Onboard Anemometry Methodology Decomposition

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North America

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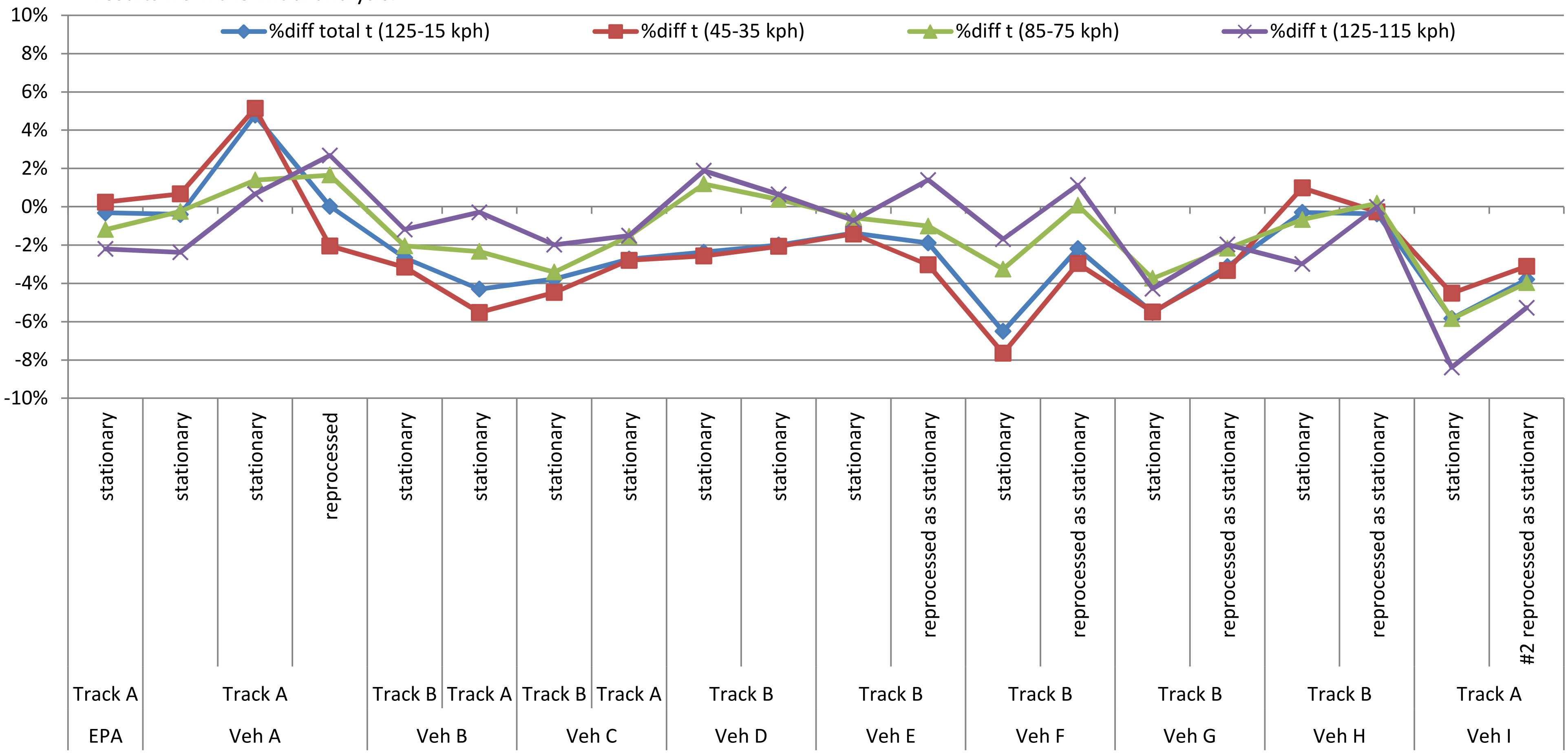
- Processing Repeatability/Robustness
- EPA Coastdown Audit Process
- Updated Conclusions/Recommendations

Previous Conclusions/Recommendations

F-terms were used to generate coastdown times for vehicles from 2013-2014 and normalized for comparison across vehicles and tracks. The percent differences illustrated below tie back to each vehicle's respective onboard anemometry test.

*Note: Vehicle I is a recent addition to the data set. Vehicles A-D, and Vehicle I were chosen for the decomposition to explore a range of results from the initial analysis.



It was concluded that a small benefit (~1-2%) may be seen when comparing an onboard test to a stationary test. A recommendation was made to explore differences between the methods using common tests to isolate contributing factors.

Analysis Updates

- The original analysis compared unique anemometry tests to unique stationary tests, introducing test to test variability, thus confounding the true differences between the methods
- The analysis of a single test using both the stationary and onboard processes was decided to isolate the methodology differences
- A decomposition of the initial results was performed on five of the vehicles (A-D, and I)
- The following analysis uses the **stationary anemometry** results as the baseline for the comparison

The analysis of a common test using both stationary and onboard processes allows for the isolation of the methodology differences without factoring in test-to-test variability.

Onboard to Stationary Decomposition

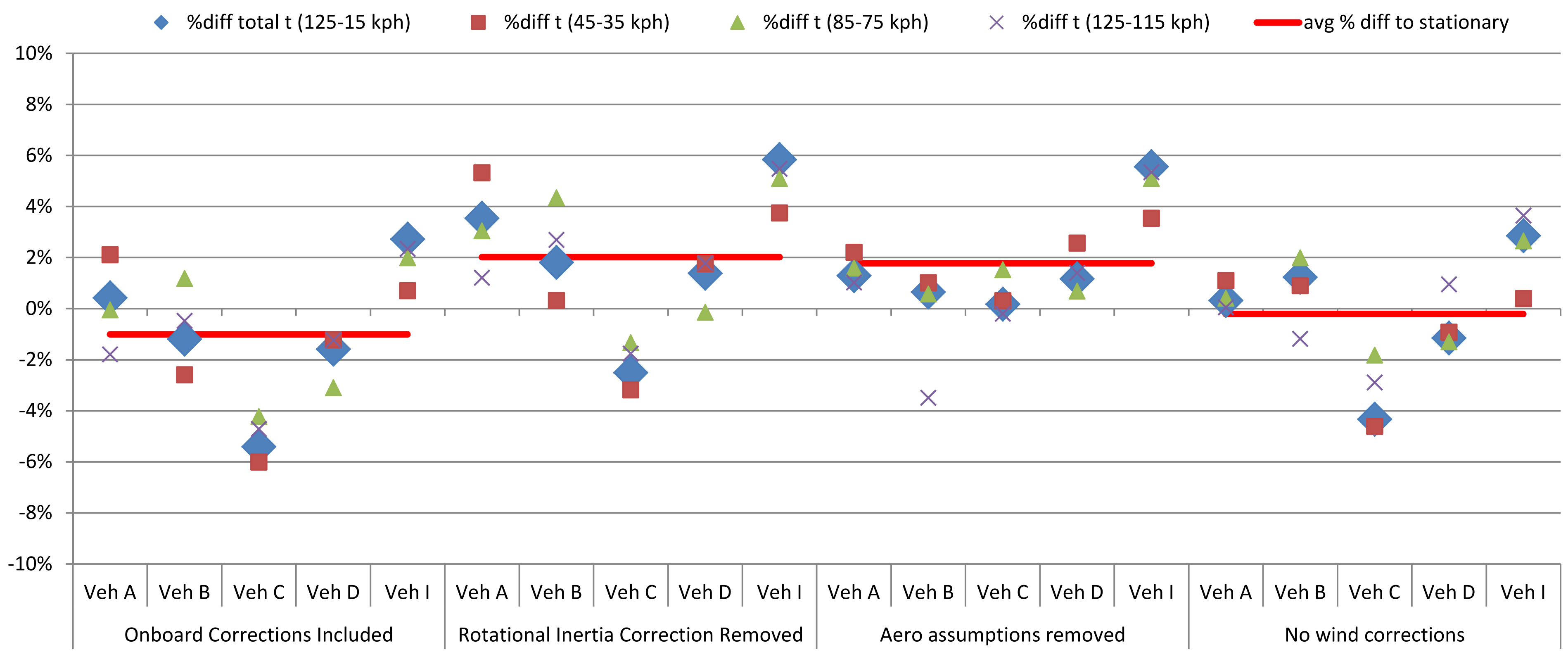
The five vehicles were analytically walked to the European (stationary) coastdown times from the force curve generated through the onboard anemometry SAE J2263 method. Methodology differences were explored, including:

- Stationary analysis:
  - If needed, gated times from a run pair are be removed from the analysis to satisfy the 2% statistical accuracy criteria
- Onboard analysis corrections include the following:
  - Rotational inertia corrections (1.5% per driven axle)
  - Aerodynamic assumptions/corrections
    - Anemometer-induced drag
    - Measured/modeled vehicle drag
  - Wind corrections
    - Head and tail winds
    - Cross winds

*Note: all coastdown runs were used in the onboard analysis

Decomposition Contributions

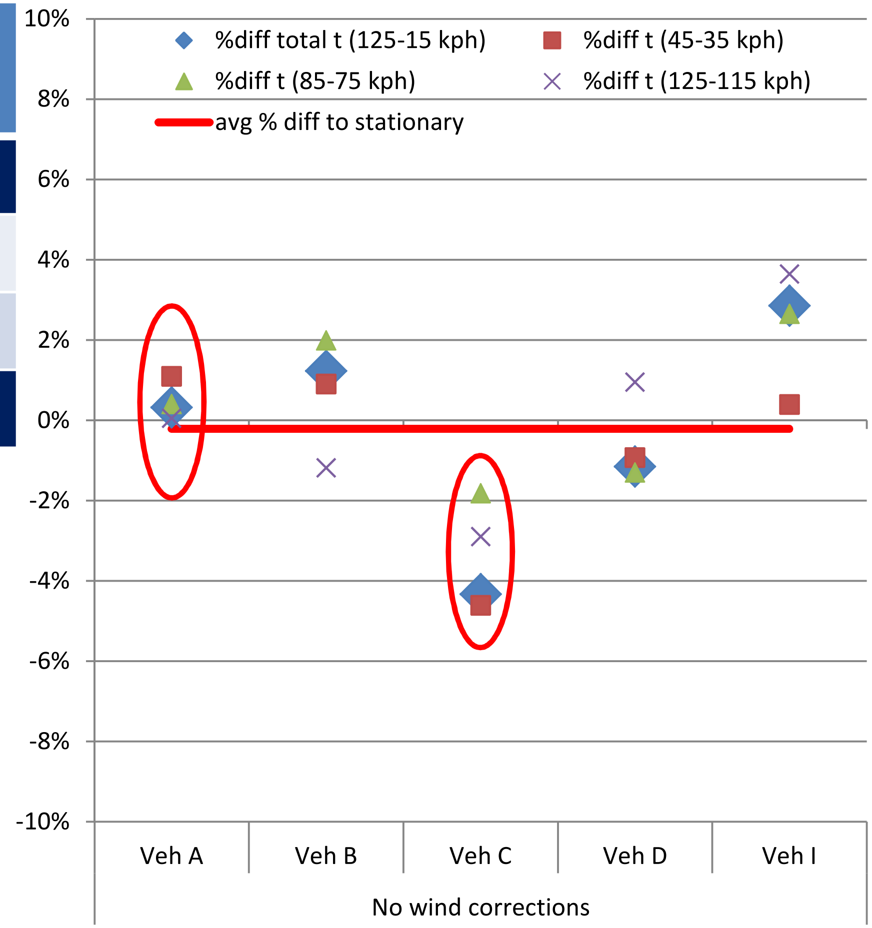
The chart below shows how the 5 vehicles performed through each step of the analytical walk vs the respective test being processed as stationary. Each vehicle was processed with all J2263 corrections initially, then corrections were factored out of the analysis one-by-one (left to right).



All 5 vehicles were subjected to the same analytical processes throughout the walk.

Decomposition Summary

% Diff to EEC Total CDT (stationary 125-15 kph)	Mean	St. Dev.
Onboard corrections included	-1.01	2.99
- Rotational Inertia removed	2.02	3.07
- Aero assumptions removed	1.77	2.17
- No wind corrections	-0.21	2.72



For these five vehicles, onboard methodology produces slightly shorter coastdown times, even after the corrections are ignored. This is contradictory to the conclusions of the initial presentation in which a 2% offset was observed on a test to test basis.

For the stationary reference points, many of the tests required the removal of gated times to reduce the statistical accuracy. This is believed to make up the majority of the remaining differences once the corrections were removed from the onboard processing.

With all of the SAE J2263 corrections removed, the mean difference is -0.21%, or nearly identical. The deviations are explored next by taking a closer look at individual runs from vehicles A and C.

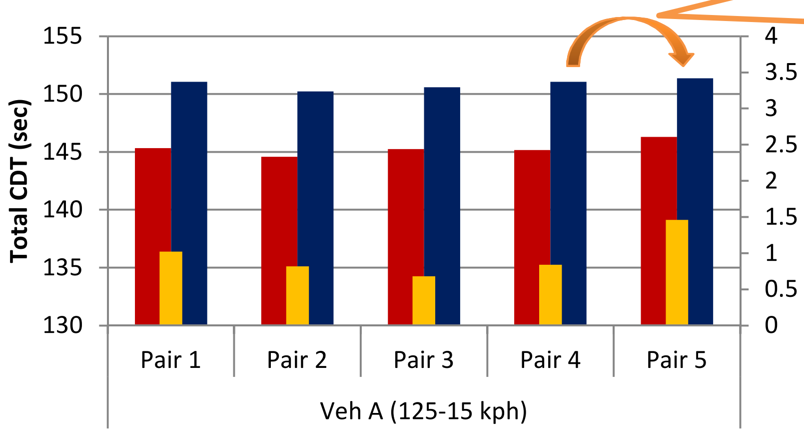
Repeatability vs Wind Speed

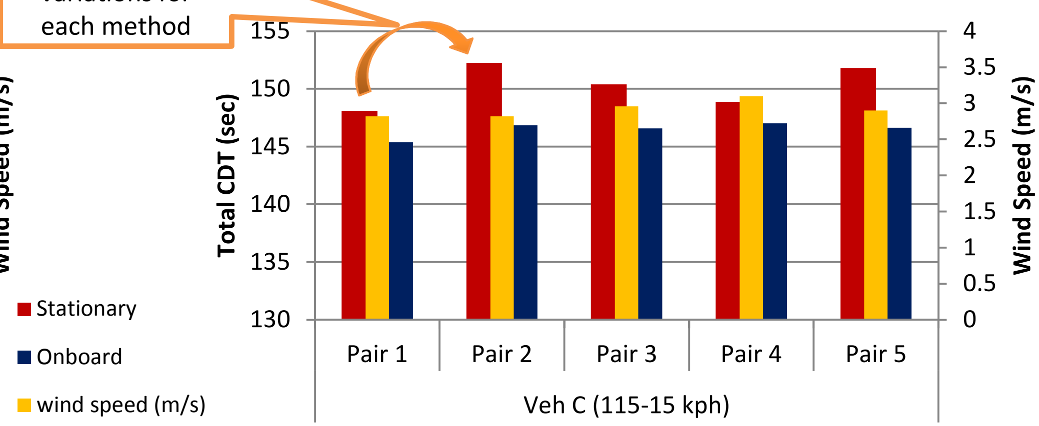
Outside of potential aerodynamic differences influencing the two vehicles, the major difference noted between the two tests was the wind conditions throughout the testing. Vehicle A tested in very low winds, while Vehicle C was tested in a relatively higher wind condition (unable to satisfy European statistical criteria).

Vehicle A - Total CDT (125-15 kph) vs Lower Winds

Notice the magnitude of pair to pair CDT variations for each method

Vehicle C - Total CDT (115-15 kph) vs Higher Winds



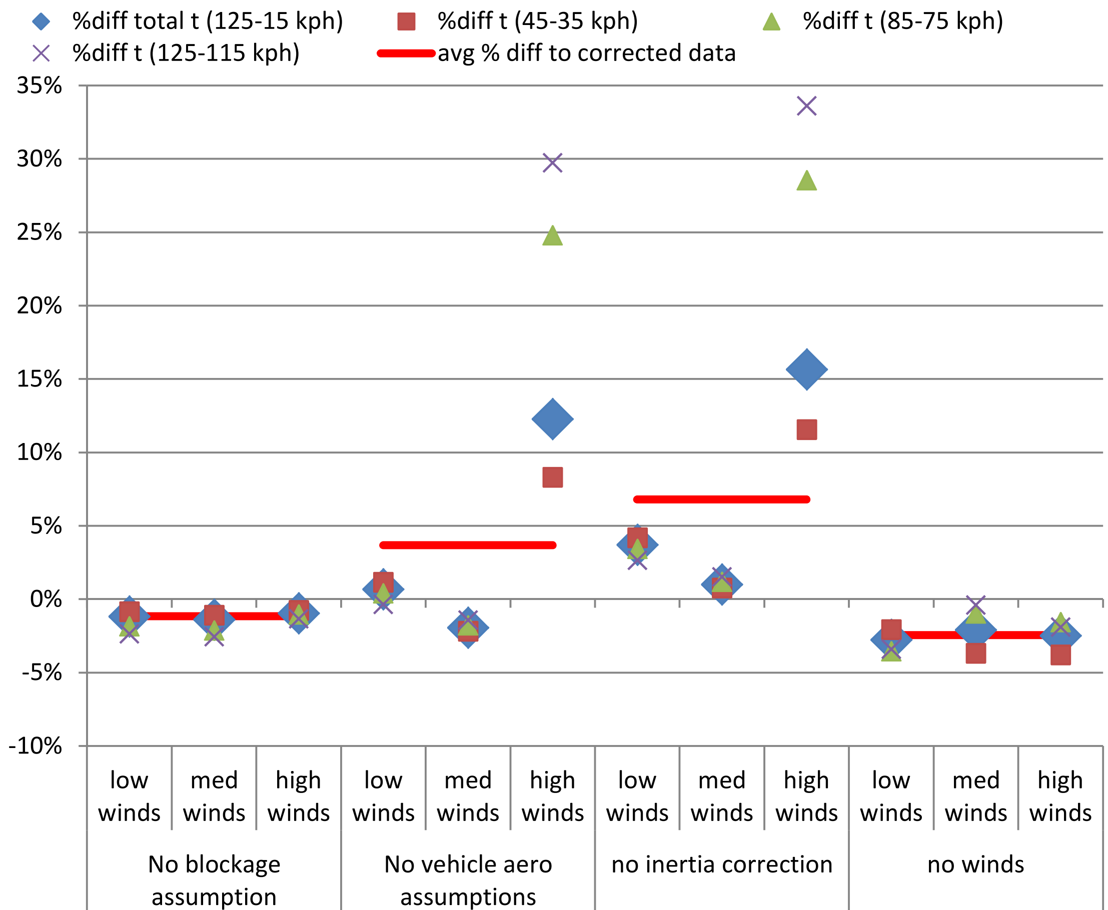


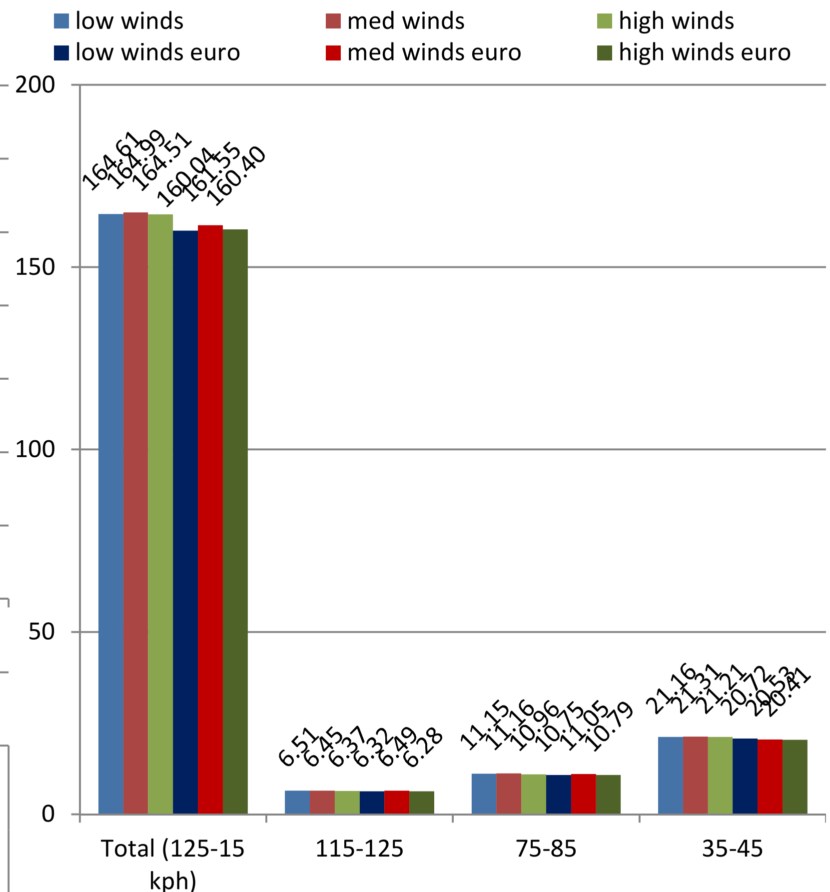
Veh A	St. Dev.	Coef. Var.
Stationary	0.62 sec	0.43
Onboard	0.45 sec	0.30

Veh C	St. Dev.	Coef. Var.
Stationary	1.80 sec	1.20
Onboard	0.64 sec	0.44

Regardless the wind conditions (high or low), the onboard anemometry method is able to produce more repeatable results through its correction process.

Onboard Fitting Robustness





The reference points of a single vehicle (correlation vehicle Z – larger sedan) under multiple test conditions are shown in the graph on the right, illustrate how consistent the results of the onboard method can be, even in the presence of high winds. As the corrections of the onboard method are removed from the analysis (working from the left to the right), variance in the results increases with as the test winds increase (see backup slides for additional samples).

EPA Coastdown Audit Process

- EPA runs a Coastdown Audit program where they perform coastdowns on selected manufacturer vehicles and compare results vs. roadloads used for certification.

- From EPA Guidance Document, discussing their roadload audit process (VPCD-98-16):

  "<u>Road Force</u>. Road force, as a function of speed, shall be determined for the representative vehicle. EPA will use the SAE J2263 procedure for confirmatory coastdown testing, manufacturers may use any procedure or method that yields equivalent results. For example, tire dynamometer or wind tunnel data may be used to adjust test results from one population to stand for another."

- SAE J2263 specifies the use of On-Board Anemometry

Updated Conclusions

- Compared to the last set of conclusions where 2% variation was noted on back to back tests (with onboard having longer coastdowns), the analysis of common test data reduced the variation to **1%**, with stationary having longer coastdowns (based on 5 vehicles)
- The decomposition of onboard corrections resulted in a remaining offset of -0.2%, which may be attributed to the data adjustments required to meet the stationary accuracy requirements
- The use of the onboard methodology provided enhanced repeatability in the presence of various wind conditions. This was further illustrated through the correlation vehicle, where results correlated under low, medium, and high wind speeds.
- The EPA explicitly states that the SAE J2263 procedure will be used during official coastdown audits for manufacturers

***Final conclusion**

The use of common test data to compare the SAE J2263 onboard anemometry method to the stationary anemometry method showed improved correlation (~1%).

WLTP Recommendations

- Adoption of the SAE J2263 methodology is strongly recommended
- Benefits may include:
  - Similar to stationary analysis when cross checking results
  - Enhanced test repeatability
  - Increase in acceptable wind limits for testing, resulting in more potential testing windows

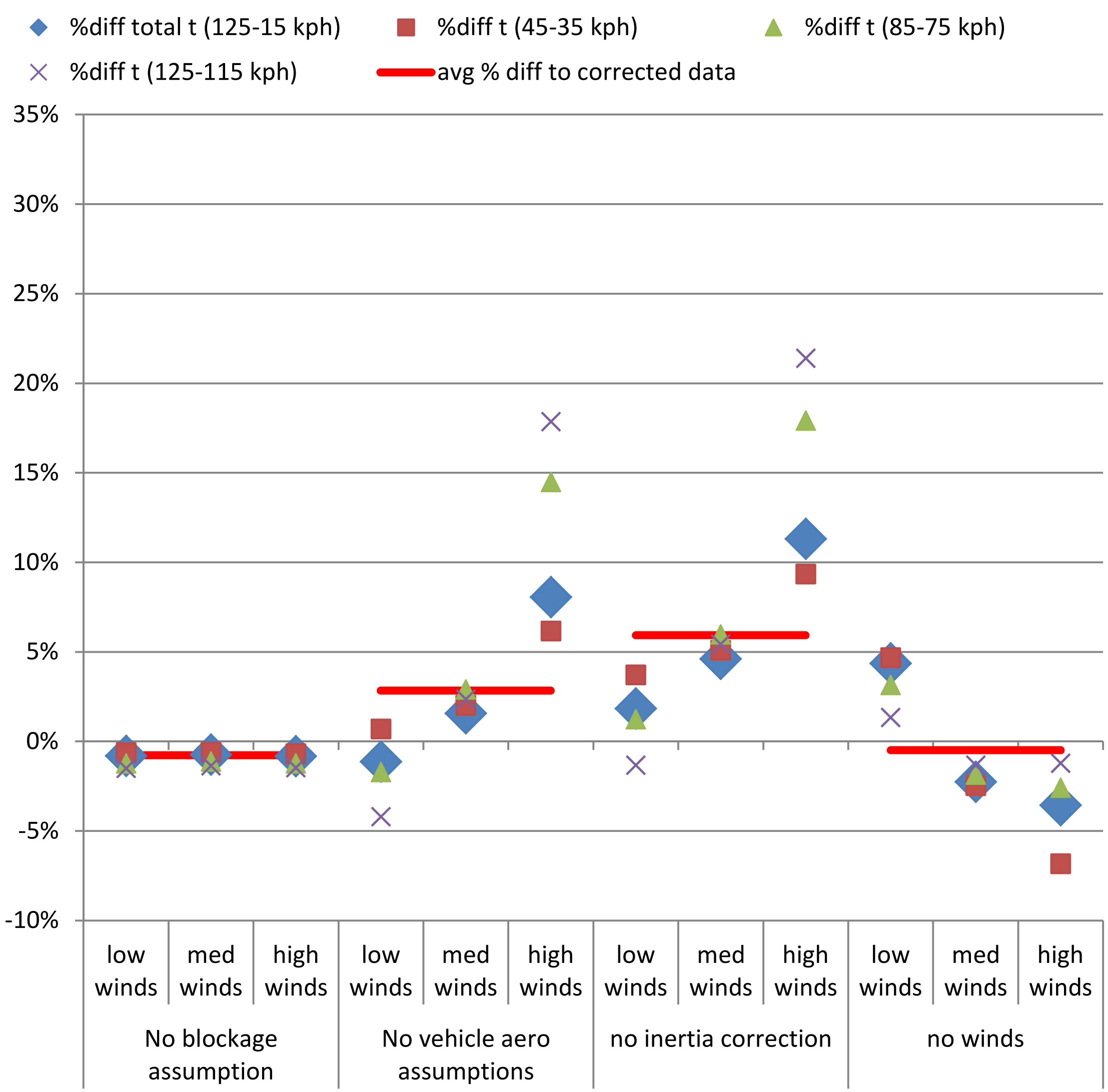
On-Board Anemometry Timeline

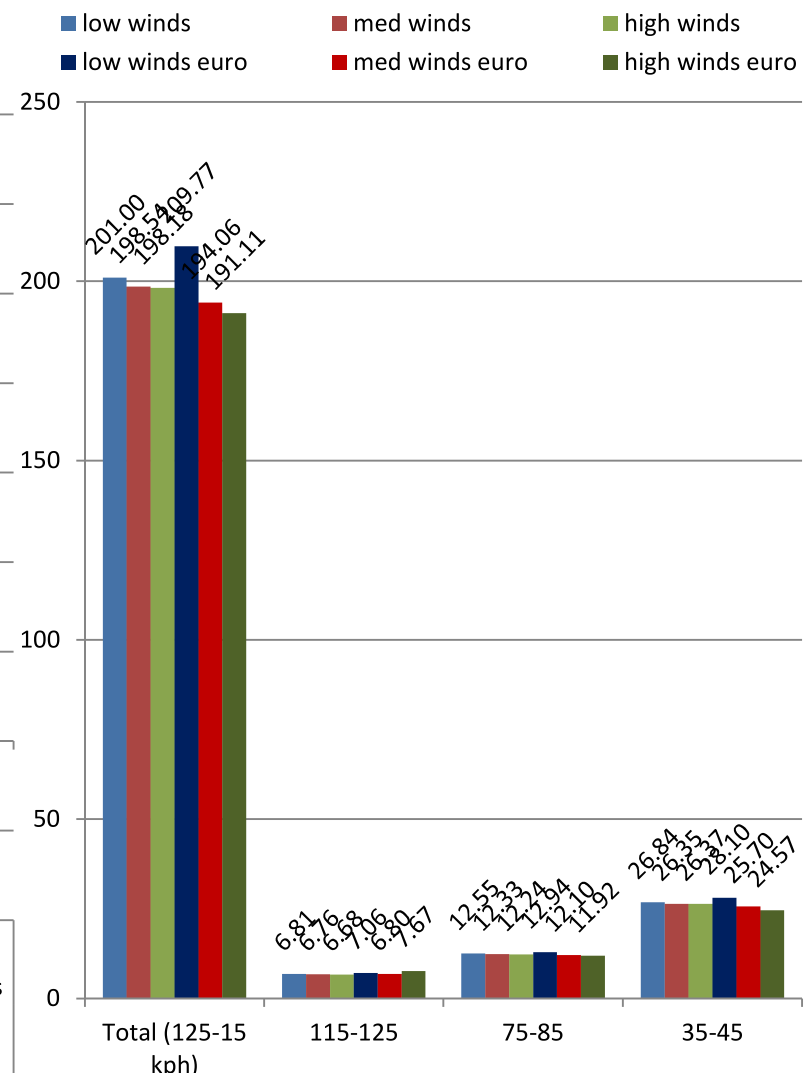
- April 14-16: WLTP IWG #10 (Stockholm)
  - Review of on-board methodology and latest analyses
- Mid-May: Annex 4 Task Force
  - Final discussions and updated WLTP language to refer to SAE J2263
- June 9-10: WLTP IWG #11 (Geneva)
  - Presentation final proposal; ready for adoption?

Go Further

BACKUP SLIDES

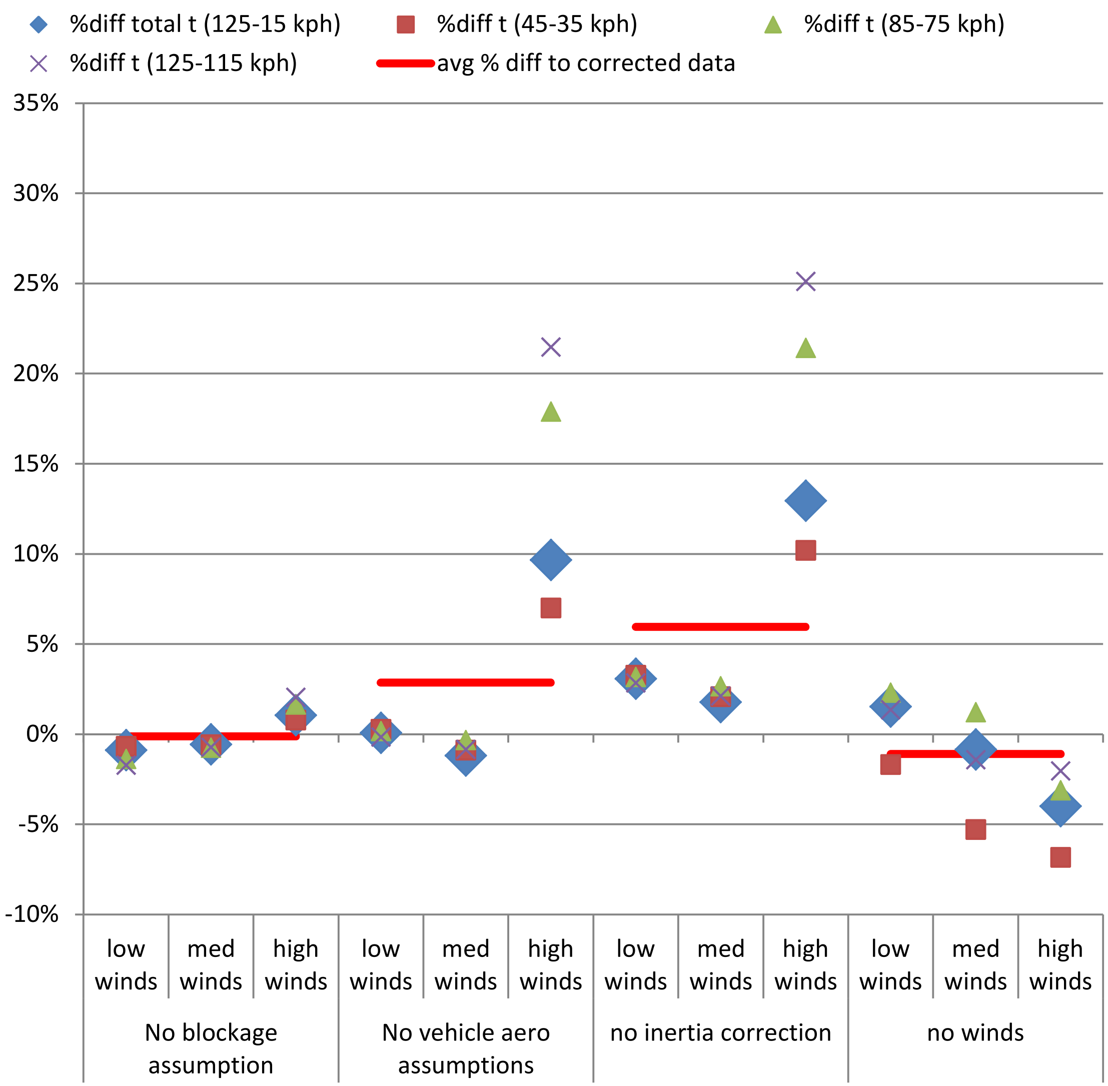
Onboard Fitting Robustness

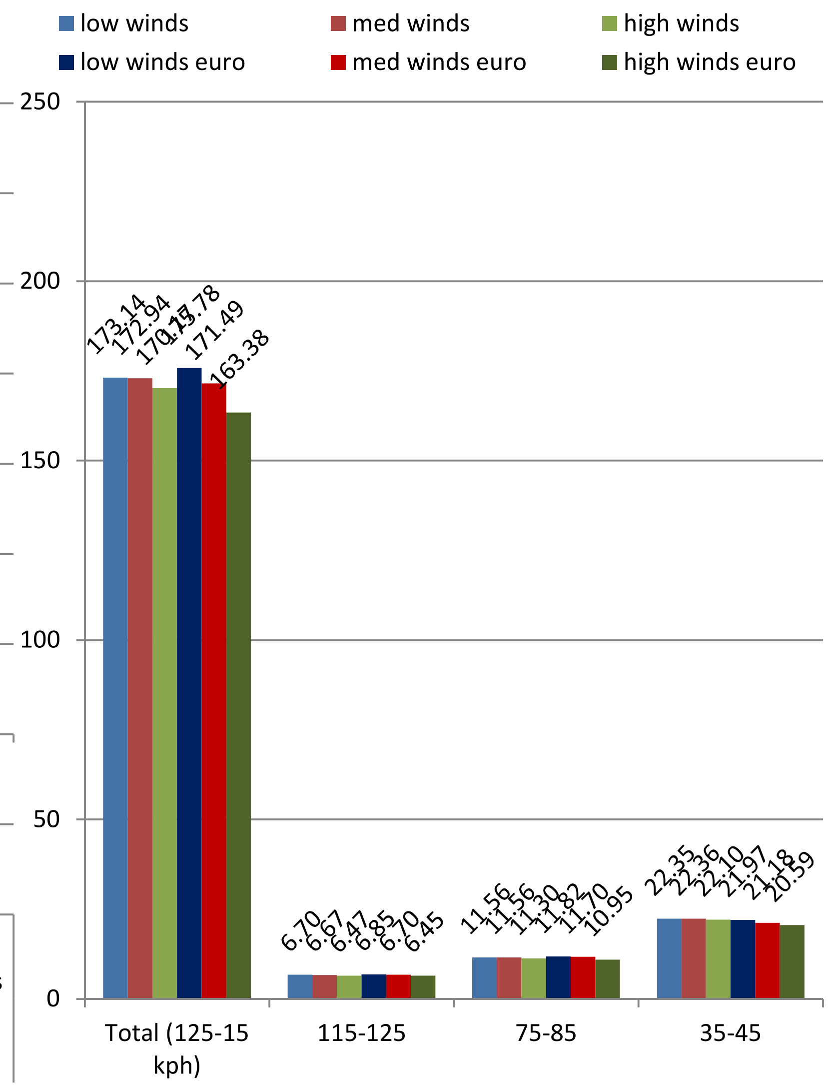




Correlation vehicle X – large vehicle

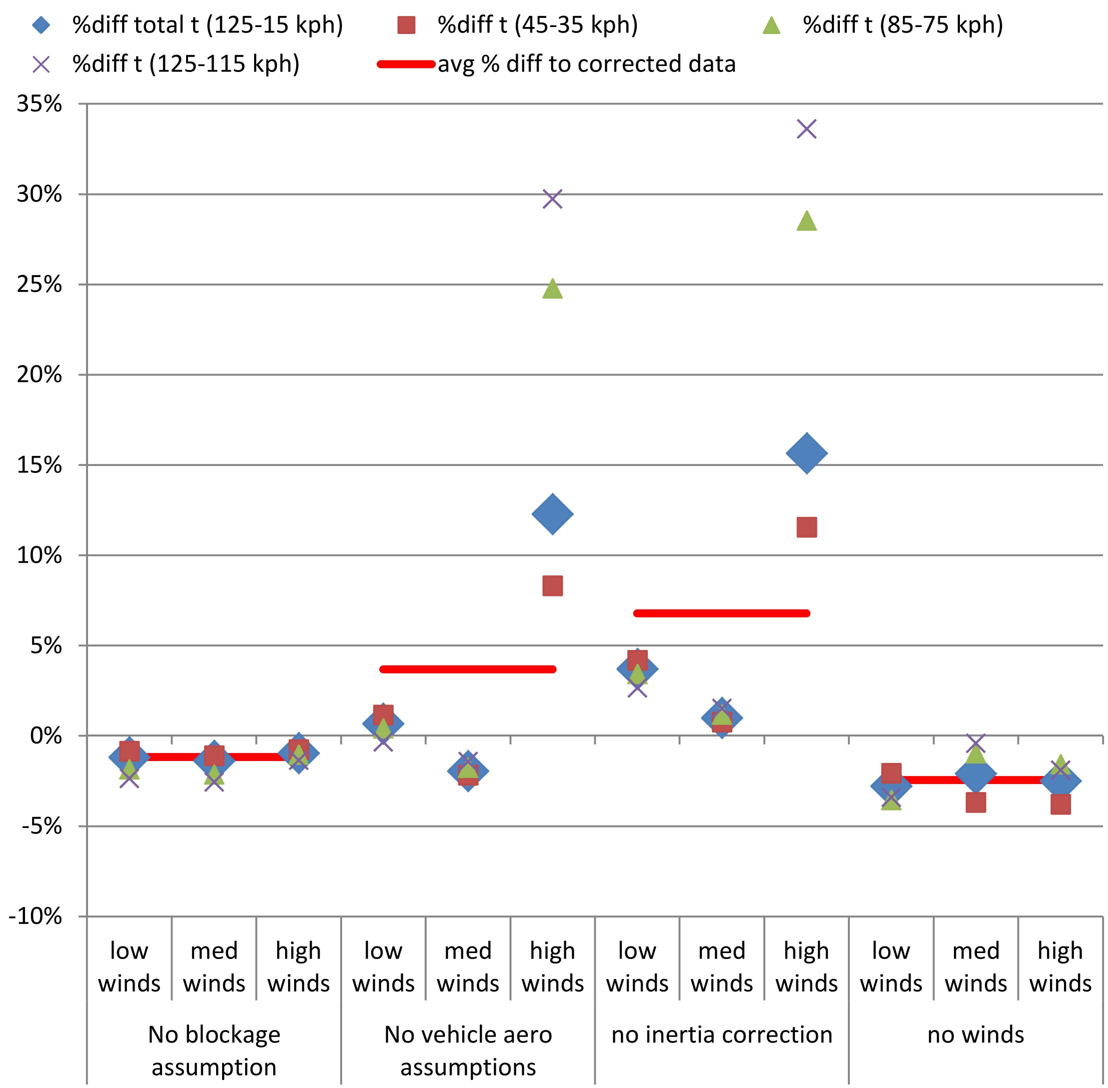
Onboard Fitting Robustness

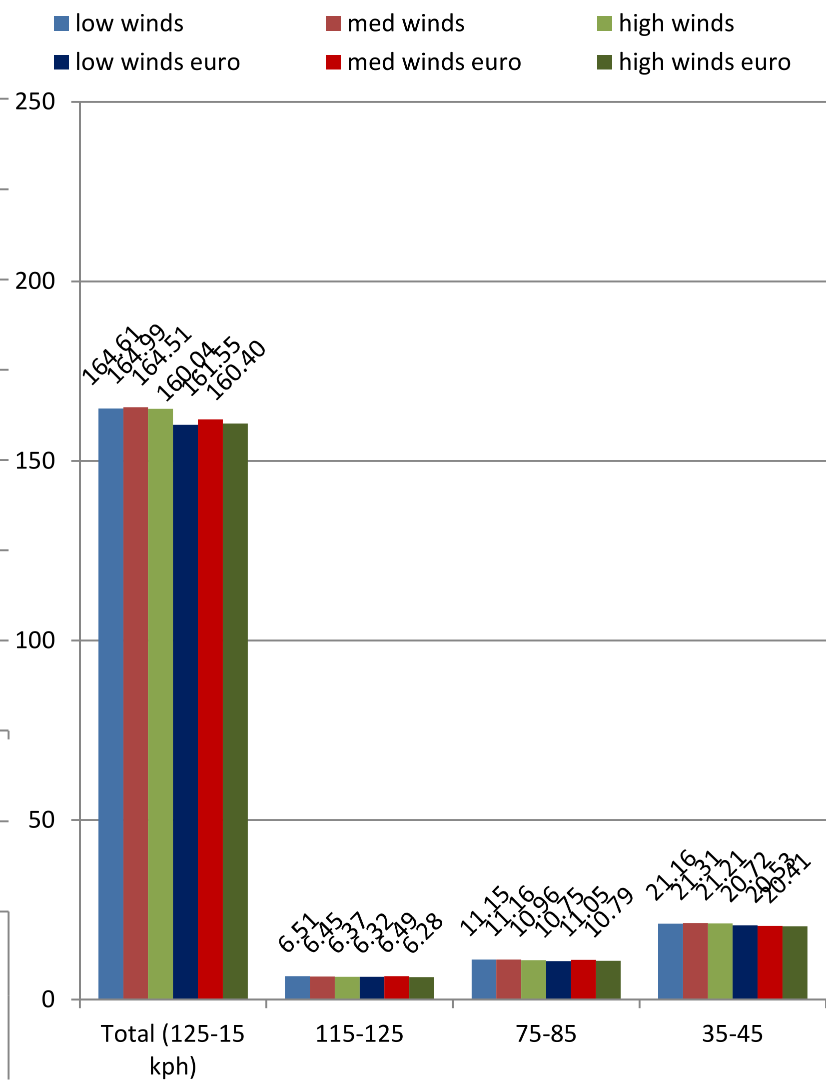




Correlation vehicle Y – smaller sedan

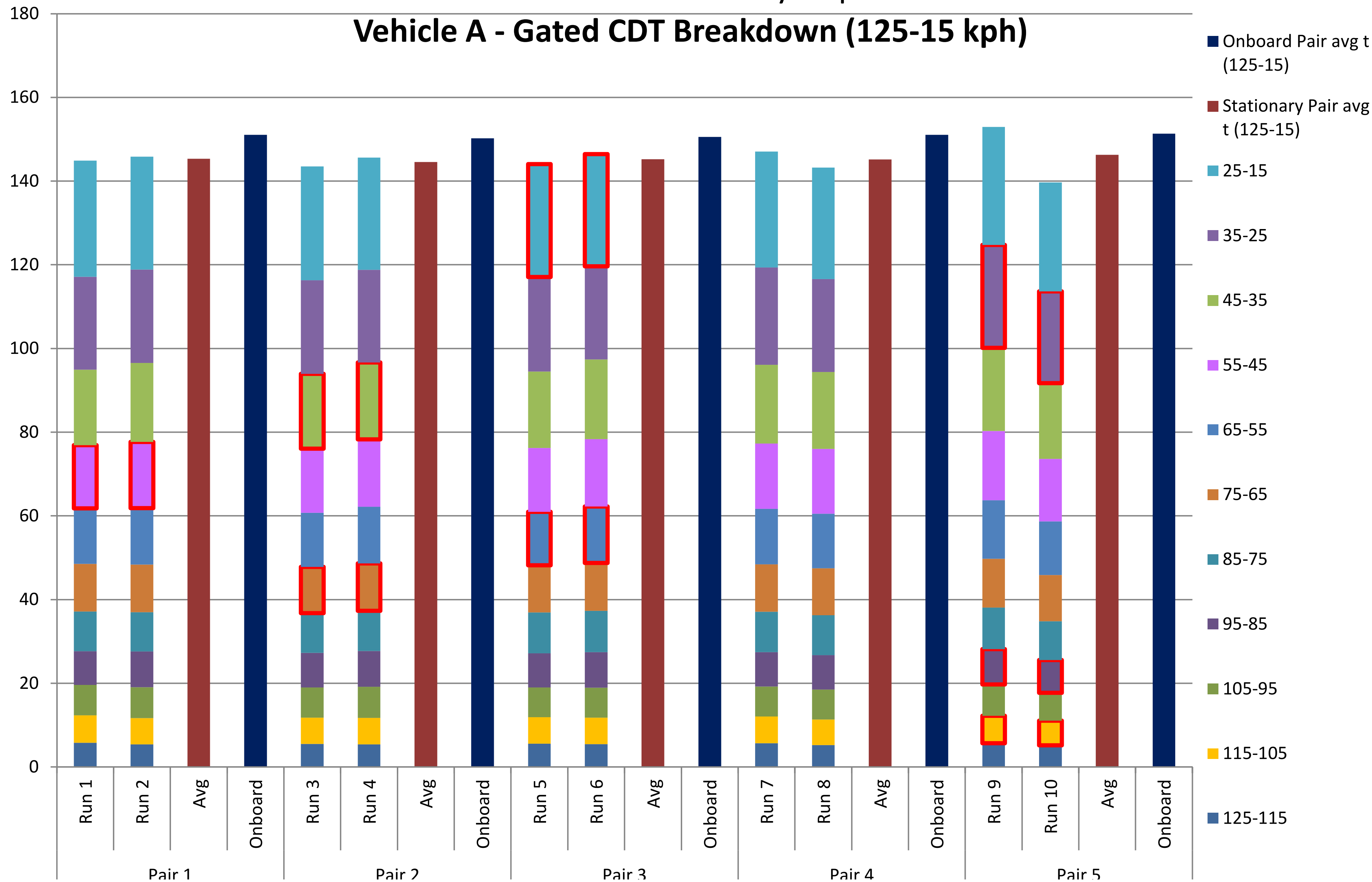
Onboard Fitting Robustness





Correlation vehicle Z – larger sedan

Gated times outlined in RED were removed from the stationary analysis in an effort to meet the statistical accuracy requirements



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