

Hot Heads 2; Advanced Cooling System Design and Diagnosis

Instructor: Donny Seyfer AAM

- 1. Cooling System Design pg 2
- 2. Components and Service pg 8
- 3. Coolant Chemistry pg 23





HOT HEADS 2; Cooling System Design and Diagnosis



Cooling systems have become as sophisticated as the engines, batteries and transmissions they protect.



Tesla battery cooling system

Transmission cooler lines



The methods we use to maintain them have changed





Utilizing old techniques may be doing more damage than good.



- Changes in cooling system chemistry make measuring coolant protection with a hydrometer outdated
- Squeezing hoses to determine their condition is no longer viable
- universal antifreeze is simply the worst thing you can do to your customers cars.
- Even our maintenance equipment has to change



What is the cooling system's job description?

- Cool the engine
- Warm the engine
- Prevent oil sludging
- Warm the transmission
- Warm the occupants



Notes



New Cooling System Requirements

Maintain consistent temperature - Why?

Warm up Quick - Why?

Retain heat - Why?

Notes



2013 Focus ST 265 Horsepower 285 lb/ft Torque 2.0L Ecoboost I-4



 \swarrow Fully warmed up within 1 minute 30 seconds on a 40 degree

day.

```
Coolant capacity - 6.4 quarts
```

☆BTU generated by engine - about 33715/min at WOT

How much BTU (British Thermal Units) margin does a typical late model cooling system have?

Where does the heat energy created by an engine go?

%	
%	
%	

In this case how much heat exchange capability does our Focus radiator need? _____ BTU





Components and Service Changes



Industry Education



Radiator hoses don't do this much anymore

- Most Radiator Hoses are made of EPDM and will last 7-10 years.
- Hoses can get hard and damage radiators and plastic attaching parts because they do not flex as designed anymore.
- Most OE's have gone to spring clamp or heat shring hose clamps to maintain even pressure and reduce cold leaks.
- Hoses absorb the additive packs in antifreeze.
- Anytime a hose is replaced the antifreeze should be replaces as well to ensure adequate protection for other parts of the cooling system.



Water Pumps



Replaced during timing belt replacement Water pumps are designed to last 150K Cooling system must be flushed and coolant replaced during replacement

When water pumps fail there is almost always something wrong in the cooling system. Mechanical failure rate on water pumps is only about 2%. Common symptoms:

- Debris in cooling system
- Exhausted add packs in coolant
- Restrictions in radiator
- Mixing of coolants
- Incorrect coolant mix



Industry Education



Incorrect Antifreeze



Incorrect Antifreeze



Debris in system

Cavitation

- Contrary to popular belief is not air bubbles
- Actually is vacuum bubbles
- Caused by a restriction in flow and coolant failure
- Results in the equivalent of a sonic boom.





How weep hole leaks damage bearings



Coolant contamination damages water pump seal

- Slight leakage is a normal part of water pump lubrication in many designs.
- Major leaks are caused by scratched or grooved seal surfaces
- Seals are damaged by lack of lubrication from low coolant or exhausted add packs
- Seals are damaged by debris in system.





Plastic Water Pump Impellers

- Because of the ability to design more sophisticated impellers plastic is more efficient
- Technician error or lack of maintenance are the most common cause of plastic impeller failure
- Coolant must not exceed 50/50 in plastic applications
- Cavitation caused by restrictions is a major cause of failure.
- There are some early 2000's applications where the plastic is not compatible with the antifreeze package that failed.
- BMW, VW and Audi have made numerous changes to coolant chemistry.



How do they work?

 Charge cylinder is filled with wax that expands with temp and pushes the piston up opening the valve.

•Bypass valve keeps block and head temp more uniform during warm up and often eliminates the need for a bypass hose seal charge spring bypass valve

typical thermostat parts

- Lower temp regulator helps engine maintain a minimum temperature
- Helps engine warm up
- Activates bypass system
- Has no effect on upper engine temperature unless it sticks closed or it is missing.
- Replaced following an overheat
- Replaced anytime vehicle warm up time increases
- Replaced during a modern flushing operation.





Wind Devices

- If a air dam or shield is missing replace it.
- Look up and perform correct fan clutch tests by application they are not all the same
- Watch for cooling fans that don't run at full speed causing low speed overheating



Radiator Caps



- The pressure valve uses spring pressure so the cooling system can maintain above ambient pressure.
- 50/50 coolant boils at about 227 f.
 under ambient pressure
- At 14psi it climbs to 263F.
- The pressure valve allows small amount of coolant to be pushed into the recovery to account for expansion.
- It is critical to keep air out of cooling systems
- When a system cools it contracts creating vacuum
- The vacuum valve normalizes system vacuum by drawing cooling back from the overflow reservoir.
- A failed vacuum valve will generally result in hoses sucked flat when the engine is cooled down.



Heat Exchangers

What Goes Wrong?

- Leaks caused by poor coolant or expansion/contraction
- Restriction caused by deposits and debris which can result in cavitation inside and poor heat exchange outside.
- This is all true of heater cores and aux coolers like intercoolers and hybrid drive coolers.

Inspecting Exchangers

- Visually inspect for debris on either the radiator or heater core fins.
- A boroscope can be handy in both situations
- Temperature drops across core.
- Drain down some coolant and visually inspect if possible.

Temperature drop testing

- Measure from inlet to outlet
- Difference should be 10-30 degrees fan running.
- Less is restricted, more is low flow
- A/B thermometer good for road testing.



A little about Hot Rods

- High flow aluminum radiators must have high volume water pumps.
- High pressure water pumps with stock radiators will often pop the cap at high RPM
- Changing pulley speed can cause cavitation
- Eliminating the heater is the most common cause of Chevy overheats I see.
- You must take a total system approach to hot rods and only modify the system as much as you have to.
- Pulleys that reduce speed of water pump are a band-aid for bad design. Try to get it done with the water pump running pretty close to stock pulley ratio

Cooling system requirements Horsepower x 42.4 = BTU/minute needs





Thermo-Siphoning

Ford and others use a technique called thermo-siphoning to protect and cool Turbo-Charger bearing housings after shutdown. This is the Ford EcoBoost 2.0L.

The coolant uses convection and a loop. The hot coolant rises and as it cools it runs back down the loop. This will continue until the bearing housing reaches temperature parity with the coolant.



- Electric Turbo cool down pump (activated on shutdown after hard use)
- 3 different cooling circuits that are mechanically controlled
- The large and small cooling circuits operate like traditional open and closed thermostat systems
- The mini cooling system is focused on warm up and routes coolant to heater core, cylinder head exhaust side and oil cooler
- Keep in mind the exhaust manifold is built into the head so the mini cooling system helps to avoid hot spots in the head and distribute and recycle thermal energy



- System Pressure test 21.7 PSI all but 3.5L appear the same
- Coolant capacity 6.1 qts new formula Dexcool WSS-M97B44-D2
- Cylinder block Thermostat begins to open at 158 fully open at 185
- Other Thermostat begins to open at 197 fully open at 223
- Behind grille there is an active shutter system to control air through radiator core. (Fiesta, Focus and Escape)

Active Grille Shutters are used to accelerate warm up and to keep the engine warm on cold days. An electric motor is utilized to open shutters in 6 degree increments. The system carries out a calibration each time the vehicle starts, fully opening and closing the shutter. Inputs utilized are:

- ECT (Engine Coolant Temperature) sensor
- IAT (Intake Air Temperature) sensor
- A/C pressure transducer (to monitor High side pressure)
- APP (Accelerator Pedal Position) sensor (Load Calculation)
- ABS module (through the HS-CAN Vehicle Speed Data)
- Engine cooling fan motor
- Engine oil temperature



Ford Escape and Ford Fiesta

Active Grille Shutter

The grille shutter actuator positions the grille shutters based on commands from the PCM. The grille shutter moves 90 degrees from fully closed to fully open and, based on the position commanded by the PCM, is set in 1 of 16 positions (approximately 6 degrees between positions).

During normal operation, the grille shutter may be partially to fully open when the engine is off, depending on the ambient temperature. After an engine starting event,

a calibration of the grille shutter system occurs, which typically takes 15-20 seconds. The grille shutter system performs the calibration sequence by detecting the end positions, open and closed. The calibration sequence can begin in either direction, open or closed, and continues until it is successful or a fault is sensed. A long pause may occur between the 2 portions (open/ close) of the calibration sequence. If certain faults are present (shutter blocked or actuator error), a recalibration is initiated in an attempt to resolve the problem. If





the problem is not resolved after a calibrated number of attempts (usually 3 or 4), a timer starts and sets a DTC when the timer reaches a predetermined limit. Other faults also trigger a recalibration request, but not until a grille shutter DTC is set in the PCM.

The PCM communicates the desired position (open or closed) of the grille shutter based on various PCM inputs (vehicle speed, coolant temperature, ambient temperature, A/C system pressure, etc.). The PCM communicates to the grille shutter actuator via a LIN. The LIN supports bi-directional communication between the grille shutter actuator and PCM, allowing the grille shutter actuator to communicate position and fault information to the PCM.

The PCM sets grille shutter Diagnostic Trouble Codes (DTCs) when the fault information is communicated by the grille shutter actuator for a predetermined amount of time. Any failures of the LIN for over 10 seconds continuously results in the grille shutter actuator positioning the grille shutter fully open. There is no indication to the driver of the vehicle when a fault with the grille shutter system is present or a grille shutter DTC is set in the PCM.





Coolant Chemistry



Coolants

- OE's are using many different coolants
- They are not interchangeable
- Current testing equipment is not reliable
- Current service methods are inadequate
- 95% of water pump repair claims indicate no cooling system flush was performed.
- Universal coolants are NOT!
- Keep the coolant the car came with most of the time

Testing and Servicing

- Refractometer to test protection no hydrometer (no longer ASTM approved) coolants have different specific gravities
- Don't worry about electrolysis. If a system has measurable voltage the coolant is already bad or you have another problem.
- PH Strips ONLY in old green coolants (not the new green coolants)
- Determine clarity and color by drawing a sample off the bottom of the system after a short cool down.
- Old school flushing techniques are no longer adequate



Sater. Industry Education

Coolant Use Chart

American	Antifreeze Type	MY used	OE Name	Aftermarket replacements
Chrysler	Conventional	up to 1999	MoPar MS 7170 specification	PEAK (original N217), Zerex (original)
Chrysler	Hybrid B NO ₂ NO ₃ Si	2000-2012	MoPar MS 9769 specification	Valvoline / Zerex G-05
Chrysler	OAT (may not have 2EH)	2013-current	MoPar MS12106 specification	Peak Global Extended Life
Ford	Conventional	Up to 2001	M97-B44-A specification	Zerex (original)/ Peak (original N217)/ Motorcraft Premium
Ford	Hybrid B NO ₂ NO ₃ Si	2002- current	M97-B51-A1 specification	Valvoline / Zerex G-05/Motorcraft Gold
Ford	OAT Only	2011- current	M97-B44-D specification	Peak Extended Life/ Prestone / Zerex Dex-Cool
Ford	NO ₃ Mo P	2009-2012	M97-B55-A specification	Motorcraft Specialty Green / Peak Global Extended Life
GM	Conventional	up to mid 95	GM 6043 specification	PEAK (original N217), Zerex (original)
GM	OAT Only	mid 95 - current	GM 6277M specification	Dexcool (silicate free)
Asian				
Honda/Acura	Conventional	up to 98		
			Honda type 2 may be blue or	
Honda/Acura	NO ₃ Mo P	99-current	emerald green -(silicate free)	Zerex Asian / Peak Global/Pentosin Pentafrost A2
Hyundai/Kia	Phosphated Hybrid	All years	MS-591-08a specification	Zerex Asian / Peak Global/Pentofrost A2
Nissan/Infiniti	Conventional	up to 2008	Antifreeze (with silicates)	Zerex Asian / Peak Global/Pentofrost A2
Nissan/Infiniti	NO ₃ Mo P	2009 up	Nissan Long Life (silicate free)	Zerex Asian / Peak Global/Pentofrost A3 or A4
Mazda	Conventional	up to 2004	Antifreeze (with silicates)	Zerex Asian / Peak Global/Pentofrost A2
Mazda	Phosphated Hybrid	2002 - 2011	G05 Mazda Premium Gold	Valvoline / Zerex G-05
Mazda	NO ₃ Mo P	2005-current	FL22/ Motorcraft Specialty Green	Zerex Asian / Peak Global / Pentofrost A2
Mitsubishi	NO ₃ Mo P	through 2011		Zerex Asian / Peak Global / Pentofrost A2
Mitsubishi	NO₃ Mo P	2011 to present		Zerex Asian / Peak Global / Pentofrost A3 or A4
Subaru	Conventional	up to 2008		Zerex Asian / Peak Global / Pentofrost A2
Subaru	Phosphated Hybrid	2009 up		Zerex Asian / Peak Global / Pentofrost A3 or A4
Toyota/Lexus	NO₃ Mo P	up to 2003	Long life	Zerex Asian / Peak Global / Pentofrost A3 or A4
Toyota/Lexus	Mo P	2004 up	Super Long Life (silicate free)	Zerex Asian / Peak Global / Pentofrost A3 or A4
European				
Audi/VW	Conventional	up to 93		Valvoline - Zerex G-05 / Peak Global
Audi/VW	Hybrid B NO ₂ NO ₃ Si	94-95	G11	Peak Global / Peak G-12 / Pentosin Pentofrost NF(Blue)
Audi/VW	Hybrid OAT (Si)	96-99	G12	Peak Global / Peak G-12+ / Pentosin Pentofrost NF(Blue)
			G12++(05 up) Backward	
Audi/VW	OAT only	00-current	compatible to G11. G12+ was pink	Peak Global / Peak G-12++ / Pentosin Pentofrost NF(Blue)
BMW	Hybrid B NO ₂ NO ₃ Si	up to 2004	82 14 1 467 704	Peak Global / Peak G-12 / Pentosin Pentofrost NF(Blue)
Ferrari	Hybrid B NO ₂ NO ₃ Si			Peak Global / Peak G-12 / Pentosin Pentofrost NF(Blue)
Fiat	Conventional			Peak Global
Jaguar	OAT Only	1997-2014	WSS-M97B44-D	Peak Long Life / Pentosin SF
Mercedes Benz	Hybrid B NO ₂ NO ₃ Si			Valvoline / Zerex G-05
Mercedes Benz	OAT Only			Peak Long Life / Pentosin SF
Porsche	Hybrid B NO ₂ NO ₃ Si			Valvoline / Zerex G-05
Porsche	OAT Only			Peak Long Life / Pentosin SF
SAAB	OAT Only			Peak Long Life / Pentosin SF
SAAB	Hybrid B NO ₂ NO ₃ Si			Peak Global / Peak G-12 / Pentosin Pentofrost NF(Blue)
Volvo	Hybrid B NO2 NO3 Si			Peak Global / Peak G-12 / Pentosin Pentofrost NF(Blue)

Created by Ed Eaton - Amalgatech and Donny Seyfer



Industry Education

VW/Audi example



Legend: G11 - green-blue G12 - red G12+ and G12++ - purple

Note: The photo above is for color identification only, your packaging may vary.

G12+ aka Phosphate-free coolant G 012 A8F

G12++ aka Phosphate-free coolant G 012 A8G

G12++ is the only 'Universal" VW coolant

While you can mix the G12++ with the earlier coolants customers might not like the resulting brownish color.

G12++ contains the latest plastic water pump chemistry





Industry Education



Subaru head gaskets

- Coolant condition is a good part of the problem with these
- There are updated head gaskets
- Subaru began using a different coolant in 2009
- The coolant is a phosphated hybrid organic acid (blue)
- When we do one of these we completely flush the system and upgrade to the new coolant
- If you use one of the green versions supply the customer with some of the coolant and make sure they do not mix.



Labels - the devil is in the details

Zerex DEX-COOL® 5/150 antifreeze coolant is approved by General Motors to the GM 6277M specification. Zerex DEX-COOL® 5/150 antifreeze coolant contains no phosphates, silicates, borates, nitrates, amines and nitrites. It's global formulation meets the phosphate-free requirements of European automobile manufacturers and the silicate free requirement of Asian automobile manufacturers like Toyota, Scion, Acura, Hyundai, Kia, Honda, Isuzu and others. It can be mixed with any DEX-COOL® and is approved by Opel, Dae Woo and Saab. It is dyed orange to distinguish it's unique chemistry from traditional green and yellow silicate coolants.

- While it's true that most Euro coolants are not phosphated due to high mineral content in their water, Most Asian coolants, particularly Japanese are due to very low mineral contents in their water. American water depends heavily on the municipality so we generally have silicate free coolants.
- American manufacturers design engines around coolants so it is best to stick with what they come with.



Barrier Coatings, Damage, Debris

- Add packs in antifreeze react with engine parts.
- Different in each formula not mixable
- · Mixing can create a slimy coating that impedes heat sink effect with coolant
- OAT Coolants like Dexcool can take many miles to lay down a barrier coating. If there is too much of any other package in there rapid corrosion can occur.
- Using an OAT coolant in a system not designed for it can cause cavitation resulting in water pump and cylinder wall damage
- If a system has been contaminated you will have to flush with water and a mild chemical cleaner to remove contamination and old barrier coating.

Damage can be caused by:

- Over-mixing coolant causing too high of viscosity and low protection levels
- Engine overheat coolant should be flushed and replaced following an overheat along with cap and t-stat.
- Wrong of mixed coolants
- Depleted add packs allowing corrosion or cavitation

Debris in system can be a result of:

- Add pack exhaustion causing fall out of silicates or rust formation.
- Sand left in block from casting
- Component damage from cavitation breaking off small pieces.
- Oxygen entering system due to leaks, low coolant, bad cap



When Should Coolant be Replaced

- Whenever a component larger than a bypass hose is replaced
- After an overheat
- About 3-5 years/60K
- If there has been an air leak into the system radiator cap failure or other leak
- When the engine is replaced
- Anytime there is a cooling system component failure
- Anytime debris is found in the system or the coolant takes on a cloudy appearance

Flushing

- Flushing equipment should be updated to a pulsing component by component approach
- Gates and Hecat both have a tool that is recommended by OE's for backflushing heater cores. This tool works extremely well to flush the engine and radiator
- It is most effective to flush components backwards and then forwards
- Many vehicles will need the thermostat removed to effectively flush the engine
- If you capture the debris you wash out of the system customers will have a visual understanding of how this is a benefit
- Some water is left behind so you must blow out, add virgin antifreeze and use your refractometer to get the mix right.





- Uses shop air and water
- Use to clean components individually
- Creates a scrubbing action by velocity
- Sold by Gates as Powerflush and by Hecat



System Refill after Powerflush

- Some water left behind blow it out
- Use an air lift system to ensure there are no leaks
- Add approximate amount of virgin antifreeze first to offset left over water in engine.
- fill rest of system with 50/50 premixed coolant leaving it about a pint to a quart low depending on system capacity
- Run engine for a couple of minute to mix coolant
- Use your refractometer to get the mix right.