Particle test shows quality particulate filter (technology)

Delft - Hilvarenbeek, 31 December 2022.

Results particle test enlightening.

How can diesel vehicles with particulate filters in a Periodic Technical Inspection (PTI) be tested properly and quickly? This question was asked in 2012 and eleven years later the particle test will be a fact in the Netherlands on January 1, 2023. Every year, approximately 1.3 million diesel vehicles with an ex-factory particulate filter will be inspected. Now ex-factory particulate filters are particularly effective and the exhausts of these vehicles are normally spotless. Black clouds of smoke are a thing of the past. But do particulate filters continue to function properly at higher mileages? And how many are removed? Nobody has insight into these numbers because there was no suitable test method. That will soon change in the PTI particle number test. This is quite exciting for a vehicle owner, because rejection has consequences. It is no less exciting for the automotive sector, because data is becoming available that will say something about the quality of particulate filter technology and the differences between car brands. Garage companies will have to make a diagnosis in case of rejection. Policymakers are also interested in these vehicle emissions because air quality calculations are partly based on PTI rejection percentages. In 2019, the Dutch research organisation TNO estimated that 9% of diesel vehicles with a particulate filter, with a PTI limit value of 250,000 particles per cubic centimetre (#/cm^3), would be rejected. Measurement data are now available and they give a first impression of the condition of the current fleet of diesel vehicles with an ex-factory particulate filter.

Initial results of particle testing are impressive.

PTI specialist Van Abeelen with branches in Hilvarenbeek, 's Hertogenbosch, Sprang-Capelle and Breda had particle counters (Mahle PMU 400) at its disposal at an early stage. From May to October 2022, 586 diesel vehicles with a warm engine were tested. Although these vehicles are not representative of the Dutch fleet, these measurement data turn out to be impressive and provide insight. Large-scale measurements have also been carried out in Belgium, and these results are very robust. Are you reading along?

Properties tested vehicles

Van Abeelen collected measurement data from 586 vehicles (356 passenger cars and 230 light commercial vehicles). Table 1 and figure 1 show the following parameters of the vehicles per Euro class: Average age, mileage and the number of vehicles tested. The average age of these 586 vehicles is 8.7 years and the average mileage is 199,594 km.

The vehicles tested by Van Abeelen include relatively few young vehicles (3-6 years old).

Table 1: Data of 586 tested Dutch vehicles

Euro class	Age	Odometer	Number of	Share
	ave	ave	vehicles	
	[year]	[km]		
Euro 4	14.2	250574	57	9.7%
Euro 5a	11.4	239593	118	20.1%
Euro 5b	8.6	207205	223	38.1%
Euro 6	5.5	150429	188	32.1%
Total	8.7	199594	586	

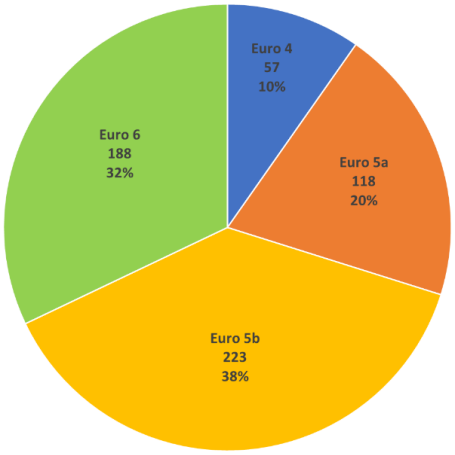


Figure 1: Distribution of 586 tested diesel vehicles per Euro class.

Impression performance of the Particle test and emissions

No problems were encountered during the implementation of the particle tests. All vehicles could be tested in a simple manner by means of a particle measurement in the exhaust. In Figure 2, the measured values are arranged from lowest to highest. The y-axis has a logarithmic scale. The readings appear to be widespread and range from zero to 90 million particles per cubic centimetre (#/cm^3)!

In table 2, the measured values are divided into classes. For 330 vehicles (56%), the reading is less than 5,000 #/cm^3. Of these, 20 vehicles showed exceptional performance, their particulate emissions were 0 #/cm^3 (zero !). To make this clear in Figure 2, these measurement values have been set to 1. More than half of the tested vehicles are therefore super clean. In 131 vehicles (22%) there is a soot filter with a very small defect, the particle emission is then between 5,000 and 250,000 #/cm^3. The soot filter was moderately defective in 36 vehicles (6%) with an emission between 250,000 and 1,000,000 #/cm^3. The particulate emissions of the last 89 vehicles (15%) exceed 1 million #/cm^3. Of these, 22 vehicles (3.7%) had an emission of more than 5 million #/cm^3, the particulate filter is then completely defective or has been removed. The absolute topper was a 1.6 liter Euro 5 engine with over 291,000 km on the clock with a particle emission of 90 million #/cm^3! Presumably this was

caused by a removed particulate filter including an engine problem. Of these 586 tested vehicles, 15.2% would be rejected on the basis of the Dutch PTI particle test.

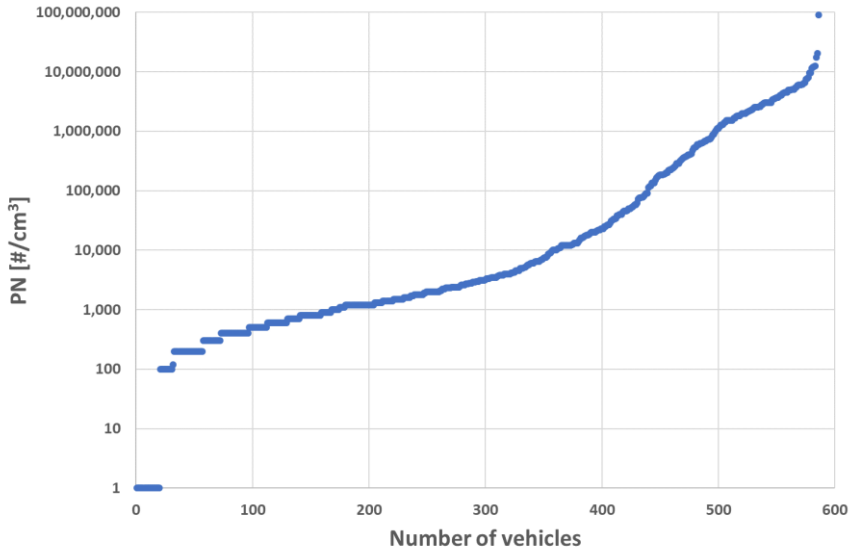


Figure 2: PTI measurement values of PN emissions from 586 tested vehicles, ranked from lowest to highest.

Table 2: Classes PTI-PN measurement values of 586 Dutch vehicles

Particle emission [#/cm³]	Number of vehicles	Share [%]	Comment
0 – 5.000	330	56,3	Super clean
5.000 – 250.000	131	22,4	Small defective DPF
250.000 – 1.000.000	36	6,1	Medium defective DPF
> 1.000.000	89	15,2	Very defective or removed DPF
Total	586	100,0	

Influence of vehicle age and mileage.

The measurement data were further analysed to gain more insight into these emissions. In figure 3 this is done on the basis of the mileage and in figure 4 on the basis of the vehicle age. Above 100,000 km and if vehicles are older than 5 years, the number of rejected vehicles increases. Age and mileage are apparently parameters that can lead to aging (increase in emissions).

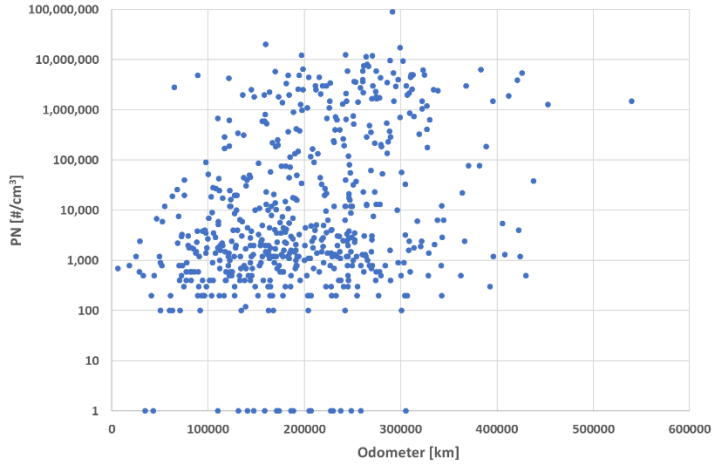


Figure 3: PTI PN emissions of 586 vehicles in relation to vehicle mileage.

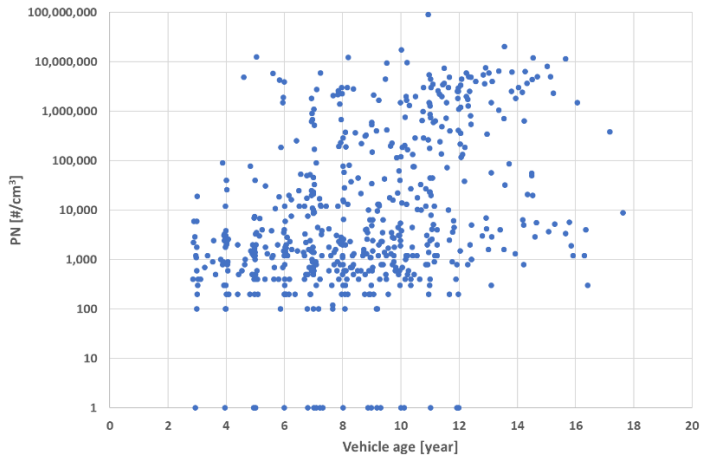


Figure 4: PTI PN emissions of 586 vehicles in relation to vehicle age.

Rejection percentages per Euro class, per age and mileage class and per car brand

Figure 5 shows rejection percentages per Euro class. At a limit value of 1 million #/cm^3, 15.2% of these 586 vehicles are rejected. Given the effects of vehicle age and mileage (see figures 3 and 4), it is logical that the rejection percentages for Euro 4 and 5a vehicles (46 and 29%) are higher than for Euro 5b and 6 vehicles (9 and 4%). Furthermore, the effect of a lower limit value of 250,000 #/cm^3 is clear, leading to higher rejection rates.

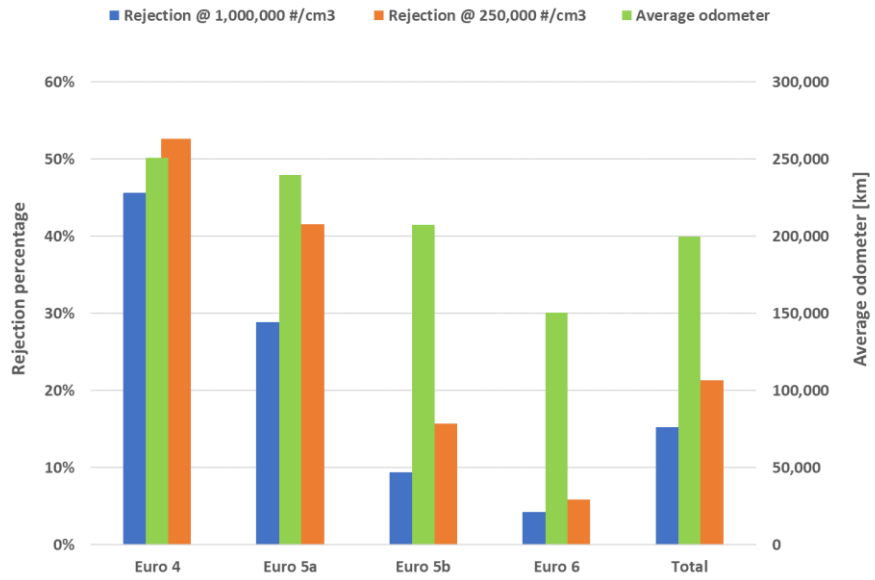


Figure 5: PTI rejection percentages per Euro class at two PN limit values.

As the age of the vehicle increases (see figure 6), the rejection percentage increases; If the vehicle age is 3 to 10 years, at a limit value of 1 million #/cm^3, it is 2 to 7%. If the vehicle age is 10 to 20 years, the rejection rate is 31%.

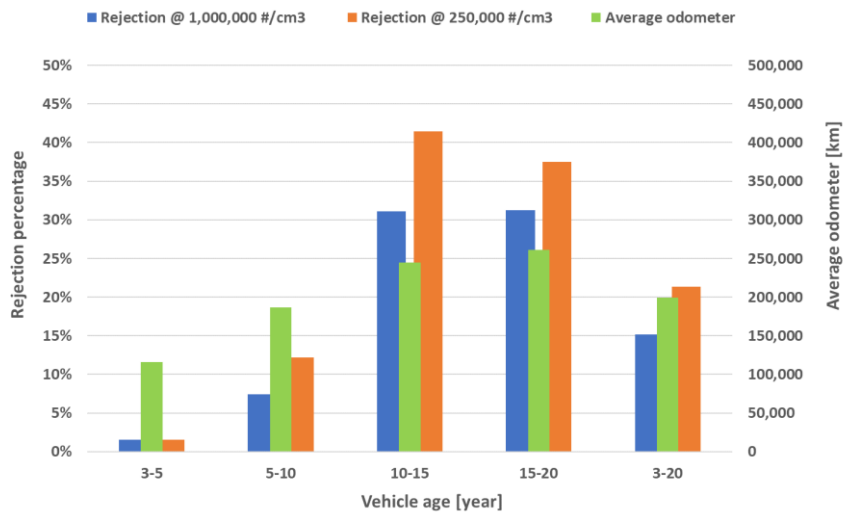


Figure 6: PTI rejection percentages per age group with two PN limit values.

Figure 7 shows the rejection percentages per kilometre class. This shows that at a limit value of 1 million #/cm^3 the average rejection percentage for vehicles up to 100,000 km is 3% and this rises to 46% at mileages above 400,000 km.

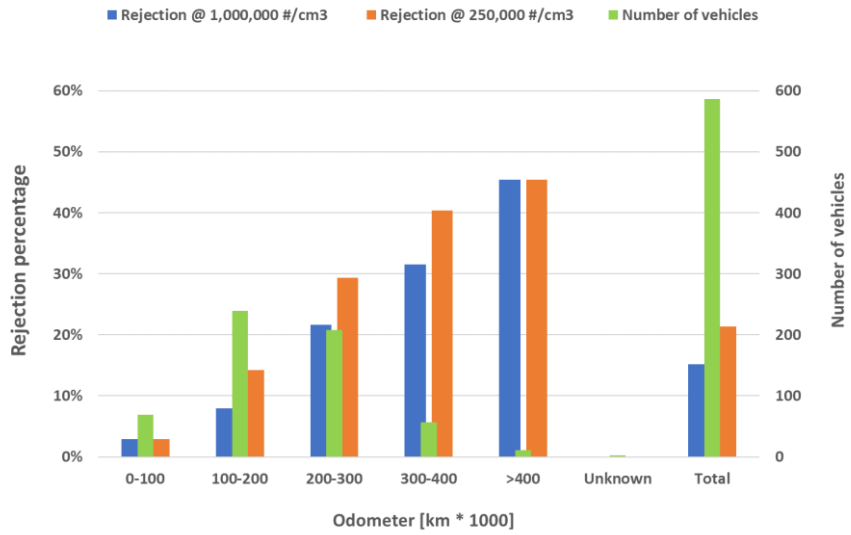


Figure 7: PTI rejection percentages per kilometre class with two PN limit values.

Figure 8 shows the rejection percentages for two limit values and the number of vehicles tested per car make. The x-axis shows the car make with the average mileage of that make; The average mileage ranges from 151,180 to 267,062 km. Few vehicles of some brands have been tested (Fiat 12 and Seat 17).

At a limit value of 1 million #/cm^3, of these 586 vehicles with an average mileage of 199594 km, 15.2% fail the Particle test. If the limit value drops to 250,000 #/cm^3, the rejection percentage rises to 21.3%. With an increasing average mileage (see figure 8), it would be plausible if the rejection percentage were to increase (see previous analysis and figure 7). However, the rejection percentages and the quality of the particulate filter technology seem to differ greatly per brand. One brand performs remarkably positively with 37 vehicles of which not a single car failed the Particle test. Cheers Renault! It is still too early to draw conclusive conclusions about the performance per brand, more data is needed for that.

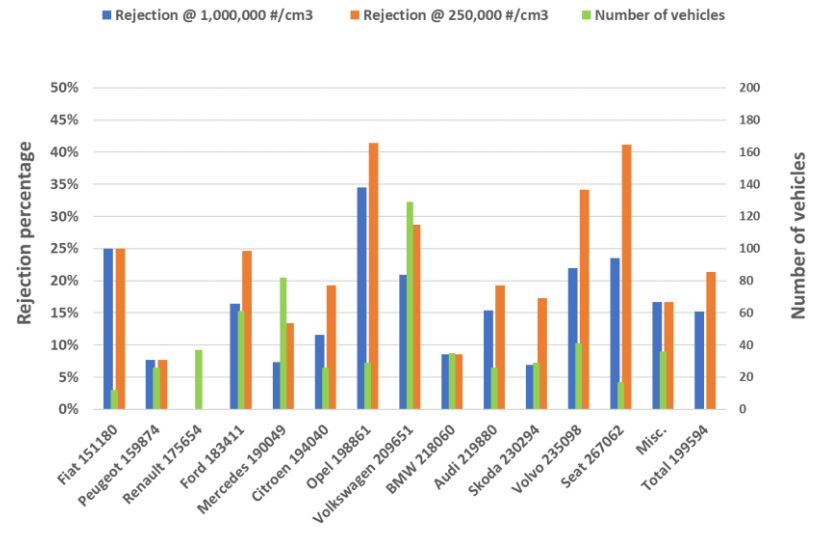


Figure 8: PTI rejection percentages per car brand with two PN limit values.

Breakdown of passenger and light commercial vehicle (LCV) results and options for vehicle owners

Due to the different Dutch MOT regulations for passenger cars and LCVs, the data has been split up. At a PTI PN limit value of 1 million #/cm^3, 58 vehicles (16.3%) of 356 tested passenger cars were rejected. Since these 58 vehicles were all registered before 1-1-2017, the owners have the choice between repair, administrative removal of the particulate filter in combination with a higher motor vehicle tax or sale of the car.

Of the 230 LCVs tested, 31 vehicles (13.5%) would be rejected. Of these, 20 vehicles were registered before 1-1-2012. These owners also have the following three choices: Repair, have the particulate filter administratively removed in combination with a higher motor vehicle tax, or sell the vehicle. Of the other 11 vans that were registered on or after 1-1-2012, the vehicle will have to be repaired for a valid PTI.

In Belgium, the particle test has already started, data of all vehicles are available

Since July 1, 2022, the particle test is mandatory in the Belgian PTI. Due to the centralized approach (approximately 80 PTI stations throughout Belgium), the particulate emissions of each vehicle are stored in a database. GOCA in Flanders has already analysed the measurement data of Euro 5 and 6 vehicles from the first four months. Of the 313,615 (!) tested Flemish Euro 5 and 6 diesel vehicles with a particulate filter with an average age of 6.72 years, 6.76% were rejected (the average mileage is not yet known, but it may be later). In the Netherlands, data on 529 Euro 5 and 6 vehicles with an average age of 8.1 years and an average mileage of 194,235 km were collected in the same period. Of these, 11.9% were rejected. Both in the Netherlands and in Belgium, tests were carried out with the engine warmed up. In order to be able to make a comparison between Dutch and Flemish vehicles, the rejection percentages are shown in Figure 9 per year that the vehicles were registered. Due to the small amount of Dutch data, caution is advised. First, more measurement data is needed to get a reliable picture of the total Dutch fleet of diesel vehicles. The rejection percentages of both countries show a similar trend, increasing as the vehicle ages. For vehicles with an age of 10 years, about 10% are rejected and this percentage seems to increase sharply in later years.

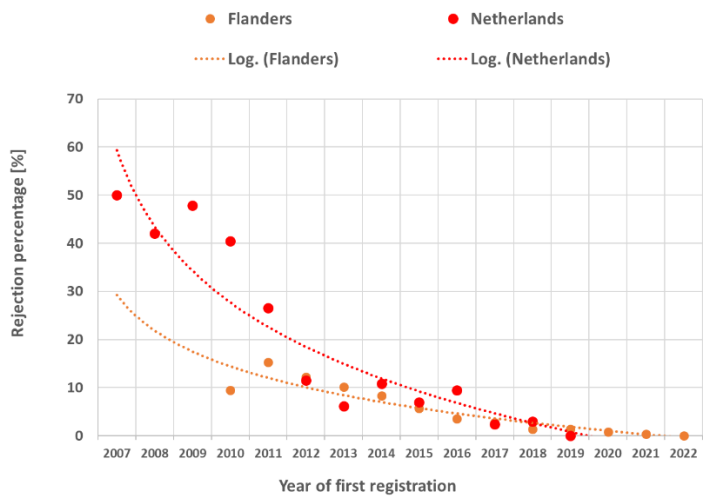


Figure 9: Rejection percentages for particle test per 'year of first vehicle registration' in the Netherlands and Flanders

Service life requirements

Vehicle emissions from Euro 5 and 6 vehicles must comply with the limit values for 160,000 km or 5 years. After that, emission requirements no longer apply to manufacturers, but they do apply to the vehicle owner in the form of the PTI.

The results of PTI particle tests provide information about the service life properties of particulate filter technology. The data shows that particulate filter technology of a large proportion of diesel vehicles is not sustainable because the particulate emissions are too high. The discussion of whether or not particulate filters have been removed is not so relevant here, because it is expected that vehicle owners will not modify their vehicle or have it modified if the technology works fault-free.

Preliminary conclusions

Of the PTI particle tests performed on 586 Dutch diesel vehicles with an ex-factory particulate filter with an average age of 8.7 years and an average mileage of 199,584 km, 15.2% would be rejected. This group of vehicles is not representative of the Dutch fleet, but the results do give an idea of the trends that can be expected. More data is needed to be able to draw conclusive conclusions about the entire Dutch fleet.

Of 313,615 Flemish diesel vehicles with an average age of 6.72 years, 6.76% were rejected. Due to the high number of tested vehicles, this set of data is representative of a national vehicle fleet.

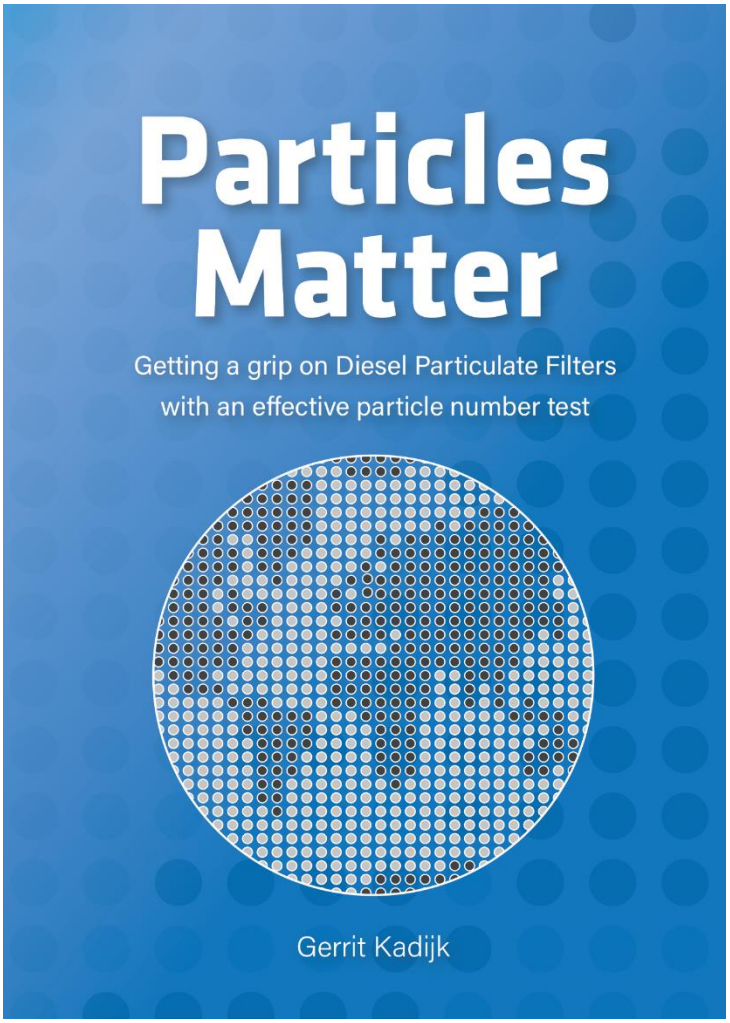
The rejection percentages of particle tests of Dutch and Flemish vehicles are fairly comparable based on vehicle age. About 10% of vehicles with an age of 10 years are rejected in the particle test. Furthermore, the rejection percentage increases with increasing vehicle age. The results show that particulate filter technology of a large proportion of (especially older) diesel vehicles is not sufficiently sustainable because the particulate emissions are (much) too high. Age and mileage have a major impact on the MOT rejection rate.

How to continue?

This research will be continued by Van Abeelen and ETS. At the end of 2023, the results will be updated on the basis of the PTI measurement data that will be available at that time. These provide information about the initial status of the diesel vehicle fleet with a particulate filter. It is expected that the share of rejection in the PTI based on the particle test will decrease in the coming years because part of the vehicles will be repaired or exported. The share of rejection will also decrease because the particle test will no longer apply to Dutch vehicles whose soot filter is administratively removed.

Diagnosis in case of excessive particle emission, knowledge is indispensable

The day will come when a PTI inspector will determine an emission of 1 million #/cm^3 or higher after optimizing the test conditions. So what? Is the particulate filter defective or does the engine emit too much? What diagnostic measurements are needed? Knowledge of particle testing, combustion engines and particulate filter technology is indispensable for proper diagnosis and repair advice. The book 'Particles Matter' describes all this on the basis of 92 questions that are divided into 12 chapters. For more information and purchase see www.particlesmatter.com/book .



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