	Pred Error	Outliers	Param	Prediction Residual
FINAL	235	0.92	1.8	18	7	
LTONLY	113	0.9	3.2	7	6	0.7 ± 0.5

Excellent Correlation Between Predicted and Actual Belt Edge Temperatures

Most Important Variables are Flat/curved, TRA % Load, % Speed, TRA %Inflation Pressure, Aspect Ratio (AR), and Ambient Temp.

Prediction Profiler



- This model is excellent at predicting Belt Edge Temperatures with an R^2 of 0.90
- This model applies to Lt-metric tires only up through Load Range 'E'
- P-metric tires may not need an adjustment, This is under review by the task group

Modeling Results: Confines of Model

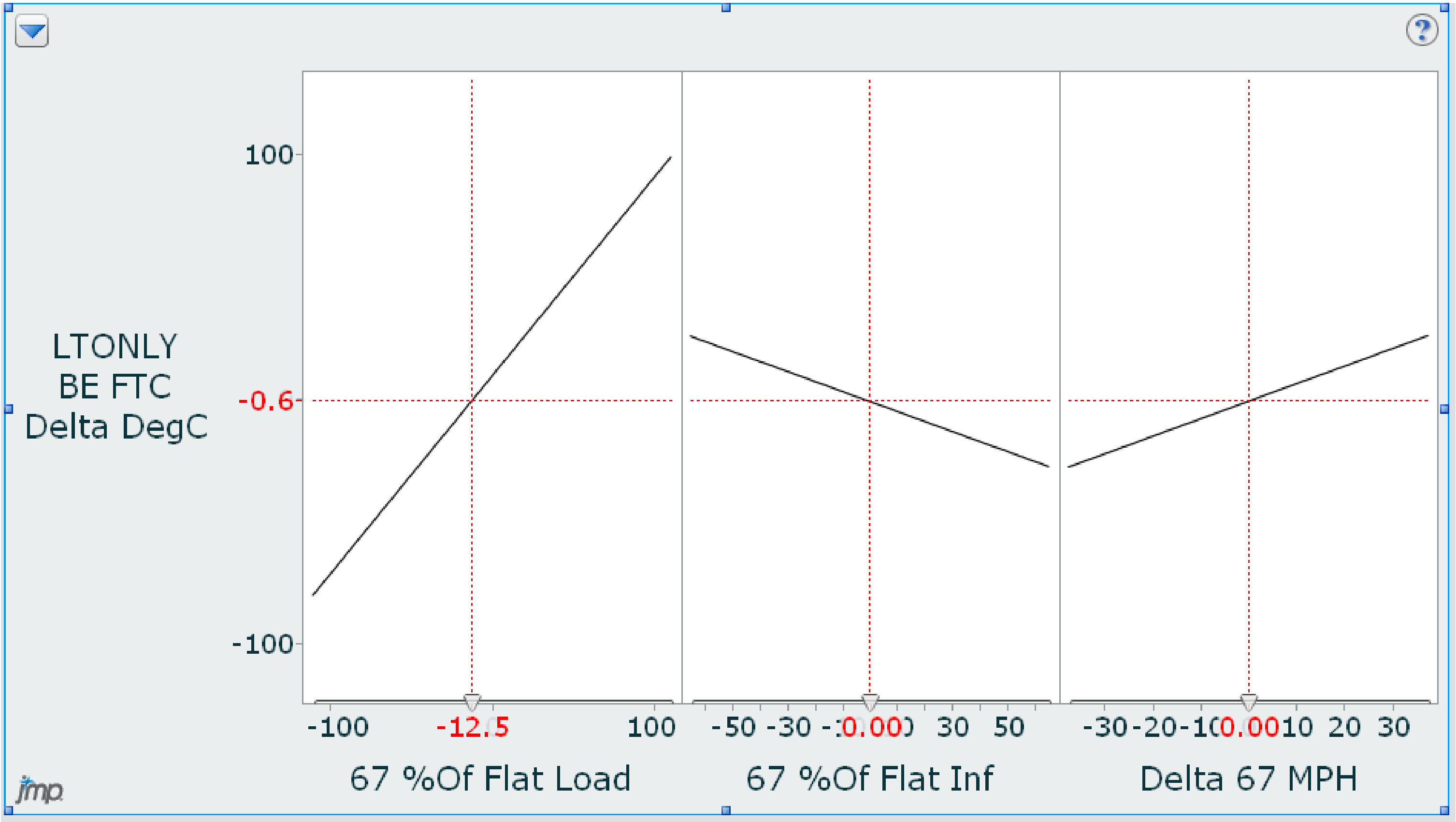
Model Range:

- Speed: 50 to 85 mph
- Inflation Pressure: 50 to 110% of T&RA SW Max.
- Load: ~50 to 115% of T&RA SW Max
- Applicable to LT-metric tires only up through Load Range 'E'

- Belt Edge (BE) temperature has an excellent fit, but, must be used within the above confines

Applications of Model: Prediction Profiler

LT-metric Tires Only up through Load Range 'E':



- **Belt Edge Temperature Prediction Profiler will be imbedded into the ASTM Practice.**
- **Allows user to predict Belt Edge Temperature differential between a flat and 1.707m surface for any combination of load, speed and inflation pressure within the confines of the model**

Applications of Model: Rule-of-Thumb (ROT) Adjustments

LT-metric Tires Only:		% T&RA Max. Load	% T&RA Max. Inflation Pressure	Test Speed
Flat to 1.707m Adjustments for Equal Test Severity (FTC)	Flat Conditions	PAR	PAR	120.7 kph (75 mph)
	1.707m Conditions	-8%	+8%	Equal
	Flat Conditions	PAR	PAR	120.7 kph (75 mph)
	1.707m Conditions	Equal	Equal	-21.7kph (13.5mph)
	Flat Conditions	PAR	PAR	120.7 kph (75 mph)
	1.707m Conditions	Equal	+23.5%	Equal
	Flat Conditions	PAR	PAR	120.7 kph (75 mph)
	1.707m Conditions	-12%	Equal	Equal
1.707m to Flat Adjustments for Equal Test Severity (CTF)	1.707m Conditions	PAR	PAR	120.7 kph (75 mph)
	Flat Conditions	+8%	-8%	Equal
	1.707m Conditions	PAR	PAR	120.7 kph (75 mph)
	Flat Conditions	Equal	Equal	+21.7kph (13.5mph)
	1.707m Conditions	PAR	PAR	120.7 kph (75 mph)
	Flat Conditions	Equal	-23.5%	Equal
	1.707m Conditions	PAR	PAR	120.7 kph (75 mph)
	Flat Conditions	+12%	Equal	Equal

Summary:

1.) An excellent Belt Edge Temperature empirical model has been developed for LT-metric tires up through Load Range 'E':

- R^2 =.90
- Model accurate to within +/- 3.17 deg-C
- Significant factors are:
  - % TRA load
  - Surface Curvature {Flat or 1.707m (67") diameter}
  - Ambient Temperature
  - % Speed
  - % TRA Inflation Pressure
  - Aspect Ratio

Model Range

- LT-metric tires up through LR 'E'
- Speed: 50 to 85 mph
- Inflation Pressure: 50 to 110% of T&RA SW Max.
- Load: ~50 to 115% of SW Max

2.) Rule-of-thumb Adjustments from flat to curved of **-8% for load** and **+8% for inflation pressure** at constant speed will provide a good approximation of equivalent test severity and belt edge temps.

3.) Prediction Profiler will be imbedded into the practice and allows user to predict Belt Edge Temperature differential between a flat and 1.707m surface for any combination of load, speed and inflation pressure within the confines of the model

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Next Steps:

1.) ASTM balloting of a ‘Practice’ is targeted for 1Q09. The practice will be for LT-metric tires only up through Load Range ‘E’. P-metric tires will not need and adjustment from a flat to curved 1.707m OD surface.

2.) Expect ASTM Practice to be approved and published 2Q09.

3.) Technical report is being developed for publication 2Q09.

4.) Review of the Technical Presentation and recommendations with NHTSA 2Q09.

Thank You !!!