ASTM F9.30
Light Vehicle Equivalent Severity Roadwheel Task Group

Summary and Status
02/02/09
Agenda:

- Background
- Objective & Scope
- Procedure
- Results
- Summary
- Next Steps
Background: Laboratory Drum Curvature Effects

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
  - 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

SURFACE = FLAT

- peak pressure ~5.9 Bar

SURFACE = 1.707m (67”) diameter

- peak pressure ~8.6 Bar

-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 Design Of Experiment
• Determine Curved Surface Operating Temperatures
  • via a lab Design Of Experiment

• 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

<table>
<thead>
<tr>
<th>Brand</th>
<th>Size:</th>
<th>ASTM</th>
<th>Sample Phase</th>
<th>Size:</th>
<th>Load % of SW Max</th>
<th>Tread Sect Sect T&amp;RA T&amp;RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>P225/60R16</td>
<td>97</td>
<td>1, 2, &amp; 3</td>
<td>36</td>
<td>85 to 100 SL 35 (240) 26 (180) 74 20 (138) 57</td>
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</tr>
<tr>
<td>H</td>
<td>P225/60R16</td>
<td>97</td>
<td>1 &amp; 2</td>
<td>31</td>
<td>85 to 100 XL 41 (280) 32 (220) 78 23 (159) 56</td>
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</tr>
<tr>
<td>D</td>
<td>LT265/75R16</td>
<td>123 LRE</td>
<td>1 &amp; 2</td>
<td>32</td>
<td>85 to 100 LRD 50 (350) 38 (260) 80 36 (256) 58</td>
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</tr>
<tr>
<td>C</td>
<td>LT265/75R16</td>
<td>123 LRE</td>
<td>1, 2, &amp; 3</td>
<td>32</td>
<td>85 to 100 LRE 80 (550) 59 (407) 74 46 (317) 58</td>
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</tr>
</tbody>
</table>

### FMVSS139 test conditions

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

- **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)

**Surface Temps.**

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

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**Data Acquired**

<table>
<thead>
<tr>
<th>Location</th>
<th>Phase 1 Outdoor</th>
<th>Phase 2 Indoor</th>
<th>Phase 3 Indoor</th>
<th>Phase 3 Indoor</th>
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<tbody>
<tr>
<td>Location</td>
<td>Texas</td>
<td>Ohio</td>
<td>Ohio</td>
<td>Ohio</td>
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<tr>
<td>Timeframe</td>
<td>Jul-Aug 05’</td>
<td>Nov 05’</td>
<td>Sep 06’</td>
<td>Sep 06’</td>
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<tr>
<td>Ambient</td>
<td>75-99 deg-F (24-37 deg-C)</td>
<td>100 deg-F +/-5 (38 deg-C)</td>
<td>100 deg-F +/-5 (38 deg-C)</td>
<td>80-105 deg-F (25-39 deg-C)</td>
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<tr>
<td>- Belt Edge</td>
<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>- Shldr Lug Bottom</td>
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<tr>
<td>- Shldr Lug Middle</td>
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<td></td>
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</tr>
<tr>
<td>- Bead Filler</td>
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<td>- Tread Center</td>
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<tr>
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<tr>
<td>- Tread Cntr</td>
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<td>X</td>
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<tr>
<td>- Shldr Surface</td>
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<td>X</td>
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<td>X</td>
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<tr>
<td>- Shldr Bottom Groove</td>
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<tr>
<td>Ambient Temps</td>
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<tr>
<td>Surface Temps</td>
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<tr>
<td>Wind Speed/Direction</td>
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</tbody>
</table>

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**Extensive resources were contributed by many companies and individuals.**

ASTM Preliminary F-09.30 Information
Sample Results: Phase 1 Flat Surface Data

**LT265/75R16 LRE All-Season**

Outdoor Flat Surface Absolute Tire Temperatures (°C)

**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..

**Sample, Preliminary Data**

Belt Edge temperatures were typically higher than any other measured area of the tire

**ASTM Preliminary F-09.30 Information**
Sample Results: Phase 2 Curved 1.707m (67”) Surface Data

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

All tire temperatures were typically higher on the 1.707m (67”) drum.

Sample, Preliminary Data

Tread Chunk-out occurred.
Sample Results: Phase 1 & 2 Flat vs. Curved Surface Data

LT265/75R16 LRE All-Seasons

Note:
- Ambient temperature on flat scaled linearly to match lab ambient conditions
- Results shown for Belt Edge Location only

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**
  - Excellent Correlation Between Predicted and Actual Belt Edge Temperatures
  - P<.0001 RSq=0.90 RMSE=9.0946

- **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

- **Prediction Profiler**

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

- 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

<table>
<thead>
<tr>
<th>LT-metric Tires Only:</th>
<th>% T&amp;RA Max. Load</th>
<th>% T&amp;RA Max. Inflation Pressure</th>
<th>Test Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat to 1.707m</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustments for</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Equal Test Severity</td>
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<tr>
<td>(FTC)</td>
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<tr>
<td>Flat Conditions</td>
<td>PAR</td>
<td>PAR</td>
<td>120.7 kph (75 mph)</td>
</tr>
<tr>
<td>1.707m Conditions</td>
<td>-8%</td>
<td>+8%</td>
<td>Equal</td>
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<tr>
<td>Flat Conditions</td>
<td>PAR</td>
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<td>120.7 kph (75 mph)</td>
</tr>
<tr>
<td>1.707m Conditions</td>
<td>Equal</td>
<td>Equal</td>
<td>-21.7 kph (13.5 mph)</td>
</tr>
<tr>
<td>Flat Conditions</td>
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</tr>
<tr>
<td>1.707m Conditions</td>
<td>Equal</td>
<td>+23.5%</td>
<td>Equal</td>
</tr>
<tr>
<td>Flat Conditions</td>
<td>PAR</td>
<td>PAR</td>
<td>120.7 kph (75 mph)</td>
</tr>
<tr>
<td>1.707m Conditions</td>
<td>-12%</td>
<td>Equal</td>
<td>Equal</td>
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<td>1.707m to Flat</td>
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<td>Equal Test Severity</td>
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<tr>
<td>(CTF)</td>
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<tr>
<td>Flat Conditions</td>
<td>+8%</td>
<td>-8%</td>
<td>Equal</td>
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<td>1.707m Conditions</td>
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<td>1.707m Conditions</td>
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<td>PAR</td>
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<tr>
<td>Flat Conditions</td>
<td>+12%</td>
<td>Equal</td>
<td>Equal</td>
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</tbody>
</table>
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

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.
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 !!!