The sense and non sense of Emission testers continued (Diesel)

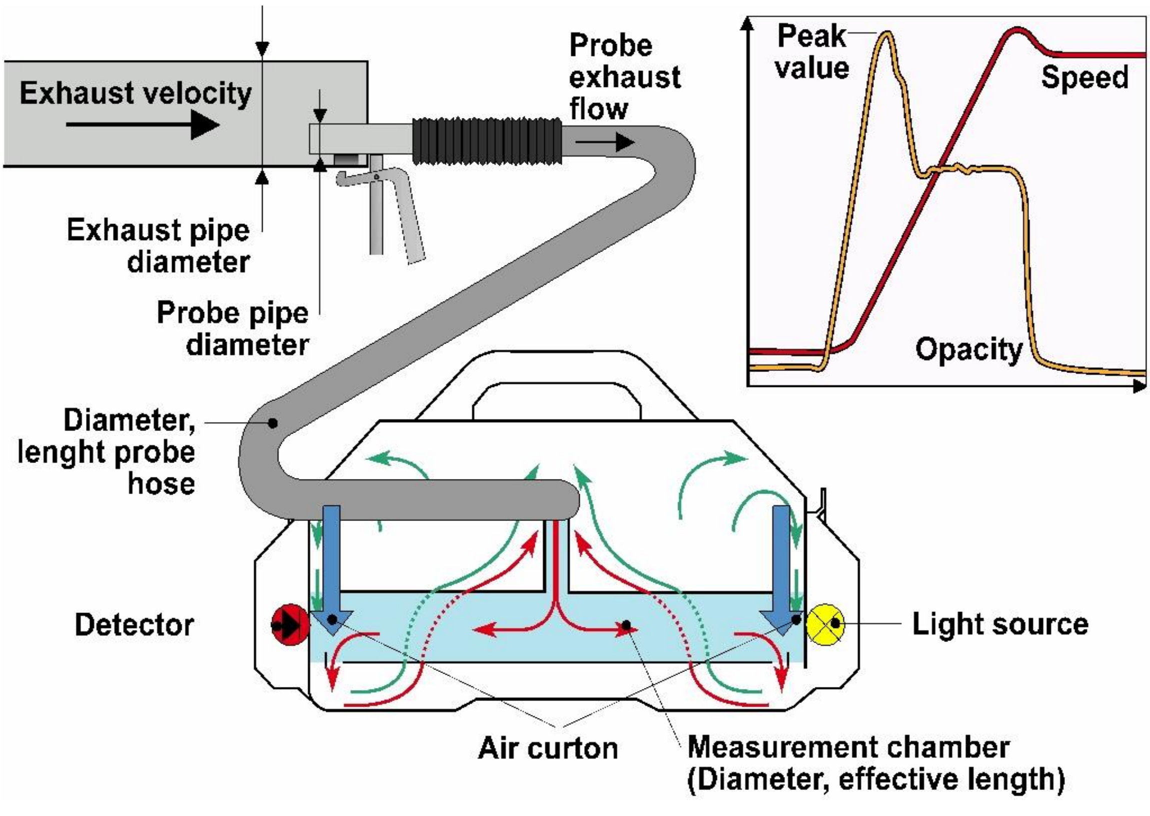
Diesel emissions need to be measured in a different manner than petrol emissions to get meaningful and accurate results.

On Petrol vehicles the actual gas values are important, the CO2, the CO, the HC and O2 values. These values are important for diagnostic and quality check purposes.

On Diesel vehilces the actual gas values are of a lesser importance. On a Diesel vehicle the opacity is measured. The opacity of the emissions is an indicator of the engine's quality and ability to combust the fuel efficiently.

The measurement method of the emission's opacity is done with visible light absorbtion, somewhat similar to the petrol emissions in an Infra red light test bench.

The actual Diesel emission tester is very different to the petrol emission tester, following is a simplified explanation of the Diesel emission testing equipment currently on the market and approved in many countries around the world.



AVL drawing opacity measure chamber set up.

Simple explanation

A petrol emission tester has a pump to draw exhaust gases into the infra red measurement chamber. The Diesel tester has no such pump, due to course nature of the particulates in the Diesel emissions.
The Diesel exhaust gasses are pushed into the measurement chamber by velocity. The fumes are drawn out of the opacity chamber by clean air flowing past the chamber's outlets. The clean air is drawn into the tester by a small fan placed near the top of the machine. The moving air is also to provide the lenses in the machine with a protection buffer of clean air (curtain air) as else the lenses soon get coated with emission deposits. The coated lenses will cause measurement error's.

The emissions flowing into the measurement chamber contain particles. The particles absorb and scatter light. The calibrated light source will put out a known amount of light. The detector will receive a lesser amount of light when Diesel particles absorb that light. The lesser value of light is transormed into an opacity value.

The first opacity tester of this kind was developed by Hartridge. The measurements and some of the values still stem from that invention, eventhough the testers have changed.

Hartridge

The Hartridge tester had a measurement tube of 430mm long. The opacity was expressed in a percentage of light received at the end of the tube. The lower the percentage of light received the higher the opacity.

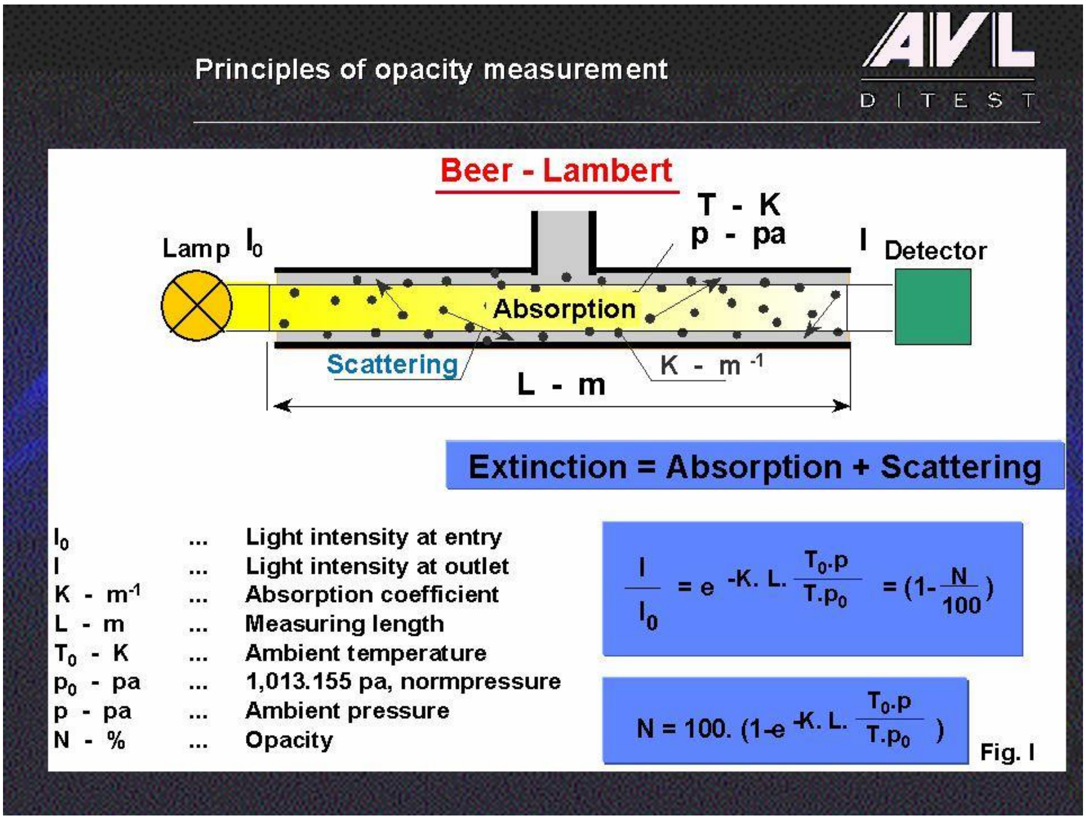


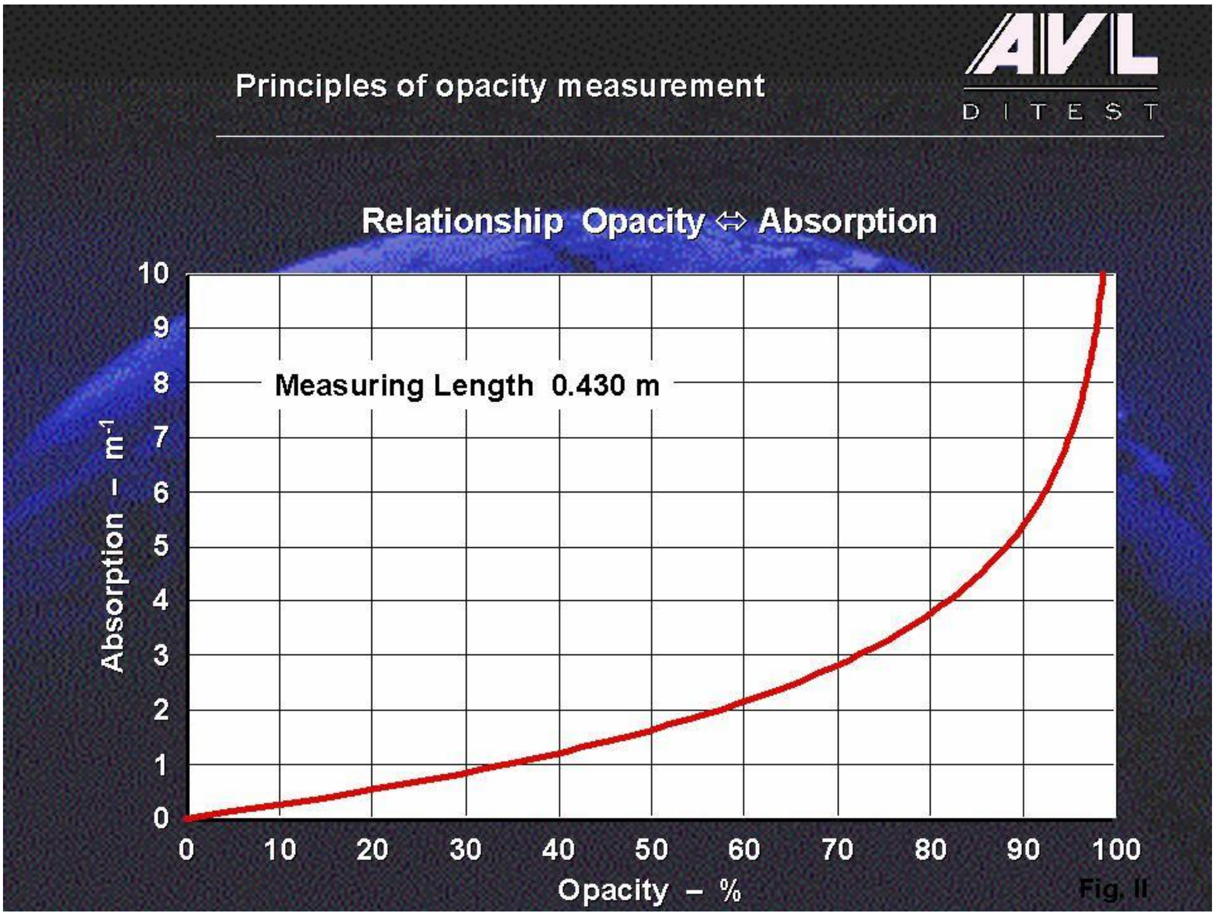
Fig. I

The length of the tube has naturally an effect on the amount of light received on the end of the tube.
Envisage this: thake the smoke from a cigarette, which is dust particles mixed with air, you can see through a small cloud of a certain density. Now put several of those clouds besides eachother and it suddenly becomes harder to see through the smoke (with other words the sample chamber length becomes longer).
This meant that from each tester with a measurement chamber length of anything other than the 430 mm the opacity values displayed where different while the smoke density was the same.

K Value

The answer was to make a reading that would give the same results no matter what tester or measurement chamber length you use, the K value.
The value is derived from the opacity percentage and opacity chamber length and is through the Beer Lambert equation transformed into an absorption coefficient. The K is from the German word ‘Koefficient’, which means coefficient.

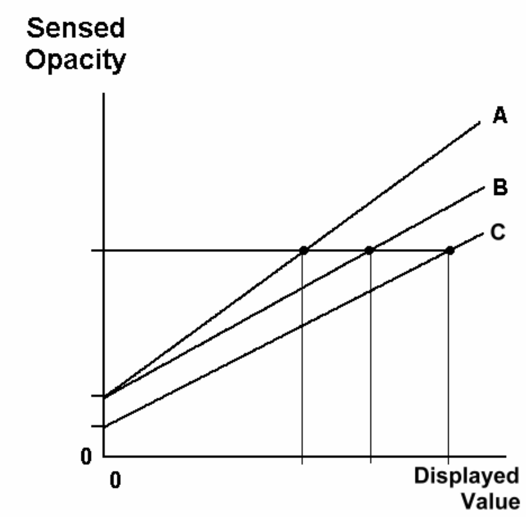
Every equipment manufacturer has its own ideas on what length of measurement chamber works best, a long one works well with modern Diesel with very low opacity percentages, where a short tube works well with heavy emitters and commercial Diesels. The value displayed on the screen should be the same K value in anycase.



In the picture above the relation is shown between the Opacity percentage and the absorption coefficient (K).

Calibration

In order to get stable and relaible readings the tester needs to be calibrated.
All ETNZ approved Diesel emission testers of any brand perform an automatic **zero calibration**. The tester will switch from measuring mode to zero calibration mode which will take up to 30 seconds. The zero calibration is done at least once a day or when negative values are being measured.
A negative value will be measured when a zero calibration has been performed with dirty or ‘foggy’ lenses. The tester will ‘see’ clear when the dirt moves or when the ‘fog’ clears. The value measured is now ‘less than zero’, which is not possible. A zero calibration will now be performed.
The zero calibration needs to be done away from a running vehicle or other emissions which could affect the opacity.



Calibration graph
A = off set calibration error (calibration agent only)
B = correct calibration
C = Zero calibration off set

Every twelve months the tester’s **offset** has to be **calibrated** by an ETNZ authorised calibration facility. Many tester faults are the result of incorrect calibration or the lack of calibration.
All testers will have some ‘drift’ over time. Drift is where the actual opacity is not displayed correctly anymore for a multitude of reasons. The drift needs to be calibrated away to be sure that the actual displayed value is true, with a calibrated set of factory supplied opacity lenses.

Warm up

The light source and measuring tube in the tester will have to **warm up** to stabilise the measurement.
The measuring tube needs to be at operating temperature as the light absorption is affected by temperature. The heating of the measurement chamber needs to get up to a reasonable exact temperature. The temperature control is done by the tester's electronics. The temperature needs to be stabilised before a measurement can be performed.
The warm-up period of the tester needs to be respected and can not be by-passed. The most efficient way is to turn the tester on at the beginning of the day and leave the tester on all day. Switch it off at night.
Most testers have a stand by function, where internal high current devices are switched off, but where the light source and measuring tube heater stay on and are kept continuously stabilised.

Different measurment methodes

Older and obsolete Diesel emission testers have a paper filter (pad) which is placed in a portion of the exhaust stream. The discolouration of the paper is measured by the tester and is a measure for the opacity. Some testers even use a light absorbtion measurement method on the pad. This is a very unprecise measurement and can not be off set to RPM, so for diagnostic purposes this method is not very usefull.

Research Diesel emission testers catch the emissions samples in a 'bag'. The content of that bag are analised. The amount of gasses in molecular weight and weight of the particulates are measured, which will return very accurate readings. Again there is no offset to RPM possible, so for diagnostic purposes it is not a very usefull methode. Also this very precise tester is VERY expensive, so not a realistic option for any workshop.

Air Fuel Ratio

Fuel is made out of Hydro Carbons (HC's). The average chemical formula for common diesel fuel is $C_{12}H_{26}$, ranging from approx. $C_{10}H_{22}$ to $C_{15}H_{32}$.

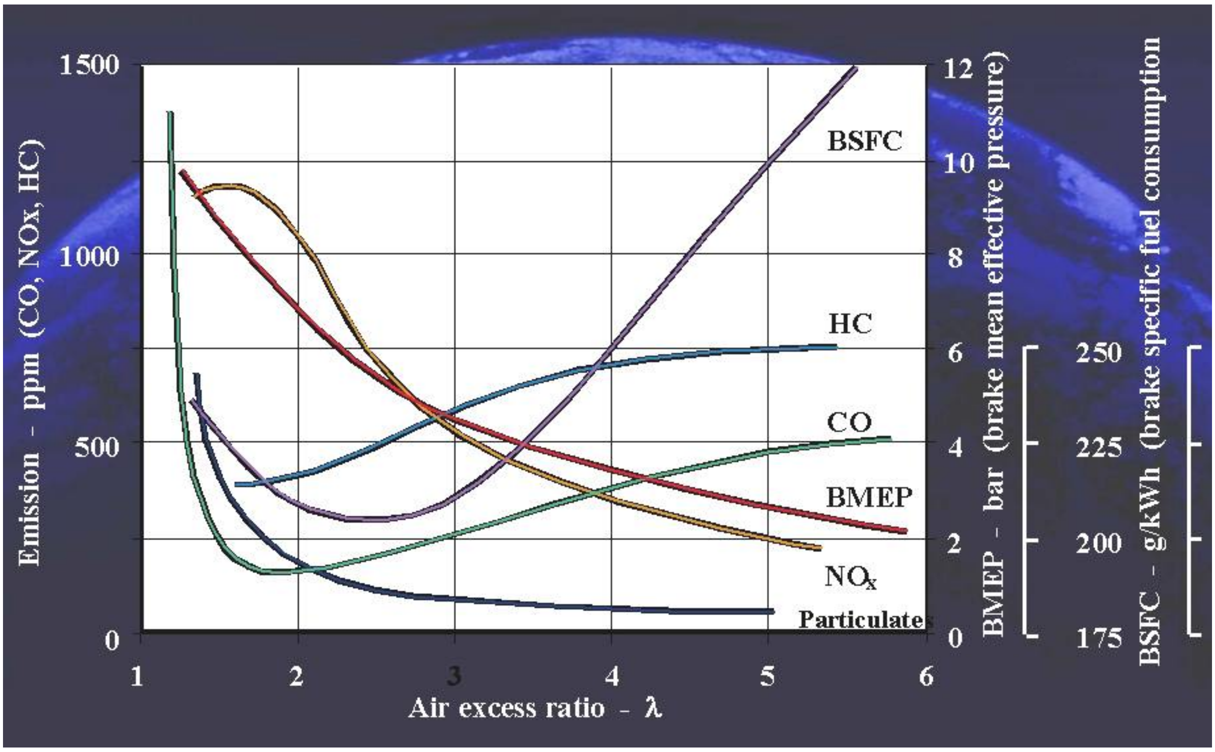
Air consists out of Nitrogen (N_2 +/- 79%) and Oxygen O_2 +/-20.8%).

During the combustion process the Oxygen (O) from the air reacts with the Hydrogen (H) and with the Carbon (C) from the fuel. The ideal out come from this chemical reaction is :

$$C_{12}H_{26} + O_2 + N_2 \quad = \quad CO_2 + H_2O + N_2 + \text{Heat}$$

How ever all conditions need to be ideal for this, the mixture, the mechanical condition of the engine and the fuel quality.

Below is a graph indicating the relation between air fuel ratio (Lambda) emissions, power and smoke:



AVL Emission graph

Diagnostics

Most modern Diesel emission testers have the ability to draw graph's indicating the relation between the engine's RPM and the opacity progression.

The relation between the two graphs can indicate problems with injection timing, oil consumption, dripping injectors, etc.
A section of the AECS training seminars deals with the diagnostic explanation of those graphs.

AECS is the NZ importer of Brainbee and AVL diagnostic emission testers, and a well respected training provider.

For AECS Ltd
Herbert Leijen
06 8749 077
info@aecs.net
www.aecs.net