***Thermal management***

**Air intake system:Air Filter**  
An air filter is an important part of a car's intake system, because it is through the air filter that the engine 'breathes'. It is usually a plastic or metal box in which the air filter sits.  
An engine requires an exact mixture of fuel and air in order to run, and all of the air enters the system first through the air filter. The air filter's job is to filter out dirt and other foreign particles in the air, preventing them from entering the system and possibly damaging the engine.

**Throttle Body**  
The throttle body is the part of the air intake system that controls the amount of air flowing into an engine's combustion chamber. It consists of a bored housing that contains a throttle plate that rotates on a shaft.

**Dirty air Inlet:**

***Symptoms of bad or failing cold air intake:***

**1.reduction of engine performance:**

The cold air intake uses engine air filter which when dirty mud struck can cause reduction in power, acceleration, and fuel efficiency and in worst cases it may not able to start the car.

## 

## Common reasons for this to happen:

* **Defective fuel pump or filter**: Since the fuel pump is responsible for supplying your vehicle with fuel, it can cause a loss of power when it begins to wear out or when the in-tank filter becomes clogged and prevents the free flow of fuel. When the fuel pump is failing or unable to push fuel through the filter, your car will sometimes make sputtering noises at high speeds, act like it is going to stall(stop or delay) as you accelerate from a stop, or simply stop running when it is under the stress of a hill or heavy load.
* **Vacuum leak**: When a vacuum leak is present in your vehicle, it interferes with the computer’s ability to regulate the air-to-fuel ratio, which can sometimes lead to power loss. Such leaks will frequently cause the Check Engine” light to come on, and you can usually hear a hissing noise come from the engine area if you listen closely under the hood of your vehicle.

***Further study on vacuum leak problems***: <https://www.youtube.com/watch?v=lzGlG_bRoCU>

Symptoms on vacuum leak: <https://www.youtube.com/watch?v=lzGlG_bRoCU>

* **Ignition system**: When the ignition system is malfunctioning, your vehicle may also have problems starting periodically in addition to power loss. Frequently, a tune-up will solve this problem, but it is important to have a qualified mechanic with the proper diagnostic tools check the system as a whole. Modern tune-ups typically involve replacing fewer parts than years past, but with more attention being paid to the fuel injection system at the same time.
* **Timing belt or chain**: A worn timing belt or chain can cause the valves on your engine to open and close at the wrong intervals, sometimes resulting in a loss of power. When the timing is off, it is frequently accompanied by a slight clattering noise at the front of the engine.
* **Catalytic converter**: When the catalytic convertor fails or become clogged, it prevents proper air flow through the engine, which can cause power losses. Aside from a loss of power, your car may also run at a higher temperature than usual or have an erratic idle. A mechanic can easily check your catalytic convertor with a vacuum gauge to determine if it is functioning properly.
* **Airflow sensor**: When your airflow sensor is failing or dirty, it can send wrong signals to your engine’s computer that can result in power losses while accelerating. This type of issue usually causes your Check Engine” light to come on and your vehicle to behave sluggishly even when there is power.

**2.Exclusively high or surging RPM:**

Another symptom for a potential problem with a cold air intake system is exclusively high RPM. An excessively high idle may be an indicator of a potential vacuum leak. Many cold air intake systems come with vacuum ports to accommodate the original manufacturers vacuum routing. If any of the hoses on these ports break or come free, or the ports themselves break, it will lead to a vacuum leak which will cause an excessively high or surging idle.

## When to check for idle speed issues

* **RPM on dash gauge does not match OEM specification.** Many cars have RPM gauges. If the engine speed displayed on the gauge does not match the original equipment manufacturer (OEM) specification on the under-hood label, there is probably something wrong.
* **Engine is idling higher than normal.** If there is no RPM gauge but the engine sounds like it is turning faster when idle, a mechanic can use an instrument to measure the actual engine speed.
* **Harsh engagement in drive.** If the idle speed is too high, the vehicle will jump forward when placed in drive.
* **Excessive brake effort is required to hold vehicle at a stop.** If idle speed is normal, only a very light force on the brake pedal will be necessary to prevent forward motion in drive.

## Idle speed problems: <https://youtu.be/cxyEn-rob3g>

<https://youtu.be/rsCFgTa8lag>

**Check engine light comes on:**

An illuminated check engine light is also a common symptom associated with a problematic cold air intake. If any of the sensors that are installed in the intake detect any issues, they may set off the Check engine Light to notify the driver of a problem. Problems such as vacuum leaks or faulty sensors are the most common reasons why the Check Engine Light can be set off.

**Problem notification**

* **If the indicator is blinking, the situation is usually serious**, such as a severe misfiring of the engine. This would allow unburned fuel to dump into the exhaust system, pushing the temperature of your catalytic converter to the breaking point. Slow the car down, find a safe place to stop, and request a mechanic to perform a diagnosis.
* **A steady light on the other hand is not an emergency situation**. You can continue driving, but you should schedule an appointment with a mechanic as soon as possible.

## Common reasons for this to happen

**Loose or damaged gas cap**: It’s hard to believe that a gas cap can prompt your check engine light to come on, but it can. Your gas cap acts as the seal for your fuel system and it helps maintain the pressure in your fuel tank. A loose or damaged cap can reduce your gas mileage and increase emissions from your car.

**Faulty oxygen sensor**: An oxygen sensor monitors the exhaust for unburned oxygen, which indicates engine efficacy and the proper air-to-fuel ratio. If you have a faulty sensor, it will not provide the correct data to the onboard computer. The majority of vehicles have two to four sensors. The OBD II code will tell the mechanic which one is giving a reading that is outside of its parameters.

List of OBD codes:

<http://www.myautorepairadvice.com/obd_2_codes.html>

**For air filter the following air drivers are important:**

* Best performance in various operating conditions
  + High filtration efficiency
  + High dust holding capacity
  + Min. restriction
  + Max. filter life etc…
* Low cost and weight optimised
* Best cost value to customer
* Modular concept to offer customised product in short time
* Conform to all legislation requirements -- present and future
* High reliability, easy serviceability, accessibility and low maintenance

Heat exchange parameters:

* Constraints:
* Most expensive component of cooling system
* Vehicle front appearance
* Packing X-member, crash protection, exchange accessories
* Long manufacturing lead time
* Design control parameters:
* Surface geometry
* Size
* coolant mass flow rate
* air mass flow rate
* air flow maldistribution(uneven)

Parameters for selecting radiator:

* Engine heat rejection
* Temp. diff between coolant and air
* Air pressure differential across core
* Cooling air flow velocity

Parts of radiator:

* Fin
* Tube
* Plate
* Reinforcement
* Upper tank
* Lower tank
* Seal pack
* Drain cock
* Radiator cap
* Built-in AT oil cooler
* **Fin**: In a convector radiator, the hot water is circulated through a tube, surrounded by small fins. These fins act to increase the contact surface with the surrounding air. As with a regular radiator, the hot air rises up and attracts cooler air to the appliance.
* **Tube:** As the coolant passes through the radiator tubes on its way to the opposite tank, it transfers much of its heat to the tubes which, in turn, transfer the heat to the fins that are lodged between each row of tubes. The cooled coolant is fed back to the engine, and the cycle repeats.
* **Plate:** Radiator cooling plate is a device to direct air to flow efficiently from grille to the radiator for better cooling that is installed between front grille and the radiator top. This result more air to flow through radiator for more efficient cooling that prevent overheating.
* **Upper tank:** This container provides extra storage space for the coolant when it expands and is called thseae expansion, or overflow tank. It is also known as the coolant reservoir, or overflow canister. As the engine heats up, the coolant inside it expands.
* **Lower tank:** it is a tank to hold coolant that has been cooled and ready to be sent back to the engine.
* **Seal pack:** material used to manufacture seal pack is  Polypropylene & Thermoplastic Elastomer and provides an effective barrier for the loss of warm air to pipe entry points behind radiator.
* **Drain cock:** works as a pipe
* **Radiator cap:** 1) It keeps the cooling system sealed from outside contaminants.

2) By keeping pressure on the cooling system, it raises the boiling point.

3) The radiator cap allows coolant to go to the expansion recovery tank

when coolant gets hot, expands, and pressures increase.

4) As the system cools down, it allows coolant to return to the engine

from the expansion recovery tank.

* A bad radiator cap can cause the engine to overheat at lower temperatures. This will cause the coolant to boil over to the expansion tank. A radiator cap that is faulty could also prevent coolant from returning to the engine. This would create a vacuum and cause the radiator hoses to collapse.
* **Built-in AT oil cooler:** During vehicle driving, vehicle should be installed with the ATF cooler for cooling the ATF that is heated up with high temperature by the torque converter operation. ... Thus, the vehicle installed built-in oil cooler that have not only cooling but also rapid warming of ATF on engine starting is increased.
* **Radiators are of three types**
  + **Cross flow radiator**
  + **Downflow radiator**
  + **Horizontal radiator**
* **Cross flow radiator:** May be used if height limitations exist but Deaeration, thermal stratification, adequate core tube coverage and freeze damage are generally more difficult to control.
* **Down flow radiator:** these are customarily used and required for heavy duty diesel engine applications.
* **Horizontal radiator:** May be used in situations were space restriction preclude the use of other types. It is essential that vent lines go to the fill tank with the cap.

 A **charge air cooler** is used to cool engine air after it has passed through a turbocharger, but before it enters the engine. This is their main function. The idea is to return the air to a lower temperature, for the optimum power from the combustion process within the engine.

* it improves fuel economy and reduces emission
* it improves the volumetric efficiency of internal combustion engine
* typical CAC inlet temperature: 160-200 C
* typical CAC outlet temperature :60-70 C

**Exhaust gas recirculation:**

* it is an emission control technology. It also used in other purpose such as:
* imparting knock resistance
* reducing the need for high load fuel enrichment in spark ignition (SI) engines
* aiding vaporization of liquid fuels in SI engines
* as a enabler for closed cycles diesel engine
* for improving the ignition quality of difficult-to-ignite fuels in diesel engines
* for improving the performance of SCR catalysts.

**EGR technique:**

* engine emissions controlled by due to lesser NOx entering atmosphere
* exhaust gasses lower the oxygen concentration in combustion chamber results the lowering flame temperature
* Thus emissions levels are attained by the engine
* 15% EGR rate found to be effective to reduce NOx emission
* EGR cooler reduces the temperature of exhaust gas for recirculation in to intake manifold.

**There are 8 rules that should be followed while manufacturing a car:**

* **Rule1:** coolant air flow rate

Anything you can increase the coolant flow rate, within the limits described, will improve the heat transfer and cooling performance. Anything you do to restrict the coolant flow rate will hurt cooling performance.

* **Rule2:** cooling air flow

Anything you can do to improve air flow through the radiator core will help. Anything that blocks or shows the airflow, either before or after the radiator will hurt.

* **Rule3:** HE Frontal Area

Increasing the face area of the radiator by making the radiator larger will help. Relocating other heat exchangers that were Infront of the radiator in order to expose more radiator face area to ambient cooling air will also help.

* **Rule4:**

Increasing the fin count may help, but it may hurt. Increasing the count above 16 fins per inch will almost always hurt.

* **Rule5:**

A plate fin radiator and a serpentine fin radiator of the same fin count, tube size, tube rows, face area, core depth, etc will have the same heat transfer performance. However, serpentine fin radiators are made with higher fin count sometimes resulting in improved performance.

* **Rule6:**

Louvered fins provide greatly improved heat transfer with some increase in cooling air restriction.

Changing from a non-louvered radiator to a louvered core almost always improves heat transfer performance.

* **Rule7:**

Adding two rows of tubes may help, but it may hurt by increasing cooling air restriction and reducing the coolant flow rate in tubes. If the cooling air flow has been increased over the installation, adding the row or two will probably help in the situation increasing the number of rows beyond 4 in a louvered fin core will almost always hurt.

* **Rule8:**

Adding two rows of tubes without increasing the coolant flow rate (bigger pump or turning the old pump faster) will probably reduce performance because of low coolant flow rate in the tubes.

Reducing the tube size or going to dimple tubes may help. Increasing the coolant flow rate may surely help.

**Air Flow Subsystem:**

**Objectives of cooling air flow subsystem**

* To achieve required heat exchanger air mass flow rate with minimum power consumption (shaft power and drag)
* Maintain aerodynamic noise within vehicle targets.

**Functional requirements:**

* dissipate heat from engine (cascaded from heat dissipation subsystem)
* dissipate waste heat from AC system
* dissipate heat from Aux. Heat exchangers (CAC, Transmission oil cooler, EGR cooler etc).

**Fan will provide a major role in the air flow subsystem:**

**Factors for selecting a fan:**

* limit fan HP to 6% of engine rated power
* select most efficient fan – largest possible size running at slowest possible speed, select suitable pully ratio)
* selecting fan should operate well below max limiting speed. (vibratory stresses included on fan from engine and vehicle vibrators)
* noise is a function of blade tip speed. (limit fan tip speed)

**Radiator system:**

* The radiator core dissipates heat picked up by the coolant from the engine and the accessories
* As a coolant passes through passages, or tubes, the air passes between the heat dissipating fins surrounding the tubes, carrying away the heat transferred from the coolant to the air moving through the radiator.

**Viscous fan clutch:**

**Fan clutch:** A fan clutch is a temperature-controlled coupling between the water pump shaft and the fan which allows the fan to be operational at low speeds and disconnected at high speeds. This allows the engine to operate more efficiency by removing the load that the fan places on it.

**There are three types of fan clutches:**

* **Non thermal fan clutch**
* **Thermal fan clutch**
* **Electronic fan clutch**
* **Non thermal fan clutch:** Non-thermal clutches operate solely based on the shaft speed of the water pump. At low and idling speeds, the clutch allows the fan blade to turn at almost a 1:1 ratio. At high speeds, the silicone fluid within in the clutch will lose its ability to transfer the energy from the shaft to the fan clutch body (and therefore, the fan) and the fan is then allowed to almost free-wheel, removing its load from the engine. A non-thermal clutch provides a steady flow of cooling air but is always engaged, so it offers lower fuel savings than a thermal-style fan clutch. However, non-thermal clutches are a lower-cost option than thermal-style clutches.
* **Thermal fan clutch:** The thermal fan clutch operates in response to underhood temperatures. As hot air blows across the radiator, it heats a thermal spring mounted at the front of the clutch. As the spring is heated, it turns and allows valve ports to open within the clutch. Silicone fluid stored inside a reservoir is allowed to pass through these open ports and enter the working area of the clutch. This engages the clutch and drives the fan. Once the engine is cooled down, the thermal spring rotates back and closes the valve ports, disengaging the fan.
  + for example, you’ll find three different types of thermal fan clutches from [Hayden](https://www.summitracing.com/search/brand/hayden-automotive) alone:
  + [**Standard-Duty Thermal Fan Clutch**](https://www.summitracing.com/search/part-type/fan-clutches/clutch-style/standard-thermal)**:** This design turns the fan at 60-70 percent of the water pump shaft speed when engaged, and 20-30 percent when disengaged. It’s made for fans with a lighter pitch.
  + [**Heavy-Duty Thermal Fan Clutch**](https://www.summitracing.com/oh/search/part-type/fan-clutches/clutch-style/heavy-duty-thermal)**:**This fan style turns the fan at 70-90 percent of the shaft speed when engaged for increased cooling. When disengaged, it turns the fan at 25-35 percent. It’s used with deeper-pitch fans (2 1/2″ of pitch), and works well with higher operating rpm.  
    [**Severe-Duty Thermal Fan Clutch**](https://www.summitracing.com/oh/search/part-type/fan-clutches/clutch-style/severe-duty-thermal)**:** Severe duty thermal fans turn the fan at 80-90 percent of the shaft speed when engaged and 20-30 percent when disengaged. It’s used with deeper pitch fans and has a larger working surface to provide cooler running and longer life expectancy.

### **Electronic – Viscous EV Fan Clutch Operation**

This style of fan clutch operates like a thermal clutch, but the ECM/PCM signal controls the level of engagement of the EV clutch. This engagement process is ultimately controlled through the ECM/PCM by the following input variables: Coolant Temperature, Intake Manifold Temperature, Transmission Oil Temperature, A/C Pressure and Engine Oil Temperature. These variables are manufacturer-specific and fan speed is dictated based on the level of cooling required.

Like all components, fan clutches will wear out and need replaced.

**Signs of Worn Fan Clutch**

According to Hayden, here are some signs your fan clutch might need replaced:

* Fan spins excessively when engine is stopped (three or more times when hot engine is shut off).
* Poor A/C performance at idle or low vehicle speeds.
* Fan speed does not increase when engine is hot.
* Fan speed does not increase until engine is excessively hot.
* Fan blade tip moves more than 1/4-inch front to back.
* Fan turns roughly or does not turn at all.
* Excessive fan noise at all speeds due to failed bearing.
* Vibration that increases with engine speed.
* Leaking fluid or oily build up around the bearing or thermal spring.

These problems are often caused by a bad bearing, which may be seized or have excessive play, or by a worn or loose thermal spring.

Armed with this information, you can identify a bad fan clutch and replace it with the proper aftermarket option.

## Electric Fan Cooling System:

### **SYSTEM BENEFITS**

* 100% EU build
* Better fuel economy (up to 10% reduction)
* Reduced noise (approximately 30%)
* Reduced CO2
* Reduced weight
* Reduced fire hazards
* Reduced vehicle downtime
* Reduced cleaning
* Easy troubleshooting
* Designed to customer specifications
* Standard 2-year warranty (extended warranty can be purchased)
* ROI estimated at 12-18 months

### **SYSTEM FEATURES**

* + Next generation CANbus controller
  + Next generation control box
  + New finger guards for fans
  + Lighter fan
  + 30,000-hour fan life
  + New lighter tube and fin design
  + Free cooling/heating system training
  + Consists of 2 heat exchangers, one radiator, and a charge air cooler (no oil cooler)
  + Up to 20 fans available depending on specification requirements
  + Thermal operated temperature settings
  + 5-year product life expectancy with regular servicing

### **PRODUCT SPECIFICATION:**

### E-DRIVE COOLING SYSTEM

* Cores are constructed of Extruded Tubes and 0.15mm dimpled Fins which are designed to reduce clogging and cleaning
* Fin are clad coated on both sides to reduce external corrosion
* Charge Air Cooler tanks are cast constructed to minimise weight
* Tested using Grayson’s exacting standards (For further details visit out testing page)

**Control mode and functions:**

* Controller is located in a weatherproof enclosure (IP66 / NEMA 4X rating), not exposed to outside elements and not located on the outside or fan cowling
* Controller has a minimum of six Thermal Sensor inputs
* Diagnostic LED and Reverse button facility
* Controller communicates with the bus network via J1939 protocol
* Controller has an independent download capability and software for information on fan usage, temperature and troubleshooting
* Module is easily accessible for quick removal and replacement

**Electric fan drive:** electric fans

In many recent car models, to save power and reduce noise, the conventional belt driven, water pump mounted engine coolant fan has been replaced with electrically driven fan

**Advantages:**

* They can be mounted on radiator shroud whenever they are needed
* Run at constant speed
* They can be turned off or on whenever they are needed
* They do not draw power directly from engine
* The electric fan uses frictional KW motor and mechanical fan uses several KW motors

Fan laws are useful to determine the fan performance

* Mass air flow rate varies directly with fan RPM
* Static head varies with fan RPM2
* Horsepower varies with fan RPM3

Heat exchanger installation parameter:

* Fan position
* Radiator core shape
* Fan shrouds
* Air exit conditions
* Down flow vs cross flow

Cooling air flow exit conditions

* Large portion of cooling air flow exhausted downward Infront of engine
* Avoid blockage od air flow or if it not decrease blockage

Pressurizing the cooling system:

* Reducing boiling
* Prevent coolant loss due to evaporation
* Maintains water pump performance

**System pressurization will not occur if pressure fill cap is installed when coolant is hot**

**Pressurization:**

* It also minimizes air bubble formation that causes linear pitting (Modern high-speed diesel engines contain cast iron replaceable cylinder **liners** that are subject to accelerated corrosion due to a process commonly known as **liner pitting**) and poor heat transfer
* A bubble next to a part in engine, such as cylinder liner, can hamper effective cooling and cause serious damage to an engine
* Even more important, bubbles in the coolant could result in pump cavitation, effect flow rate, and cause a overheating problem.

Cooling system air flow fans:

Ring fans:

* Less noise compared to open blade fan
* No air recirculation at the tip of the blade
* Easy to install compared to open blade with fan ring

General requirements of coolant:

* Good heat conductor
* Low freeze point
* High boiling point
* Non corrosive to metals
* Non-foaming
* Compactable with other
* Commercial coolants

What is coolant made of?

* Water
* Glycol
* Inhibitor package
* De-former
* Dye(colorant)

**Coolant filters:**

**Contamination filtered:**

40% contained modern contamination levels over 10% of the used filters contains heavy contamination

Reduction in scale formation helping the engine maintain effective heat transfer for optimum performance.

HVAC (heating, ventilation, air conditioning)

Compressor

Function: To compress and circulate the superheated refringent vapour

Operation: driven by engine pully

Suction side refrigerant vapour enters at low pressure and temperature discharge of vapour at high pressure and temperature

Range:

Pressure: 150 to 3000 kPa

Temperature: 0 to 150 degC

**Compensator sub components and details:**

Function: to dissipate heat from refrigerant to the atmosphere

Heat rejection occurs in three phases: de superheating zone, condensation (two phase) zone, sub cool zone.

**Types:**

* **Serpentine flow**
* **Parallel flow**

**Receiver- drier/ accumulator**

**Function:**

* Remove moisture from refringent
* free from dust
* temporary reservoir to supply under varying load conditions
* allows only liquid refrigerant to flow to expansion valve
* point for diagnostics