Fuel Economy Study

Effects of Unbalance Tire / Wheel Conditions

Clemson Tire Conference

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Itinerary

- Background Statement
- Objective
- Procedure
- Results
- Conclusions

Background Statement

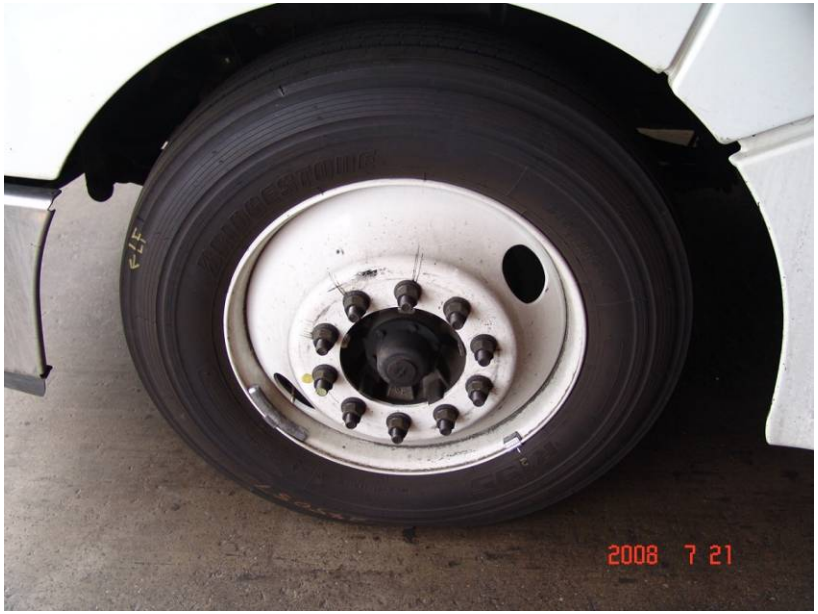
- Tire, tire/wheel assembly, or axle end total rotating mass balance/uniformity has been identified as a way to:
  - smooth ride or vibrations
  - reduce driver fatigue
  - reduce vibration related vehicle component fatigue
  - reduce vibration related payload damage
  - extend tire tread life
  - reduce the occurrence or severity of tread irregular wear
  - improve casing durability for retreadability
  - significantly improve vehicle fuel economy

Objective

- To evaluate the impact on fuel consumption resulting from the deliberate unbalancing of all wheel positions on a tractor / trailer combination

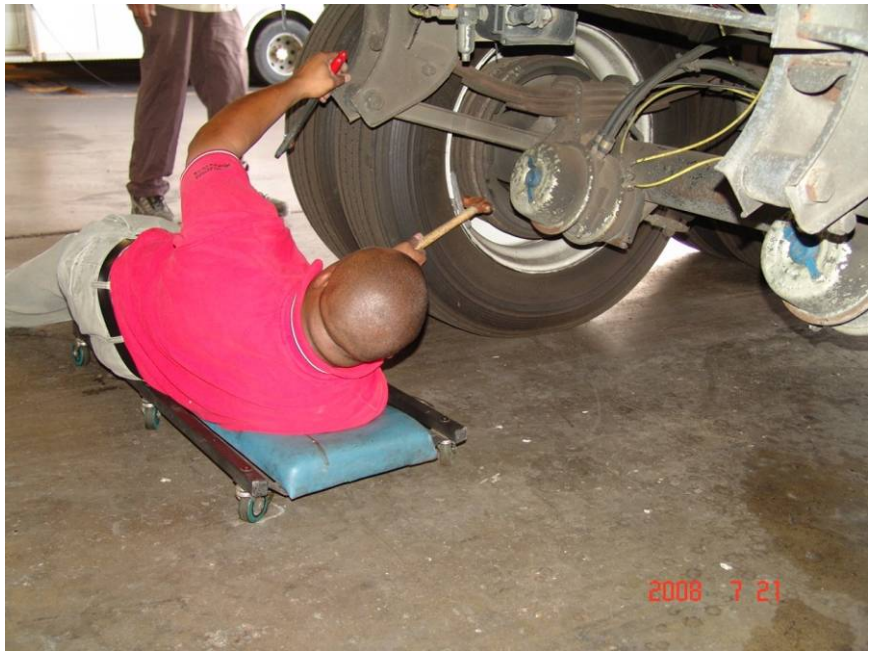
Procedure

- Tires used for test vehicle
  - 285/75R24.5 Bridgestone R195 (G) – all wheel positions
    - All tires run 10,000 miles ± 0.02
    - Drive position – Bridgestone CDS tractors
      - Stabilize casing growth
      - Stabilize initial compound change
    - New steel wheels (Accuride)



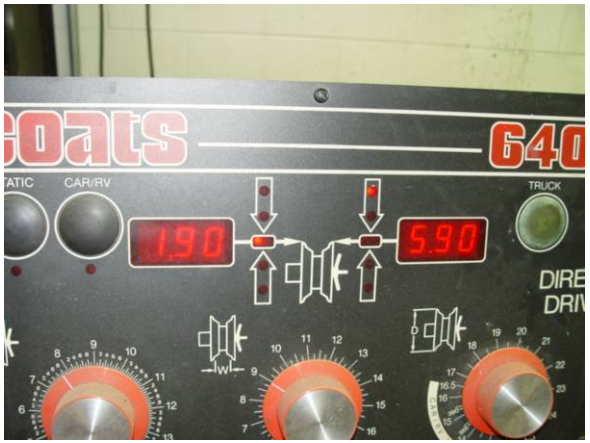
Procedure

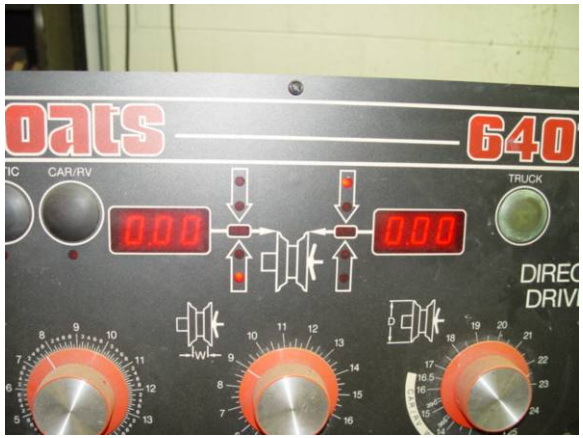
- Tires used for test vehicle (continued)
  - Control configuration
    - Tires dynamically balanced at the Bridgestone Technical Center
  - Test configuration
    - Added 16 oz weight to all wheels to create imbalance
    - On dual assemblies, weights placed at same clock position so effect was cumulative.

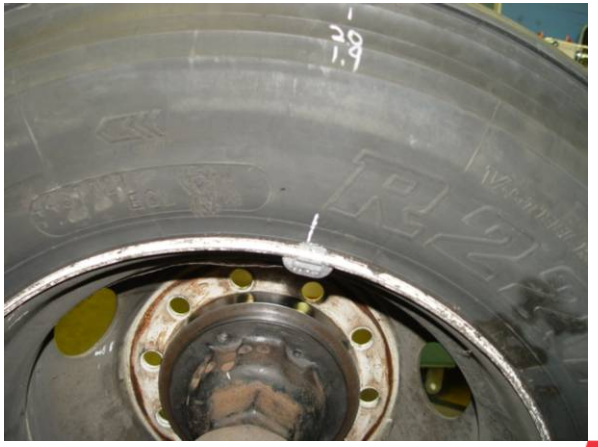


Procedure (continued)

- Verification of balanced / unbalanced condition accuracy
  - Test of balance equipment performed at the Bridgestone LaVergne, TN Technical Center.
  - Balance machine calibrated by machine's manufacturer
  - All balance procedures performed by Technical Center's Manager and observed/verified by Bridgestone Engineer
  - Tire/wheel assembly balanced to 0 / 0
    - Balancing weights installed
    - Locations of weights marked on tire

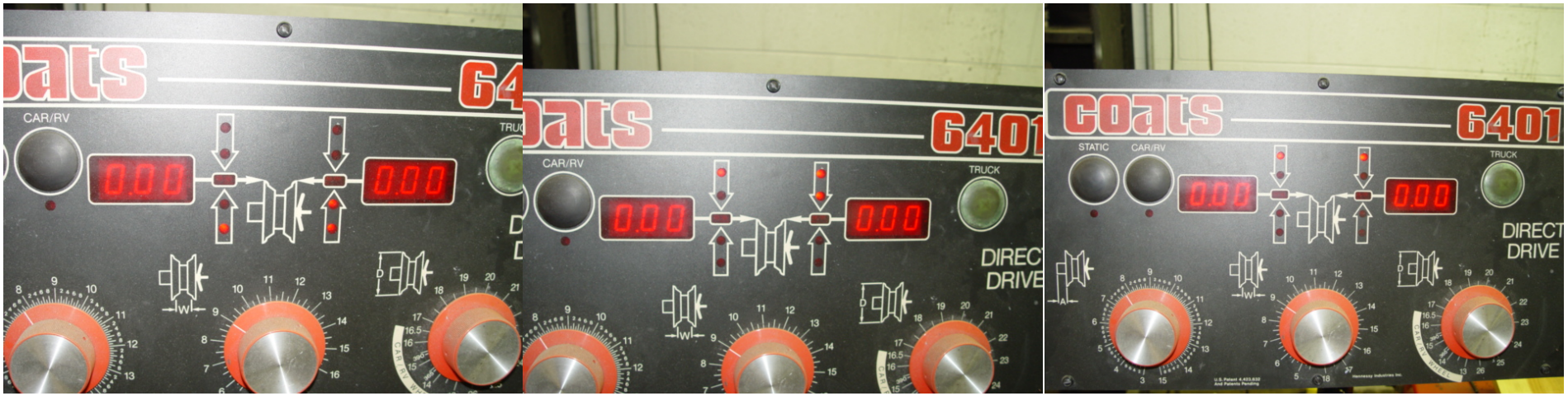






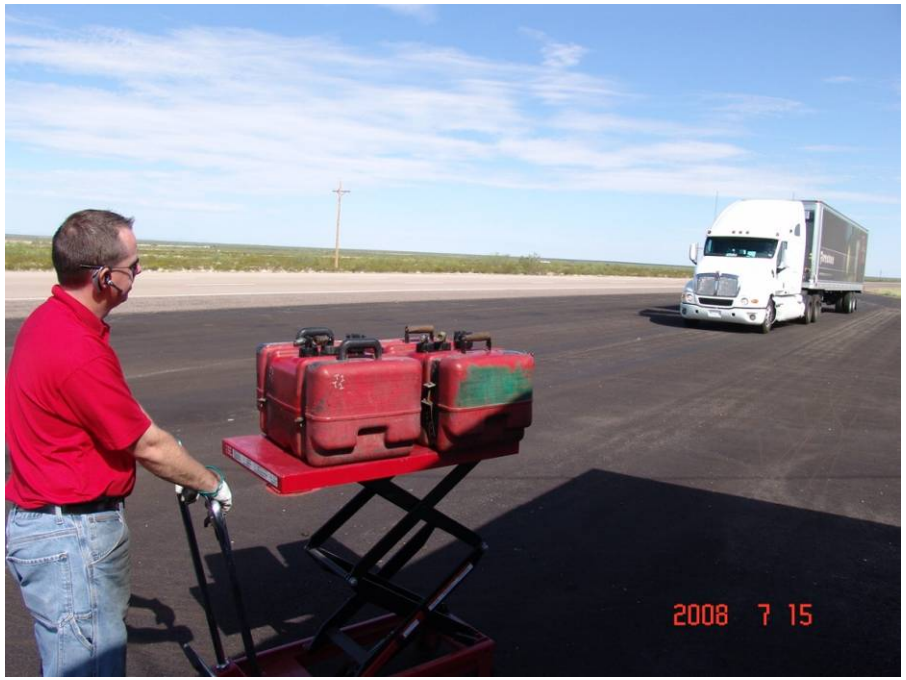
Procedure (continued)

- Verification of balanced / unbalanced condition accuracy
  - Tire/wheel assemblies balanced; weight amount and location marked
  - Weights removed, unbalance condition verified on balance machine
  - Weights reinstalled at marked locations
  - Verification of restoring 0 / 0 balance condition
  - Procedure repeated (33) times to establish statistical significance



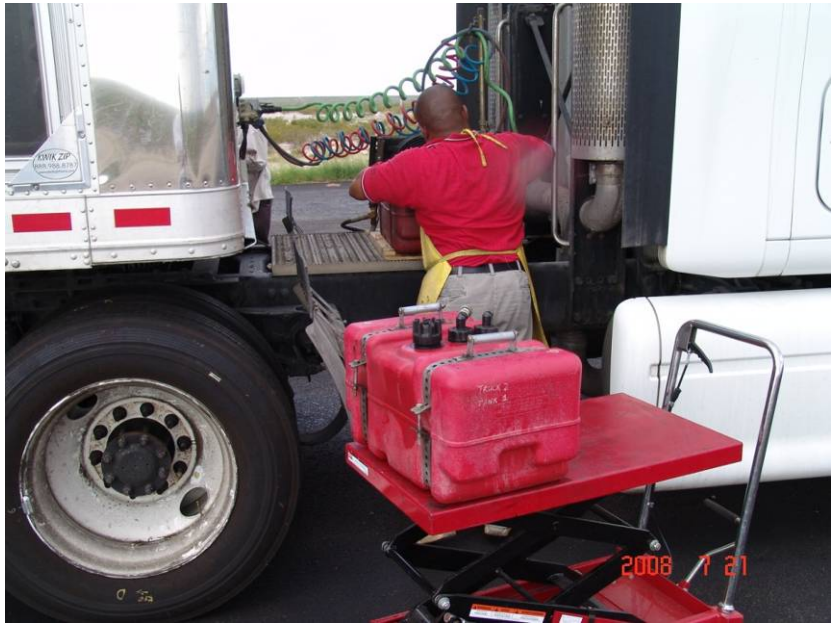
Procedure (continued)

- Testing performed July, 2008 at the Bridgestone Texas Proving Ground (7.712 mile oval)
- Joint TMC/SAE Fuel Consumption Test Procedure – Type II, SAE J-1321.
- Vehicles (2)
  - Brand: Peterbilt
  - Model: 387
  - Engine: Cat C-15, 475/1200
  - Trans: Fuller RTL018913A
  - Trailers: Great Dane 48’
  - Test speed: 55 mph (88.5 kph)
  - Test weight: 80,000 lbs ± 0.002



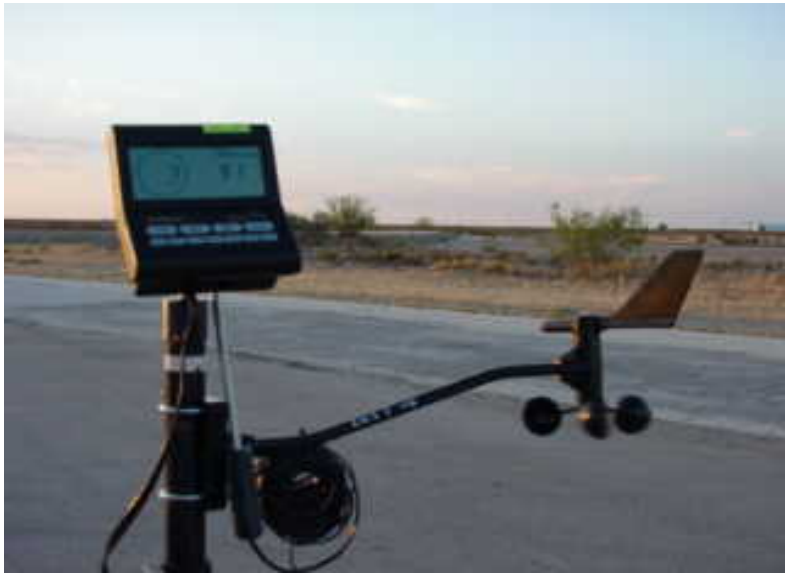
Procedure (continued)

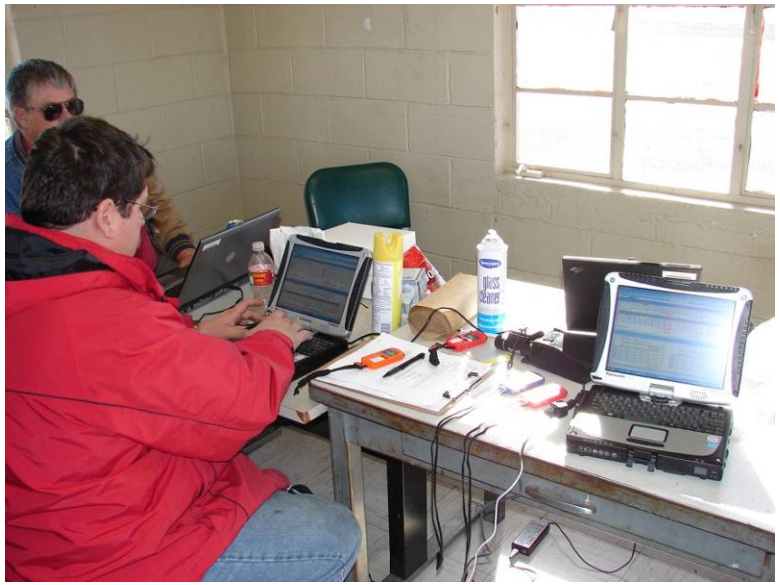
- (2) vehicles: Control / Test
- Detachable / portable fuel tanks
- Scale certified accurate to within 1/20th lb.
- Isolated fuel source



Procedure (continued)

- Professional drivers
- Minimum of (2) engineers monitoring test at all times
- Vehicle ECM(s) set to identical specs
- Weather monitoring equipment
- GPS + Stop watches





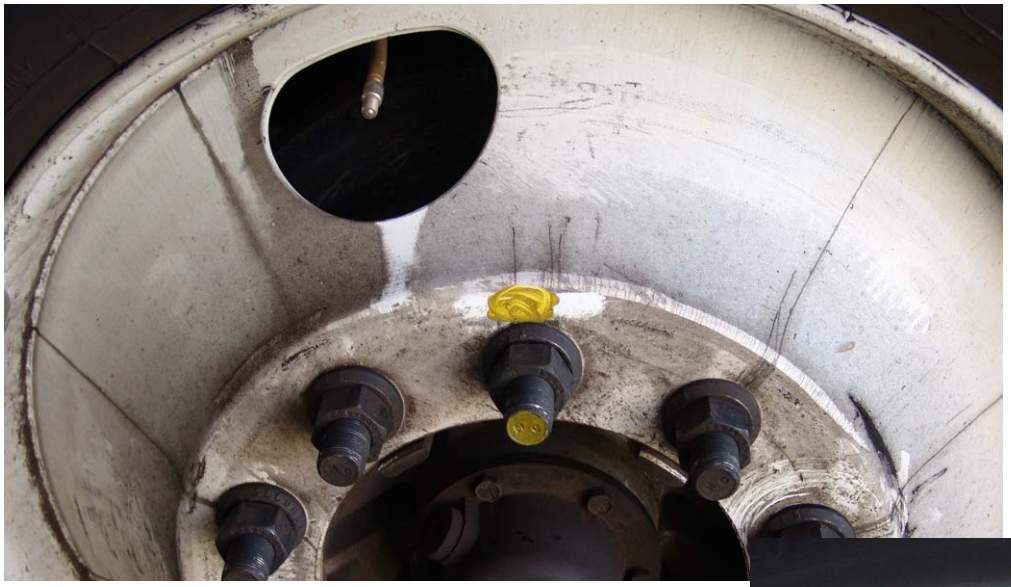
Procedure (continued)

- Prior to testing
  - Vehicles loaded and weighed
  - Driver / engineer meeting
    - Test schedule
    - Speed
    - Communications
    - Vehicle settings (i.e. windows up, lights on, A/C on at all times)
  - Set up cones to mark track location for
    - Disengaging cruise control
    - Begin brake application
    - Stopping point
  - New fuel filters installed
  - All fluid levels checked (repeated each morning)
  - All tires checked for inflation pressure (repeated each morning – cold)

Procedures (continued)

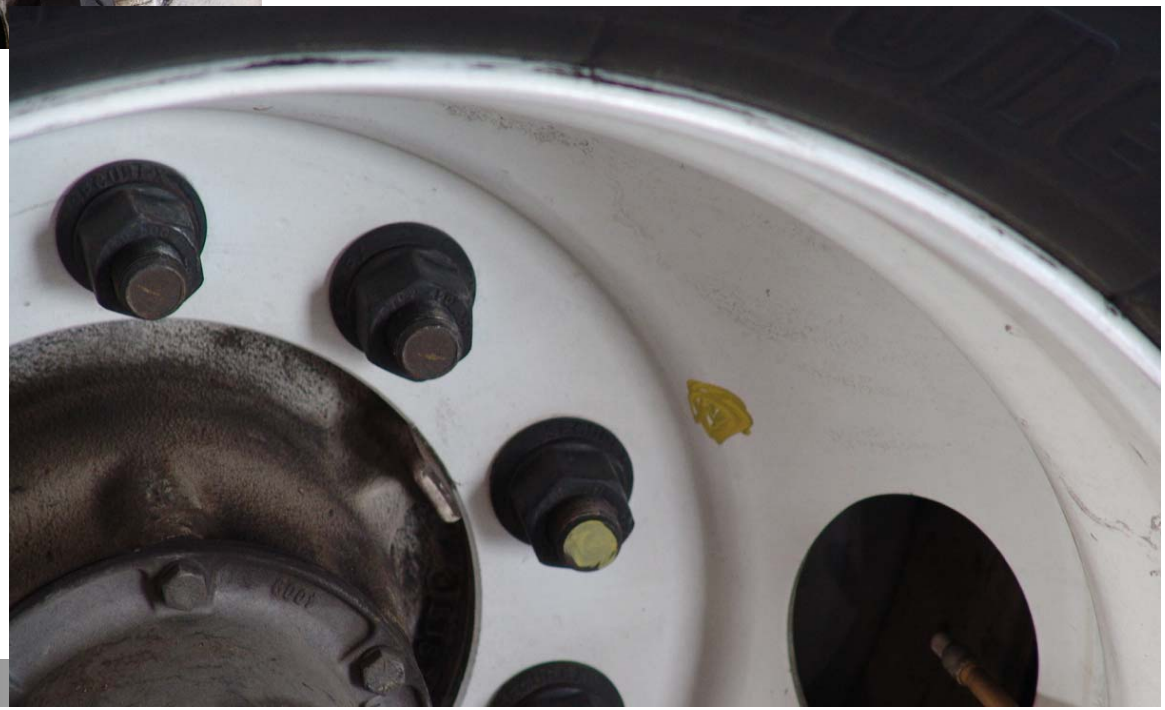
- J-1321 highlights
  - Control vehicle + test vehicle
  - One hour warm up
  - Run Baseline segment and determine initial T/C fuel economy ratio between the vehicles
  - Make desired modification to test vehicle (control vehicle always remains constant)
  - One hour warm up
  - Run Test segment and determine final T/C fuel economy ratio between the vehicles
  - Calculate effect of change between Baseline and Test segments
  - Repeat all of above to verify repeatability

Remounting modified assemblies



Single

In the event of any needed tire service that required the assemblies to be dismounted from the vehicles they could be reinstalled with the same tire/wheel assembly to the same wheel position in the same position relative to the drum and hub assembly. None was required.



Dual

Procedures (continued)

- How a segment is run
  - Both vehicles warm up for one hour
  - Vehicles stop at predetermined / marked points
  - Pre-weighed fuel tanks installed on both vehicles
  - Start control vehicle
    - Activate stop watch when engine fires
    - Driver immediately accelerates to test speed
  - At elapsed time of 3.5 minutes (½ lap) start test vehicle
    - Activate stop watch when engine fires
    - Driver immediately accelerates to test speed
  - Both trucks run 6 laps (>40 miles) at test speed
    - Speed verified each lap using stop watches and GPS
  - At end of 6 laps, vehicles stop at marked stopping point
  - Both trucks idle for (1) minute (timed) before engine shutdown
  - Remove fuel tanks, install new pre-weighed fuel tanks
  - Weigh fuel tanks removed

Procedures (continued)

- How a test segment is run
  - Repeat procedure a minimum of three runs per segment
  - J-1321 requires (3) runs with T/C ratios within 2% for each segment
  - Maximum of (5) runs allowed to achieve the (3) runs within the 2%
  - Run times monitored to assure they meet J-1321 requirements
  - T/C ratio calculated by dividing weight of fuel burned by test vehicle by weight of fuel burned by control vehicle
  - During all runs
    - Start / end times recorded
    - Elapsed run time monitored and recorded
    - Weather conditions monitored and recorded (i.e. temp, wind speed, wind direction)
- Upon completion of Baseline and Test segments, percent of change calculated
- J-1321 results are accurate to ± 1%: any percent difference less than ±1% must be considered equal

Procedures (continued)

- Example of a segment data sheet

			Control Vehicle		Test Vehicle 'BaseLine'	
Test Number:	Baseline - Pete		Vehicle Type:	Peterbilt 387	Vehicle Type:	Peterbilt 387
Test Coordinator:	J. Garrett		Vehicle No:	903 Red / 702670	Vehicle No:	904 White / 702671
			Driver:	Manny	Driver:	Joe
Test Date:	07/23/08		Tire Configuration	GVW	Tire Configuration	GVW
			Position / Size / Pattern	Load / Inf.	Position / Size / Pattern	Load / Inf.
Test Speed:	Control Truck	55	Steer: LP 24.5 / R 195	11930 / 110	Steer: LP 24.5 / R 195	12096 / 110
	Test Truck	55	Drive: LP 24.5 / R195	34408 / 100	Drive: LP 24.5 / R 195	34060 / 100
			Trailer: LP 24.5 / R195	34028 / 100	Trailer: LP 24.5 / R195	34052 / 100
# of Laps per Run:	6		Total GVW	80366	Total GVW	80208

Run #	Time Start	Time Finish	Amb. Temp.	Wind Spd / Dir.	Tank No.	Tank Weight (lbs) Start	Tank Weight (lbs) Finish	Fuel Used (lbs)	Run Time	Tank No.	Tank Weight (lbs) Start	Tank Weight (lbs) Finish	Fuel Used (lbs)	Run Time	Test T/C	Final T/C
1	10:17	11:12	83	6/ESE	1	91.15	41.80	49.35		2	92.45	44.95	47.50		0.9625	
2	11:13	12:08	86	5/ESE	3	92.20	41.05	51.15		4	93.10	42.90	50.20		0.9814	0.9814
3	12:08	1:03	89	8/SE	5	88.50	36.35	52.15		6	90.45	39.20	51.25		0.9827	0.9827
4	1:03	1:58	94	8/SE	1	98.30	45.05	53.25		2	95.70	44.05	51.65		0.9700	0.9700
5	1:59				3	83.20				4	86.60					
						Mean:		51.48				23	50.15	Mean:	0.9742	0.9780
						Avg. MPG:		6.43				Avg. MPG:	6.60			

Validation of Test:

T/C Range: 0.0128 % of Mean T/C: 1.3076

TEST RESULTS ARE ACCEPTABLE

Notes: Wednesday morning

Humidity 37.2% Pressure 30.02 inHg

Test Weight = 53.10

Procedures (continued)

- Example of a time record

Test # BL Run 1

	Test Truck				
	Total Lapsed Time		Individual Lap Time		Total Lapsed Time Plus or Minus
	Minutes	Seconds	Minutes	Seconds	Seconds
Lap 1	8	55	8	55	0
Lap 2	17	19	8	24	1
Lap 3	25	44	8	25	1
Lap 4	34	8	8	24	1
Lap 5	42	34	8	26	0
Lap 6	51	9	8	35	0

Plus is Too Fast
Minus is Too Slow

Test Truck

Target Times	Minutes	Seconds	Minutes	Total
Lap 1	8	55	8.92	8.92
Lap 2	8	25	8.41	17.33
Lap 2	8	25	8.41	25.74
Lap 4	8	25	8.41	34.16
Lap 5	8	25	8.41	42.57
Lap 6	8	35	8.58	51.15
Total	51	9	51.15	

Test Truck Target Speed 55 MPH

Track Length 7.712 Miles
Lap Time 8.41 Minutes or 8 Minutes 24.79 Seconds

8.00 51.00

	Minutes			
Lap 1	8.92		8.00	
Lap 2	17.32	8.40	17.00	8.00
Lap 3	25.73	8.42	25.00	8.00
Lap 4	34.13	8.40	34.00	8.00
Lap 5	42.57	8.43	42.00	8.00
Lap 6	51.15	8.58	51.00	8.00

	Control Truck				
	Total Lapsed Time		Individual Lap Time		Total Lapsed Time Plus or Minus
	Minutes	Seconds	Minutes	Seconds	Seconds
Lap 1	8	54	8	54	0
Lap 2	17	20	8	26	-1
Lap 3	25	43	8	23	1
Lap 4	34	8	8	25	0
Lap 5	42	33	8	25	0
Lap 6	51	7	8	34	0

Plus is Too Fast
Minus is Too Slow

Test Truck

Target Times	Minutes	Seconds	Minutes	Total
Lap 1	8	54	8.90	8.90
Lap 2	8	25	8.41	17.31
Lap 2	8	25	8.41	25.73
Lap 4	8	25	8.41	34.14
Lap 5	8	25	8.41	42.55
Lap 6	8	34	8.57	51.12
Total	51	7	51.12	

Control Truck Target Speed 55

Track Length 7.712 Miles
Lap Time 8.41 Minutes or 8 Minutes 24.79 Seconds

8.00 51.00

	Minutes			
Lap 1	8.90		8.00	
Lap 2	17.33	8.43	17.00	8.00
Lap 3	25.72	8.38	25.00	8.00
Lap 4	34.13	8.42	34.00	8.00
Lap 5	42.55	8.42	42.00	8.00
Lap 6	51.12	8.57	51.00	8.00

Results

Baseline 1	T/C Ratio
Run 1	0.9658
Run 2	0.9758
Run 3	1.0028
Run 4	0.9815
Run 5	N/A
Final	0.9744

Baseline 2	T/C Ratio
Run 1	0.9625
Run 2	0.9814
Run 3	0.9827
Run 4	0.9700
Run 5	N/A
Final	0.9780

Baseline 1	0.9744
Baseline 2	0.9780
Average	0.9762
Std.Dev	0.0025

- Baseline Segments
  - To determine the difference between the control vehicle and the test vehicle
  - Run with all tires on test vehicle dynamically balanced
  - Run twice to confirm repeatability
  - Runs fall within the required +/- 2% accuracy of the test
  - Established baseline at T/C ratio of 0.9762.

Results (continued)

Test 1	T/C Ratio
Run 1	1.0062
Run 2	0.9749
Run 3	0.9755
Run 4	0.9887
Run 5	N/A
Final	0.9797

Test 2	T/C Ratio
Run 1	0.9824
Run 2	0.9825
Run 3	0.9868
Run 4	N/A
Run 5	N/A
Final	0.9839

Test 1	0.9797
Test 2	0.9839
Average	0.9818
Std.Dev	0.0030

- Test Segments
  - To determine the difference between the test vehicle with balanced tires and with unbalanced tires
  - Run with all tires on test vehicle 16 oz. unbalanced
  - Run twice to confirm repeatability
  - Runs fall within the required +/- 2% accuracy of the test
  - Established test at T/C ratio of 0.9818.

Results (continued)

- Percent of improvement

$$\frac{\text{Baseline T/C Ratio - Test T/C Ratio}}{\text{Test T/C Ratio}} \text{ X } 100 = \text{Percent of Improvement}$$

$$\frac{0.9762 - 0.9818}{0.9818} \text{ X } 100 = -0.57\%$$

Conclusions

- Testing resulted in a percent of improvement of (-0.57%)
- SAE J-1321 testing is accurate to within ±1%
- Any test results with a smaller percent of change than the test's accuracy must be considered equal
- Balancing of the tire/wheel assemblies has no measurable effect on fuel consumption

Thank you