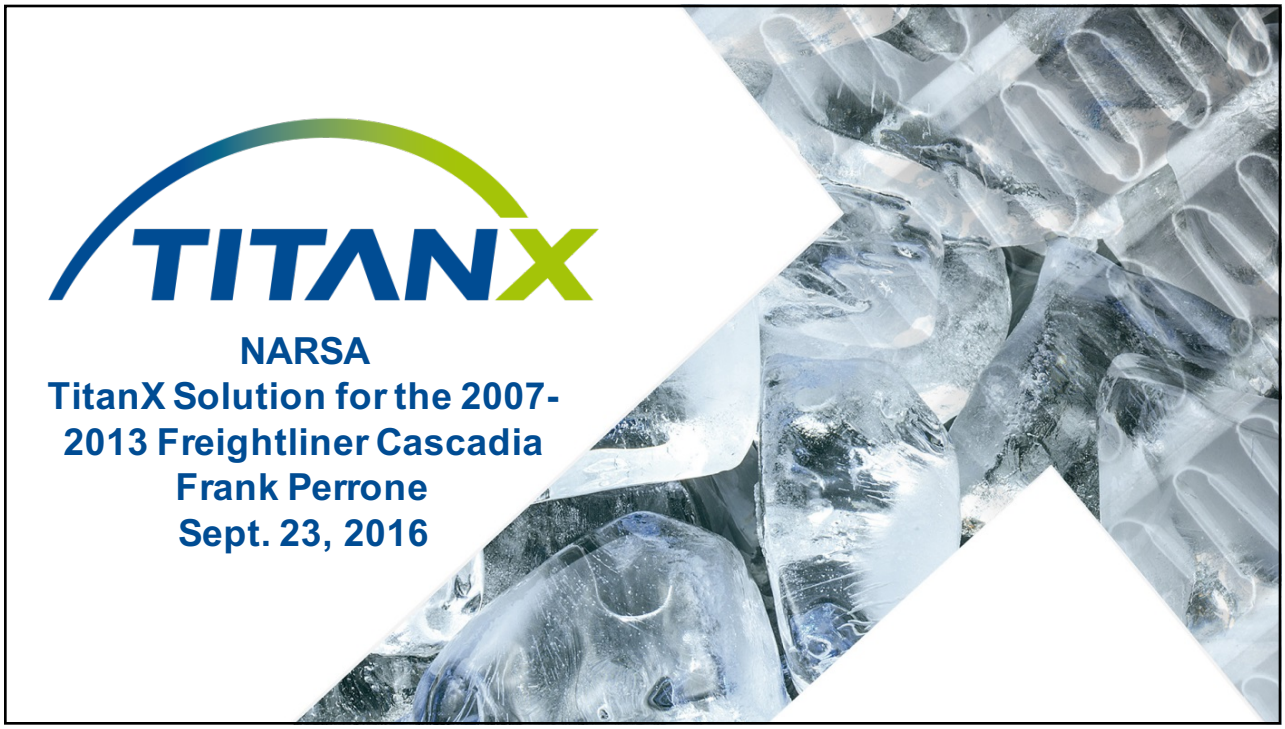


NARSA
TitanX Solution for the 2007-2013 Freightliner Cascadia

Frank Perrone

Sept. 23, 2016

Agenda

- Cascadia Radiator Failure Mode
- OEM Solution
- TitanXtend Alternative Solution

TITANX

- **Cascadia Radiator Failure Mode**
  - Freightliner Service Bulletin
    - Vehicles Effected
    - Failure Mode
  - Vibration Issue
    - Engine Modes
    - Resonance
  - Pressure Effect
    - Unsupported tube
    - Pressure Fatigue

Freightliner Service Bulletin

114SD Radiator Mounting, Update—EPA10 **20-76**

FLA COE, FLB COE, FLD Conventional, Business Class, FLC 112 Conventional, Century Class Conventional, Argosy COE, Cargo, Columbia, 122SD and Coronado Business Class M2, Cascadia, > 108SD/114SD

Freightliner Service Bulletin

General Information

Some EPA10 compliant Freightliner 114SD vehicles with Detroit engines, manufactured March 2010 and later, with specific combinations of engine operating parameters, may have radiator failures resulting in a coolant leak due to a crack in the coolant tube. See Fig. 1. Leaks in other places (at the end tank, header, fittings, or any place other than the coolant tubes) do not apply for this bulletin. If leaks occur in the coolant tubes, Freightliner recommends a radiator update to an isolated engine-mounted radiator. Isolated engine-mounted radiators were production installed in 114SD models beginning July 30, 2012. This procedure is to replace a standard engine-mounted radiator with an isolated engine-mounted radiator.

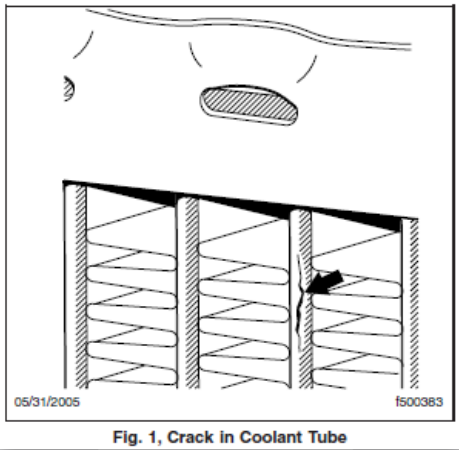
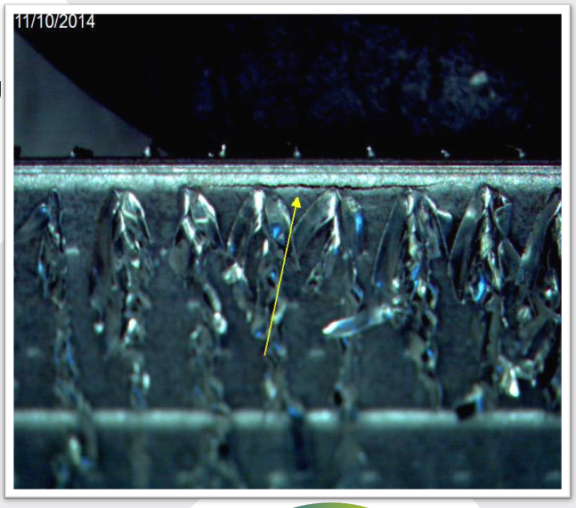


Fig. 1, Crack in Coolant Tube

Failure Mode – Tube Leak

- The ultimate failure is a Tube Leak.
- However, a combination of factors are happening in sequence which leads to ultimate failure.
  - Engine Vibration Modes
  - Radiator Core in Resonance
  - Unsupported tube pressure fatigue



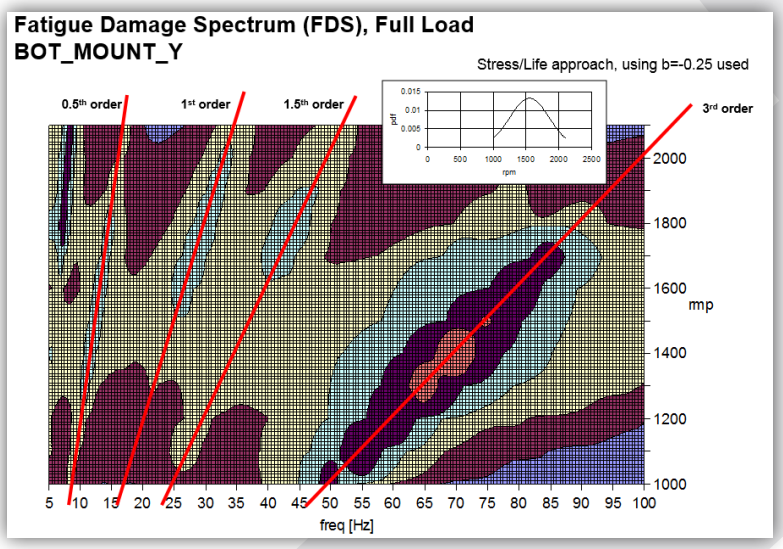
Vibration Issue

- Engine Modes

Engine Orders of Importance for Various Engine Types

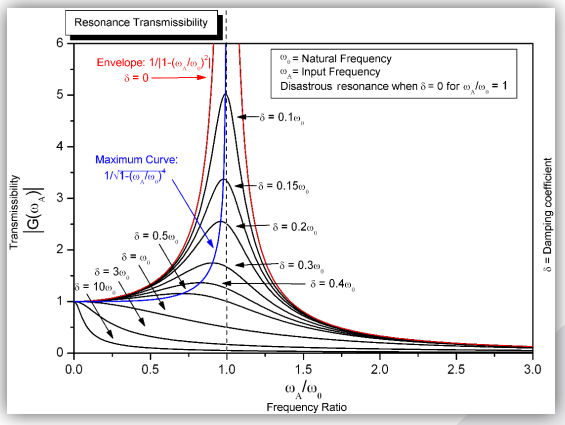
Engine Order	L3	L4 W/O Bal Shaft	L4 With With Bal Shaft	L5	L6	V6 60	V6 90 With Bal Shaft	V6 90 W/O Bal Shaft	V8 90	V10 90	V12 60
1/2 Order	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire	Single Cylinder Misfire
1st Order	Normal Free Moments	-	-	Normal Free Moments	-	-	-	Normal Free Moments	-	Normal Free Moments	-
1.5 Order Torque Sensitive	Normal Firing Frequency	-	-	-	-	Bank-to-Bank EGR/Fuel Variation	Bank-to-Bank EGR/Fuel Variation	Bank-to-Bank EGR/Fuel Variation	-	Normal Rocking Motion	-
2nd Order Torque Sensitive	Normal Free Moments	Normal Crankshaft Deflection	Normal Firing Frequency	Normal Free Moments	-	Normal Free Moments	Normal Free Moments	Normal Free Moments	Bank-to-Bank EGR/Fuel Variation	-	-
2.5 Order Torque Sensitive	-	-	-	Normal Firing Frequency	-	-	-	-	-	Bank-to-Bank EGR/Fuel Variation	-
3rd Order Torque Sensitive	Piston movement	-	-	-	Normal Firing Frequency	Normal Firing Frequency	Normal Firing Frequency	Normal Firing Frequency	-	-	Bank-to-Bank EGR/Fuel Variation
4th Order Torque Sensitive	-	Piston movement	Piston movement	Normal Crankshaft Deflection	-	-	-	-	Normal Firing Frequency	-	-
5th Order Torque Sensitive	-	-	-	Piston movement	-	-	-	-	-	Normal Firing Frequency	-
6th Order Torque Sensitive	-	-	-	-	Piston movement	Piston movement	Piston movement	Piston movement	-	-	Normal Firing Frequency

Vibration Issue



Data Acquisition of Engine Modes

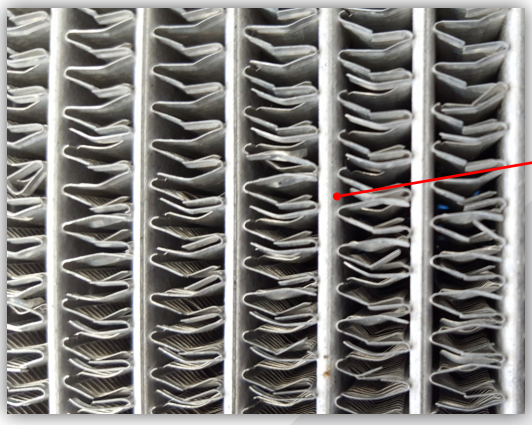
Vibration Issue

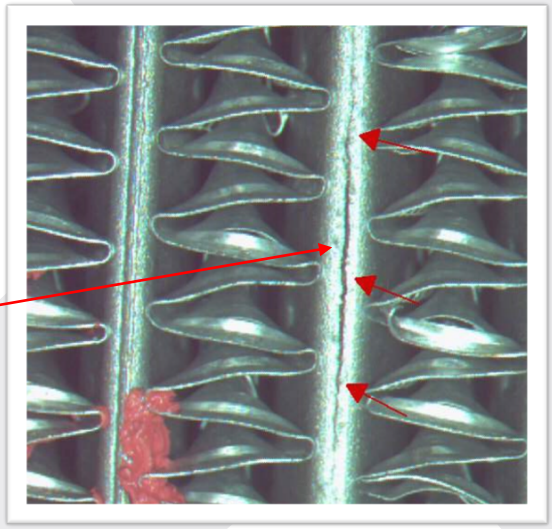


- Resonance
  - Resonance is a phenomenon in which a vibrating system or external force drives another to oscillate with greater amplitude at a specific frequency
  - Every Radiator core has a unique natural frequency at which resonance will occur. This is called its resonant frequency.
  - At resonant frequencies, small periodic forces have the ability to produce large amplitude oscillations
  - In the case here, there is an Engine Mode which is delivering a vibration force which places the Radiator core in Resonance and eventually the fin to tube bond is broken.

Pressure Effect

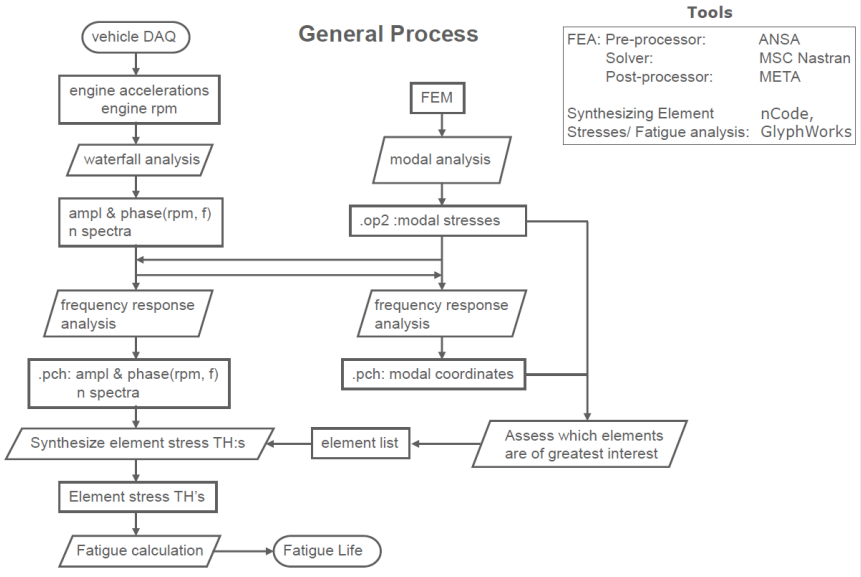
- Unsupported tube
- Pressure Fatigue





Test Plan

- Goal is to determine at what frequency the lowest damage occurs

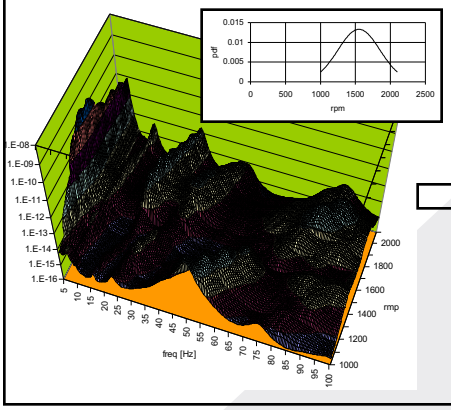


Data Analysis

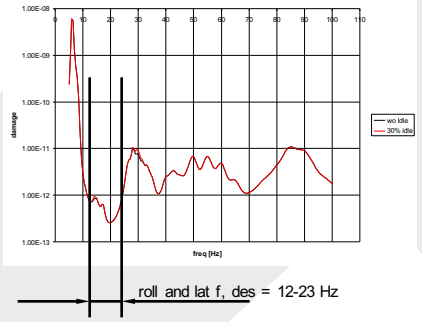
Assessing desired natural frequencies for module suspension

Example: Panhard rod Y-direction

Damage spectrum (rpm) for Panhard Rod Y-dir



Damage spectrum for Panhard Rod Y-dir



roll and lat f, des = 12-23 Hz

Results:
- roll and lat: 18 to 23 Hz
- pitch and long: 18 or 35 Hz
- vert: 12 to 23 Hz

11

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- **OEM Solution**
  - Engineered Solution
    - Radiator Replacement
    - New Mounting and Stay Rods

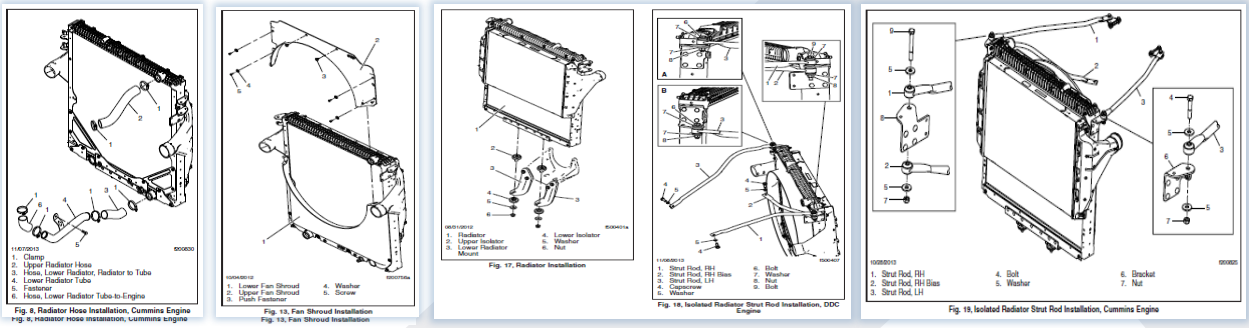

Fig. 8, Radiator Hose Installation, Cummins Engine

Fig. 13, Fan Shroud Installation

Fig. 17, Radiator Installation

Fig. 16, Isolated Radiator Strut Rod Installation, DDC Engine

Fig. 19, Isolated Radiator Strut Rod Installation, Cummins Engine

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- **TitanXtend Alternative Solution**
  - Why TitanXtend SHP Radiator
    - Vibration
    - Pressure
      - Thicker Tube Gauge
      - Smaller flow area – Internal Rib design
  - Benefits for this application
    - Radiator is a Drop In Replacement
    - No New Mounting or Stay Rods
    - Performance

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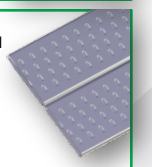
Super High Performance (SHP) Radiators

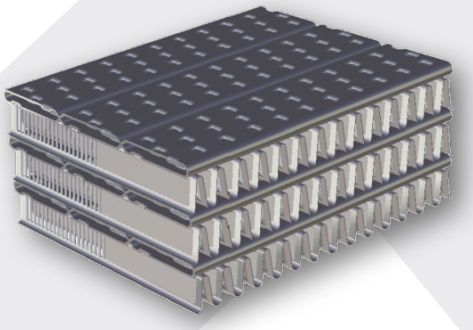
- TitanXtend SHP Radiators have a different natural frequency than the OEM & other aftermarket cores
- Provides increased structural resistance due to core density (It's Stiffer)

Header plate:
- 2 or 3 channels matching the tube design for higher pressure resistance
- Lower amplitudes – enhanced structural resistance

Tubes:
- Electro-welded tubes with internally brazed ribs for increased pressure capability
- Enhanced structural resistance
- High strength material
- Increased tube gauge



Fins:
- Low amplitude



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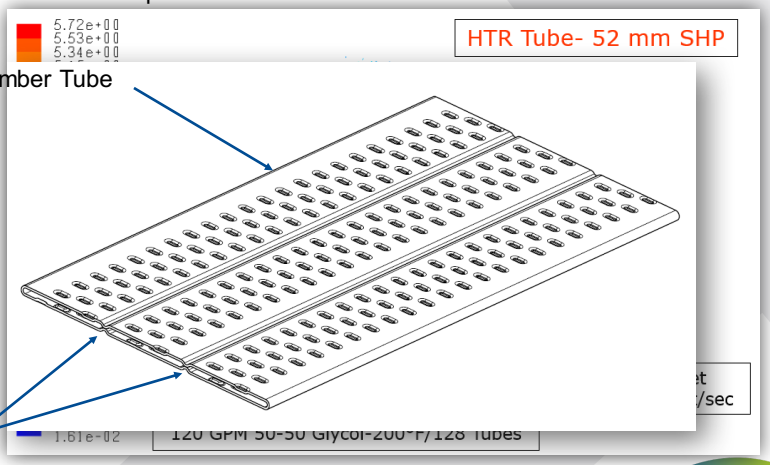
Super High Performance (SHP) Radiators

- Higher Pressures due to Higher Coolant flows
- Operational pressures 40 - 53 psi.



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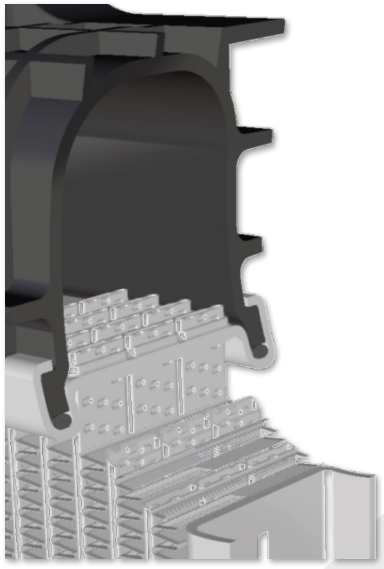
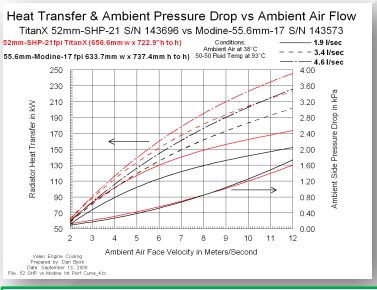
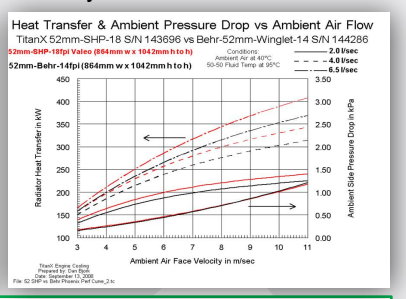
Super High Performance (SHP) Radiators



- Multi-chamber tubes (2 / 3 channels) with internal brazing, give this core both enhanced heat performance and structural resistance.
- Together with an increased core density, TitanX' SHP RAD delivers maximum heat transfer per cubic area when you need it most





Heat Performance vs. competitors:
average +5% heat rejection vs. Modine origami design (@ 11% lower airside dP)
average +13% heat rejection vs. Modine standard core (@ iso airside dP)
average +8% heat rejection vs. Mahle standard core (@ iso airside dP)
Heat Performance vs. standard FH Rad: +2,5% heat rejection @4% lower dP ambient

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What Have We Learned??

- ✓ Cascadia Radiators fail due to resonant vibration coupled with pressure fatigue
- ✓ The OEM has provided a highly engineered solution
- ✓ TitanXtend provides a radiator which addresses the major issues and will provide increased field life
- ✓ TitanXtend SHP Technology also provides increased performance
- ✓ OEM Validated Product made every day

TITANX

Thank you

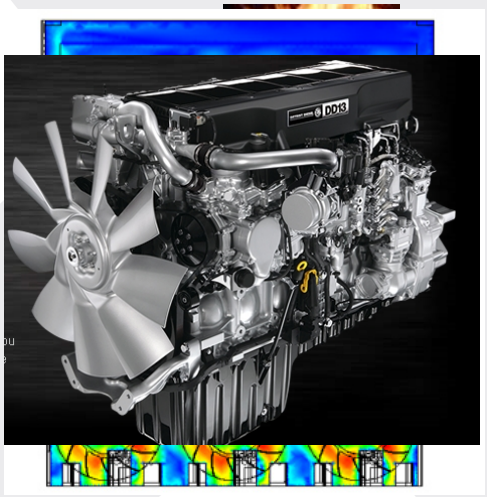
WE HAVE YET TO SEE AN
ENGINE WE CAN´T **COOL**

TITANX

Fuel Efficiency – Engine Cooling

- Effect on Heat Exchangers

Temperatures and Pressures go UP!



- TITANX will need to design for:
  - Higher Temperature & Pressure resistance
  - Trucks are getting more Aero-Dynamic
    - Smaller Grill Openings
    - Fuel Economy, Styling benefits
    - More Compact – Same Performance
  - Higher levels of Heat Transfer
  - Fan On Time @ Highway Speeds

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