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The Influence of Bogie Configuration on the Aerodynamic Performance of Van Trailers

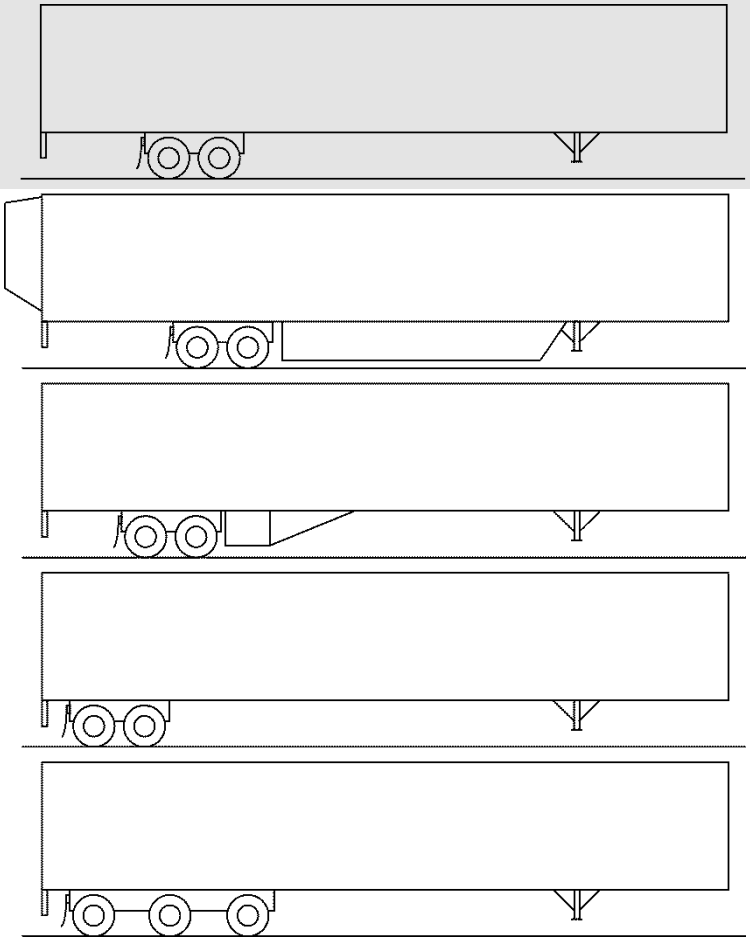
Brian McAuliffe

September 10, 2019

SAE Commercial Vehicle Engineering Congress 2019

MOTIVATION

Ideal vs. Real Operations



Regulations and Efficiency programs specify a standard trailer configuration for aerodynamic evaluations

Real operations require a large variability of bogie positions (up to about 10 ft range)

Most aerodynamic under-trailer technologies are stationary and do not move with the bogie

Previous Work

Numerous research and testing publications of under-trailer aerodynamic technologies

Side Skirts: 5% to 10% drag reduction, 4% and 5% SmartWay fuel-savings

Bogie Fairings: ~5% drag reduction, 4% and 5% SmartWay fuel-savings

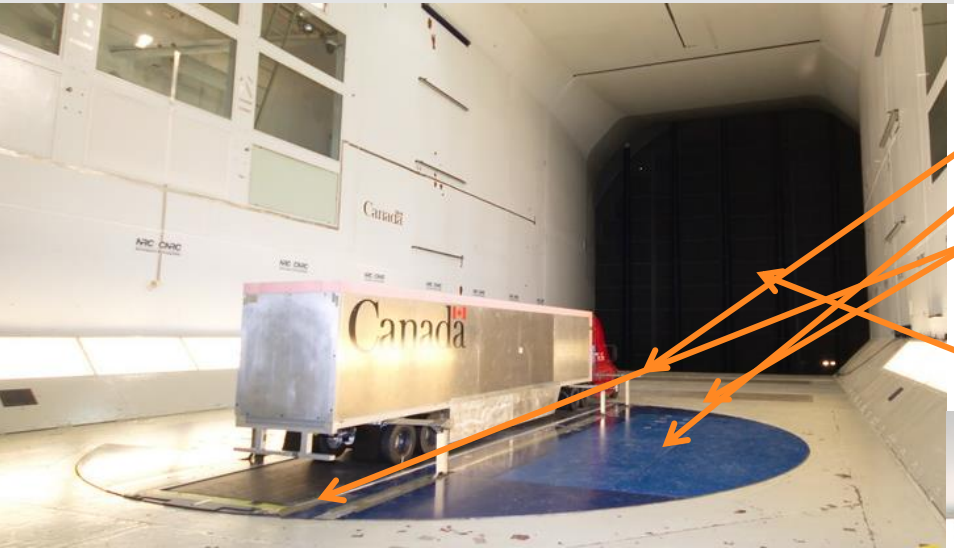
Wheel Covers and Mud-Flaps: ~1% drag reduction, 1% SmartWay fuel-savings

How do these perform with a range of trailer bogie positions?

Are base devices impacted by bogie position?

TEST SETUP & DATA SETS

Experimental Setup



9m Wind Tunnel

- Under-floor balance with low-interference mounts
- Turntable to vary yaw-angle/cross-wind
- Ground Effect Simulation System (GESS)
  - Boundary-layer suction + Rolling Road
- Road Turbulence System (RTS)

30%-scale truck model

- Spinning wheels + aero-torque measurement
- Cooling airflow measurements
- >140 surface pressure taps

Experimental Conditions

Wind/ground speed: $U_W = U_G = 50\ m/s$

Reynolds number: $Re_W = 2.8 \times 10^6$

Yaw angle range: $\psi = \pm 15°$

Freestream turbulence: $I_U = 4\%$ $L^x{}_U = 1m$

Followed SAE J1252 procedures, with following exception:

Drag coefficient (C_D) includes contribution from wheel aerodynamic torque

Data Set

Data gathered from 4 test programs:

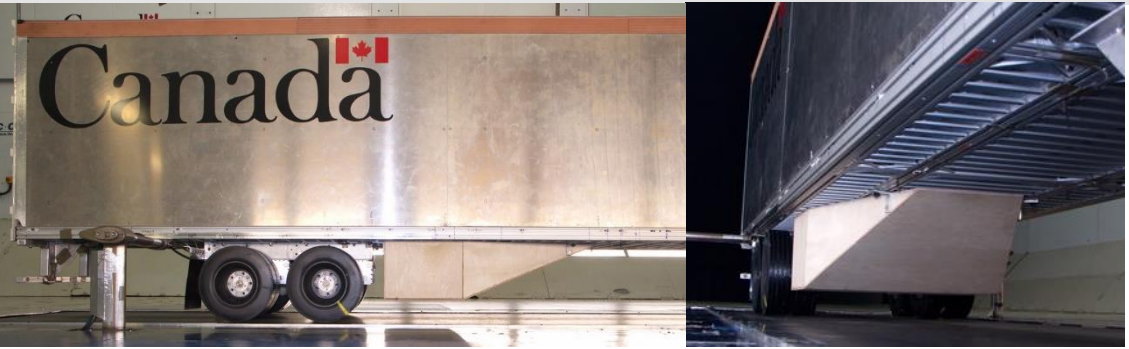
Oct. 2014 – tridem- vs. tandem-axle trailer — day-cab

Dec. 2015 – tridem- vs. tandem-axle trailer — short sleeper-cab

Dec. 2016 – bogie movements, side-skirts, boat-tails, mud-flaps

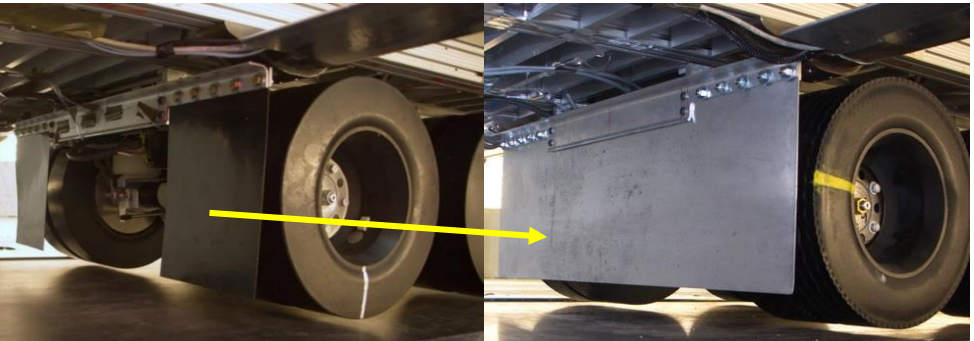
Jan. 2018 – bogie movements, side-skirts, boat-tails, bogie-fairing — long sleeper-cab

Trailer Devices



bogie fairing (stationary and sliding)

single full-width mud-flap



large
boat-tail
(4-panel 4 ft)

small boat-tail
(3-panel 3ft)

Trailer Devices

large

bogie

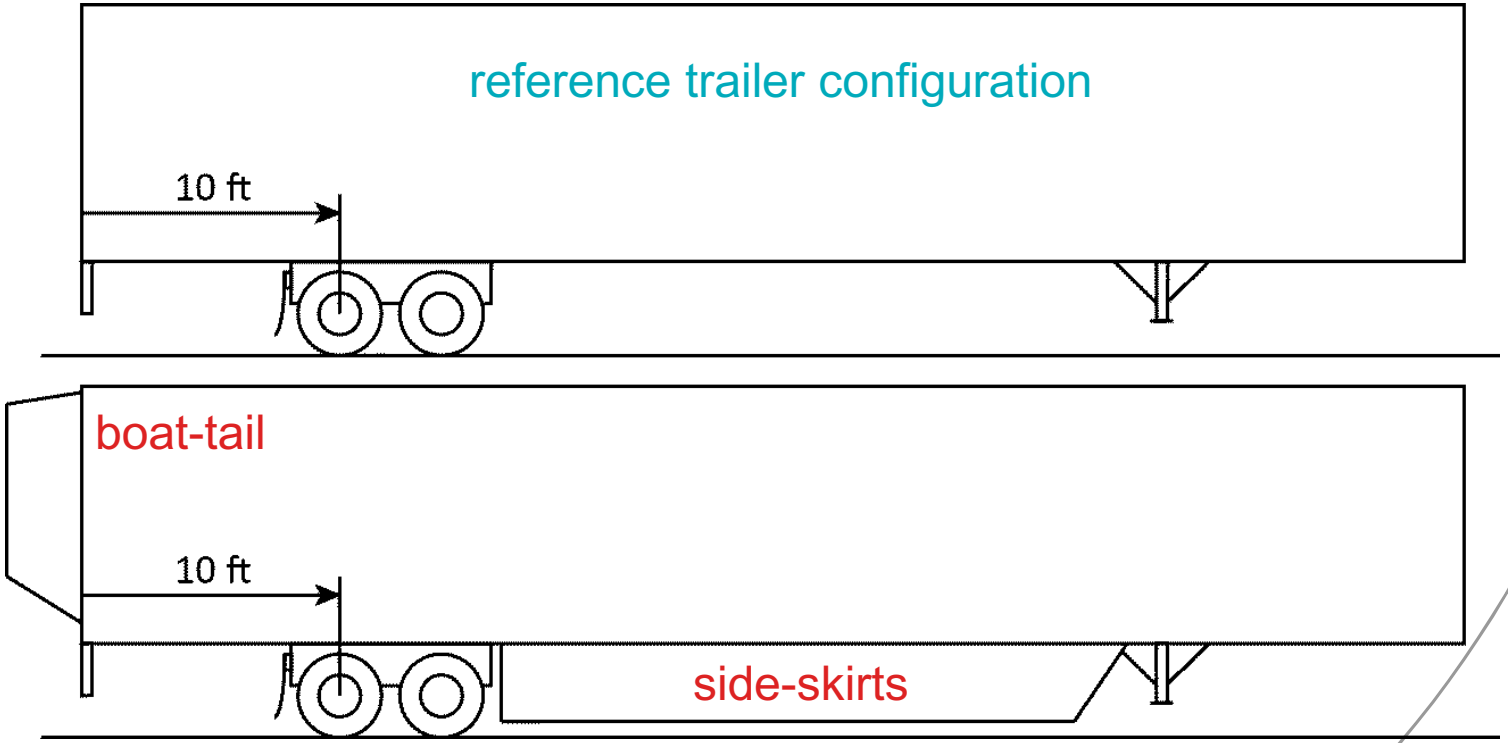
single

Models do not represent commercial products

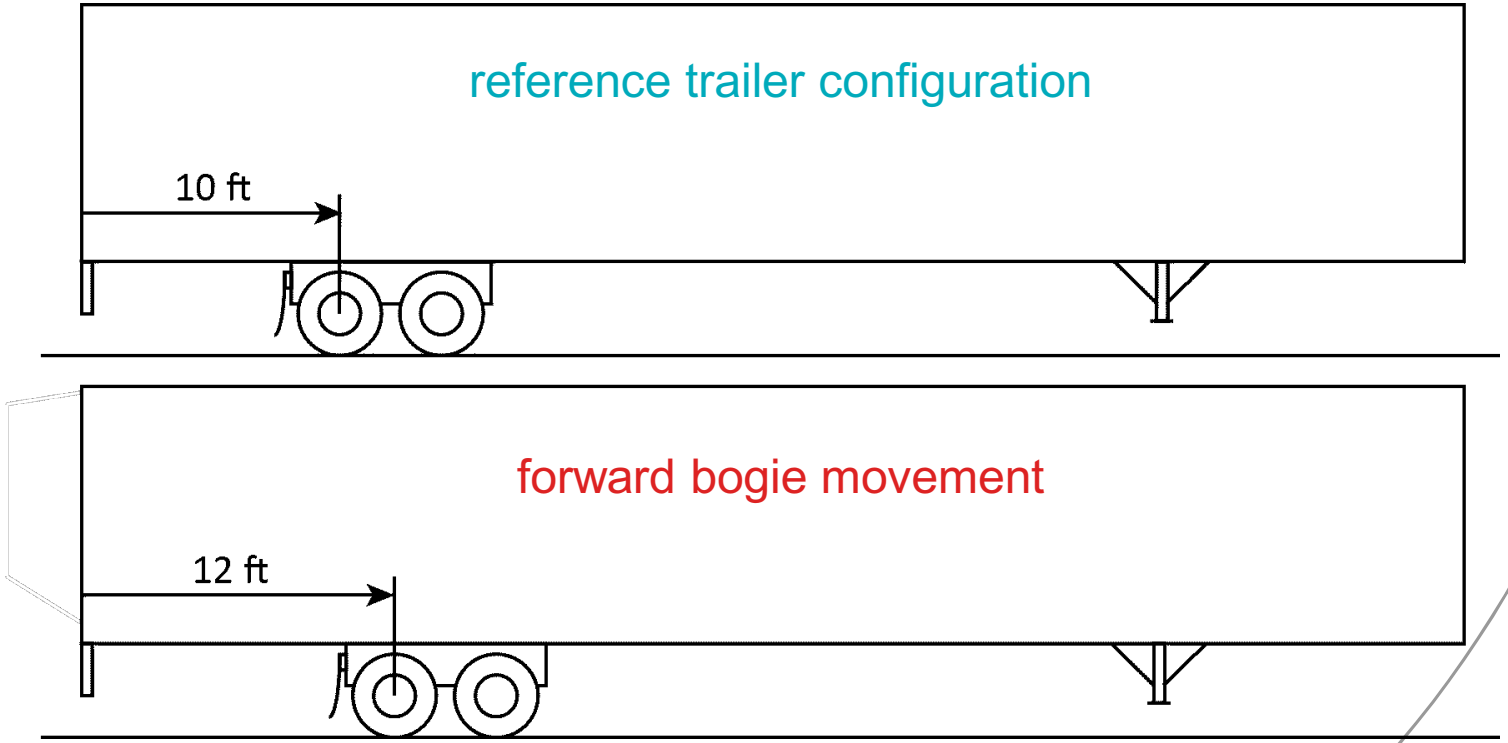
Concepts have been developed by NRC for research purposes only

Commercial products may perform differently than what is presented herein

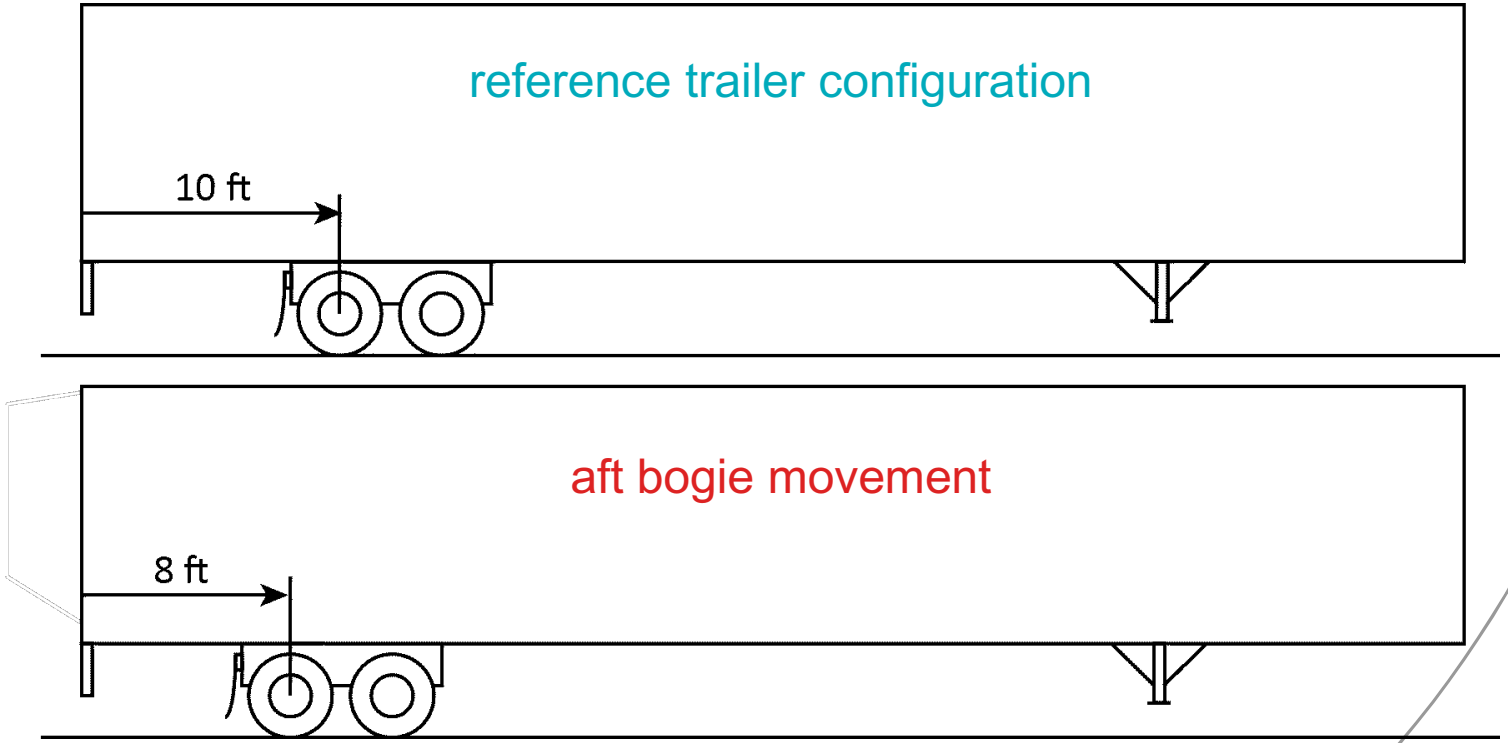
Bogie Positions



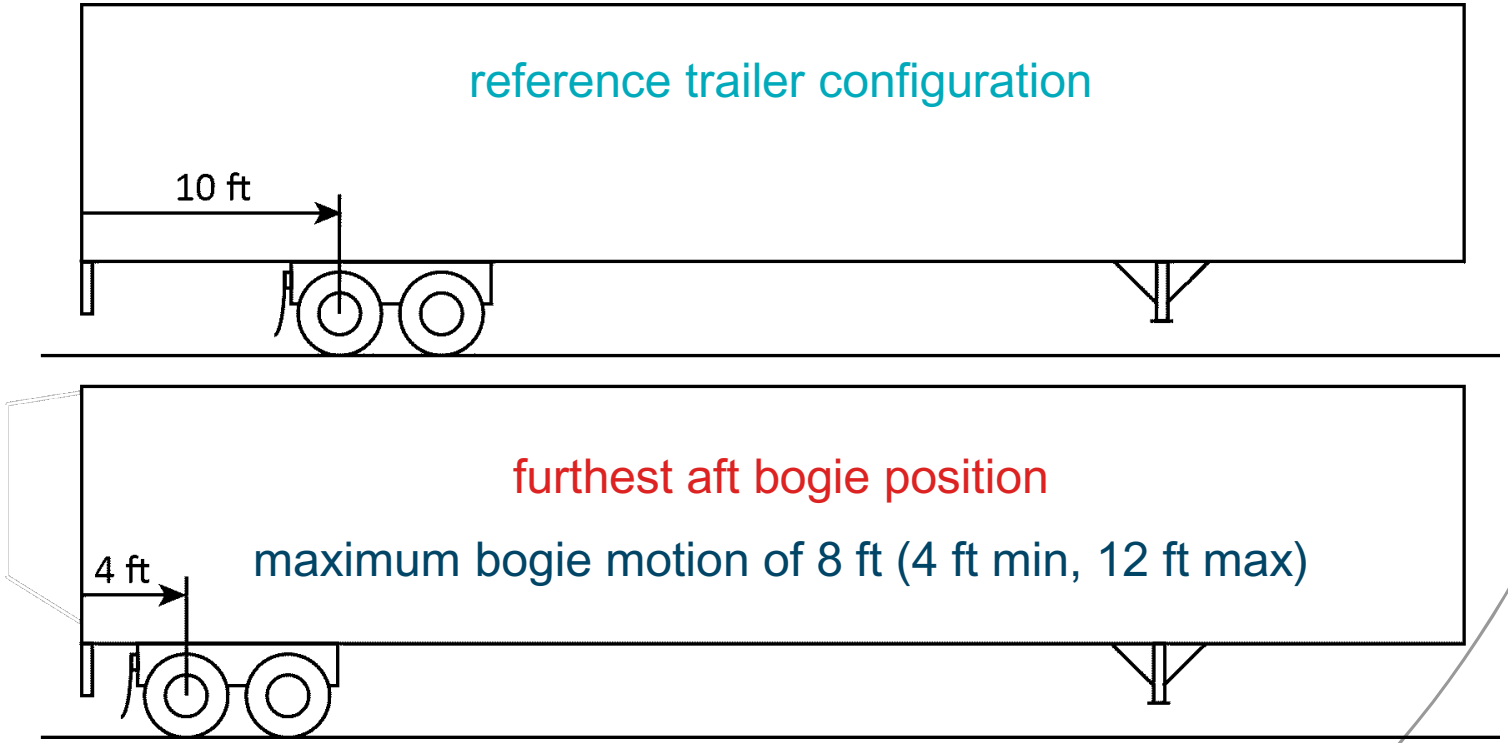
Bogie Positions



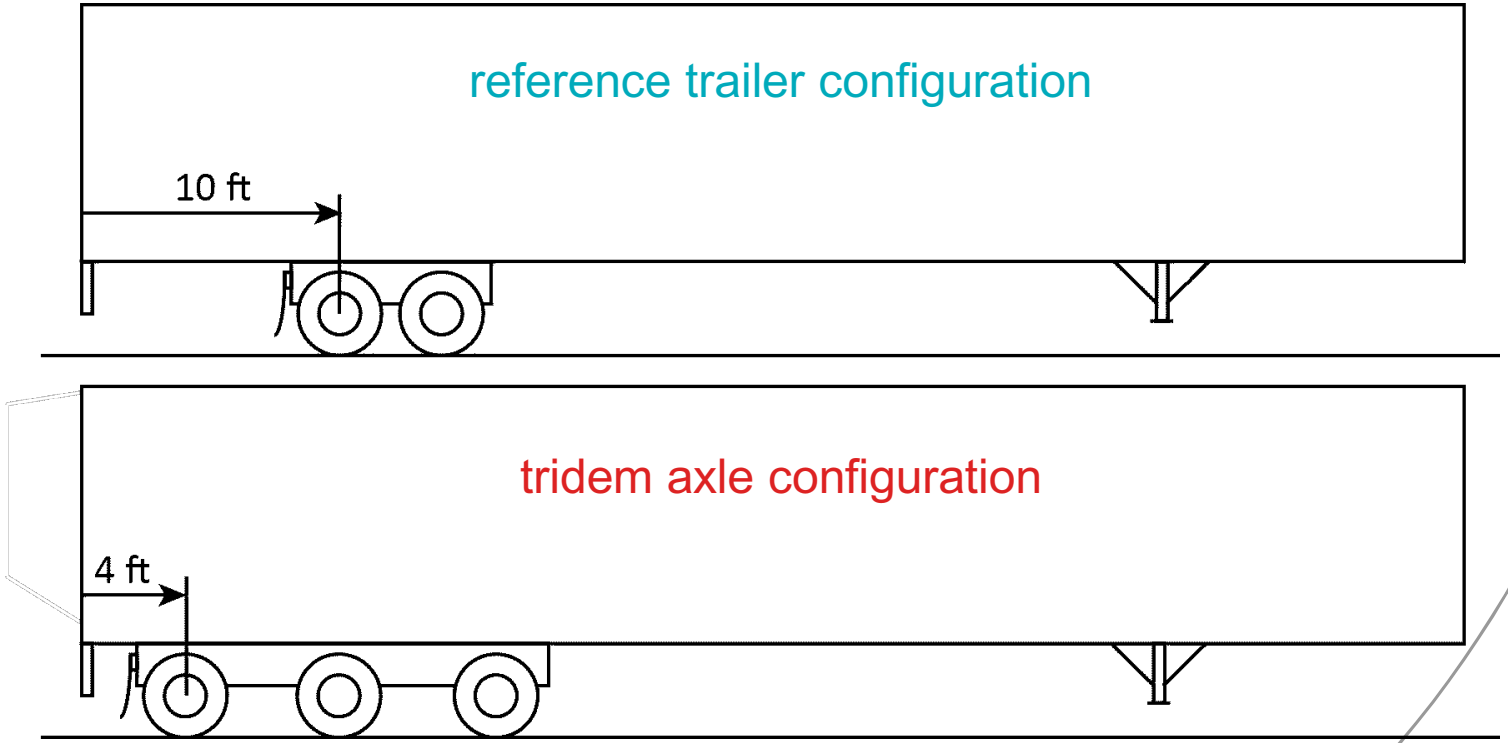
Bogie Positions



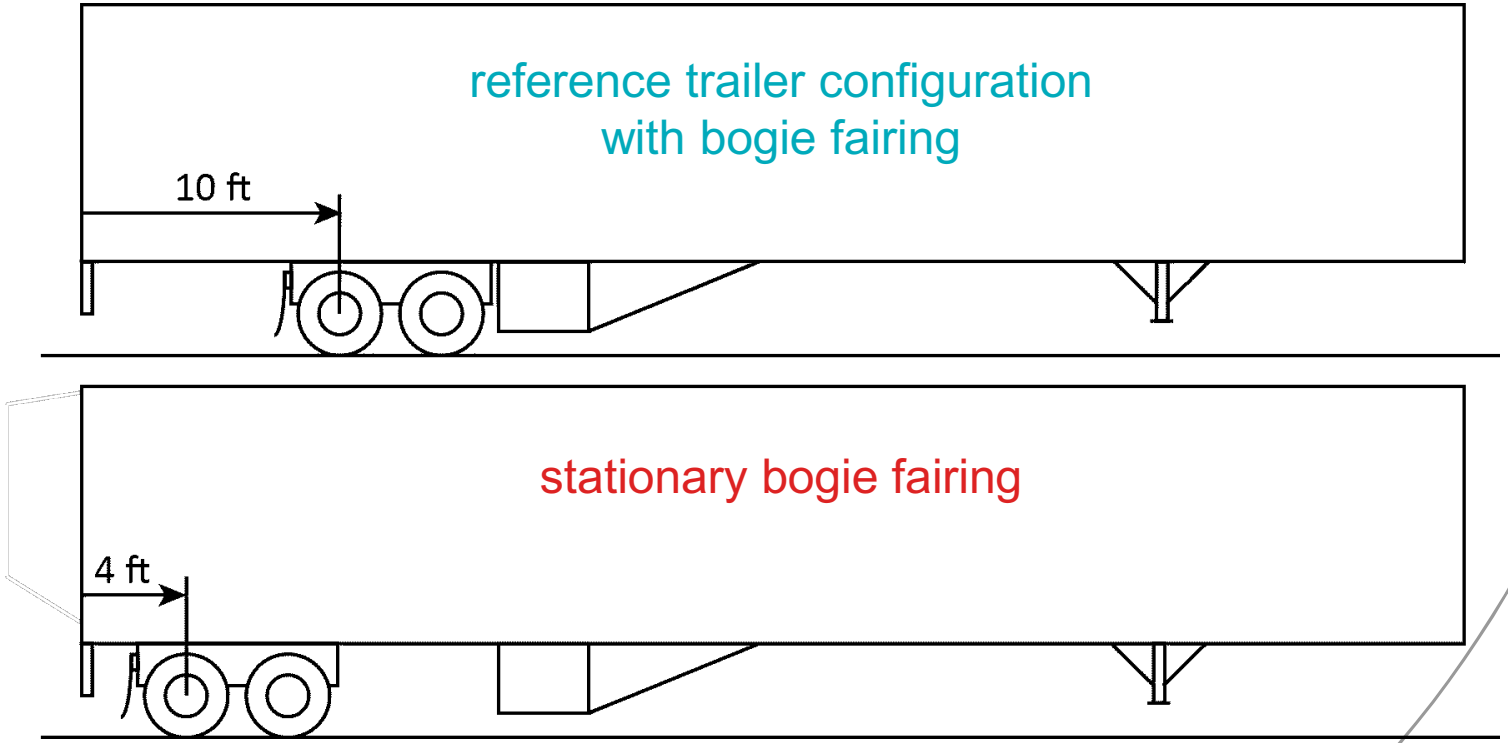
Bogie Positions



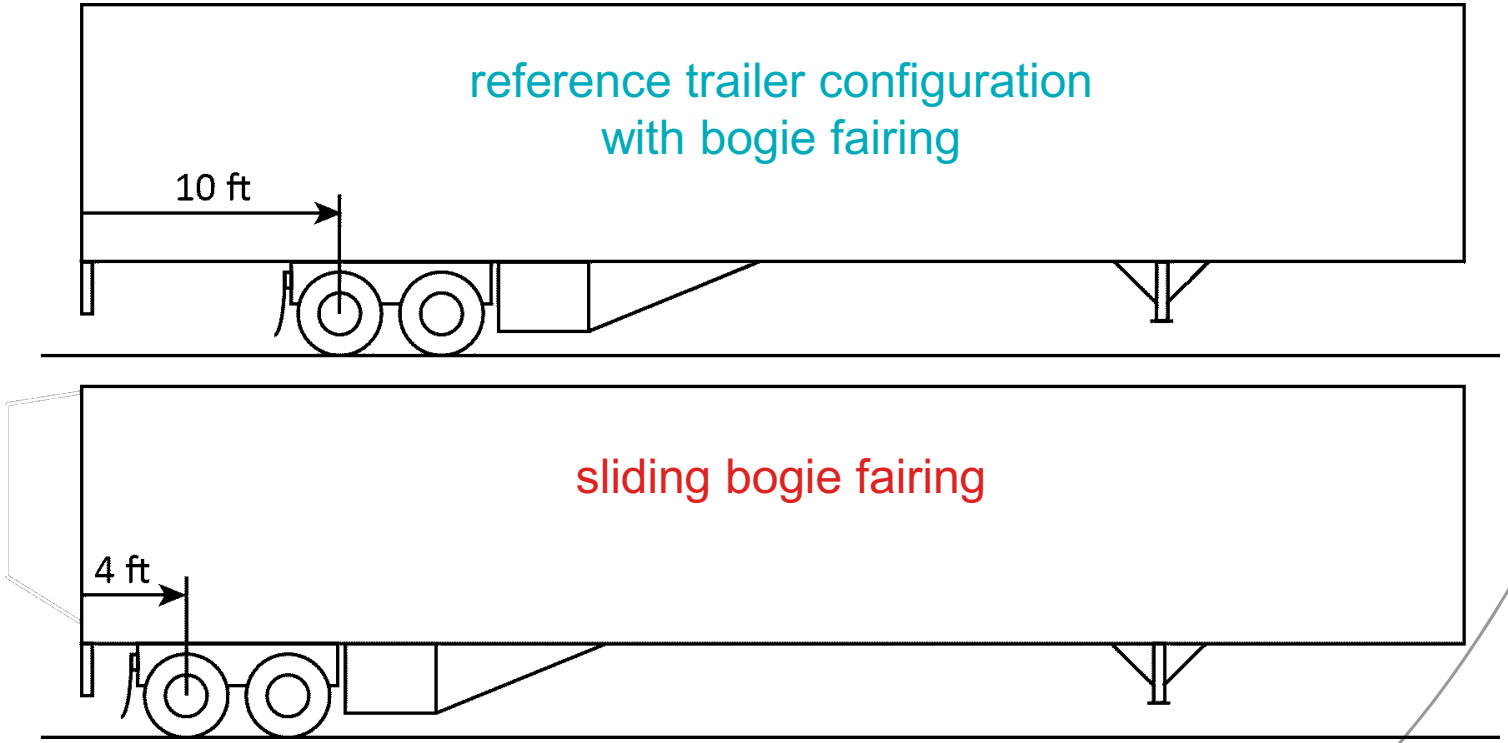
Bogie Positions



Bogie Positions



Bogie Positions



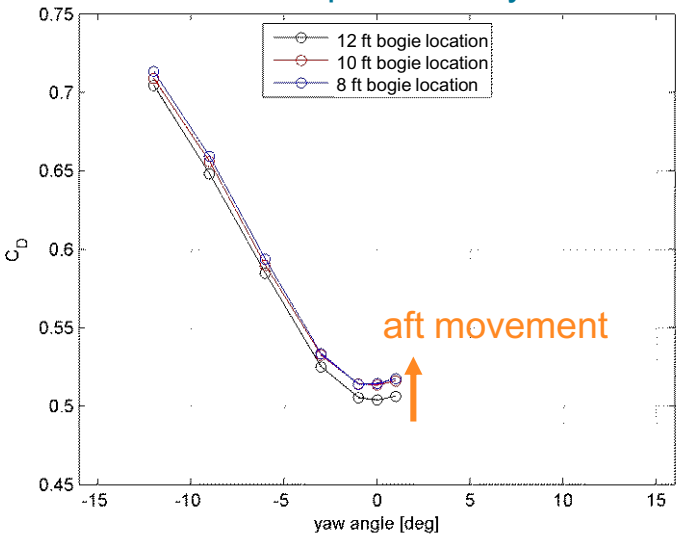
RESULTS

Bogie Movement

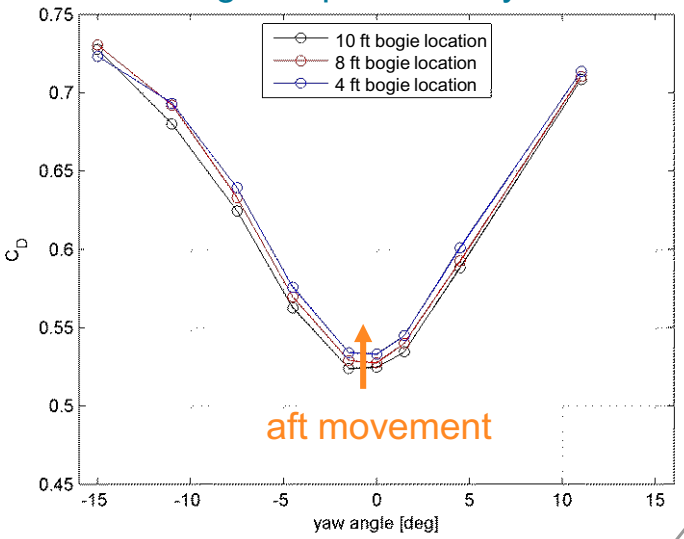
Drag coefficient increases with aft bogie motion

NOTE: range of bogie motion different for the two tractors

Short Sleeper with Dry Van



Long Sleeper with Dry Van

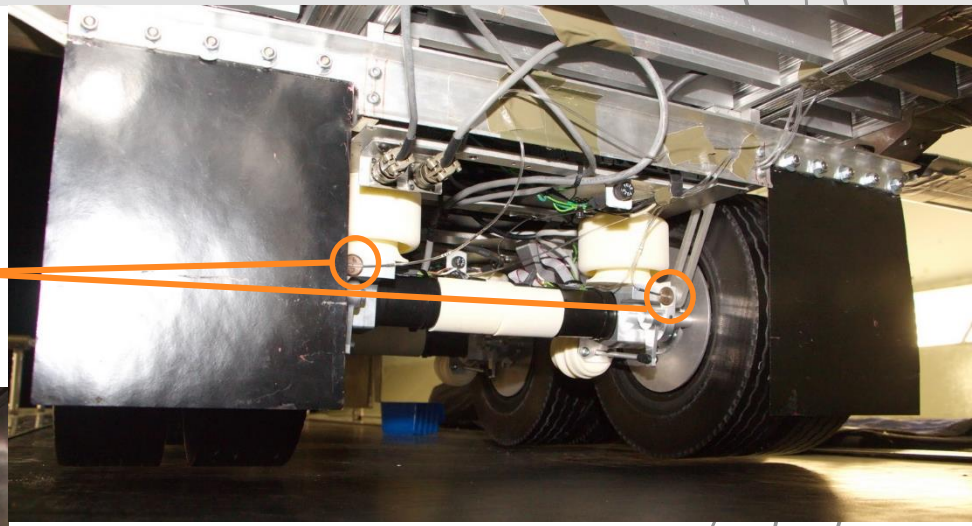


Bogie Movement

Bogie drag investigated using surface pressures

bogie aft pressure taps

bogie forward pressure taps



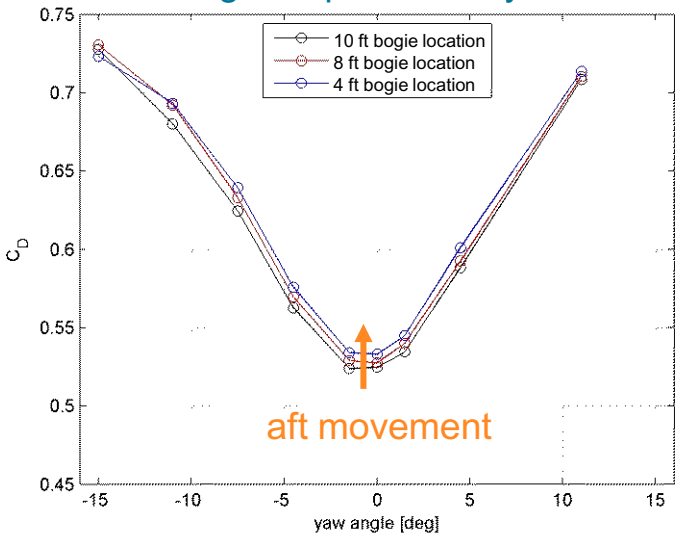
Average of forward or aft pressures

$$C_{P,avg} = \frac{1}{N}\sum_{i=1}^{N} C_{P,i}$$

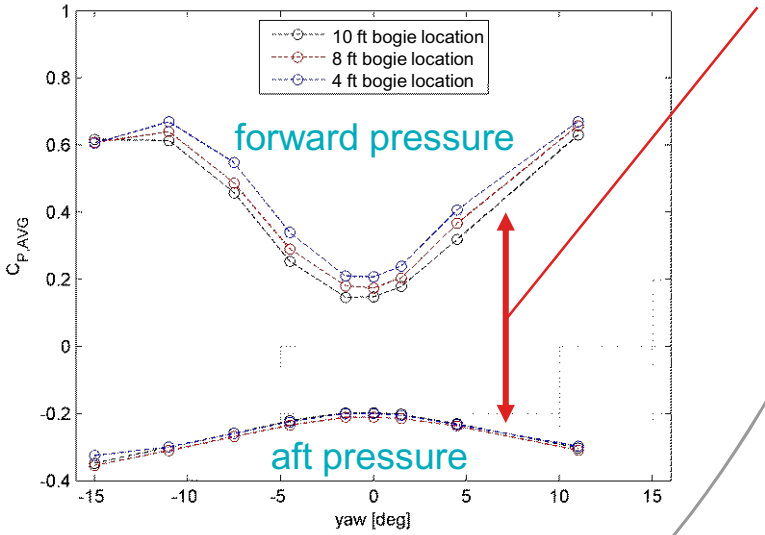
Bogie Movement

Bogie drag identified as the primary source of drag changes

Long Sleeper with Dry Van



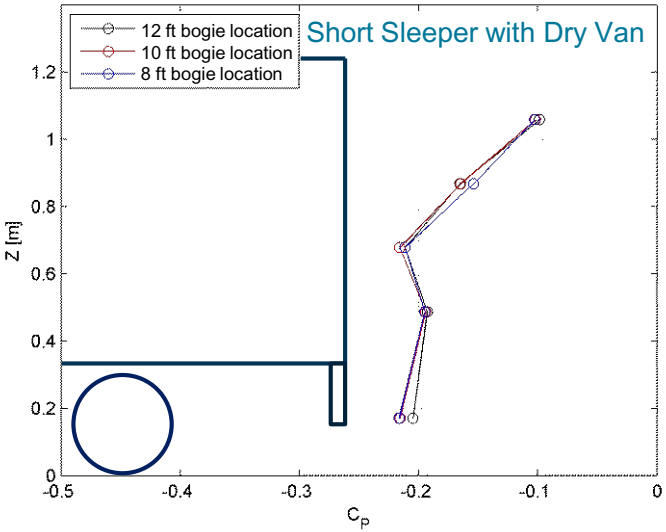
increasing pressure difference with aft movement

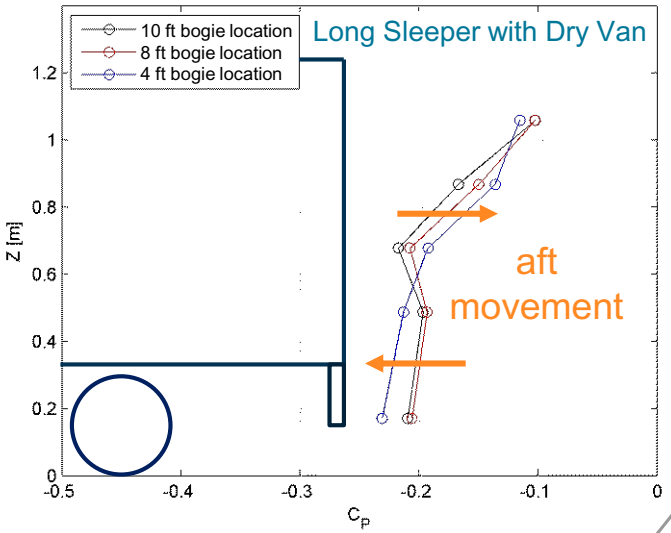


Bogie Movement

Base pressure affected - more so with far aft bogie positions

suggests a potential influence on base devices

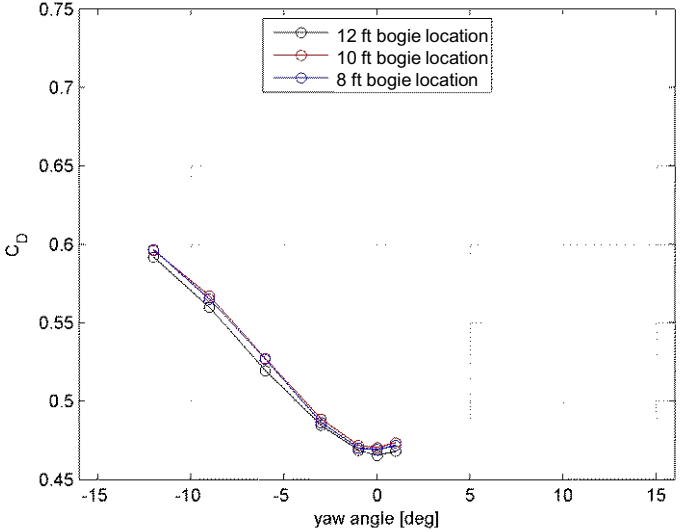




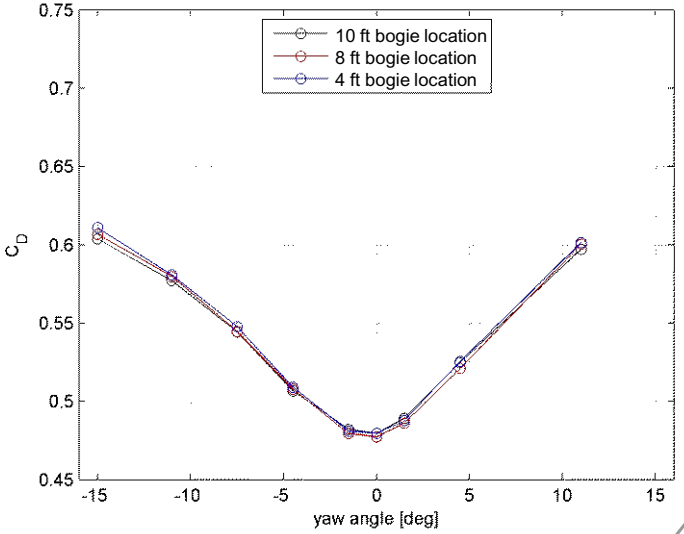
Bogie Movement with Skirts

Side-skirts reduce the sensitivity of drag to bogie movement

Short Sleeper with Dry Van



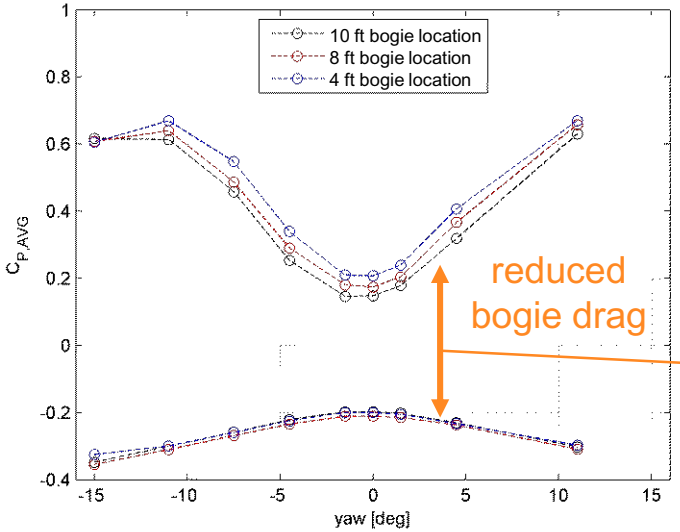
Long Sleeper with Dry Van



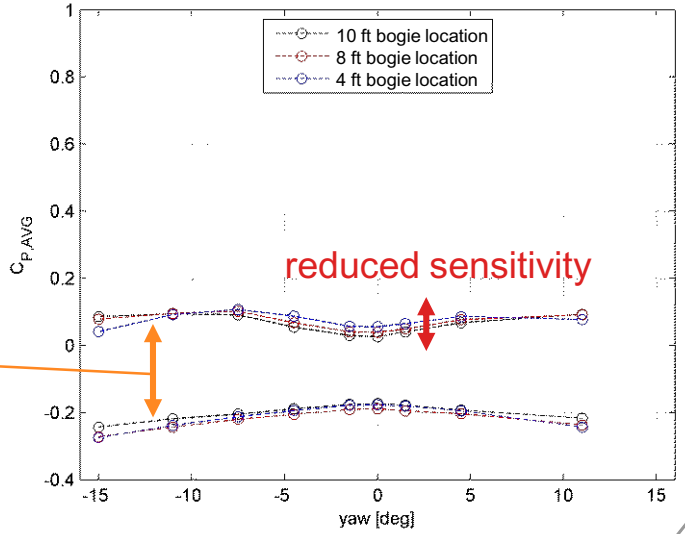
Bogie Movement with Skirts

Side-skirts shield the bogie, reducing the sensitivity to movement

No Side-Skirts



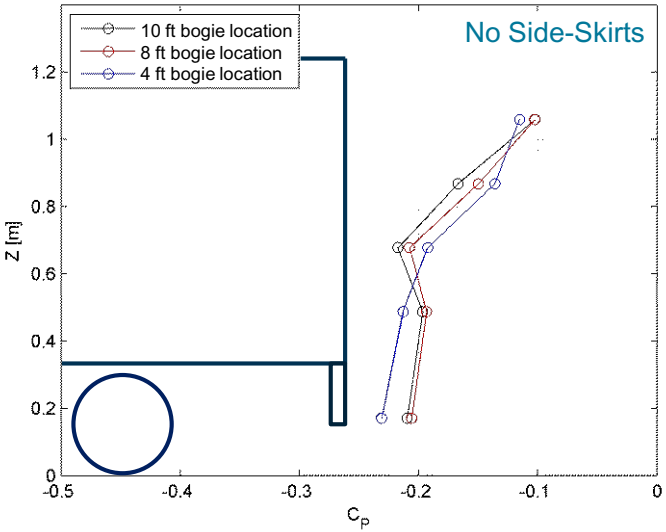
With Side-Skirts

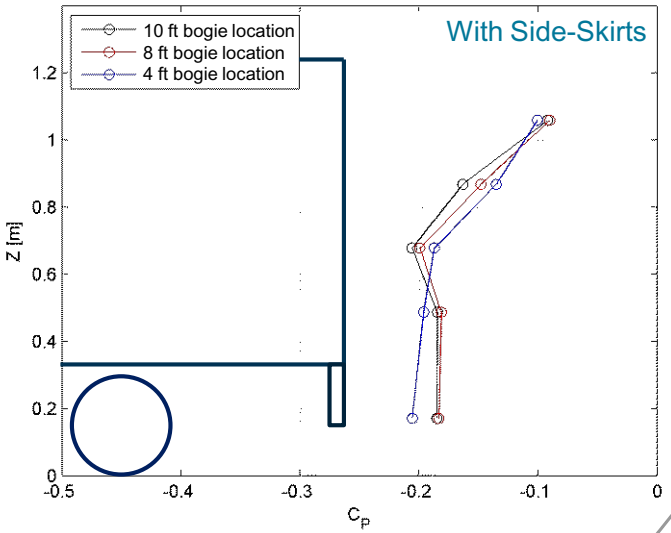


Bogie Movement with Skirts

Base-pressure trends not influenced by side-skirts

suggests an effect of flow entrainment behind the wheels

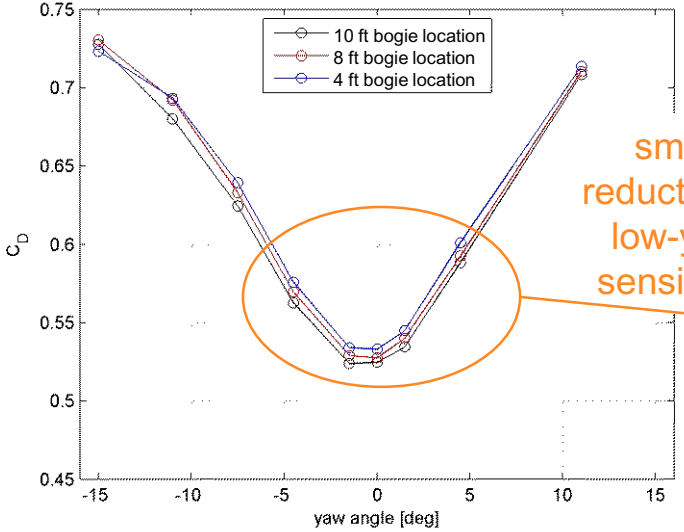




Bogie Movement with Bogie Fairing

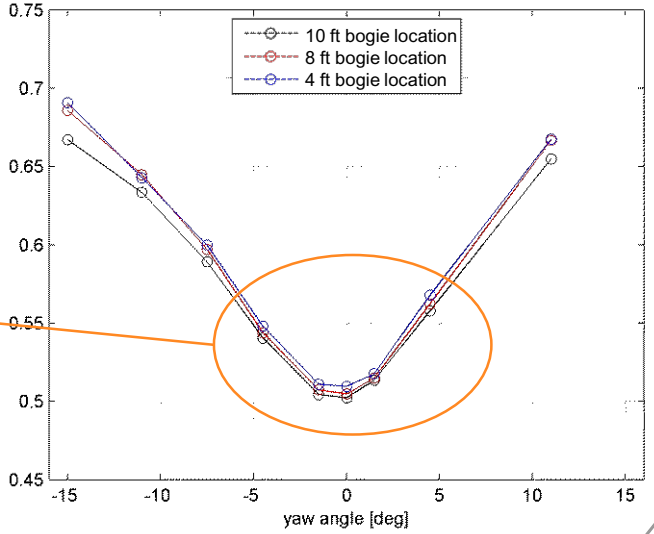
Bogie fairing reduces drag and sensitivity to bogie movement

No Bogie Fairing



small reduction in low-yaw sensitivity

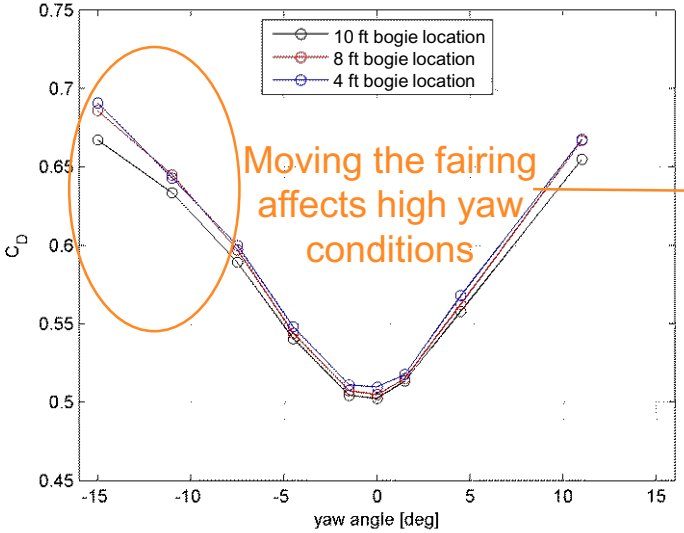
With Stationary Bogie Fairing



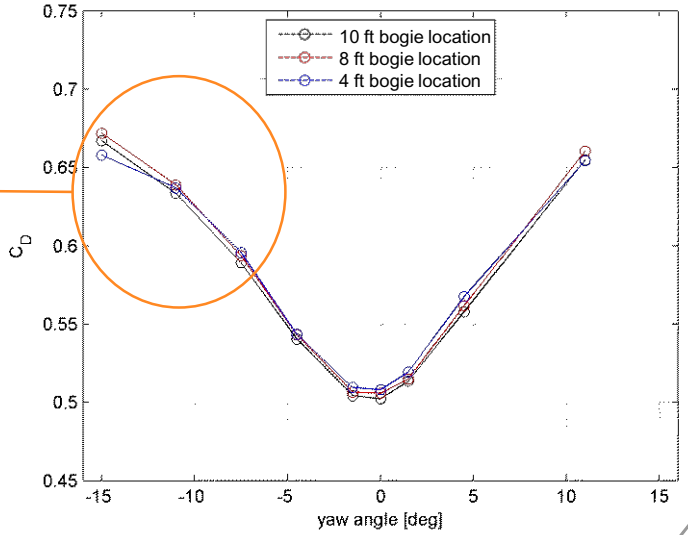
Bogie Movement with Bogie Fairing

Sliding bogie fairing reduces effective at high yaw

With Stationary Bogie Fairing



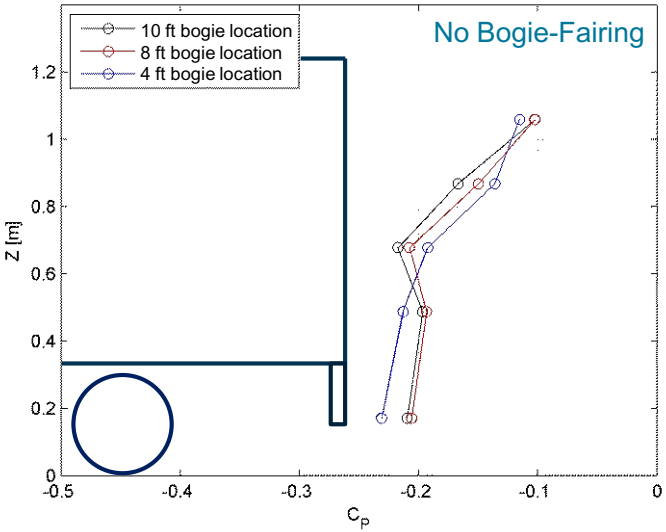
With Sliding Bogie Fairing

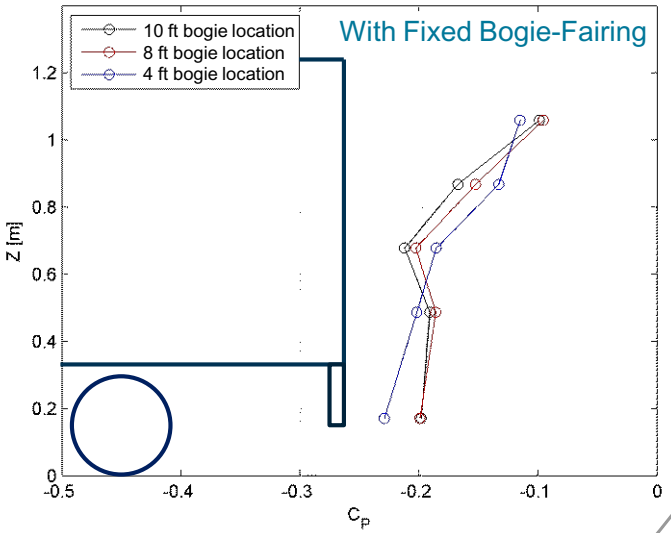


Bogie Movement with Bogie Fairing

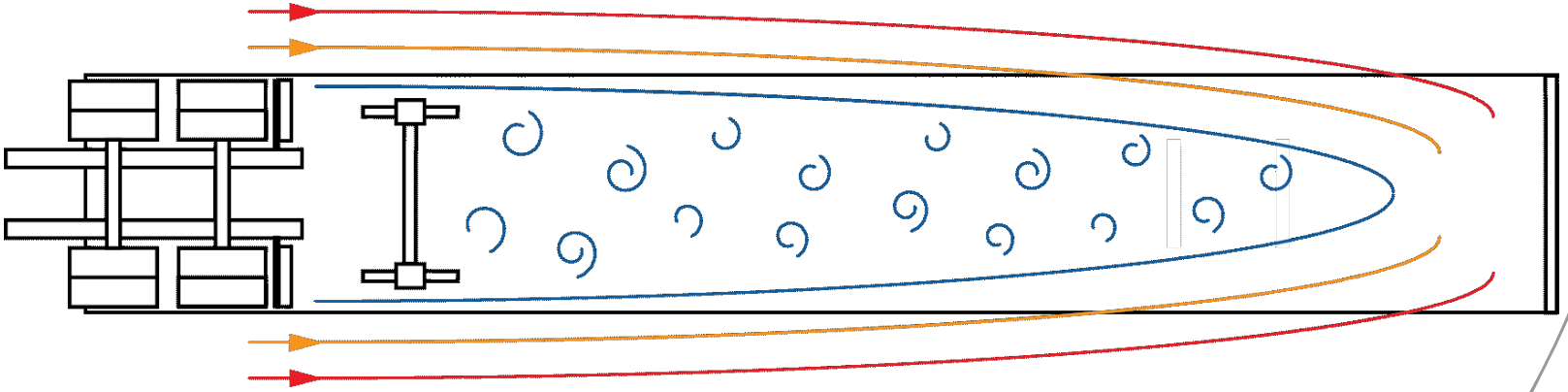
No significant effect of bogie fairing on base pressures

behaviour similar to skirts





Mechanism for Bogie-Movement Influence



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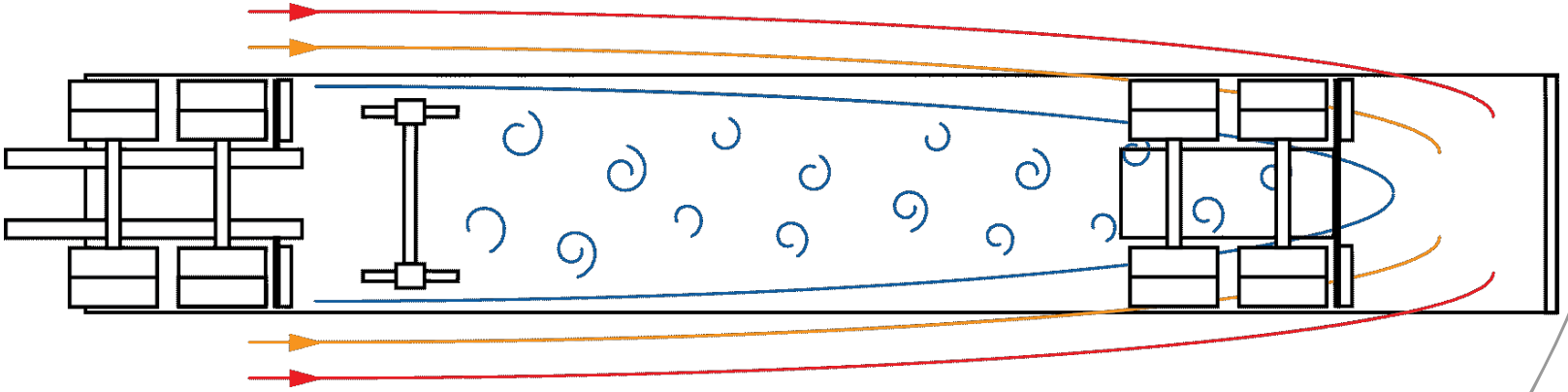
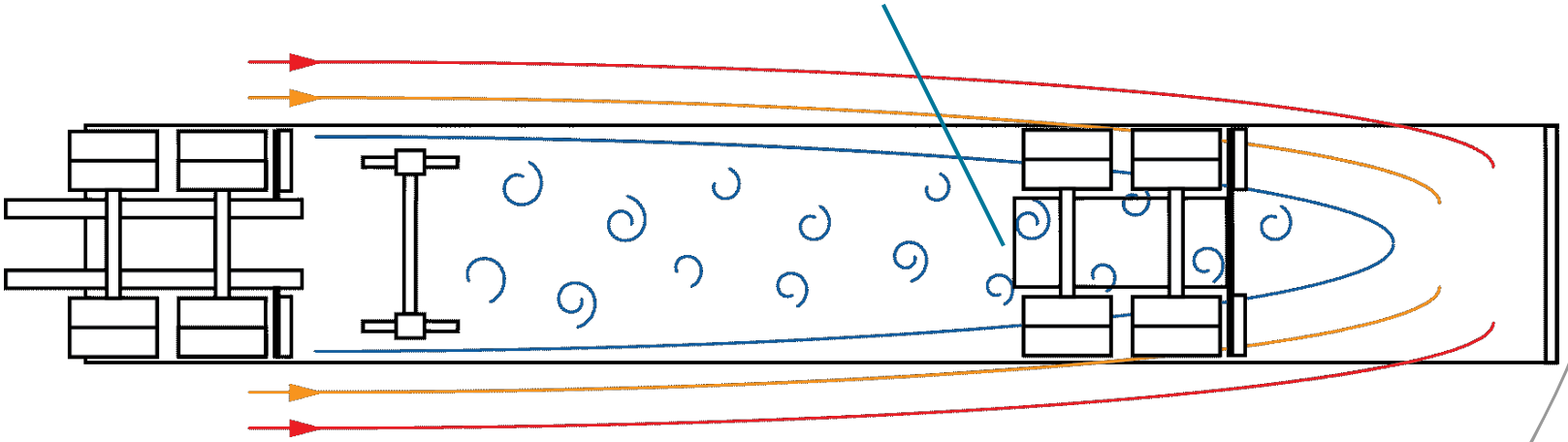


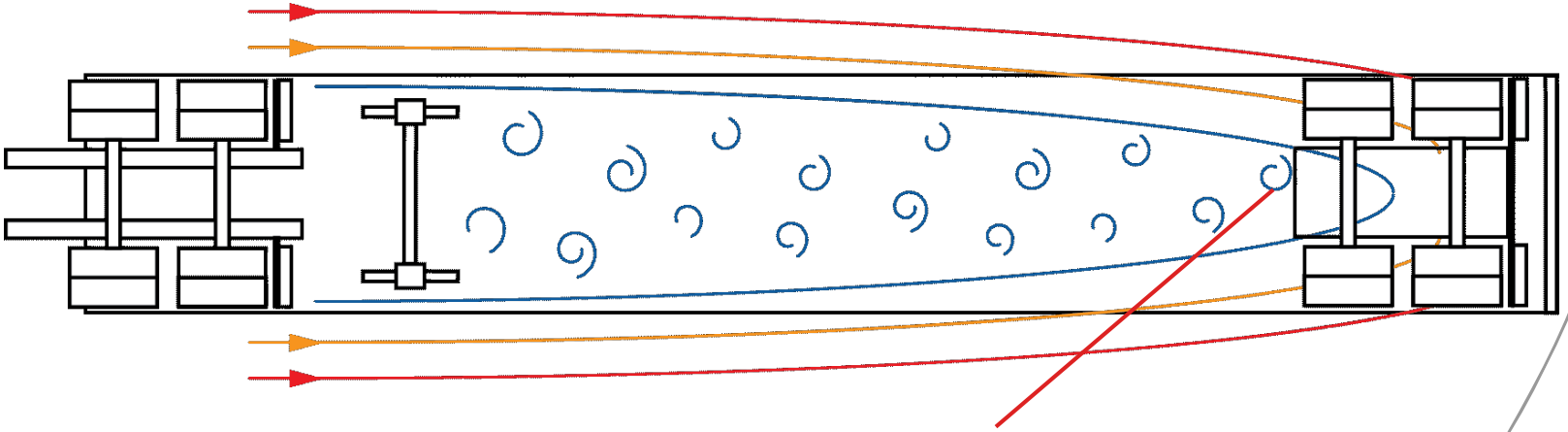
Mechanism for Bogie-Movement Influence

forward position = greater magnitude of low-speed flow



Mechanism for Bogie-Movement Influence

forward position = greater magnitude of low-speed flow

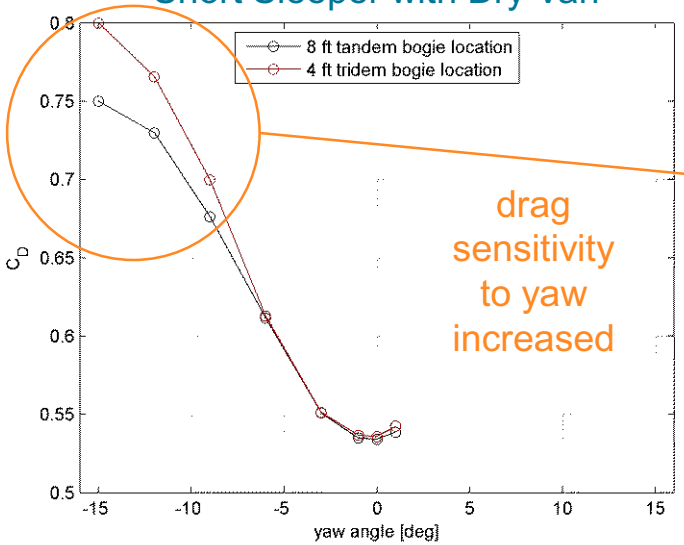


aft position = greater magnitude of high-speed flow

Tridem vs. Tandem Bogie

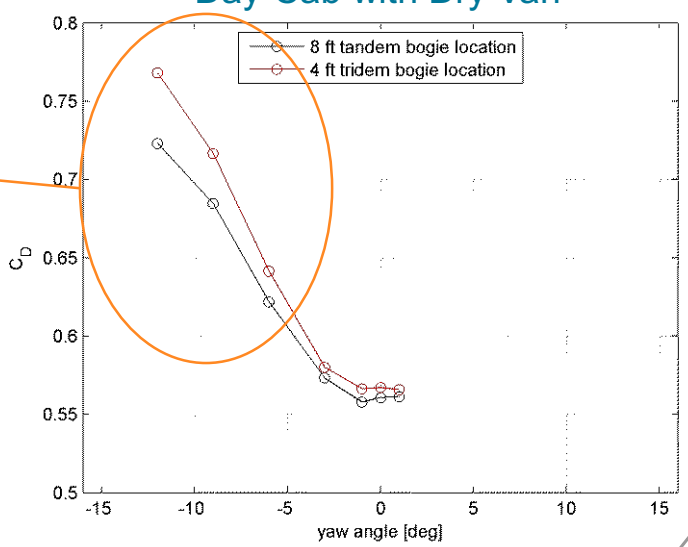
Higher drag with third axle

Short Sleeper with Dry Van



drag sensitivity to yaw increased

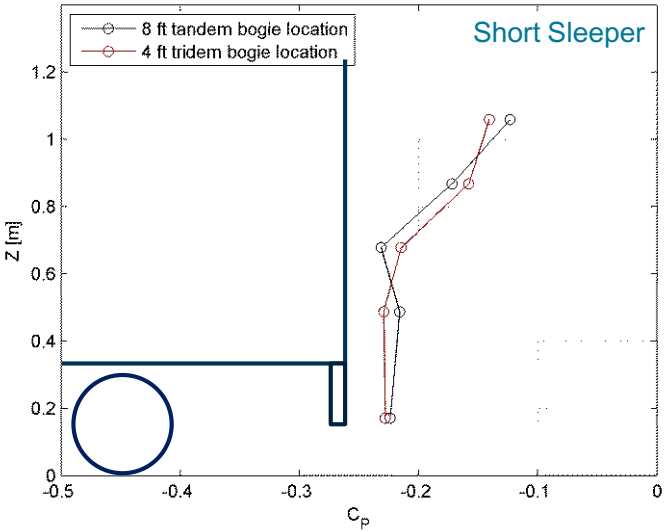
Day-Cab with Dry Van

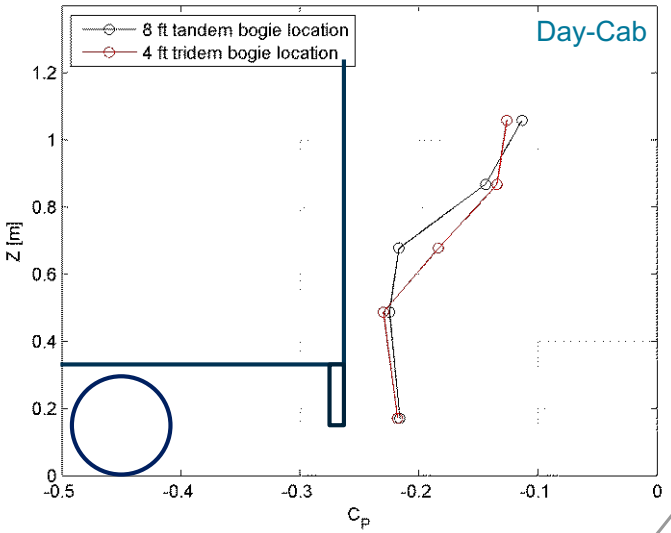


Tridem vs. Tandem Bogie

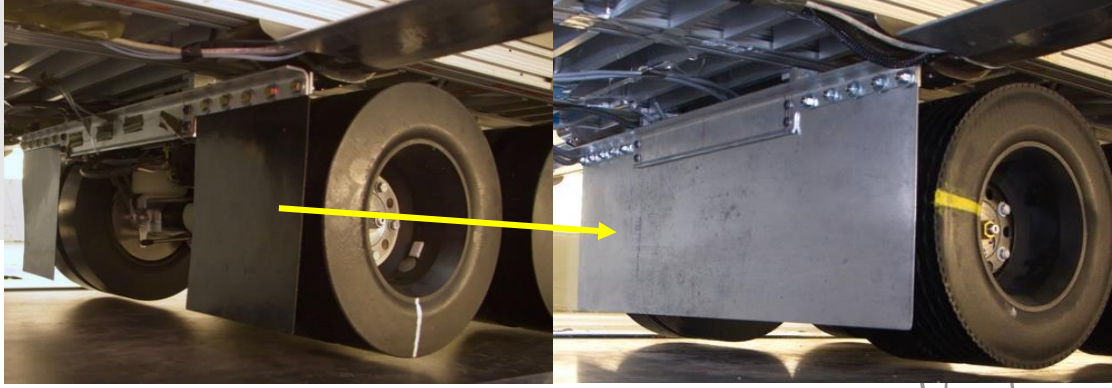
Redistribution of base pressure similar to aft bogie movement

suggests aft-axle location is the dominant factor

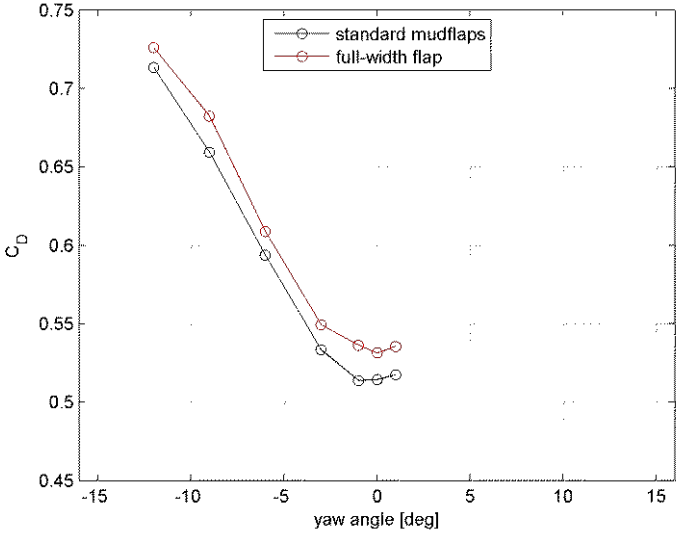


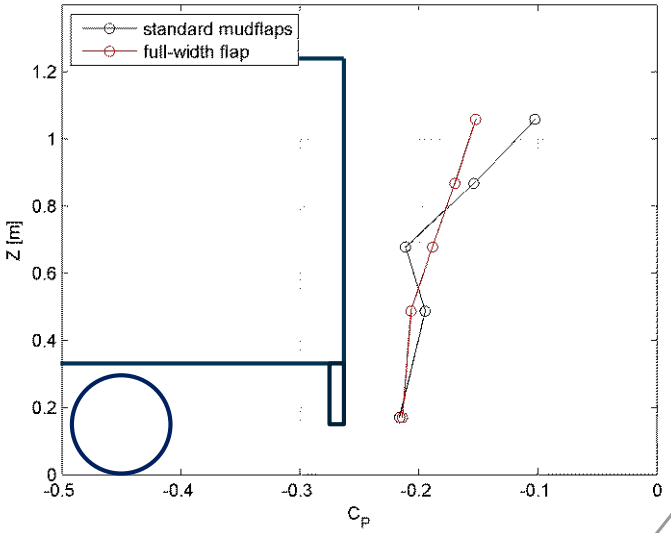


Wide Mudflaps



Significant increase in drag and change in base-pressures



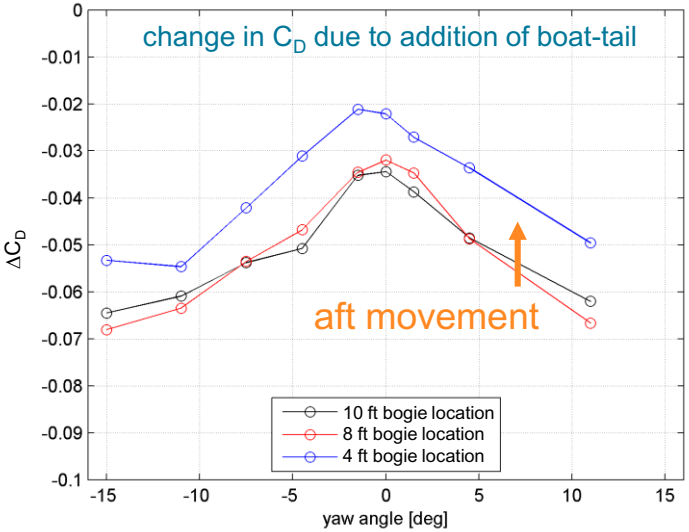


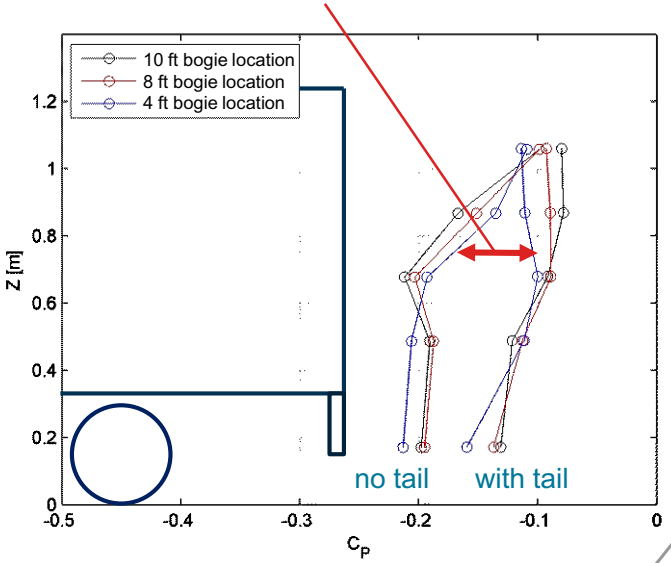
suggests that bogie open area might be important

Boat-Tail with Bogie Movement

Significant boat-tail-performance loss with aft bogie movement

aft bogie movement reduces the pressure-rise associated with the boat-tail

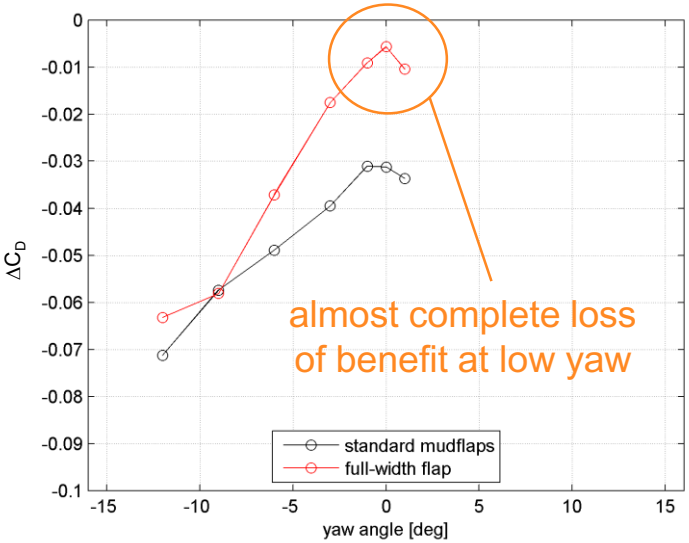


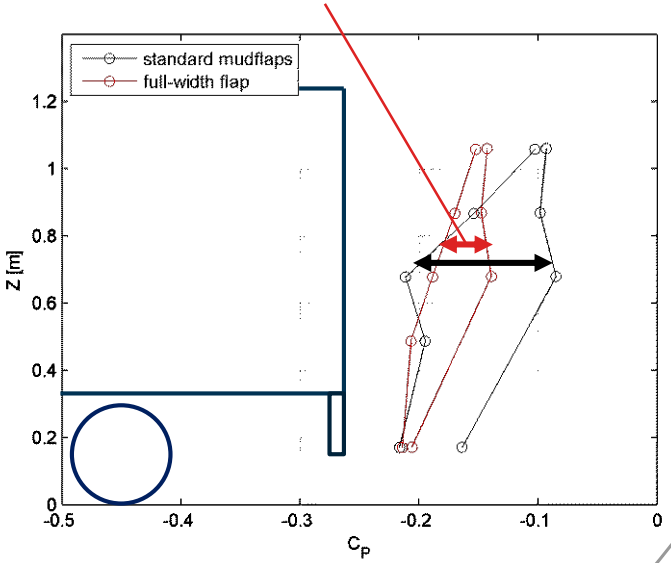


Boat-Tail with Wide Mudflaps

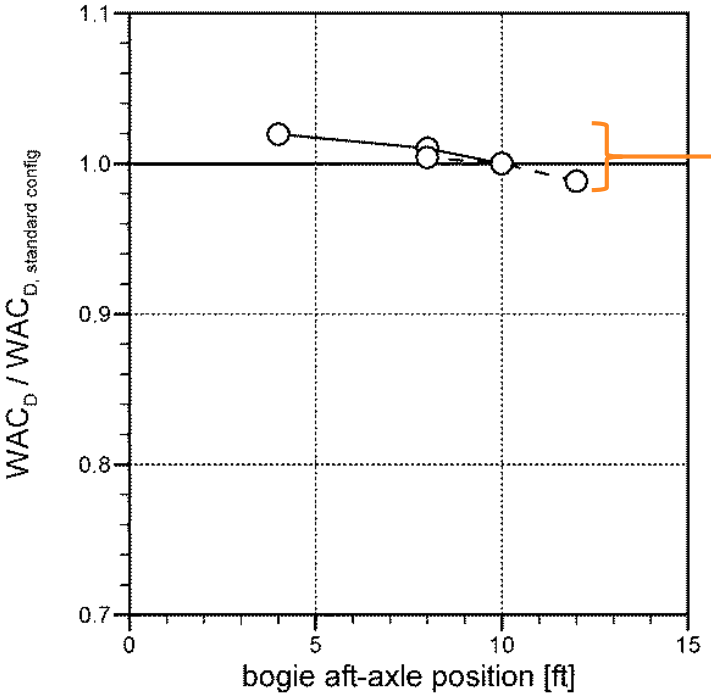
Significant boat-tail performance loss with wide flaps

large difference in the pressure-rise associated with the boat-tail





Wind Averaged Drag Coefficient Results

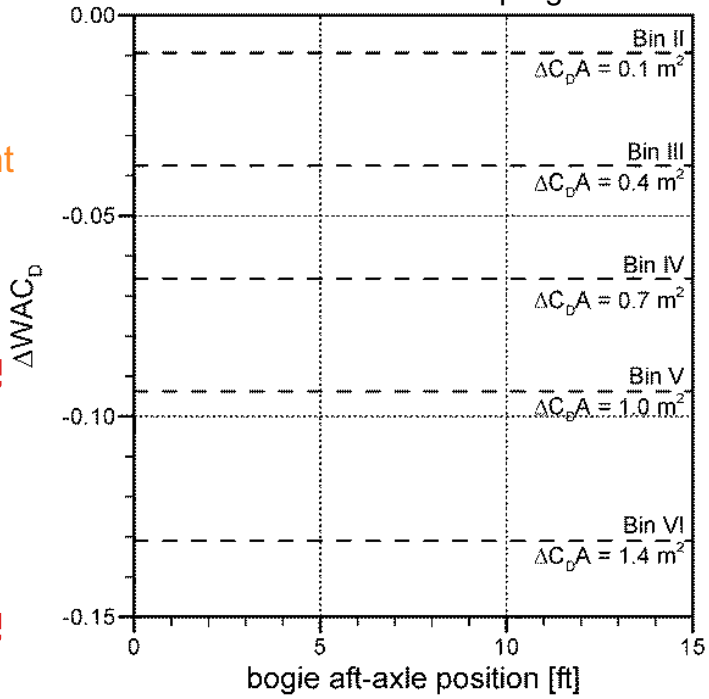


3% variation in drag with range of bogie movement examined

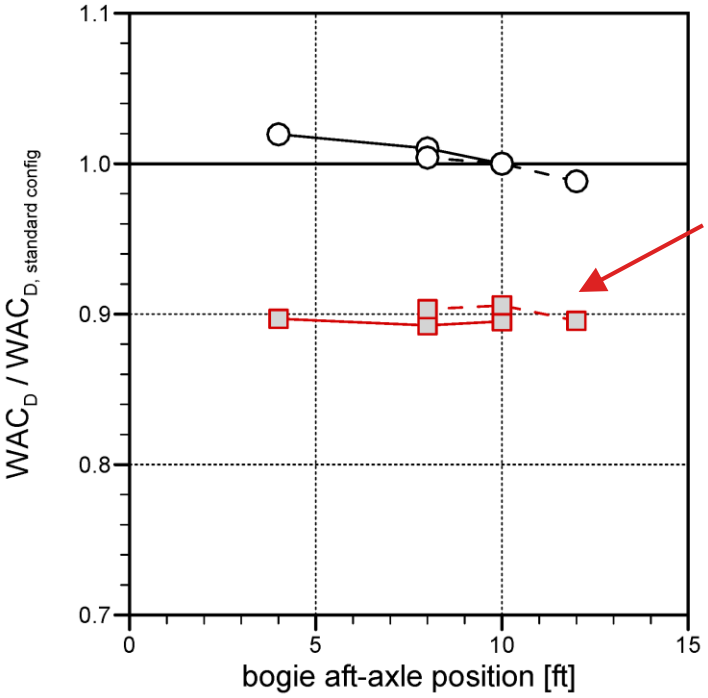
Long Sleeper + 53 ft Dry-Van
- basic trailer
- side-skirts
- bogie fairing (stat.)
- bogie fairing (mov.)
- side-skirts + boat-tail
- bogie-fairing (m) + boat-tail
- boat-tail (w/ bogie fairing)

Short Sleeper + 53 ft Dry-Van
- basic trailer
- short side-skirts
- long boat-tail

* trailer program bins



Wind Averaged Drag Coefficient Results



side-skirts reduce sensitivity to bogie movement

Long Sleeper + 53 ft Dry-Van

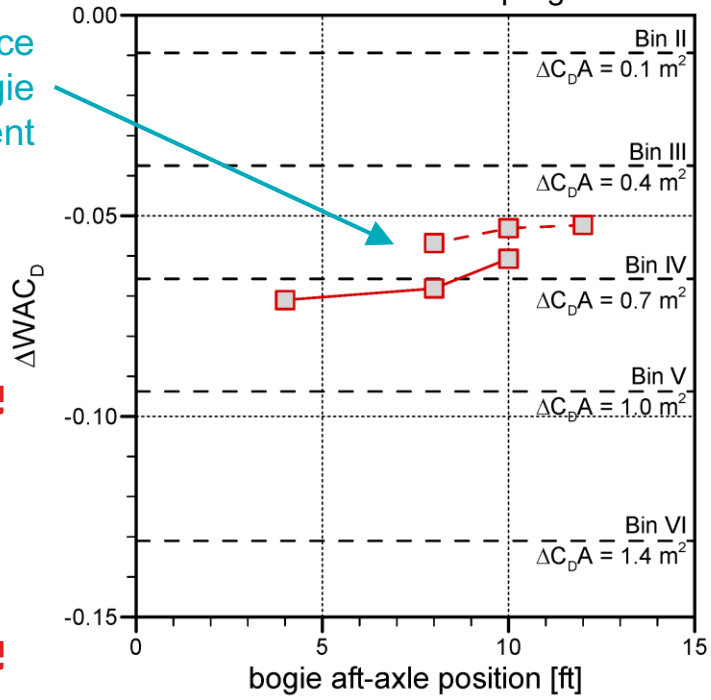
- basic trailer
- side-skirts
- bogie fairing (stat.)
- bogie fairing (mov.)
- side-skirts + boat-tail
- bogie-fairing (m) + boat-tail
- boat-tail (w/ bogie fairing)

Short Sleeper + 53 ft Dry-Van

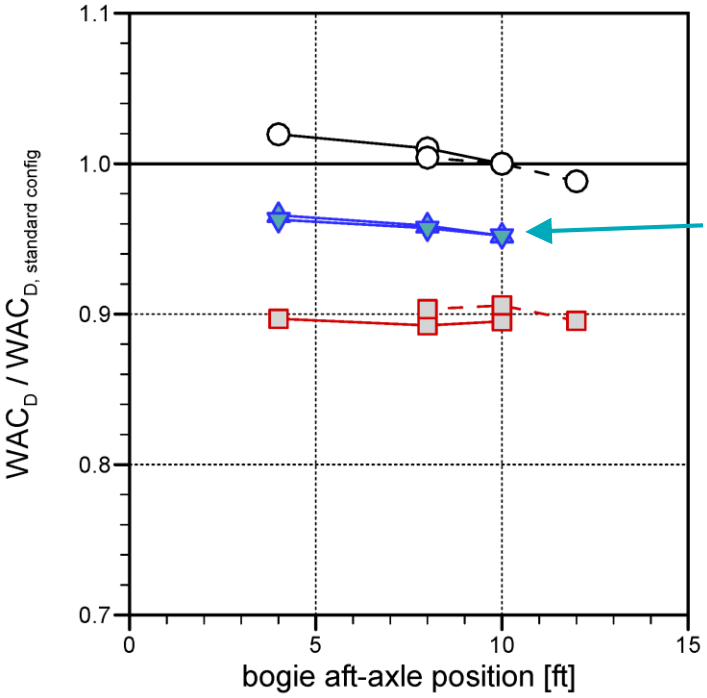
- basic trailer
- short side-skirts
- long boat-tail

side-skirt performance improves with aft bogie movement

* trailer program bins



Wind Averaged Drag Coefficient Results



negligible effect of stationary vs moving bogie fairing

bogie fairing not as effective as side-skirts

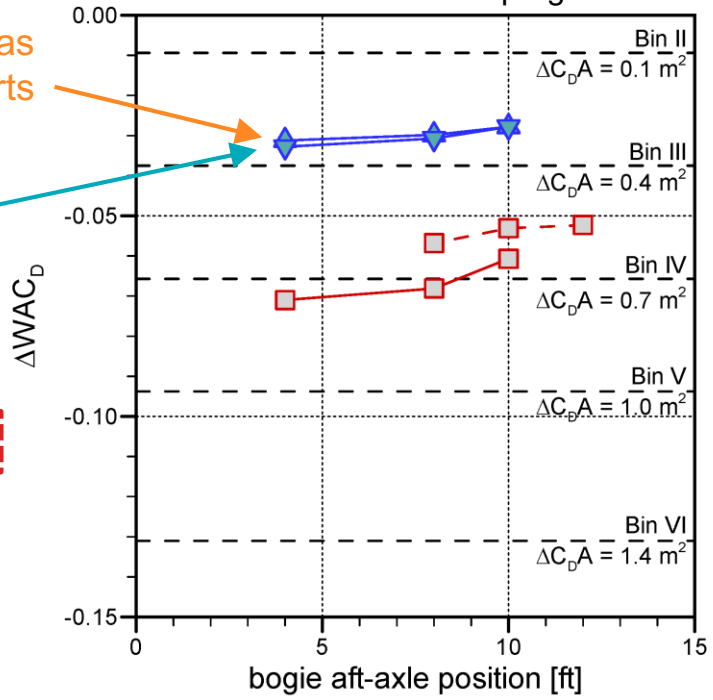
Long Sleeper + 53 ft Dry-Van

- basic trailer
- side-skirts
- bogie fairing (stat.)
- bogie fairing (mov.)
- side-skirts + boat-tail
- bogie-fairing (m) + boat-tail
- boat-tail (w/ bogie fairing)

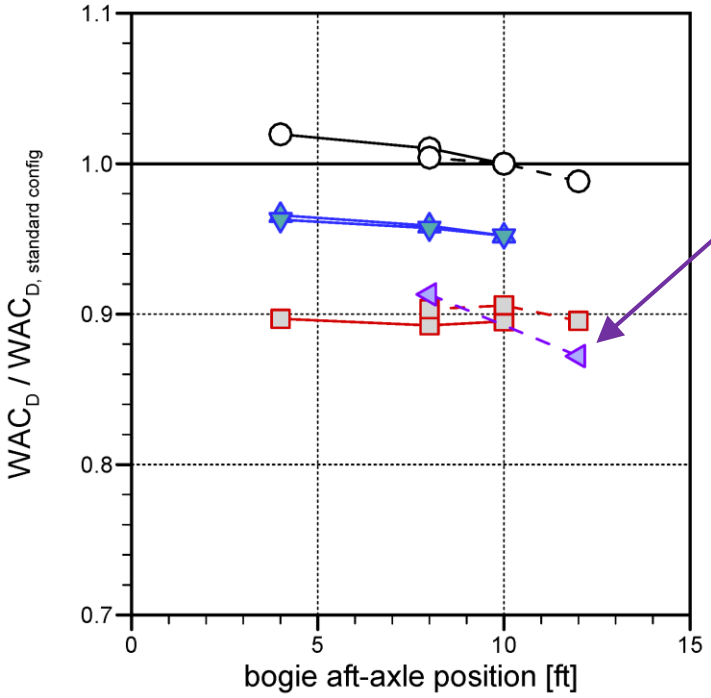
Short Sleeper + 53 ft Dry-Van

- basic trailer
- short side-skirts
- long boat-tail

* trailer program bins



Wind Averaged Drag Coefficient Results



boat-tail performance exhibits strong sensitivity to bogie position

Long Sleeper + 53 ft Dry-Van

- basic trailer
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- bogie fairing (mov.)
- side-skirts + boat-tail
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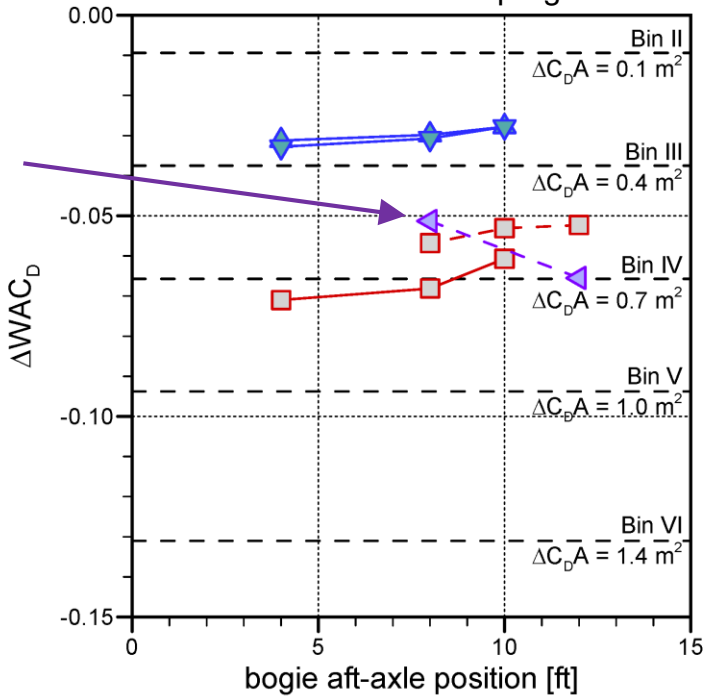
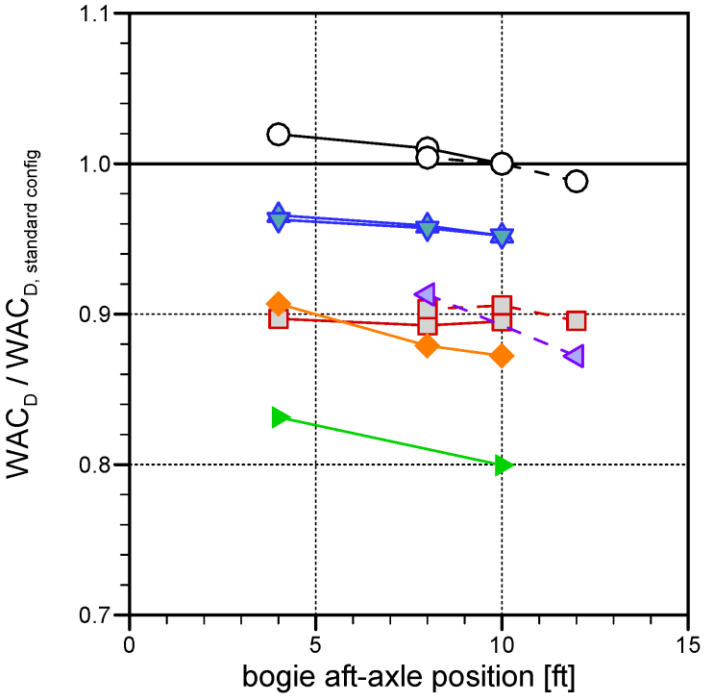


Wind Averaged Drag Coefficient Results



incremental drag reduction from boat-tail

boat-tail sensitivity also observed with skirts and fairings

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- basic trailer
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- bogie fairing (mov.)
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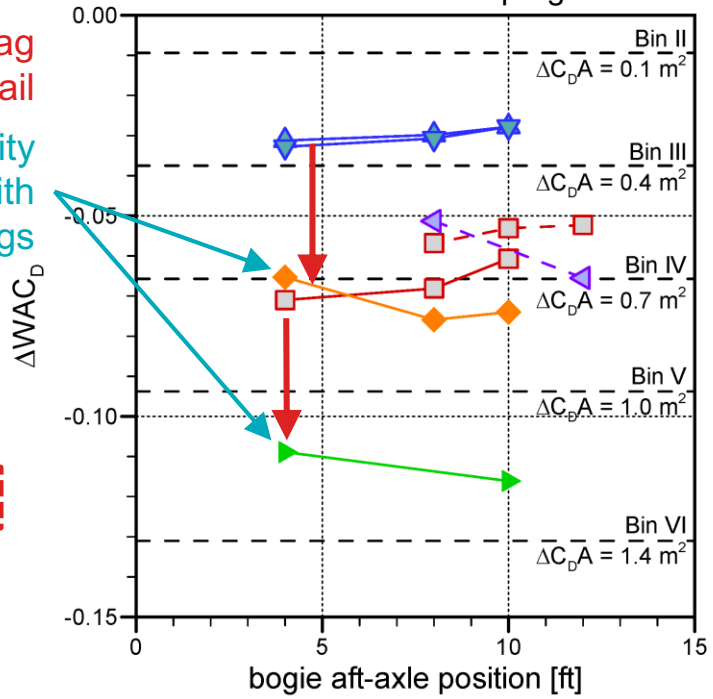
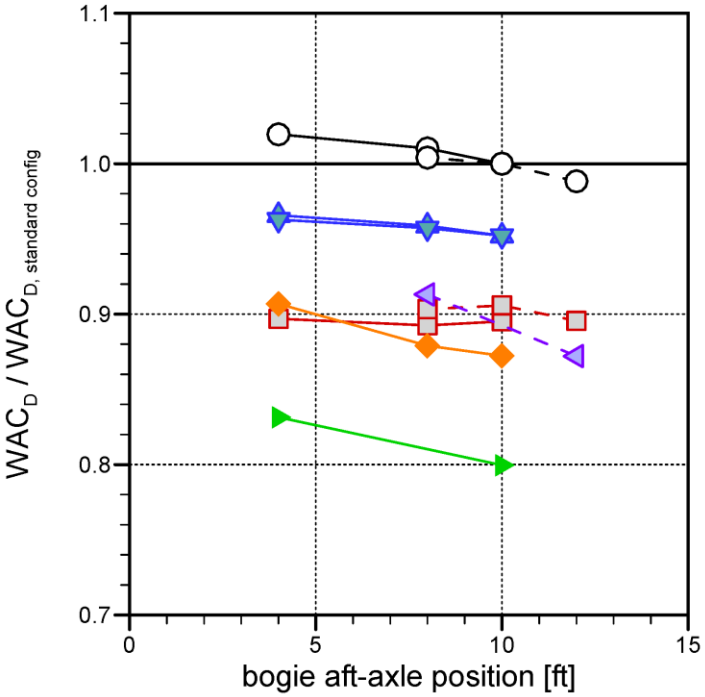


Wind Averaged Drag Coefficient Results



boat-tail sensitivity also observed when added to a trailer with a bogie fairing

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- basic trailer
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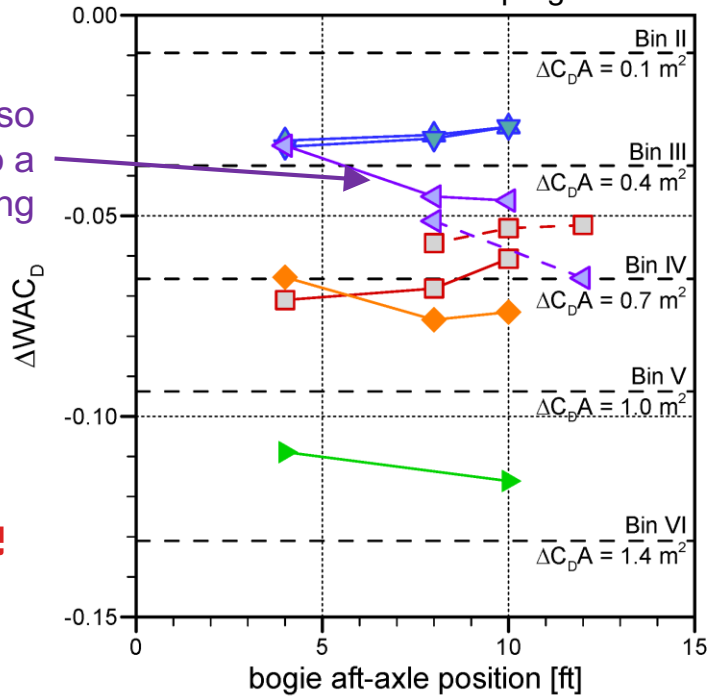
- bogie fairing (stat.)
- bogie fairing (mov.)
- side-skirts + boat-tail
- bogie-fairing (m) + boat-tail
- boat-tail (w/ bogie fairing)

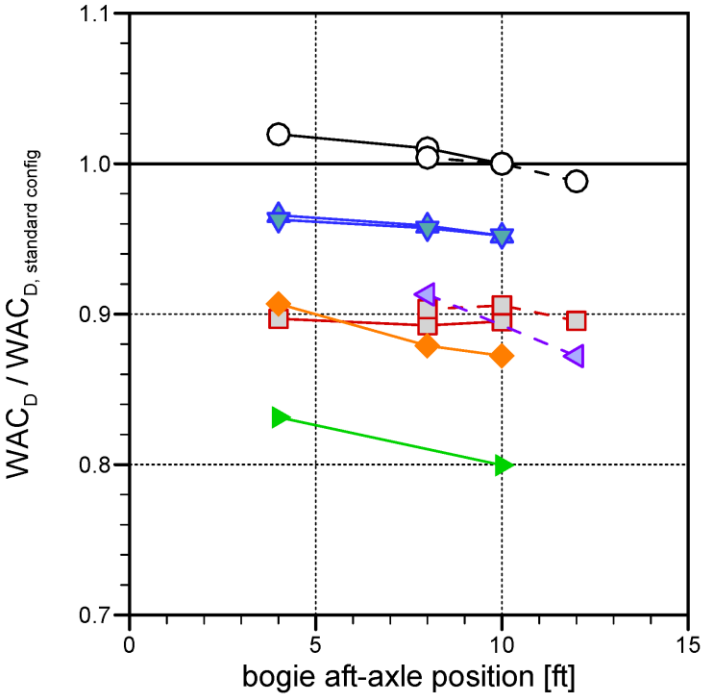
Short Sleeper + 53 ft Dry-Van

- basic trailer
- short side-skirts
- long boat-tail

* trailer program bins



Wind Averaged Drag Coefficient Results



boat-tail performance straddles almost 3 EPA/CARB bins

Could this be a major source of the disparity observed in fleet performance?

Long Sleeper + 53 ft Dry-Van

- basic trailer
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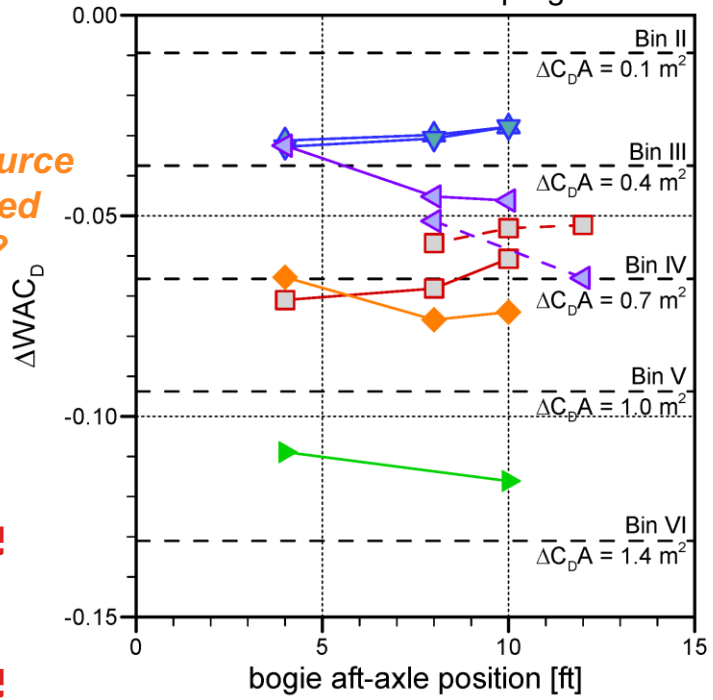
- bogie fairing (stat.)
- bogie fairing (mov.)
- side-skirts + boat-tail
- bogie-fairing (m) + boat-tail
- boat-tail (w/ bogie fairing)

Short Sleeper + 53 ft Dry-Van

- basic trailer
- short side-skirts
- long boat-tail

* trailer program bins



Summary

Bogie movement influences the drag performance of dry-van trailers

Side skirts shield the bogie from the bulk underbody flow and reduce the sensitivity to bogie position

Bogie fairing provided drag reduction but retain sensitivity to bogie position

Bogie fairing exhibited similar performance whether stationary or sliding

Boat tail performance observed to be highly sensitive to bogie position and under-trailer configuration

Questions?

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