GENERAL MOTORS DYNAMOMETER INTRODUCTION AND BRAKE COOLING DISCUSSION

Matt Robere – 14 Dec 2017

GENERAL MOTORS

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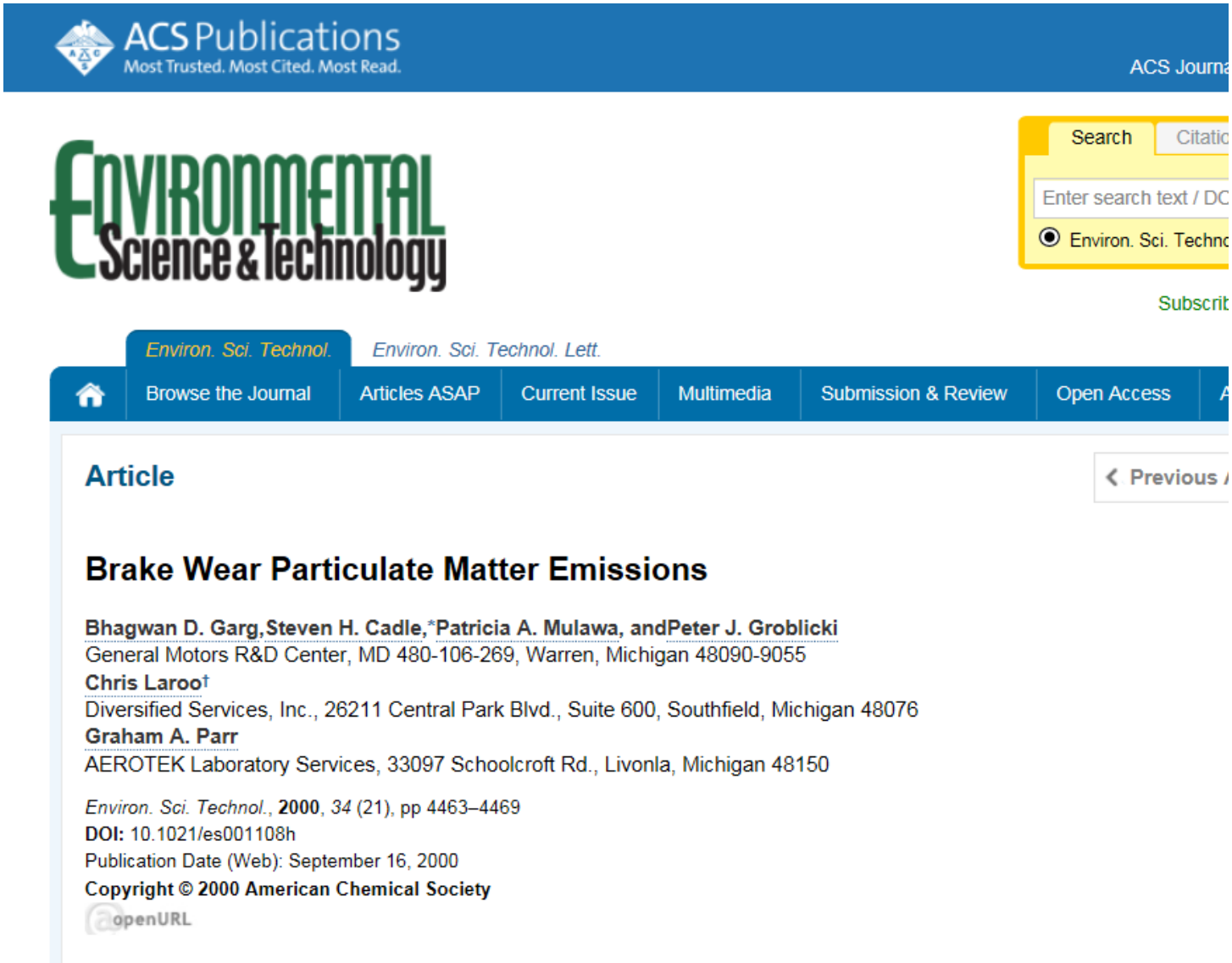
Overview

- Prior GM brake wear debris study
- GM brake dynamometer overview
- Brake cooling study

Prior GM Brake Wear Debris Study



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Article

Previous

Brake Wear Particulate Matter Emissions

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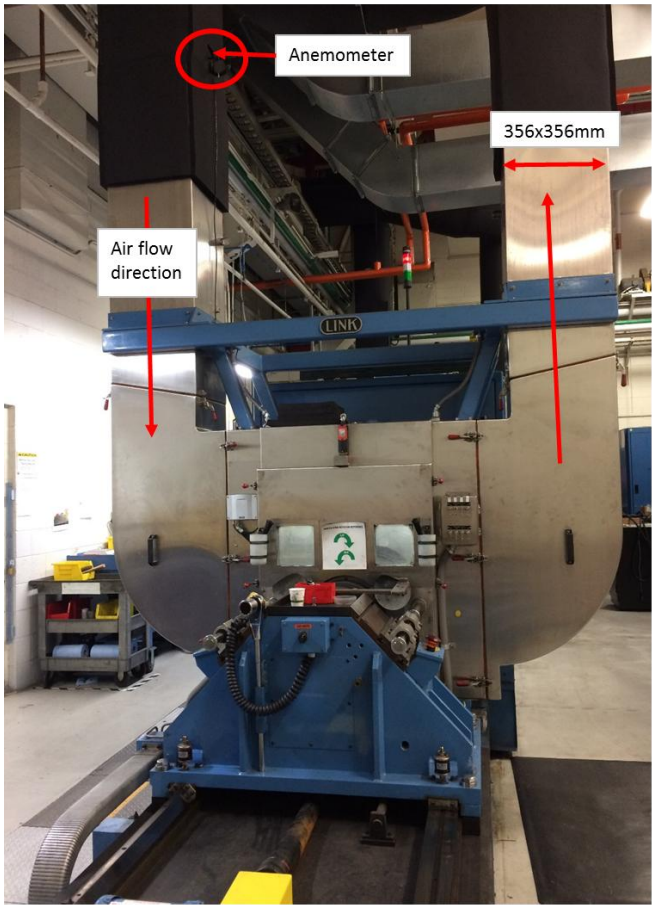
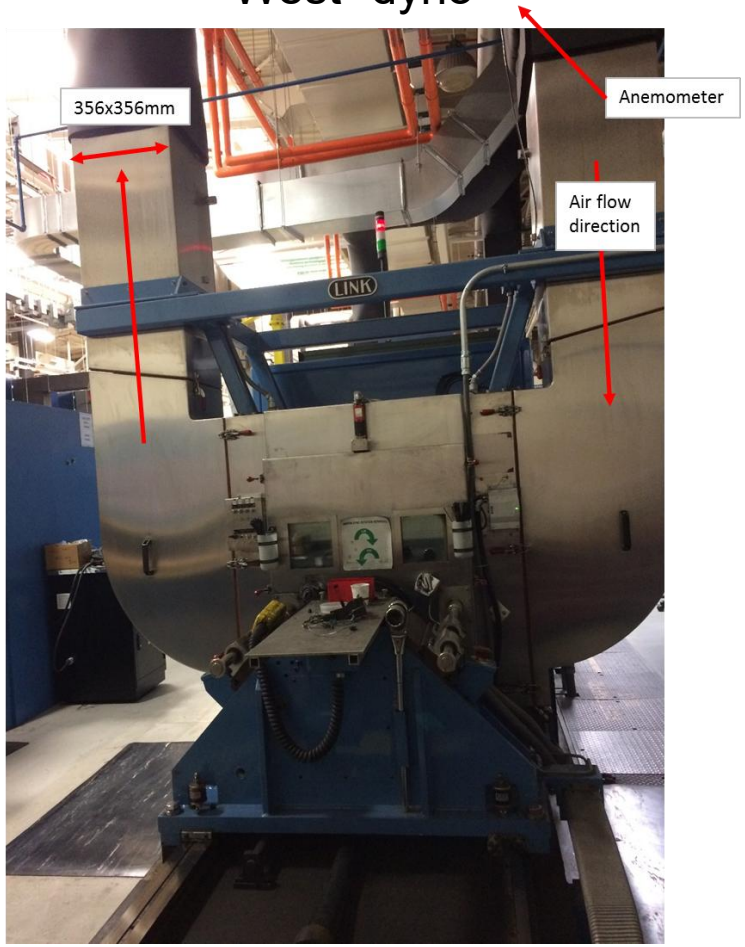
Environ. Sci. Technol., **2000**, *34* (21), pp 4463–4469
DOI: 10.1021/es001108h
Publication Date (Web): September 16, 2000

Dynamometer Description

"East" dyno



"West" dyno



Dynamometer Description

item	Description	GM
1	airflow orientation	Horizontal
2	maximum air speed / km/h	Fresh air = 43, Conditioned = 39
3	maximum air speed / m/s	11.9 (10.8)
4	maximum airflow / m^3/hr	5400 (4900)
5	air speed/flow measurement	upstream from brake
6	environmental control	Yes
7	airflow direction	East end = Left to right, West end = right to left
8	main inlet duct	
a	shape	square
b	height / mm	356
c	width / mm	356
d	**hydraulic diameter equivalent**	**389**
e	diameter for round duct / mm	n/a
9	duct entry to brake enclosure	
a	shape	square
b	height / mm	356
c	width / mm	356
d	diameter / mm	n/a
10	brake enclosure	
a	shape	Rectangular, closed box
b	width / mm	1219
c	depth / mm	940
d	height / mm	1092
8	main outet duct	
a	shape	square
b	height / mm	356
c	width / mm	356
d	**hydraulic diameter equivalent**	**389**
e	diameter for round duct / mm	n/a

Dynamometer Testing

Dynamometer benefits:

- Better repeatability
- More data channels typically available (torque, displacement, etc)
- Fewer development resources required (vehicle properties, test materials, employee resources)
- Data can be used in CAE modeling to predict vehicle-level performance

Dynamometer drawbacks:

- Cooling airflow into brake corner is difficult to accurately represent
- Variations due to wheel influences are difficult to represent
- Brake balance interaction/effects between left/right and front/rear brakes are difficult to represent
- Typically don’t include chassis control interactions or other vehicle integration concerns

Dynamometer Cooling Air Settings

Project Information

- This project was initiated to **improve** correlation between dyno and vehicle cooling, especially for schedule based testing where equilibrium temperatures and fade behavior need to be understood
- Initial dyno scripts used 50% of initial speed as the “rule” for air speed; (For example – 100 kph initial braking speed → 50 kph cooling air speed during apply)
  - What should the cooling air set point rule be for schedule driven testing?
  - Which fixture/setup factors increase cooling accuracy?

- Two midsize vehicle brake corners were used in this study, both fit a 16” wheel envelope:
  - Single piston front sliding (colette) caliper, NAO lining material on a vented brake disc
  - Single piston rear sliding caliper, NAO lining material on a solid brake disc

Test Procedure

Test procedure

- Schedule based heating cycle was performed
  - Repeated brake energy inputs until brake temperature equalizes
  - Cycle time driven
- Constant speed cooling period (record temperature decay)
  - 50 kph
  - 80 kph

- Testing was repeated on:
  - Two different dynamometers (with and without inertia simulation)
  - Two corner designs: Solid brake disc and vented brake disc
  - With and without a wheel simulation
  - With caliper in “design intent” position relative to airflow and in the opposite “mirrored” position
  - Using two different methods for determining inertia setting

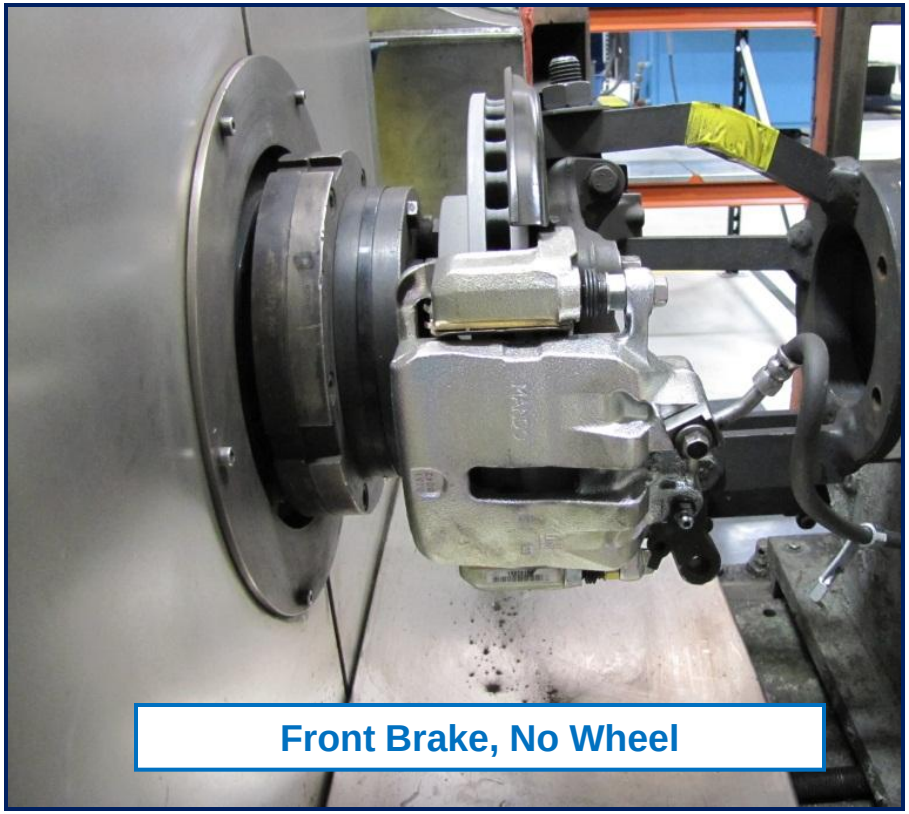
Test Control Strategy - DOE

Factor Name	Level 1	Level 2	Explanation
A: Wheel Profile in Place	None	Simulated wheel profile between brake and dyno cooling duct outlet	Wheel has strong influence on airflow, and can be simulated in dyno
B: Caliper Clock Position	**Design** Intent (with dyno cooling duct outlet representing front of vehicle)	Caliper rotated to **mirror** the design intent position	Clock position (forward or rearward of axle) has strong influence on cooling
D: Inertia Calculation	According to Fixed Decel Standard **Traction** Distribution inertia	According to **Brake Force** Distribution	Affects how much energy brake must absorb, and therefore BET temperatures

	A	B		D
Test Configuration	**Wheel?**	**Caliper Position**	C	**Inertia Setting**
1	**None**	**Design Intent**	1	**Traction based**
2	**None**	**Design Intent**	1	**Brake force**
3	**None**	**Mirrored**	2	**Traction based**
4	**None**	**Mirrored**	2	**Brake force**
5	**Yes**	**Design Intent**	2	**Traction based**
6	**Yes**	**Design Intent**	2	**Brake force**
7	**Yes**	**Mirrored**	1	**Traction based**
8	**Yes**	**Mirrored**	1	**Brake force**

Each of the 8 test configurations noted were run on **two brake corners**, on **two dynamometers**, with **two speeds**, and at **three different air speed settings** (5%, 25% and 50% of initial braking speeds)

Example Test Set-up

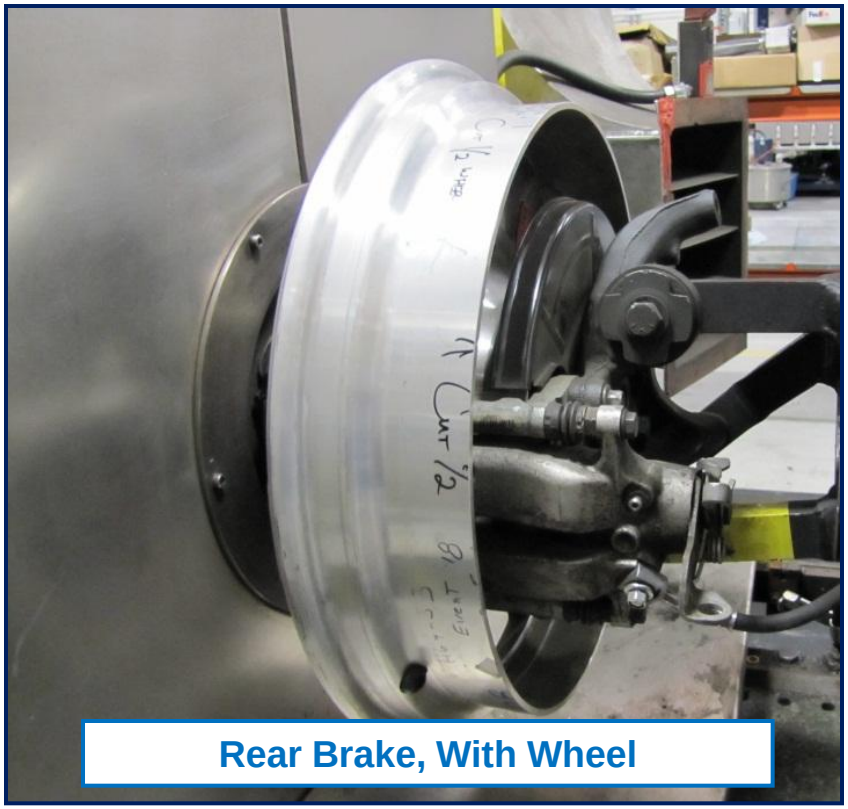


Front Brake, No Wheel

NOTE: Wheel was cut in half through the circumference for two key reasons:

1) ***The full wheel would come very close to the dyno test chamber wall, likely resulting in unrealistic restriction***
2) ***The dyno could not accommodate a tire, and the full wheel would add considerable convective cooling air normally covered by the tire.***

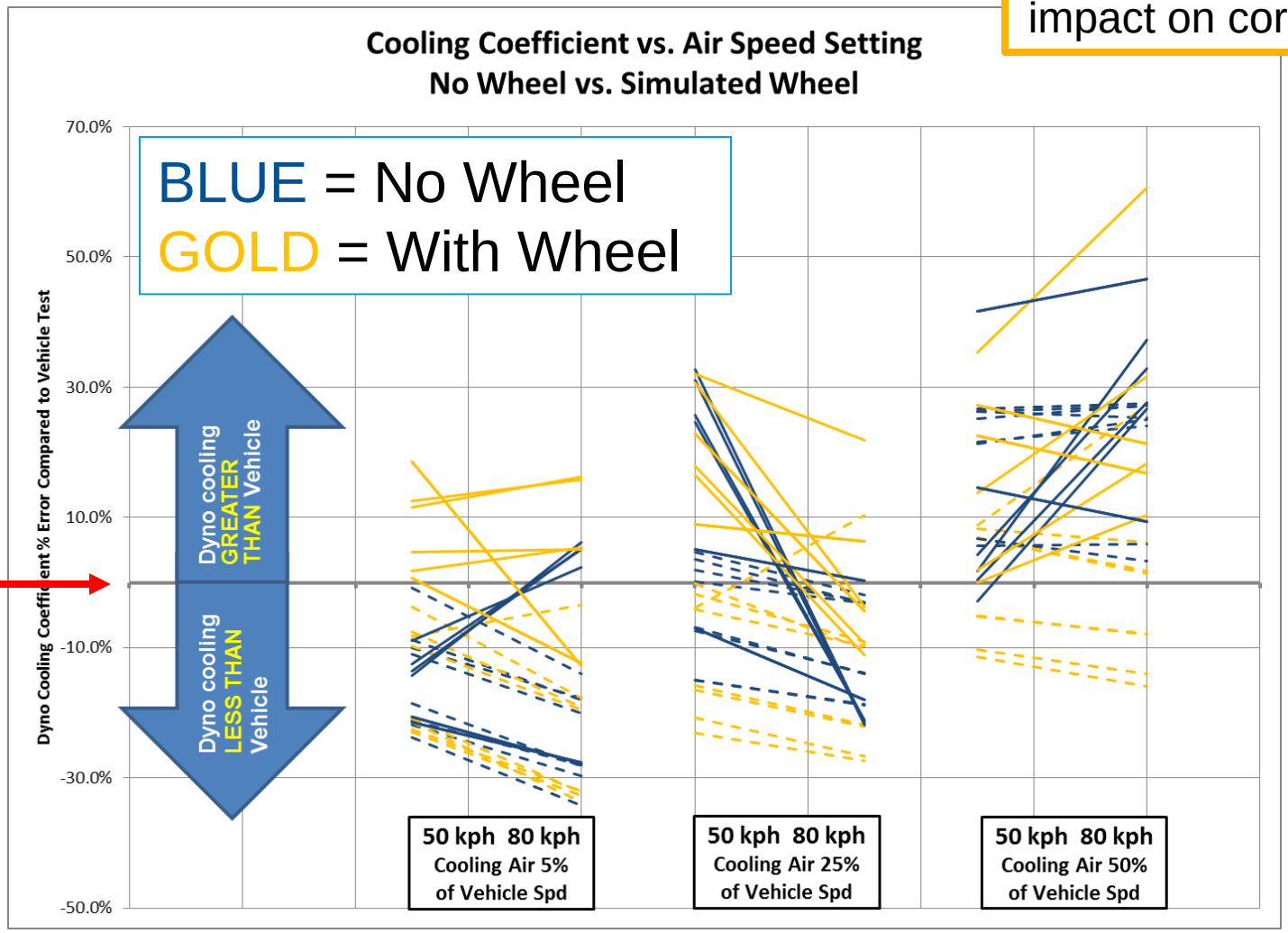
The half wheel was viewed as the best compromise for including the wheel factor.



Rear Brake, With Wheel

Simulated Wheel Effect

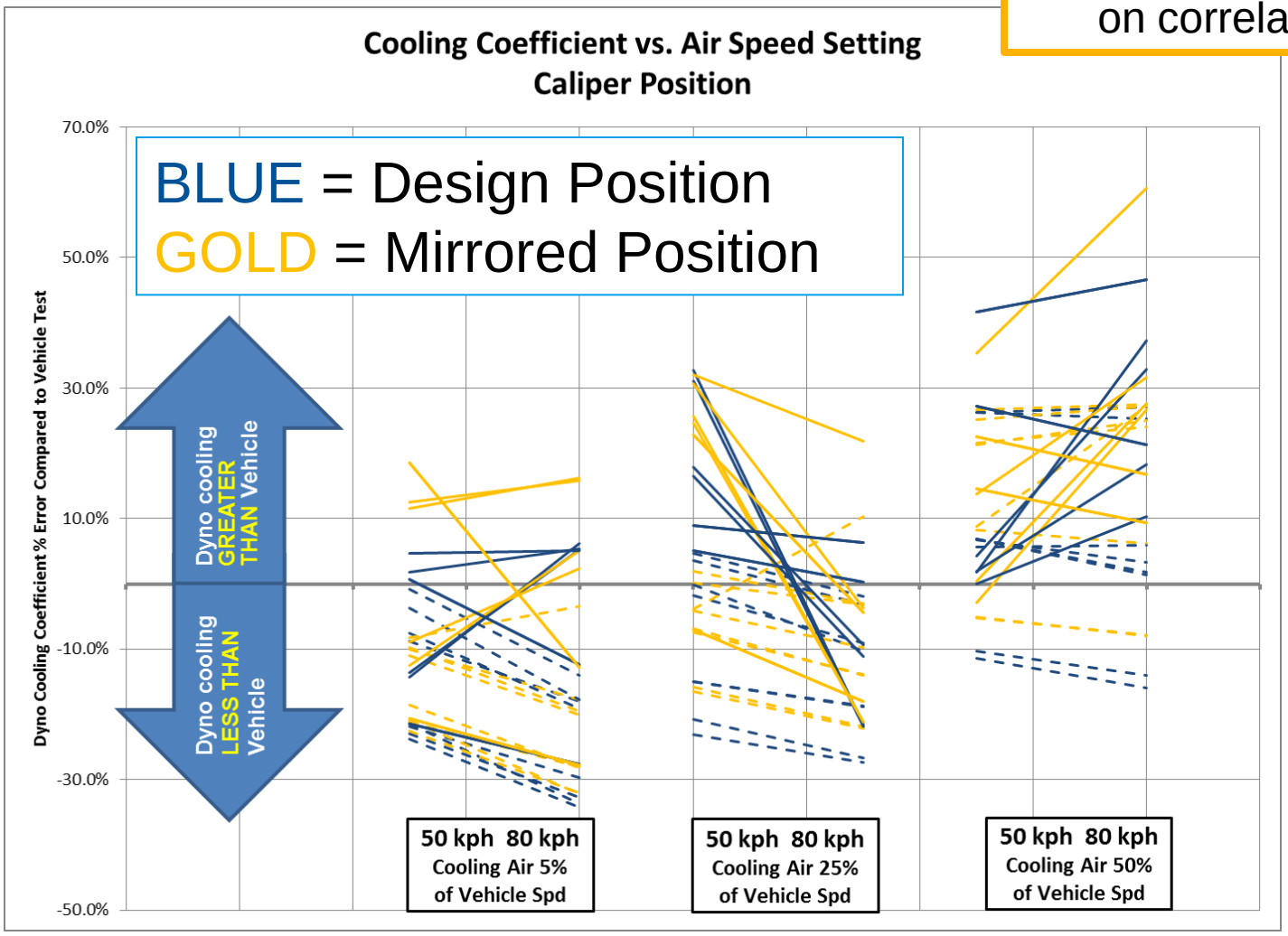
Presence of wheel has no significant impact on correlation



Target is 0% Error

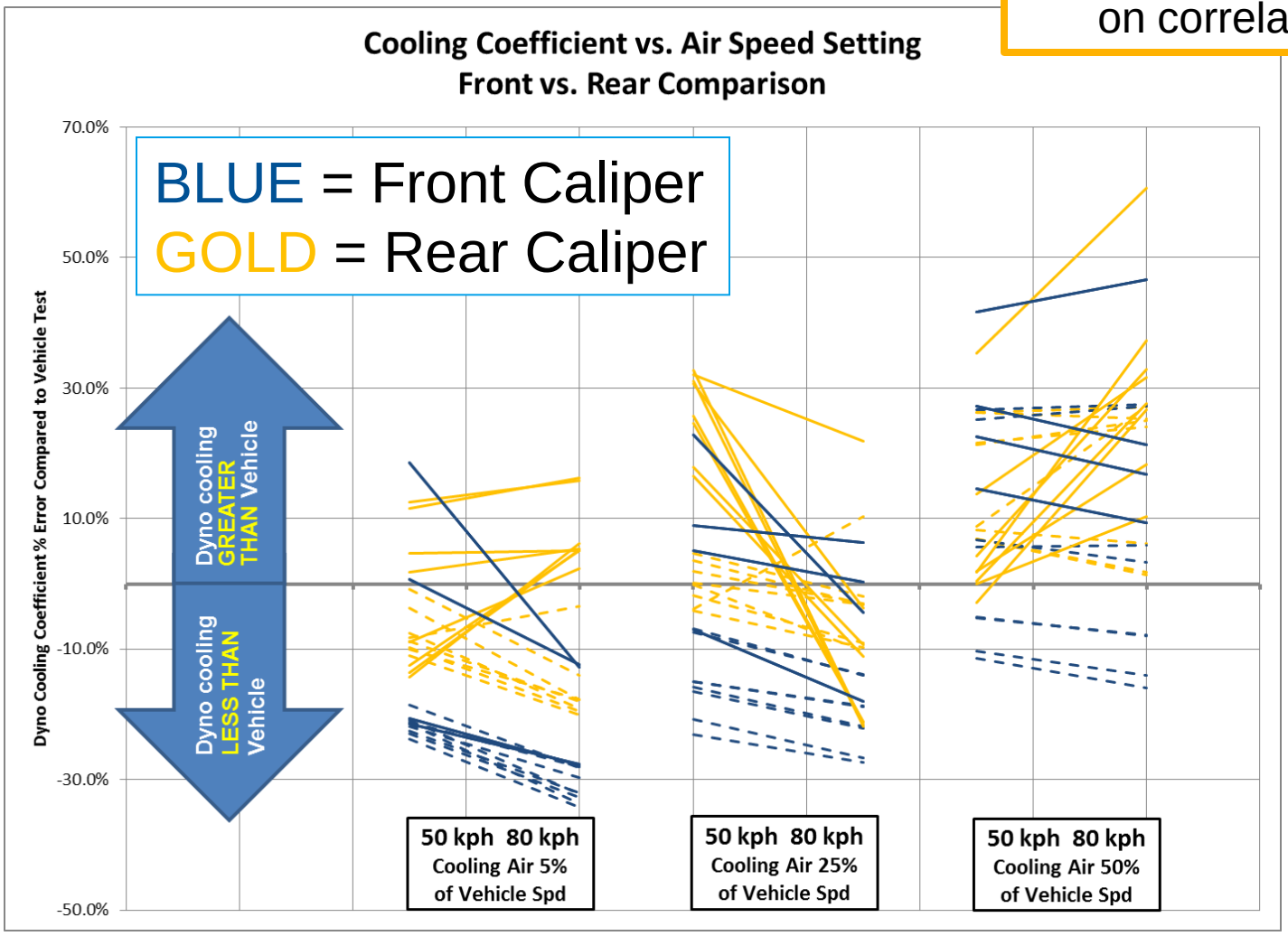
Caliper Position Effect

Caliper position has no significant impact on correlation



Corner Design Effects

Corner design has no significant impact on correlation



Overall Test Results