Air Induction Systems

Air Supply Requirements of Diesels
All internal combustion engines need an adequate supply of air that is clean, dry, filtered, fresh, and relatively cool.

Adequate Supply
Diesel engines have higher air intake volume requirements because they operate using excess air even under full fuel conditions. It is sometimes difficult for those more familiar with gasoline combustion to understand that diesel engines do not operate at a fixed stochiometric ratio. At idle, the air fuel ratio may be as high as 1000:1. (All air fuel ratios are measure by weight not volume). At full load the air fuel ratio is still high in comparison to a gasoline-fuelled engine. For example, indirect injection (IDI chambers) according to Bosch, typically have a smoke limit requiring an excess air at a minimum air fuel ratio of 20:1 Direct injection (DI chambers) engines require a minimum of 30:1 excess air. IDI’s require less air due to their inherent ability to mix air and fuel better. These excess air requirements of a diesel are necessary for several reasons. First, large amounts of intake air are required to achieve good combustion. Since diesels have a short amount of time for atomizing, distributing, vaporizing and heating fuel vapours, it is important that the fuel finds enough air to make contact and react with the oxygen. The more air there is, the greater the likelihood the fuel will burn completely.

Above: Air intake systems of diesel are classified by weather they are naturally aspirated or supercharged - pressurized above atmospheric pressure

One pound of fuel needs approximately 20 pounds of air to burn efficiently
Excess air is also necessary for cooling of critical cylinder components in a diesel. Since the flame temperature of diesel is 3900F, combustion heat will readily melt pistons and burn valves. By adding additional air volumes, combustion temperature is lowered through dilution with extra air. Engines lacking sufficient airflow will naturally have increased exhaust and combustion chamber temperatures. A diesel engine of 350Hp typically requires an air intake capacity of close to 1000cfm.

Clean Air
Dirt ingestion into an engine results in rapid engine wear often referred to as “dusting out”. Less than two tablespoons of dirt can rapidly wear internal engine components. It is suggested by GM that in gasoline fueled engines having as small as a ¼” hole in the air intake of an engine (i.e. a vacuum line leak) will produce the same amount of wear having no air filter.
Dirt will “stick” to the cylinder walls of an engine because of the oil film. Rings and cylinder wall wear will accelerate. From there dirt will wash into the lubrication system where it remains. An oil analysis can reveal the presence of silica – (the primary constituent of sand) in the oil that may indicate the presence of a leak in the air induction system.

Air Inlet Temperature
Diesel engine performance is optimal when air inlet temperature to the cylinders is approximately 35 to 38C (95 to 100F). Air inlet temperature will be increased by the turbocharger. Air inlet temperature changes combustion chamber and exhaust temperatures by a 3:1 ratio. For example, a 100 degree F (46C) temperature change will produce as much as 300 F or 150c exhaust temperature difference. Very low air temperatures cause poorer fuel vaporization, longer ignition delay and reduce engine power.
High temperatures will accelerate the production of NOx. The use of aftercooling and compound turbocharging – a strategy pursued by Caterpillar, reduces NOx formation caused by high intake and combustion chamber temperatures.
- Two stroke Detroit diesels use airflow through the cylinders to accomplish 30% of engine cooling.
Above: Air Inlet temperature Effects On Pre-Ignition Temperatures

Water Content of Air
It is important for the technician diagnosing performance complaints to note water vapour or humidity in the air displaces oxygen. A room with a relative humidity of 50% at 20°C will have more oxygen content than a room at the same temperature with will have with 80% relative humidity. (The chemical law that explains this observation is Avogadro’s Theorem.) Higher humidity results in lower oxygen content. Warmer temperatures also are capable of dissolving more water than cooler air temperatures. You may notice on warm humid days that your breathing becomes more difficult or one becomes short of breath faster when physically active on those days. This is because there is less oxygen content in the air. Engines experience similar problems when high temperatures are combined with high humidity. The result is often lower power output and higher levels of exhaust smoke. (Emission testing is restricted on those days!)

Below: Note the differences in Oxygen content under different temperature and atmospheric conditions
Above: A gasoline engine with water injection through the intake manifold - these systems can enhance performance by allowing for higher compression ratios or advanced timing. In diesels, higher fuel rates can be used with the water as a combustion chamber coolant. This technology also reduces NOx emissions. See also: http://www.frii.com/~maphill/wi.html

Intakes

Air intakes design is important to minimize noise, and the quantity of dirt and water entering the air filter. They are used to also optimize the airflow into the engine.

Air intakes ideally should have minimal bending and smooth interior surfaces for maximum airflow.

Resonator boxes or chambers may be located on the intake system in passenger applications to inject pressure waves which cancel intake noise from created from the large amount of valve overlap that is characteristic of a diesel engine.

Factors Affecting Air Intake Efficiency:

- Smoothness of air intake passages.
- Degree and number of bends in air passages.
- Size, design (Crossflow Vs Uniflow) of ports and passages.
- Valve timing, lift and duration of valve opening.

Because diesel engines often have large amounts of valve overlap, some exhaust gases may leak by the intake valve during overlap. Soot loading of an intake manifold is normal in a diesel. Intake noise is louder in a diesel for the same reason. The intake valve can become very hot to the point of being damaged. Valve adjustment is important!

Lack of sufficient airflow to an engine can result in these conditions:

- Low turbocharger or blower boost pressure
- Higher exhaust temperatures
- Incomplete combustion
- Lower fuel economy
- Lack of power
- Smoke at the exhaust stack
- Increased exhaust emissions
- Shorter valve and piston life
- Increased lube oil use

Many current engines, which are electronically controlled, are equipped with a variety of air inlet system sensors. These three sensors can help identify a problem in the intake system and cause the engine ECM to adapt protection or performance strategies. For example, intake air
temperature is monitored on many engines to prevent damage from high intake temperatures. Typically, the engine power will be de-rated if temperatures are excessive.

Other intake air sensor strategies include:
- Ambient air pressure sensor (barometric pressure sensor) for altitude compensation.
- Intake manifold temperature sensor. This is data is used to modify fuel timing/injection rates to minimize emissions and is monitored by the engine protection system in the event of excess intake temperature.
- Turbocharger boost pressure sensor; data used to adjust fuel rates and sense engine load.

**Moisture & Dirt Removal From Intake Air**

Intake systems can be designed a number of ways to minimize the entry of moisture and dirt entry into the air induction system. A frontal intake system alone with inlets close to the ground will results in more ingestion of road salt and water into the air intake. Water will dissolve the salt and allow it to pass through the induction system causing corrosion to components like the aluminium intercooler and eventually cylinder component damage.

**Below: frontal air intake system with induction passage through the hood. Note the dirt-air drain**

**Above: Side mounted intake systems eliminate more moisture and dirt aspiration than frontal systems but lose the “Ram Air” effect**
Above: Air Intakes with optional summer or winter air inlets. Note flap in top picture.

In some applications, the entry to the air induction system is located high to avoid road spray. The above Freightliner uses the force of air deflected by the windshield to push air into the induction piping. The use of the optional winter/summer intake allows warmer air to be drawn from under the hood where it is less likely to be moisture or snow contaminated. Snow-plow trucks are especially suited to require this configuration.

Above: Ram air induction

An intake that is located in the side or top of a hood will result in less water/dirt ingestion into the air intake since the air can change direction more quickly than the dirt/water.

Precleaners
Precleaners remove as much as 90% of dirt and contaminants from the incoming air often using centrifugal force.
1. Air enters through recessed vanes in bottom of preseparator.
2. Curved particle accelerator rotates much faster than incoming air; debris is captured and passed down the length of the spinning blades.
3. Debris is deposited on inner wall of separator chamber.
4. As particle accelerator spins, it sweeps debris on inner wall toward ejection slot, where it is released.
5. Clean air is folded, compressed, and forced into air inlet opening.
Filter Elements
A number of filter media are used to remove particle contamination from the air induction system. While paper-cellulose elements are the most popular, felt, foam, oil soaked paper foam, and synthetic glass fibres (microglass) are also used. None of these will effectively remove some contaminants such as cement dust that can be so small that it will pass through many media types. Electrostatic filtration is often used in industrial applications. Also, road salt dissolved in water will also pass through many media types causing contamination and corrosion of air induction/cylinder components.

Dry Air Cleaners
Paper filters are made from compressed cellulose fibers. The spaces between these fibers provide microscopic holes the air must pass through. As dirty air flows through one by one, these holes become plugged with dirt and dust particles. Once a hole becomes plugged, the air must find an alternate route through the medium. It should be noted that the larger holes tend to plug up faster since greater air volumes will flow through those channels. Since there are generally more smaller holes in the filter media, these will plug up later. This phenomenon will result in better filtration (i.e. more particles are blocked) as the filter loads with contamination. Over servicing of filters should be avoided to obtain the best filtration since a new filter will pass more dirt than a used one. However, it should also be noted that as the filter collects more dirt, its resistance to air flow increases because there are fewer and fewer holes are left open and as resistance or restriction to airflow goes up. Eventually horsepower and fuel economy decrease. Ideally, the paper must be thick and/or the fibers must be tightly compressed and dense to load as much dirt and obtain effective filtration.

Paper filter elements are made from treated paper (to resist water damage which causes the pores to close) and pleated to form “V’s”. The pleating will allow more surface area to pass air and greater dirt loading capacity before the filter becomes restricted. In some filter models, this pleated paper element can be opened to a full length of 12 to 18 m (40 to 60 ft). The chemicals used to treat the paper can be dissolved through the use of solvents found in cleaners used to wash filters.

The paper element is surrounded and protected by a perforated steel mesh screen (shell). Inside the filter, the mesh can act as a flame retarder in the event of engine backfire. On the outside it functions to smooth out turbulence in the air stream.

- Trucks used in applications such as construction will use a primary and secondary filter arrangement. The inner filter may have a
separate/integral restriction gauge or indicator to prevent over servicing.

In composite filters, dirty air enters through the inlet opening, where it travels through a plastic ring of vanes (called a pre-cleaner) around the outside of the element. These vanes are designed to create a cyclonic twist to the air to throw the heavier dust and dirt particles outward against the filter housing walls by centrifugal force and downward into the dust cup.

Above: Two stage – primary & secondary filter used in “dump truck application

Composite Filter
Filter Efficiency
A filter’s effectiveness must be stated as the % of dirt trapped at a particular micron size. Typical numbers for paper element filters are 40% efficiency at 10 microns, 60% at 20 microns, 93% at 30 microns, and 97% at 40 microns.
Power Core Filters

Using a new design and material, Donaldson has introduced a new filter technology using a polymer (Plastic) type filtration media. Power core filters use a layered type fluted cells. The fluted channels are alternately sealed allowing air to enter through an open flute and forcing it to exit out an adjacent flute. Advantages claimed by the manufacturer include:

- **Improved efficiency:**
  Power Core is 10 times more efficient than average conventional filters
  Gain over 100% more dust holding capacity in a given volume.
- **Improved engine protection:**
  No media movement, expansion, contraction or bunching, with less dust and dirt passed on to the engine
• Improved contaminant encapsulation:
  Dust and dirt won’t dislodge during servicing
• Improved handling and maintenance:
  Lighter and smaller, changing filters is a snap
• Improved disposal ease:
  No metal, incinerable

The other major benefit is the filter uses significantly less space, this allows manufacturers the freedom to design unique configurations to fit tight spots, and overall design simplicity.

Heavy Equipment Air Intakes
To improve the pre-cleaner efficiency of some HD diesels in off-road applications, the velocity of exhaust gases is used to clean the pre-filter. A venturi like device is used at the exhaust outlet to draw dust and contaminants out of the filter housing pre-cleaner trap or bowl.
Komatsu Intake System

D8R AIR INLET AND EXHAUST SYSTEM