NARSA
Why do the truck OEM's want a "Cooling System" and not just components

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Sept. 23, 2016

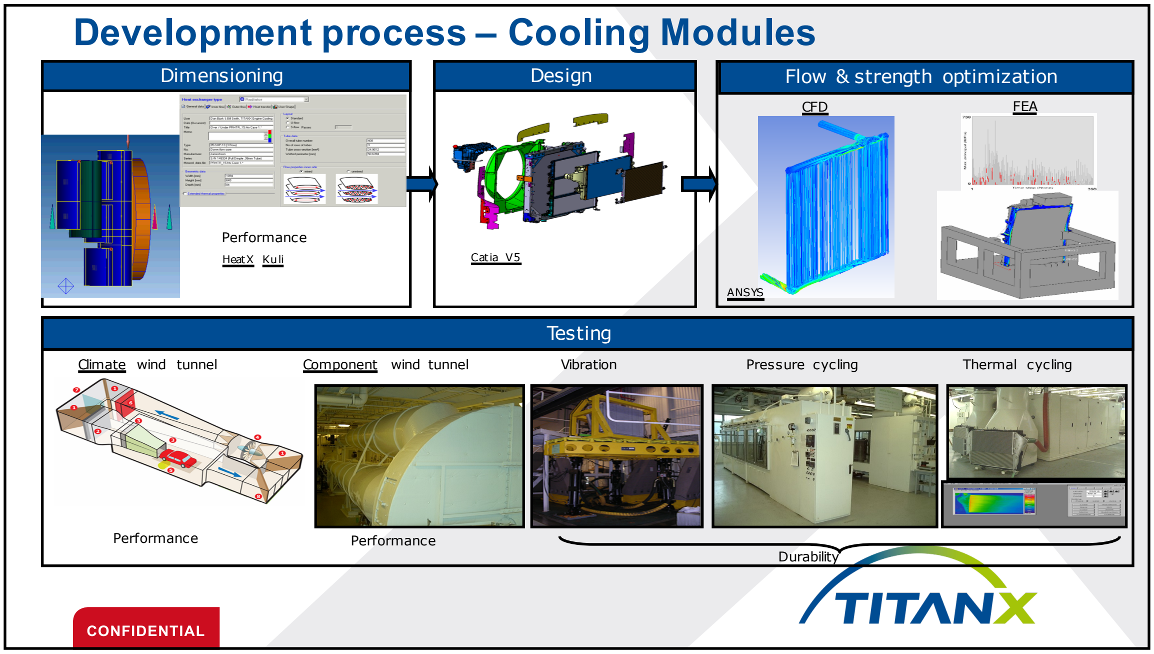
Agenda

- How is the OEM "Cooling System" Designed or "Balanced"
- What are the potential effects of an "Un-Balanced" system
- MCD – Matching Customer Demand
  - TitanXtend process

- **Cooling System Design**
  - Methodology
    - Goals
    - Development Process
    - Testing
    - Cooling System Performance & Design Set
  - Customer Integration into Vehicle Architecture
    - Fan & Fan Drive Matching
    - Engine Strategies

OEM Goals for Product Development

- ONE PART FITS ALL
  - All Engines, All Horse Powers, All Vehicle Configurations
- Lowest Cost Solution
- Meets All Specifications
- Quality, Delivery


Development process – Cooling Modules
Dimensioning
Performance
HeatX Kuli
Design
Catia V5
Flow & strength optimization
CFD
FEA
ANSYS
Testing
Climate wind tunnel
Component wind tunnel
Vibration
Pressure cycling
Thermal cycling
Performance
Performance
Durability
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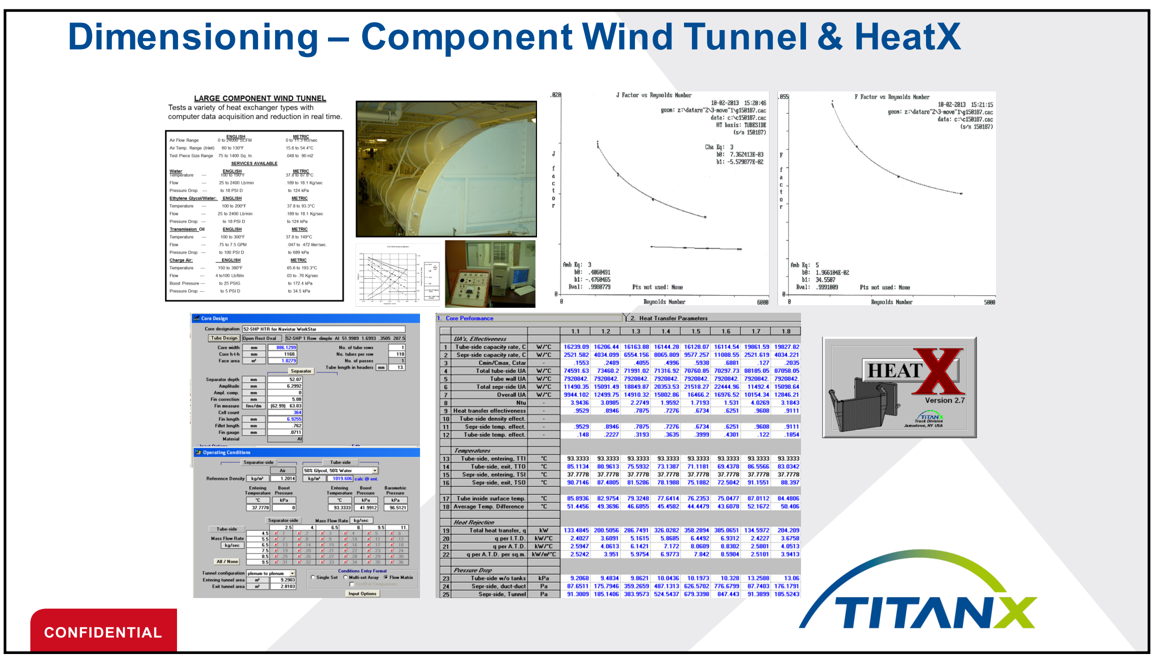
Dimensioning – Component Wind Tunnel & HeatX
LARGE COMPONENT WIND TUNNEL
Tests a variety of heat exchanger types with computer data acquisition and reduction in real time.
J Factor vs Reynolds Number
F Factor vs Reynolds Number
Reynolds Number
Core Design
Operating Conditions
1. Core Performance
2. Heat Transfer Parameters
HEAT X
Version 2.7
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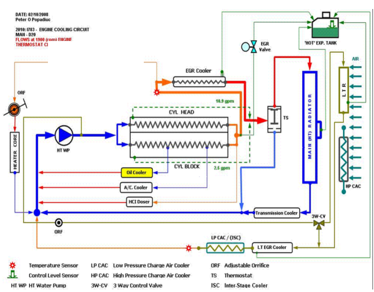
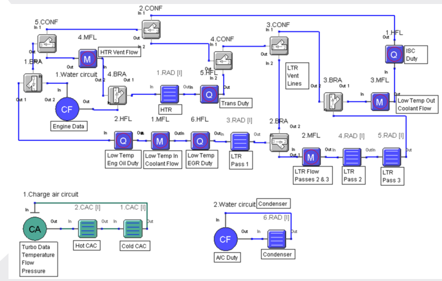
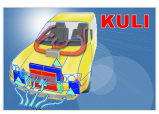
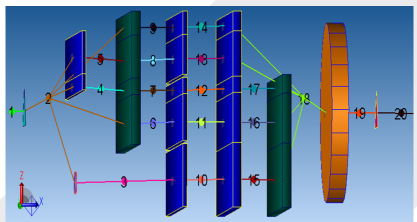
Dimensioning - KULI









- Using the Vehicle Cooling System Schematic, Engine Data Sheets, and any Customer Specific Specifications – A KULI model is constructed which is used to predict in vehicle performance.

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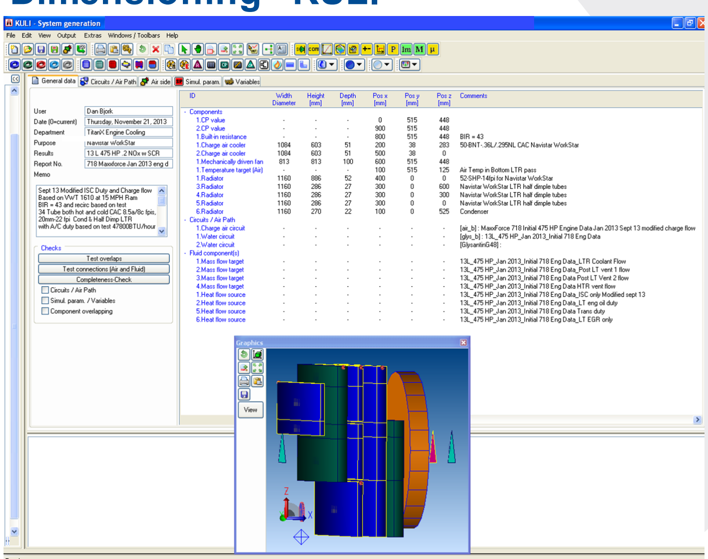
Dimensioning - KULI



- Air Flow, Pressure Drop, Heat Balance, Core Placement are all initially established.

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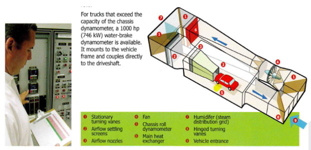
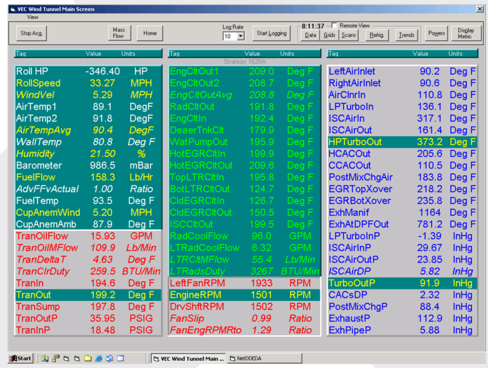
Testing – Climatic Vehicle Wind Tunnel

Vehicle Climatic Wind Tunnel





- Determine the Air Flow characteristics of the truck based on the cooling data generated from the VWT test
- BIR – Built In Resistance: All the un-measured restriction under hood that helps determine the air flow through the cooling system

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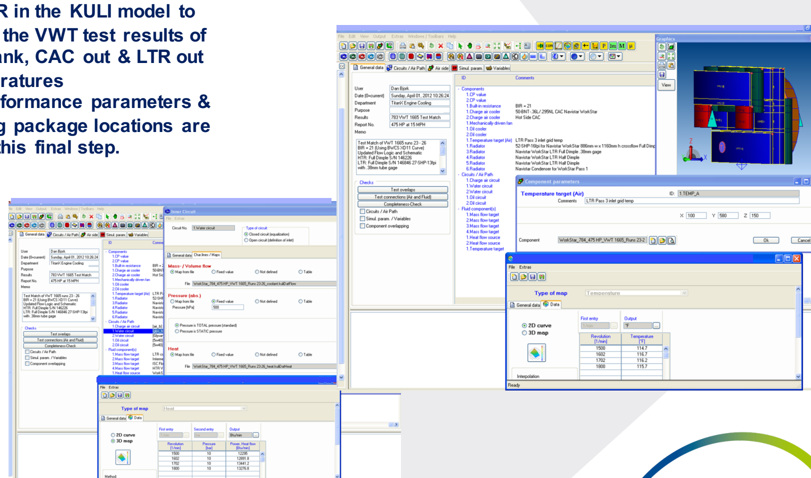
Cooling System Performance & Design Set

- Iterative process of adjusting the BIR in the KULI model to match the VWT test results of Top Tank, CAC out & LTR out Temperatures
- All performance parameters & cooling package locations are set in this final step.



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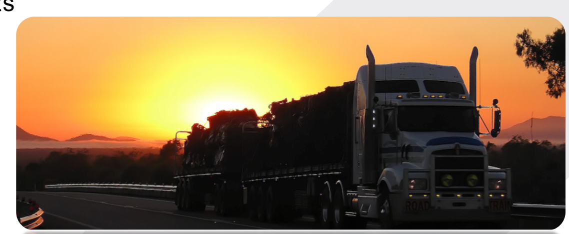
Customer Integration

- The final Kuli model & performance results could lead to customer changes in Fan & Fan Drive Ratio pending module performance parameters across the board.
  - Example: Applications could utilize the same cooling package but require different fan or fan ratio for air flow / fan on time / fuel economy / cost reduction
  - Example: The fan location could change. Closer or further away from the Radiator cooling face.
- Engine strategies are programed using the cooling package performance data and vehicle operating parameters to ensure that all HP Ratings of all Engine Applications are "Tuned" to the optimal performance possible.
  - Turbo Lag, De-rates, Fuel Economy, Engine Power, etc
- Engine strategies are programed to ensure all Government Requirements are met.
  - EGR rates, ReGen & SCR usage, etc
- Engine Strategies are programed ensuring all other vehicle systems are meeting their goals as well as Engine Cooling.
  - HVAC, Transmission Cooling, Power Steering, Fuel Cooling, etc

- **"Un- Balanced" System effects**
- Synopsis
- Cooling Component vs Vehicle Performance
  - Cooling system controls
  - Fan, Radiator, Charge Air Cooler
- System Effects
  - Radiator
  - Charge Air Cooler
  - System Air Flow

Synopsis

- In the aftermarket environment, it is common to replace an OEM part with a replacement part that is not "tuned" to match the parameters of the OEM part.
- Some Heat Exchangers show significant deviations in tested performance compared to OEM specification. This could leave the system "Un-Balanced"
- Functionally the component may work, but the effect on Engine Diagnostics, Fan on Time, Fuel Economy, Emission's, and Durability could be deteriorated – hence effecting operating costs



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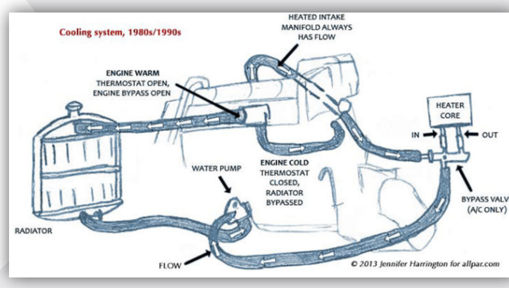
Cooling System Controls

- Coolant Temperature
  - Thermostat which is wax or electronically controlled (Engine Thermal Load)
  - Fan Speed which is viscous clutch or electronically controlled (Power usage)
  - Engine Strategies to avoid boiling and protect the engine by limiting power (Power Drop)



- Intake Air Temperature
  - No direct control of temperature itself
  - The fan is engaged if the CAC outlet temperature is too high (Fuel Consumption & Power Drop)
- The OBD (On Board Diagnostics) system per emission regulations looks at sensor signals, e.g Nox levels, and internally calculated system variables. If faults are detected, the environment is protected.
  - Loss of engine power and default codes which require attention

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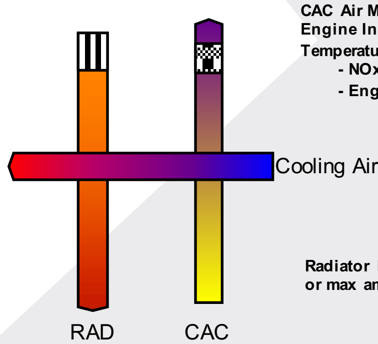
Cooling Component vs Vehicle Performance

FAN

Fan Power = Fuel Consumption
"Fan On Time"



CAC Air Mass Flow = Engine Power
Engine Inlet Temperature = Combustion Temperature =>
- **NOx Emissions**
- **Engine Thermal Load**

Radiator Heat Rejection = Max Engine Power, or max ambient temperature until boiling

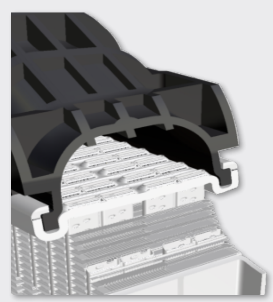
Radiator Effects

- Lower radiator performance will force:
  - Lower speeds for the same hill climb to avoid overheating
  - Lower ambient temperature capability before boiling
    - Air-To-Boil temperature (ATB, SAE J1393)

3.3.1 AIR-TO-BOIL (ATB)

The ambient temperature at which the engine coolant outlet temperature reaches 100 °C (212 °F), the boiling point of water at standard conditions.

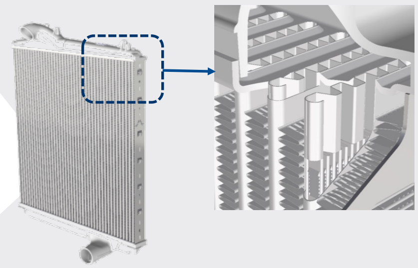
3.3.1.1 ATB = 100 °C – engine coolant outlet temperature + ambient air temperature.



- **Based on testing – A Radiator drop in performance of 3°C at higher ambient temperatures will result in a coolant temperature rise into the Red Zone, and the engine will lose power.**
- If the driver does not down shift early, and down shifts on the hill, thus a huge drop in speed, the OBD system will trigger a light on the dash suggesting that the NOx emissions have exceeded limits.

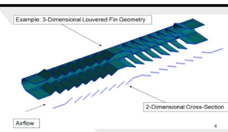
CAC

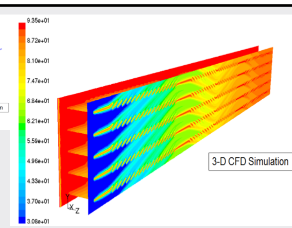
- Lower charge air cooler performance will force:
  - Higher engine inlet temperatures
  - The result is the engine strategy is forced to use more EGR & SCR to reduce NOx levels
    - Investigations show at higher engine inlet temps, there is increased fuel consumption & increased DEF (Diesel Exhaust Fluid) usage.
    - **Testing showed - An increase of 4°C IMTD is in the range of a 1% fuel penalty**



- Higher engine inlet temperatures at high load also cause the exhaust temperature to increase, and hence the thermal load on the engine. The result is increased engine wear, reduced service life and premature failure of exhaust valves, pistons, manifolds and turbo.
  - This also forces an increased load on the catalyst, particulate filters, and the environment
  - **Testing showed – An increase of 25°C at full load is ~8% lower air mass flow due to density effects which increases the exhaust manifold temperature >70℃.**
- Large deviations in inlet temperature and hence emission control, may also trigger the OBD to force the engine into limp home mode, i.e. >60% torque limitation or 30% loss in power.

System Air Flow





- System Air Flow could also be effected when utilizing non-tuned aftermarket replacements
  - Increased air side restriction means stacked components see higher heat loads and reduced performance
    - When each component is replaced, if air flow is effected (slower or faster), there is a net effect on the system
  - Fan on time could be increased due to lower performance of a strategically controlled component
    - Example: Condenser performance is effected by higher air side restrictive CAC, Fan on time, lower power, higher fuel consumption
    - Example: High Radiator restriction could decrease the performance of all heat exchange components having a net effect on complete engine cooling system
  - Engine Strategies will always attempt to compensate for performance, but the eventual outcome is usually less engine power, more fuel consumption, & more wear and tear on engine components
- Radiator internal flow
  - Increased internal pressure drop in the radiator could cause system cavitation if the pump can not compensate.
- CAC internal flow
  - Although lower CAC pressure drop could be good in terms of fuel consumption, the net effect is usually lower CAC performance which leads to higher intake manifold temperature and a multitude of issues as previously discussed.

- **MCD – Matching Customer Demand**
  - TitanX MCD Process
    - Benchmarking
    - Matching

TitanXtend MCD Process

- Benchmarking
  - Purchase targeted OEM product
  - Perform component wind tunnel test
    - Establish parameters for performance (Heat Transfer & Pressure drops)
  - Understand component related field issues
    - Consider warranty, test to failure
  - Establish all Dimensional Characteristics required
    - Ensure direct replacement including all pierce points
- Matching Customer Demand
  - Design new component as direct replacement
    - All required pierce points match
  - Design new component to match performance (Heat Transfer and Pressure Drop)
    - Perform component wind tunnel test
  - Develop efficient test plan based on core type, application, and previous validation
    - Based on core type, OEM validation is considered and used as surrogate when possible
    - Consider specific warranty issues as required
- The goal is to Match as close as possible, the OEM product performance, and when possible, increase the value of TitanXtend product by addressing warranty and providing added performance as long as total system performance is considered OK.


Thank you
WE HAVE YET TO SEE AN
ENGINE WE CAN´T COOL