AUTO RESEARCH CENTER LLC.

CLASS EIGHT SEMI TRUCK AERODYNAMIC

FUEL ECONOMY COMPONENT TEST

May 14, 2013

Conducted by:

Auto Research Center LLC.

For

Transtex Composite Inc.

PRODUCTS TESTED

Transtex Model: Transtex Skirt 19-32

TABLE OF CONTENTS

Section	Title	Page
	Table of Contents	2
1.0	Objective	3
2.0	Approach	3
3.0	Why is this modification needed?	4
4.0	Summary of Results	4
5.0	Description of Test Vehicle	4
6.0	Description of Test Facility	11
7.0	Test Procedure	14
8.0	Data Reduction	14
9.0	Conclusions	15
	APPENDIX A	16

1.0 OBJECTIVE

Transtex conducted a rolling road wind tunnel test at the Auto Research Center (ARC) in Indianapolis, Indiana. The objective was to report the fuel economy change of each item over a range of varying road speeds. This test was conducted to compare the baseline of an already approved SmartWay aerodynamic device with a modified/changed device.

The installation configuration originally used and verified by EPA SmartWay as an advanced trailer skirt positions the majority of the devices surface on the outside edge of the trailer. The new installation configuration provides an extra 2 inch height and reduce length of 4 ft. To insure the same amount or more fuel is being saved using this modified device the square footage of the device has been increase to offset the drag created by the air hitting the exposed trailer cross members.

2.0 APPROACH

ARC measured and scanned what was necessary as well as utilized detailed drawings provided by Wabash to duplicate a 1/8 scale trailer model. Cad data was provided to ARC for each of the products and their mounting specification by the manufacturer of the products tested. All items tested were pre-manufactured and pre-fit on the model prior to the test date.

ARC provided a Navistar Prostar Sleeper in combination with a Wabash 53 foot Trailer. The model was a detailed 1/8 scale model of this configuration. Every detail of the full scale tractor/trailer that touches the air was accurately modeled. This model had articulating suspension and rotating wheels. Every part of this model was adjustable (i.e. trailer/tractor gap or bogey position). ARC also provided the rolling road testing facility, model makers, technicians, aerodynamicists and computer hardware and software for data reduction.

The test consisted of two phases: 1) Setting the initial baseline; 2) Component testing of the changes to the tractor/trailer. To set the baseline, a reference tractor trailer gap was used with a conventional bogey position. All testing was completed at 50 m/s. All tests were conducted with multiple yawing angles sweeping the model through the following yaw angles (0 deg; 9 deg; 6 deg; 3 deg; 1 deg; 0 deg; -1 deg; -3 deg; -6 deg; -9 deg; 0 deg). Preceding every individual test run were two model tares. The first was a static weight tare, which removed the static weight of the model. The second was a rolling tare without wind completed at 50 m/s which removed any mechanical drag imparted on the balance through the rotating wheels. For the second tare, multiple tares were recorded for each yaw angle listed in the sequence above for EACH run.

All aerodynamic forces were measure using an AEROTECH 6 component load cell balance. This balance provided three forces: Lift, Drag and Side force as well as three moments: Pitch, Roll and Yaw moments. The repeatability recorded during our baseline setting was under 0.25% for fuel economy.

3.0 WHY IS THIS MODIFICATION NEEDED BY FLEETS?

Transtex's clients are working very hard to reduce GHG's and save fuel. This is being accomplished by installing aerodynamic devices on the trailer and using intermodal service where possible. Additionally it should be noted that this modification is especially attractive to customers who utilize their equipment extensively in inner city or non-highway operations because it moves the skirt in board out of harms way.

4.0 SUMMARY OF RESULTS

The individual results for each yaw angle were measured and put through the SAE recommended process for wind averaging. The wind averaged Cd values for the individual speeds were then cross referenced to a study completed by NASA that related the fuel economy savings for each percentage change in drag at various speeds. A summary of the results are shown in table format. A negative value reflects an improvement over the baseline tractor/trailer combination. All values are given in percent (%) improvement.

5.0 DESCRIPTION OF TEST VEHICLE

The test vehicle used was a 1/8 scale tractor and trailer. The tractor was a Navistar Prostar sleeper. The trailer was a 53 foot Wabash trailer. The model had articulating suspension. It also included pressure taps that were not used for this test. Any part of the tractor/trailer that touched the air was accurately represented in this model. This model also included internal flow modeling from the tractor grill into the radiator and then into the engine bay. The bogey was adjustable for multiple positions. Pictures of the model used are below.

Navistar Prostar Sleeper Tractor & Wabash Trailer

Navistar Prostar Sleeper Tractor

Front of Wabash 53’ Trailer

Tractor/Trailer Starting Configuration - Truck to trailer Gap of 45” with a 36” trailer king pin position

Wabash Trailer Landing Gear

Rivets on Side of Wabash Trailer

Rear Door & Bumper of Wabash Trailer

Trailer Boggy positions is 40’ from the center line of rear axle to the king pin

Transtex Model 23-30 EPA SmartWay Verified Skirt:

Trantex's Model 23-30 EPA SmartWay Verified Skirt: second view

Transtex Model Transtex 19-32 modified EPA SmartWay Verified skirt

Transtex Model Transtex 19-32 modified EPA SmartWay Verified skirt second view

6.0 DESCRIPTION OF TEST FACILITY

Wind Tunnel

Type	Closed single return tunnel with 3/4 open-jet working section and moving ground plane
Construction	Tubular steel frame with birch plywood skin, 20mm thick, 9 ply, controlled grain panel
Corner turning vanes	Rolled steel vanes welded into assemblies
Air settling	Two stainless steel settling screens 1800mm apart at the entrance to the contraction
Mesh screen specification	57.4% open area, 1mm aperture size
Air straightening	Honeycomb wall in settling chamber, 75mm thick x 10mm core size
Tunnel volume	1,111 m^3 (39,235 ft^3)
Surface area	2,147 m^2 (23,110 ft^2)
Average duct area	13.94 m^2 (150 ft^2)
Circuit length	75.84 m (249 ft.)
Temperature control	Water cooled to ± 1° C (1.8° F) by a cooling coil

Working Section

Type	3/4 open jet contained in a plenum
Length	Adjustable up to 5.75 m (18.9 ft.)
Contraction ratio	4.46:1
Maximum air velocity	50.0 m/s (164.0 ft./s) CDP
Maximum dynamic pressure	1,513 Pa (31.60 lb./in.) at standard conditions
Nozzle width	2.500 m (7.414 ft.)
Nozzle height	2.060 m (6.824 ft.)
Plenum dimensions	10.62 m (34.8 ft.) W, 16.46 m (54.0 ft.) L, 8.28 m (27.2 ft.) H
Plenum NET volume	1,141 m^3 (40,294 ft^3)
Maximum model scale	50% open wheel, 40% yawed +/-8° NASCAR
Maximum model height above road	330 mm
Strut movement rate	8 mm/sec
Strut movement time from 10 mm to 330 mm	39.5 sec
Model support	A vibration isolated balance frame surrounds the working section and supports the model strut. The strut position is fully adjustable to accommodate model geometry.
Primary boundary-layer slot	0.050 m (0.197 ft.) high
Boundary-layer elimination	Three stage fully adjustable system

Fan Section

Fan description	Fixed geometry single stage axial pusher fan with nine equally spaced carbon fibre blades
Fan diameter	3.790 m (12.434 ft.)
Fan power	373 kW (500 hp) variable speed DC motor
Maximum rotational speed	610 rpm
Maximum tip speed	121.1 m/s (397.2 ft./s)
Fan support	Fourteen upstream stators with pre-rotation shrouds, eleven down-stream stators with flow straightening shrouds
Fan mechanical drive	Two-piece drive shaft on axis of tunnel through turning vane
Fan section total weight	21,729 kg (48,000 lb.)

Moving Ground Plane (Rolling Road)

Construction	Tubular Steel Frame, concrete filled with Cast Iron Platen
Yaw table	5.18 m diameter
Yaw range	+/- 8.0º
Moving ground length	4.180 m (13.58 ft.)
Moving ground width	1.66 m (5.44 ft.)
Belt type	Ammeraal Flexam with Sandblast Profile
Maximum belt speed	50.0 m/s (164.0 ft./s) CDP
Belt suction	33 individually controlled suction chambers
Platen instrumentation	33 pressure sensors and 71 K-type thermocouples
Temperature control	Water cooled to +/-3.0° C (+/-5.4° F) with 110 cooling tubes
Steering	Hydraulically actuated steering roller controlled using two optical belt-edge sensors and a roller tachometer

Data Acquisition and Control

Data acquisition	Pi Research Mistral system
Motor control	6 Control Techniques 'Mentor' DC drives
Tunnel Control	PLC direct to Control Techniques drives
Model balance	Aerotech 6-component internal balance
Model pressure measurement	Two 32 port PSI pressure scanners
Wheel drag balances	4 x single component strain-gauge load cells
Wing/body panel balances	2 x three component strain-gauge load cells
Model exhaust simulation	Maximum flow 2.1 m^3/s (75 SCFM)

Equipment Ratings

Main fan motor	373 kW (500 hp) variable speed air cooled DC motor
Rolling-road motor	186 kW (250 hp) variable speed air cooled DC motor
Primary boundary-layer motor	93 kW (125 hp) variable speed air cooled DC motor
Top-plate boundary-layer motor	11 kW (15 hp) variable speed air cooled DC motor
Secondary boundary-layer motor	22 kW (30 hp) variable speed air cooled DC motor
Belt suction motor	11 kW (15 hp) variable speed air cooled DC motor
Hydraulic power pack	2.5 kW (3.4 hp) AC motor
Road chiller capacity	281 kW (80 Tons)
Air chiller capacity	440 kW (125 Tons)

The tunnel is a scale model rolling road tunnel that tests models of vehicles. The model is mounted to a balance cradle that houses a 6-component load cell balance. The balance cradle is attached to a sting that is attached to a steel beamed structure that is mounted on vibration pads 8 feet underground. This mounting allows for the model to be completely isolated from any building noise. The model's wheels run on top of our rolling belt that has a surface roughness to match the average surface roughness of highways and roads. The belt speed matches the wind speed to +/- 0.01 m/s.

Within the balance cradle is mounted a vehicle model motion system. The VMMS allows the vehicle to automatically yaw, pitch; roll, heave and front wheel steer during a test session. To maintain the road flatness, a multi-suction port system is used throughout the platen. To eliminate any belt edge curl, a pneumatic tensioning system is used to apply constant tension to the belt during a test session. To eliminate the static electricity build up before it gets to the model and effects test repeatability, a static electricity discharge system is utilized.

To minimize the road boundary layer that builds up in wind tunnels, a four stage boundary layer suction system is utilized.

7.0 TEST PROCEDURE

7.1 Pretest Inspection and Warm up

At the beginning of each testing session, the tunnel and its data acquisition systems are run for a minimum of 30 minutes to warm up the facility. The balance and laser systems are warmed up for a minimum of four hours prior to use. The model was inspected for any wheel bearing issues or suspect/damaged parts that could affect testing. The tunnel and road system were inspected. The yaw position, heave position and roll position were all measured and maintained.

7.2 General

Each test series began with a static weight tare of the model. Following the static weight tare, a rolling wheel tare was taken for each model position that data was to be recorded. The model position remained the same for all of the runs. The positions were standard road height at yaw equaling 0, 9, 6, 3, 1, 0, -1, -3, -6, -9, 0 degrees. There were three 0 degree points to allow for a “first to last” run match that is used to determine potential belt stretch, or in test model issue. Positive 9 degrees is yawing the truck 9 degrees to the driver’s left. All rolling wheel tares were completed with the belt running 50 m/s without any air speed.

Following the rolling wheel tares, the data sampling process took place for all 9 yaw angles listed above. After all model point’s data samples were measured, the tunnel was shut down and a change was made to the model. Following a model change, the general process would repeat itself.

8.0 DATA REDUCTION

All force and moment data measured using an AEROTECH 6 component load cell balance, 124 static pressures and all associated tunnel parameters (i.e. DC motor information, belt temperature, wind speeds etc.) were recorded using a PI Mistral system. The data was organized through a program called PI AERO which utilizes an ACCESS database. PI AERO was used to display the reduced and raw data into Excel. Using Excel, the data was then summarized for reporting purposes.

9.0 CONCLUSIONS

Run 3 baseline Cdw at 65 MPH is 0.573 with this specific truck and trailer configuration.

Run 4 Transtex Model 23-30 SmartWay verified skit in the configuration originally tested when originally SmartWay verified at 65 MPH has a Cdw of 0.529 with a projected 4.15% fuel saving with this specific truck and trailer configuration

Transtex Skirt 19-32

Run 21 Transtex Model SmartWay approved skirt with and increased height of 2” at 65 MPH has a Cdw of 0.527 with a projected 4.31% fuel saving with this specific truck and trailer configuration

The results are displayed in the Appendix A.

APPENDIX A

All Test Runs: Tractor / Trailer Configuration

Tractor Variables		Trailer Variables					
Tractor	King Pin	Trailer	Trailer Ra-dius	Bogey Posi-tion	Truck to Trailer Gap in inches	Trailer ride height REAR	Trailer ride height LEAD EDGE
Int. Pros-tar	36"	Wabash	5"	40’	45”	13'6"	13'6"

Truck: 2008 International Navistar- Full Sleeper, hood mounted mirrors, cab extenders with chassis fairings

Truck to Trailer gap 45”.

Trailer: 2008 Wabash 53’ dry van-bogeys in California position, king pin at 36”, 102” wide.

Front radius 5”, landing gear in std. position.

Trailer ride height is 45” and is measured at cross-member to ground.

CAL bogey position is defined as 40’ from the center of the king pin to the center of the rear most axle on the trailer.

Note: above measurements are full scale measurement conversions

Start Time of Test was 8:00 AM May 14, 2013

Baseline Configuration

Run #	Description	Yaw AOA	CD	MPH	CDW	del CDw	% CDw	%F
						Baseline STD Bogey in Cal position bare		
Run 3	Baseline with STD Bogey in Cal position	0.000	0.526	50	0.603	0.000	0.00%	0.00%
		1.000	0.528	55	0.590	0.000	0.00%	-0.02%
		3.000	0.548	60	0.580	0.000	-0.07%	-0.03%
		6.000	0.606	65	0.573	-0.001	-0.09%	-0.05%
		9.000	0.682	70	0.567	-0.001	-0.11%	-0.06%
		0.000	0.526	75	0.562	-0.001	-0.13%	-0.08%
		-1.000	0.526					
		-3.000	0.541					
		-6.000	0.590					
		-9.000	0.660					
		0.000	0.526					

Wind Tunnel Test Result of the MFS-2330 SmartWay Approved Transtex Skirt Device

						Compared To Run #3 - Baseline Repeat 2		
Run #	Description	Yaw AOA	CD	MPH	CDW	del CDw	% CDw	%F
Run 4	Transtex 23-30 23' X 30" STANDARD FRONT SECTION (NJL0047)	0.000	0.480	50	0.555	-0.047	-7.83%	-3.40%
		1.000	0.486	55	0.544	-0.046	-7.77%	-3.61%
	This is the Smartway approved Skirt 23-30	3.000	0.513	60	0.536	-0.045	-7.72%	-3.86%
		6.000	0.563	65	0.529	-0.044	-7.68%	-4.15%
		9.000	0.621	70	0.524	-0.043	-7.64%	-4.37%
		0.000	0.482	75	0.519	-0.043	-7.61%	-5.08%
		-1.000	0.484					
		-3.000	0.501					
		-6.000	0.551					
		-9.000	0.607					
		0.000	0.482					

Pictures of the device as tested:

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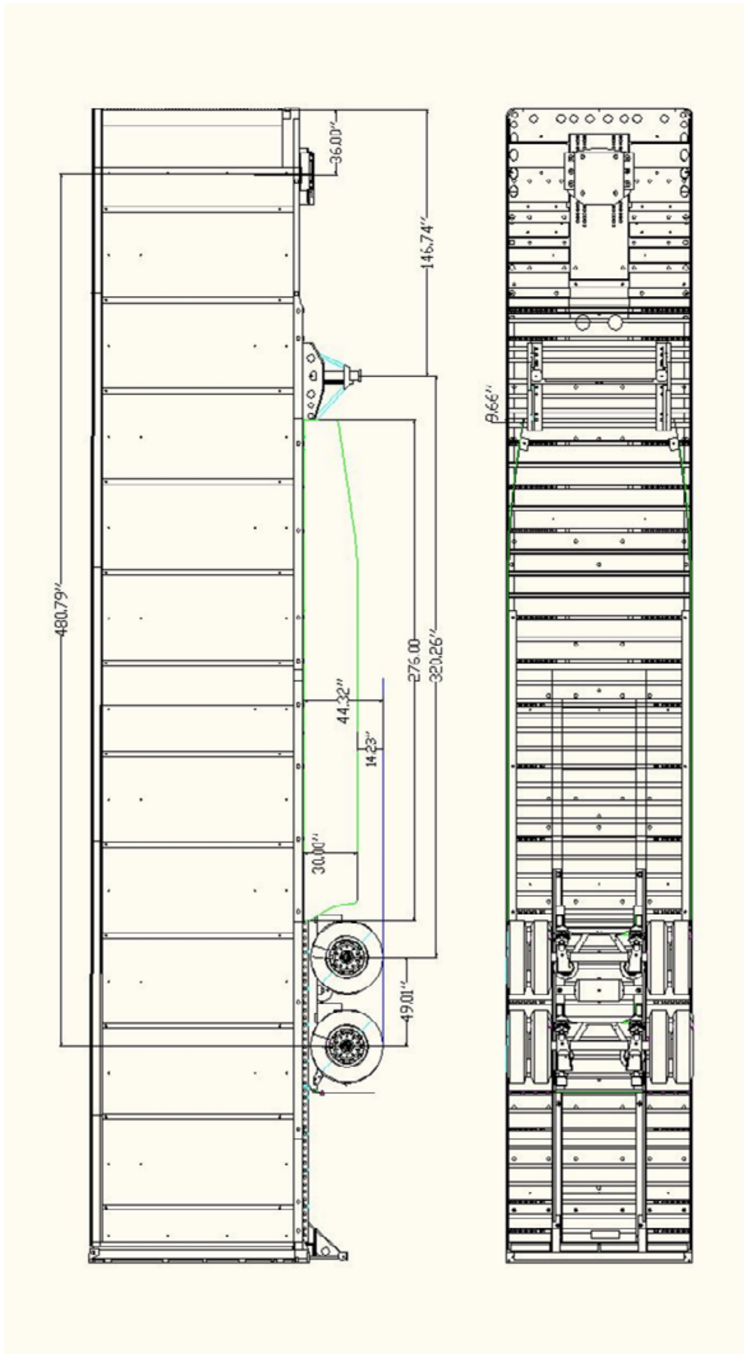
Drawing of Transtex Model MFS-2330 SmartWay verified



Wind Tunnel Test Result of the Skirt 19-32 Device

						Compared To Run #3 - Baseline Repeat 2		
Run #	**Description**	**Yaw AOA**	**CD**	**MPH**	**CDW**	**del CDw**	**% CDw**	**%F**
Run 21	MFS-1932 19' X 32" STD FRONT SECTION	0.000	0.483	50	0.553	-0.049	-8.20%	-3.57%
	(NJL0059LH/RH, NJL0061-36LH/RH)	1.000	0.486	55	0.542	-0.048	-8.11%	-3.77%
	This shorten space between LG and	3.000	0.510	60	0.534	-0.047	-8.04%	-4.02%
	the rear most axle on the trailer	6.000	0.560	65	0.527	-0.046	-7.98%	-4.31%
	TRANSTEX SKIRT 19-32	9.000	0.618	70	0.522	-0.045	-7.93%	-4.53%
		0.000	0.482	75	0.518	-0.044	-7.88%	-5.26%
		-1.000	0.484					
		-3.000	0.501					
		-6.000	0.552					
		-9.000	0.608					
		0.000	0.483					

Pictures of the device as tested:

Drawing of Transtex Skirt 19-32