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CHALLENGES OF COMPARING PROPULSION COOLING CFD TO TEST CHAMBER AND OFF-ROAD PERFORMANCE

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Outline

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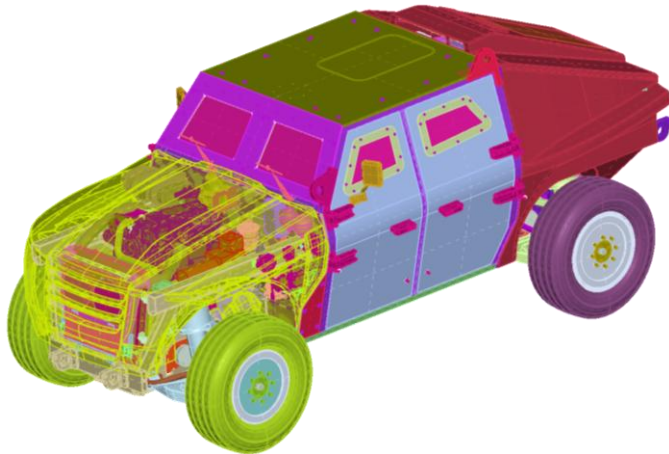
- Introduction
- Methodology
- Wheeled Vehicle
- Tracked Vehicle
- Conclusions

- Full load cooling tests are used to predict vehicle tractive effort, maximum speed, and speed on grade
- Test cells at TARDEC differ in size, inlet, and outlet geometry
- Test cells only approximate off-road condition
- Simulation can be used to compare test cell to off-road conditions
- Comparing simulation to test cell data requires knowledge of test cell geometry and setup

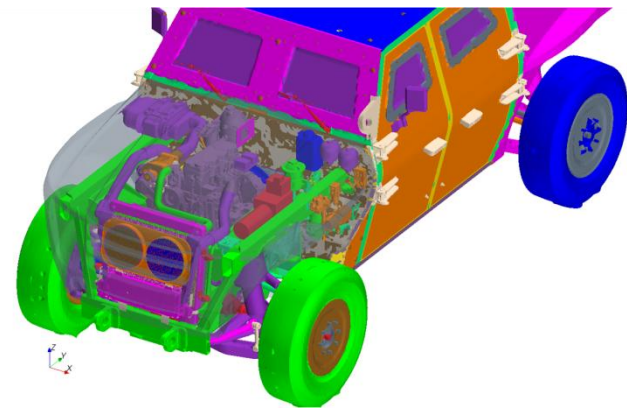
Analysis Method - Preparation

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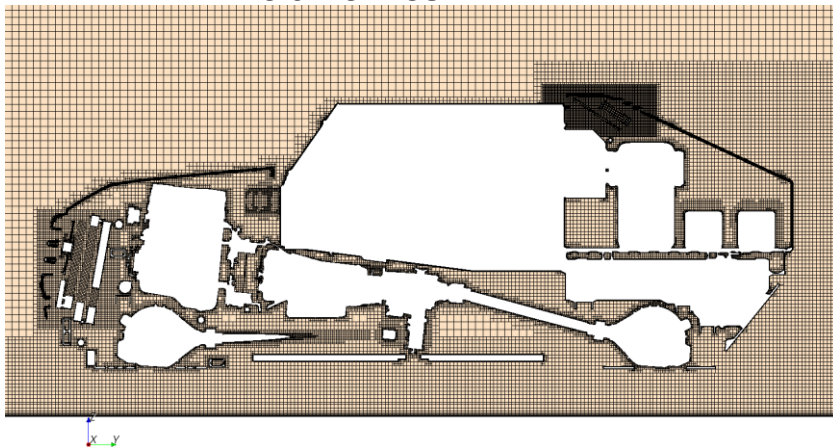
CAD Geometry



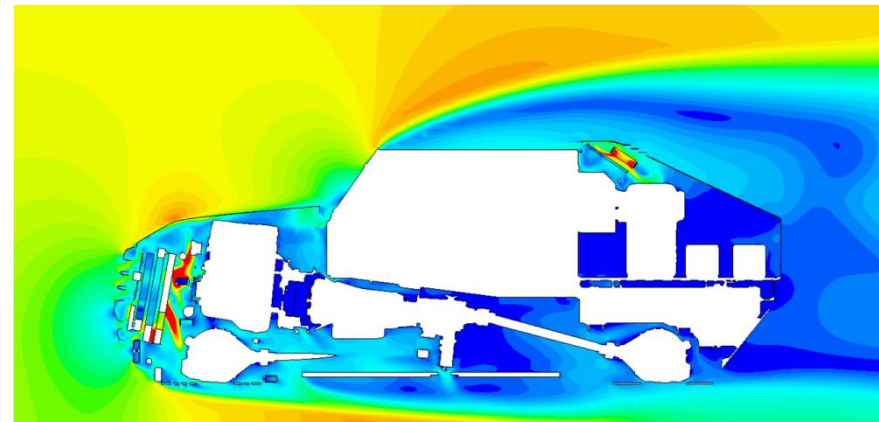
Cleaned Surface
(Wrapping)



Volume Mesh



Solution/Post-Processing

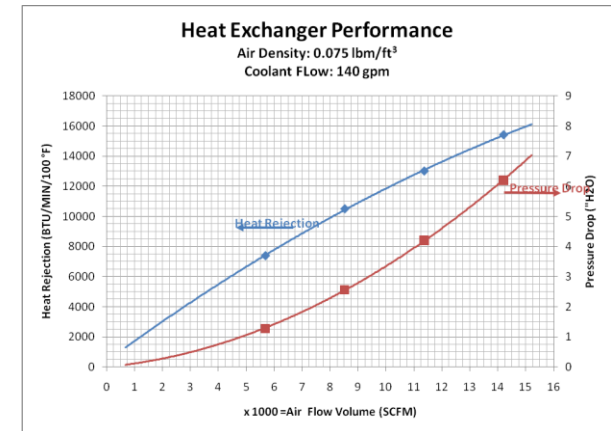


Method - Heat Exchangers and Fans

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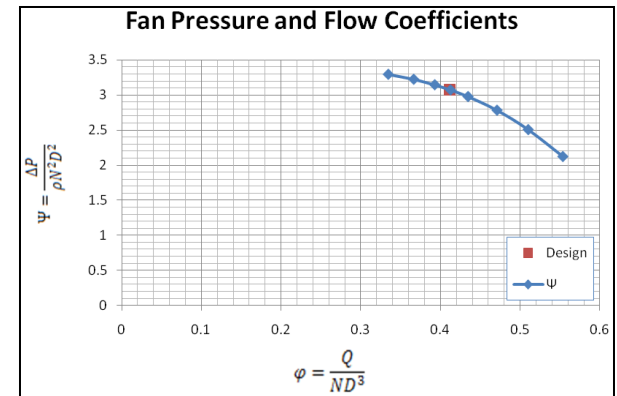
- Heat Exchanger

- Model using single stream and porous media
- Pressure drop vs. flow
- Heat rejection vs. flow



- Fan

- Fan geometry typically not available
- Model using momentum source



- User routine (java class) to automatically update heat rejections and momentum sources



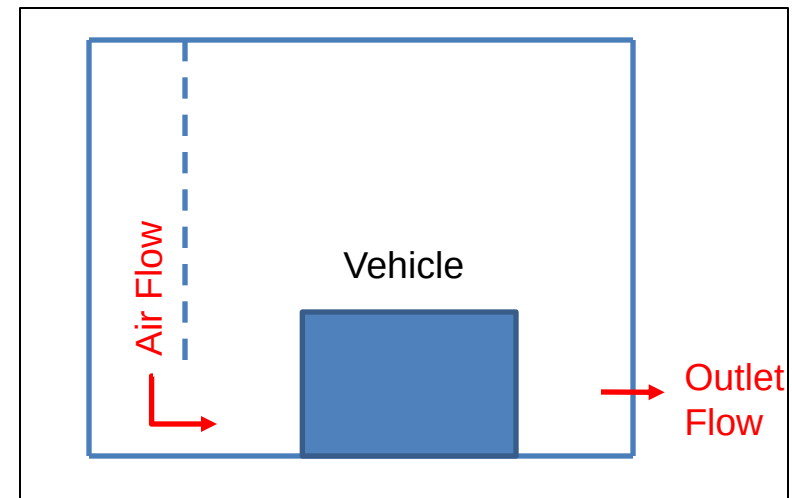
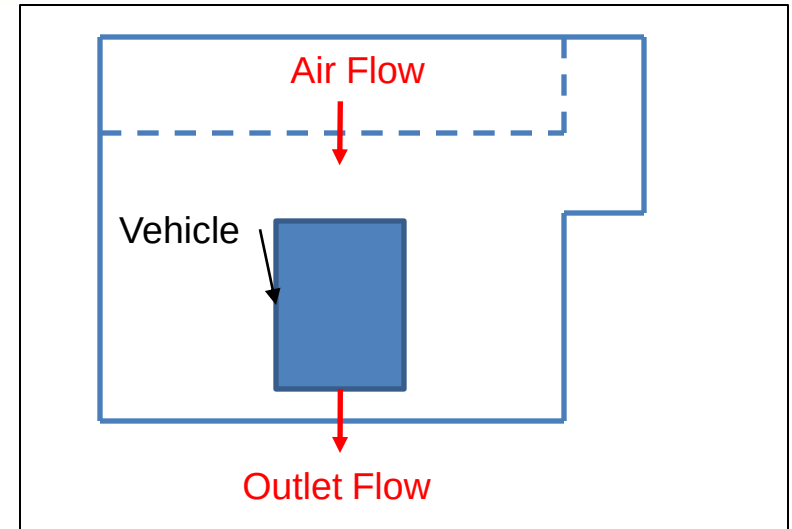
- Test cell setup is different than off-road simulation setup

Off-road	Test cell
• Sides • Symmetry • Inlet • Specified velocity • Ground • Moving ground plane	• Sides • Walls • Inlet • Specified velocity • Ground • Stationary wall

To simulate tunnel tests, may need to specify a velocity distribution or model cell inlet geometry

Wheeled Vehicle - Tunnel

- Tunnel is small relative to vehicle size
- Air flows down from top and turns once it hits the tunnel floor
- Air speed is ~5mph





Wheeled Vehicle Cell and Off-Road Streamlines Colored by Temperature

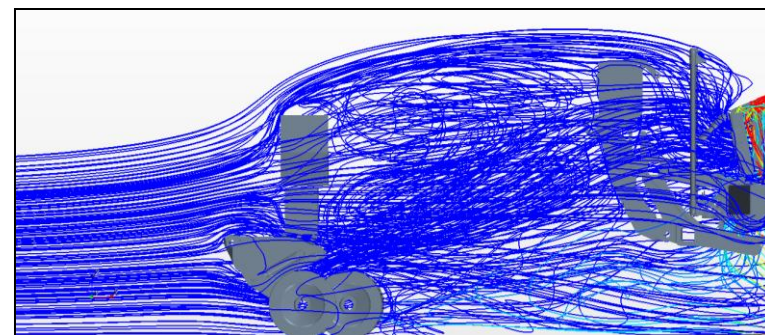
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- Warmer air re-circulates back to heat exchanger in test cell
- Underhood flow pattern is altered in test cell



Test Cell



Off-road

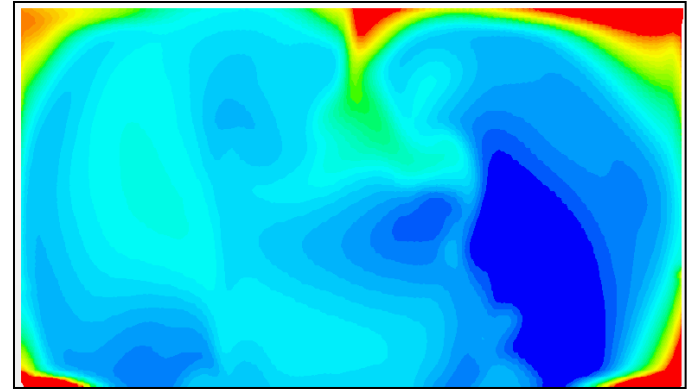


Wheeled Vehicle – Temperatures in Front of Condenser

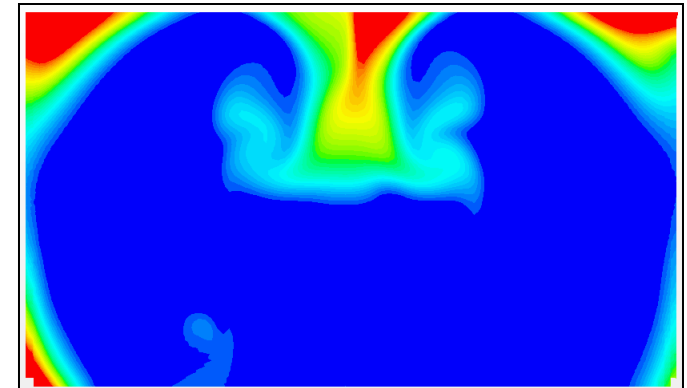
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- Mass flow matched well between simulated test, physical test, and off-road simulation
- Temperature at condenser inlet is hotter in test cell due to recirculation



Test Cell

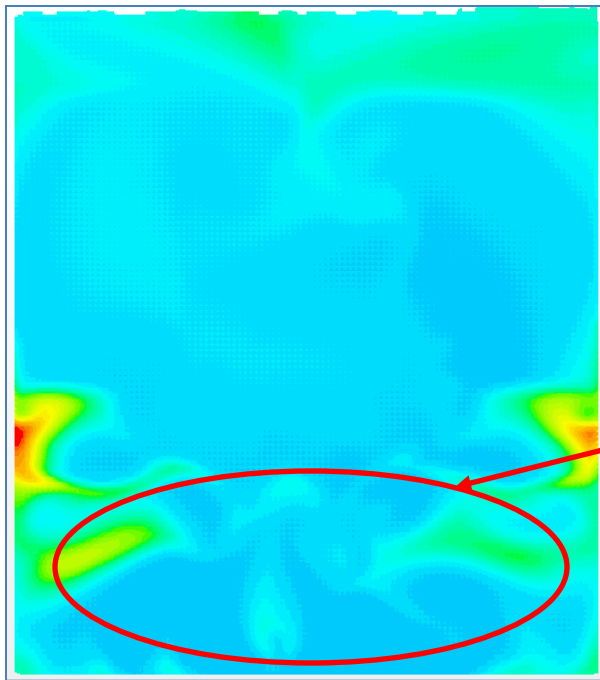


Off-road

Wheeled Vehicle – Temperatures in Front of Radiator

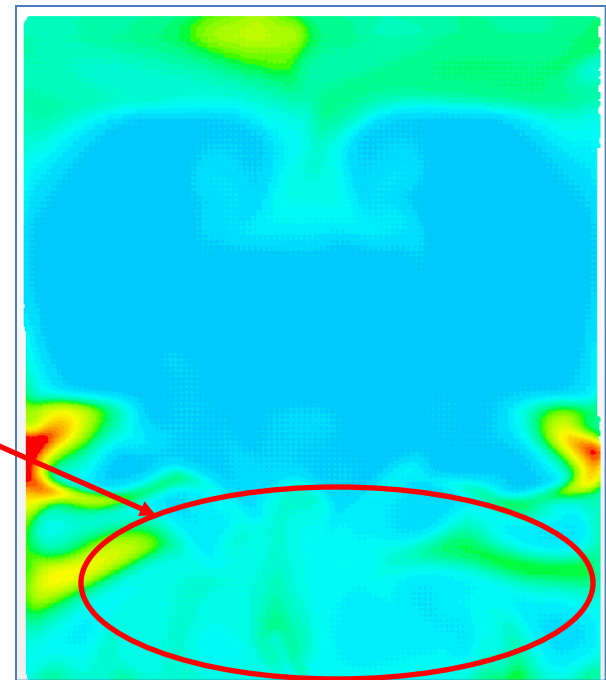
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- Air temperature at radiator inlet is cooler in test cell than in off-road condition due to flow hitting the ground as it enters the test cell



Test Cell

Higher temps
in off-road



Off-Road

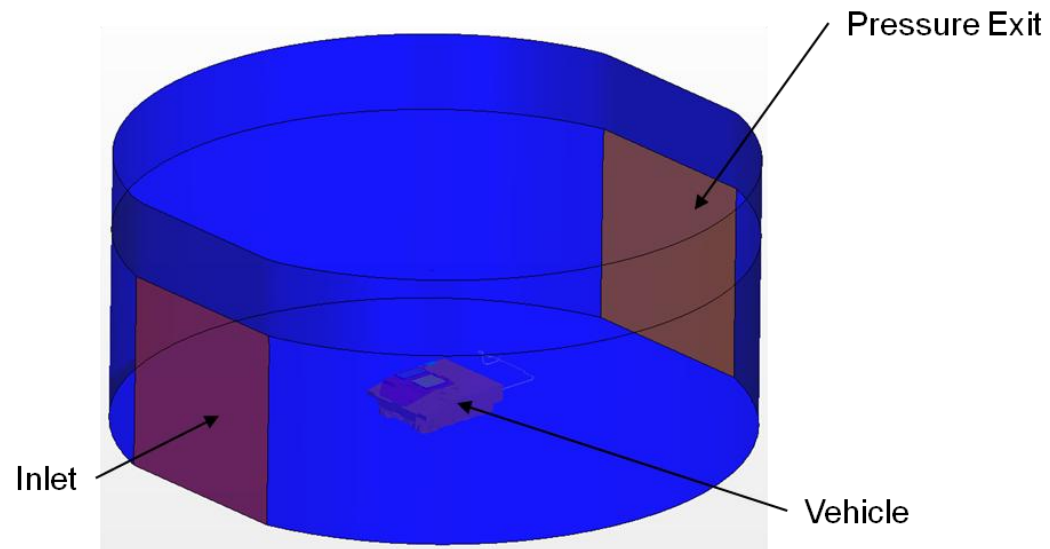
Tracked Vehicle – Test Cell

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- Test cell is large compared to vehicle

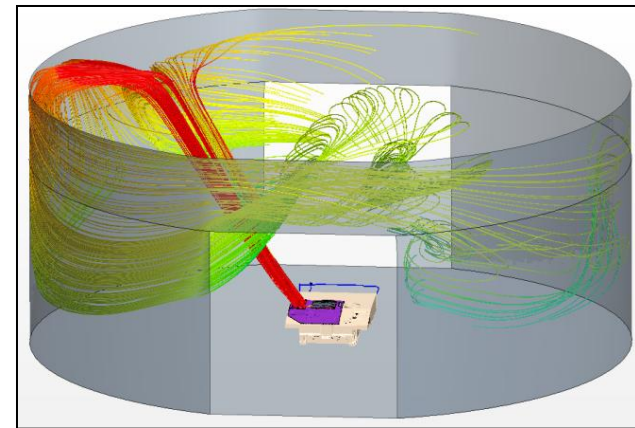


Vehicle in test cell



CFD

- During testing temperature at inlet grille was several °F higher than cell ambient (measured upstream of vehicle)
- At high temperature this can affect test results because of increased inlet temperature to radiators
- Analysis of vehicle in test cell showed flow was not recirculating back into inlet
- Investigation showed that there was temperature stratification at the cell inlet

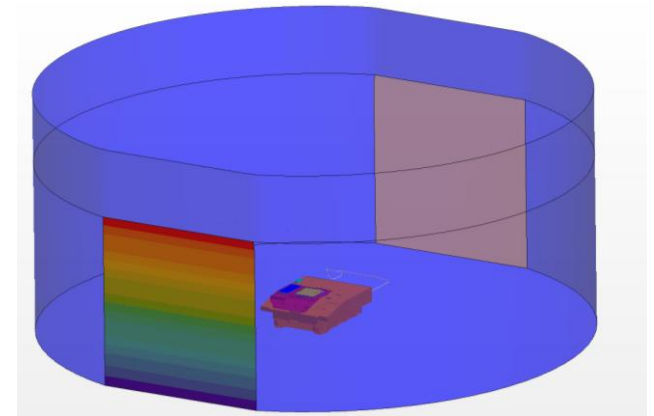


Streamlines from exit grille

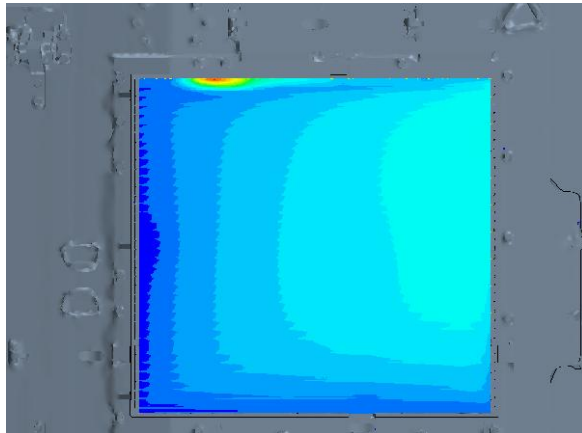
Tracked Vehicle – Temperature Results

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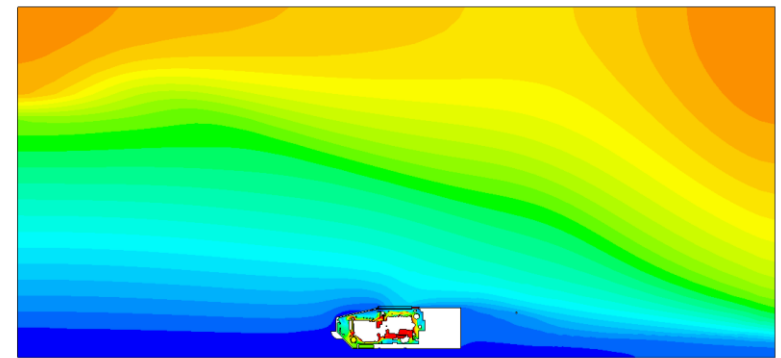
- Stratification at inlet of cell leads to higher temperatures at cooling inlet grille



Tunnel Inlet Temperature



Inlet Grille Temperature

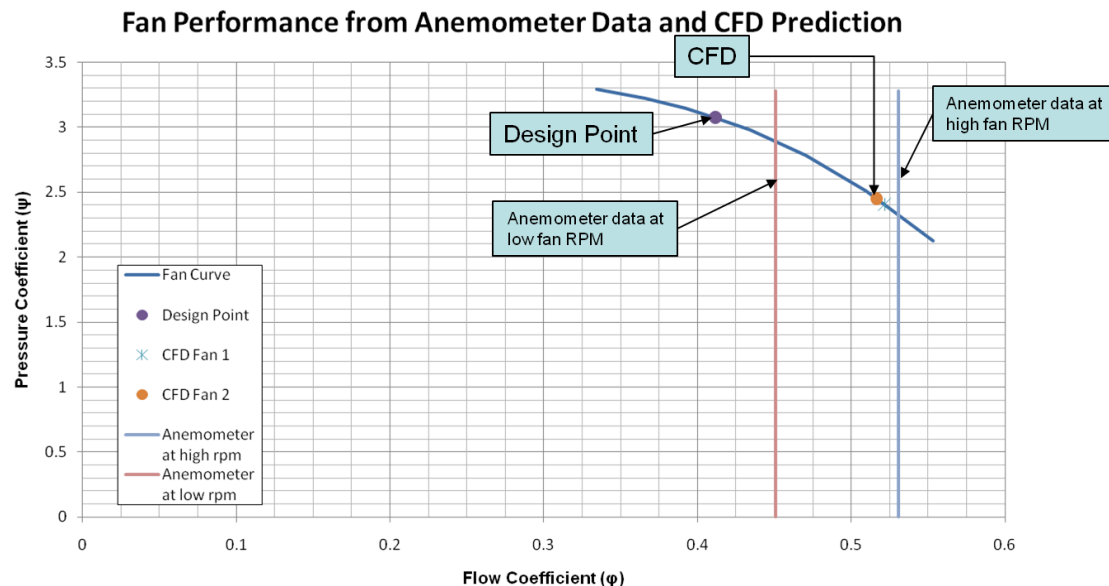


Temperature Along Vehicle Centerline

Tracked Vehicle – Operating Points

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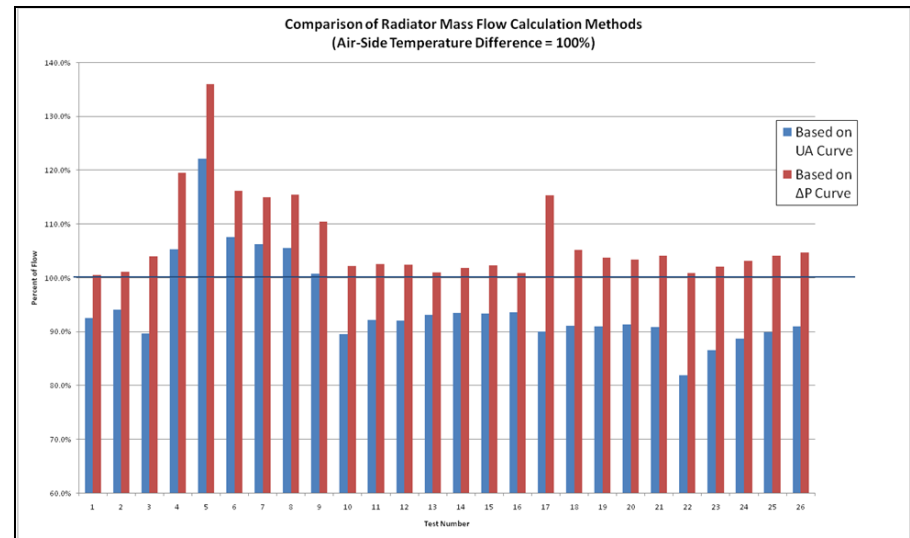
- CFD matched well with anemometer data taken at similar rpm
- Data and CFD both indicated higher flow than original design



Tracked Vehicle – Flow Rates

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- Calculating flow rate through cooling system can be challenging
 - It is not always possible to mount anemometers in cooling system, so alternate means must be used to back out radiator air flow rate
 - Air-side temperature difference can be difficult to measure accurately if there is recirculating flow or equipment problems
 - Helps to compare flows with radiator heat rejection and pressure drop curves to find potential problems



- Obtaining accurate CAD geometry can be challenging, especially for fans
 - Model using momentum source if fan curve is available
 - Note that fan curve is often generated under ideal conditions
- Test cells do not always accurately model real-world scenarios
 - Flow recirculation and inlet non-uniformities are possible
 - Temperature stratification can also be an issue
 - For high speed also be aware that non-moving ground plane could produce different underhood flow patterns
- Check data for consistency using alternative calculation methods— a few bad measurements can change calculated air flow volumes significantly