HISTORY AND WORLD WIDE TRENDS IN CABIN AIR FILTER TESTING

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ABSTRACT

The current status of European cabin air test standards will be presented. They are compared to its US-equivalents. As the development of these standards is a historical process and is influenced by the differing demands of the different markets there are still significant deviations if the national approaches are compared.

The history of these standards is described and the state of international harmonisation is discussed.

The Institute of Toxicology and Aerosol Research in the Fraunhofergesellschaft was one of the European driving forces in creating and developing the German draft within the DIN organisation. The establishment of the facilities at the Fraunhofer Laboratory in the past decade under influences from overseas and the development of European automotive specifications is presented.

Recent international round robin tests disclosed still significant problems in some aspects of cabin air filter testing. This is true for particle filter evaluation as well as adsorption testing. The problems and proposals for solutions will be discussed.

The filter laboratory at Fraunhofer has been spun off into a private company in late 1999. The new venture „fiatec“ will provide improved service to the industry. The company’s extended capabilities and their significance for its customers will be also discussed.

INTRODUCTION

Cabin Air Filters are on the market for about thirteen years now. The first products were particle filters implemented in passenger cars in northern Europe in the late eighties. The main purpose of these early products was to protect passengers from pollen and dust. With increasing public concern about air quality the traffic related contaminants themselves became an issue. The general attention shifted to particles like diesel soot and gaseous substances like sulphur dioxide, nitrous oxides, hydrogen sulphide, ammonia and benzene derivatives from uncompleted combustion, just to name a few. The industry reacted, again at first in Europe, with adsorptive filter systems. The adsorbent of the choice is up to now activated carbon, which is available in a multitude of brands, grades and performance characteristics. By applying chemical treatments its chemisorptive capacity has been greatly improved in recent years. Therefore, cabin air filters are on a high technical level. Parallel to this development the prices for these products have been cut down to about a forth of what initially was paid for them.

In Europe the percentage of cars equipped with filters in general is more than ninety percent today. The share of adsorptive systems is reaching fifty percent. In the United States the market development has been much slower than in the old world. It can be assumed that this is due to different population (and subsequently traffic) densities. While air quality problems worse enough to be realised even by untrained individuals are restricted to some major metropolitan areas in the US, in Europe and Japan people complain about poor air quality even in more or less rural regions. The typical US customer is naturally less aware of the problems as he is, for the given reason, less able to realise them in everyday life. This is indicated by the comparably low aftermarket sales figures and the facts expresses itself in the reluctant response of the market to the new products.

Another essential structural difference in the markets is the fact, that European car manufacturers keep their customers in a tight grip if it comes to spare parts and aftermarkets. Distribution of auto parts in Europe is controlled by the automotive companies. Car warranties are lost if the cars are not serviced according to the OEM specification, which means, that only OEM approved service parts can be used. It is self understanding that these parts are distributed and handled by the automotive companies themselves. This means that every service filter sold contributes directly to the OEM's revenues. Therefore if VW implements a filter to the rabbit, and every rabbit consumes about five filters in its life cycle Volkswagen sells five filters with every car. In the US the aftermarket is just to a very small degree controlled by the original equipment manufacturers. Cabin air filters in the US can reliably only be sold by the car company as original equipment. All aftermarket business for the automotive companies is restricted to unpredictable sales figures in OES parts. Logically the economical motivation for integrating cabin air filters into the platforms is much lower in the US on the car manufacturers side.

These phenomena result consequently in widely differing market approaches of the industry. The market strategies of the major automotive companies where influenced by global platform approaches in recent years. But still the issue of cabin air filters is handled very flexible due to differences in the cultural perceptions. For example: one of GM´s upcoming high volume platforms will have a combination filter (particles and odors) as a standard content in all European models and brands, but it will have a particle filter only for the North American operations business and this filter will be just an option.

Naturally these issues had influence on the development of product specifications which resulted in different test procedures. The first major portion of this paper will try to explain differences in test standards in that context.

HISTORY

Cabin Air Particle Filtration

When Saab released its latest model in 1987 it was equipped with an optional particle filter. The specification of this product was, compared to today's standards, rather simple. It included basically the flow restriction and some vague overall particle collection efficiency. Test conditions, methods and procedures were hardly determined at all. The filter was meant to keep pollen and dust out of the interior of the car. It provided benefits and improved the overall air quality in the passenger compartment. Some other manufacturers followed with similar optional filters on their high end models. When the industry began to think about marketing strategies for this add on to increase customers demand it soon it became evident, that the customers where hardly aware of the benefits of the products unless passengers suffered from allergies against pollen. Furthermore every driver could realise odorous substances and smells while driving through densely populated areas of Europe, which were mostly traffic related emissions. The untrained customers faith in air purification devices would not be very deep if the effects could not be realised by his nose, but could only be proven with mysterious graphs recorded with sinister test devices. Coincidentally the growing awareness of pollution problems at this time made traffic related emissions also a public issue.

Another significant odor problem encountered in European traffic is diesel soot due to the large share of diesel engines in European cargo traffic. The particles themselves not being odorous provide a huge surface to which, similar to activated carbon, smellable molecules are adhered. The particle sizes range from clusters of several hundred carbon atoms up to particles of several microns in diameter. If it could be managed to provide filters being effective with diesel soot, a major step to recognisable air quality improvement inside cars would be made.

Cabin Air Odor Filters

The only reasonable approach to come up with a widely accepted product was to implement an odor reducing functionality to the filter. The population densities being significantly higher in Europe and South East Asia than in North America this development first took place in Central Europe and Japan. Although there were different technical approaches to reduce odors in the passenger compartments the method of choice seemed to be the utilisation of activated carbon as an adsorbent. The materials were affordable, well understood and since many decades applied in industrial air and water purification processes. Simple activated carbon did the job for many hydrocarbons which are the major contributors to traffic related odors. The mechanisms involved are based on physical adsorption, where molecules are captured on the walls of the pores of the carbon by London- and van der Waals forces. Unfortunately this effect does not work with inorganic substances. But exhaust emissions from cars and trucks contain significant amounts of sulphur dioxide and nitrous oxides, besides HCs from incomplete fuel combustion. To improve the performance of the cabin air filters in that respect chemically treated activated carbon was used.

History of Cabin Air Filter Testing

It was obvious that the marketing goals outlined above could only be achieved if the essential performance parameters of the filters could be written into specification sheets. These parameters had to be defined and reasonable adjustments for them developed. Tests of cabin air filters with significance to real world applications had to be worked out.

In 1991 the German VDA (Society of the German Automotive Industry) established a standardisation committee to develop a DIN draft for cabin air filters. According to the historic development of the product the committee addressed the particle filtration issue at first. The companies initially involved where not the classical filter manufacturers and customers. Hence the committee was rather open to new approaches to particle filter testing. In the past filters were tested with gravimetrical methods mainly. The disadvantage of these methods was that the efficiency of an air cleaning device could just be determined as an overall efficiency without telling the efficiency for certain particle sizes. Commercially available optical particle counters, however, where able to provide the fractional collection efficiency of filters. This is an important feature, especially with regards to the mentioned diesel soot problems. As these particles show high concentrations at very small sizes they do not contribute significantly to the mass increase during loading (for comparing a .1 µm sphere to a 10 µm particle the mass ratio is 1 : 10^6). Due to well known basic particle filtration mechanisms all textile and paper filters show an efficiency gap for particles in the size range from .05 to 1 µm. Therefore it was important to look at the efficiency of the filters at this size range more closely. But a lot of questions related to this new approach where yet unanswered, for example:

- What aerosols or contaminants should be used?
- How repeatable and valid where the results of particle counting?
- How stable could the aerosols be generated?
- Would the triboelectric charges inflicted on the particles affect the tests?
- Could the aerosols be discharged and how should this be done?

The committee was convinced that some fundamental research work had still to be done to answer at least some of the questions. One of the participating parties in the working groups was the Institute of Toxicology and Aerosol Research for the Fraunhofer Gesellschaft (FhG-ITA) in Hannover. The aerosol group of the ITA had already vast experience with particle monitoring and it was decided that a prototype test duct should be erected at the institute, financed by the companies being represented in the committee. The institute would, after completion of the standard, serve as a neutral test lab for the automotive industry and its suppliers. In 1992 a first draft of Part 1 of DIN 71 460 was issued and during subsequent years modified according to the insights and findings of the ITA.

The first serious approach to odor filtration was made by the brand Mercedes Benz in 1991 with their S-class model. The odor filter was a separate unit implemented into the AC unit of the car. This filter contained nearly two pounds of activated carbon and showed, due to its design, an excellent performance. The next car on the market with available odor filtration was BMW 1993 7-series. This filter was the fist automotive combination filter on the market. Consequently the standardisation group addressed these products in Part 2 of DIN 71 460.

The basic testing principles for adsorption testing had already been established in the industry between customers and suppliers. Hence the discussions focused the matter of the right set of appropriate challenging agents and the appropriate concentrations. Until then testing had been done with butane and toluene, mainly for the following reasons:

- Low costs
- Safety
- Already in Use in Automotive Industry (e.g. Testing of Evaporative Emissions canister)
- Performance figures indicate the physisorption capacity for many hydrocarbons
- Simple Monitoring and Handling

As far as the pilot agents representing the chemisorptive capacity of inorganic molecules where concerned it was soon agreed that sulphur dioxide and nitrogen dioxide should be pinned as required agents in the standard. However the latter turned out to be more critical in several aspects than initially assumed. Again Fraunhofer did set up a test duct for this part of the standard at the ITA.

US Developments

In the meanwhile the new products had evoked some interest in the United States. Especially the global automotive companies being present in German and European markets had to face the issue and investigate the potentials for their own domestic markets. Ford came up with the first optional particle filters in some of the models in 1994 and others where soon to follow. The SAE established also a national working group to draft a standard, again for particle testing first. Some of the basic features of the German draft were readily accepted especially as European performance specifications where already used in the US on an intra-company basis. On the other hand there where some major disagreements concerning the following questions:

- Selection of the Particulate Contaminants
- Neutralisation of the Aerosols

The second part of J 1669 which deals with adsorption testing was from the start closer to the German draft. This was probably due to a lack of practical experience from the field, as these odor and combination filters where not commercially available in the US yet. The marketing aspects in the US however were significantly different. Due to the low overall population density most Americans do not feel a necessity to protect themselves while driving in their cars. Air quality problems recognised by individuals are restricted to some metropolitan areas. Hence traffic related odors play a less important role for US customers than for Europeans and American automotive engineers ask for performance and functionality of the filters if exposed to agents typical for industrial plants and agricultural emissions.

STATE OF HARMONSATION OF STANDARDS

The harmonisation efforts between the national approaches let in 1993 to the formation of an international committee whose objective is the creation of an ISO standard.

As the automotive industry rejected the idea of using known paper filter media due to problems regarding the growth of micro-organisms like fungi and bacteria on humid media substrates the particle media in use are typically nonwovens based on man made fibres. These media are themselves more or less electrostatically charged. Some manufacturers try to purposely utilise this effect as it can enhance the collection efficiency in the above mentioned critical efficiency gap tremendously. If this is an approach of practical value under real world conditions shall not be discussed here. Nevertheless the test results depend for obvious reasons on the electrostatic state of the aerosol. More neutral aerosols better unveil performance abilities of the products. As salt particles generated from solutions show less charges and can be produced in narrow size bands below one micron it was unanimously agreed, that the collection efficiency has to be tested with salt. Traditionally the Europeans had used sodium chloride, accepting the disadvantage that they could not produce a statistical sufficient number of large particles for the determination of efficiency. The efficiency on the large particle end of the scale had to be performed with mineralic dust. After intense studies at the ITA it was decided that SAE dust should be used. The American working group however produced results using potassium chloride which showed high numbers of large particles due to a wider size distribution. The group therefore decided to use potassium chloride for efficiency testing. Another deviation in the drafts was the specific grade of SAE dust (fine and coarse) in use.

The second major disagreement was the neutralisation of the aerosol. The SAE group having realised in a first round robin test that the charges on the particles could cause tremendous problems with the efficiency tests included a statement in their standard that the aerosol has to be neutralised, without being specific how this has to be done. The Europeans, not arguing about the necessity of neutralisation, where reluctant to prescribe it in the standard without defining exactly how it should be done and how the state of the aerosol should be monitored. Several groups were still working on a solution and the final results where not available yet. The main point of objection was that some studies showed that uncontrolled neutralisation of the aerosols could make the results even more questionable and increase the confusion. This argument still lingers on. Fraunhofer´s ITA** has developed a device which allows to monitor the state of the aerosol and so to adjust the neutralisation device to reduce charges to a minimum. This device will soon be commercially available.

** Fraunhofer´s ITA is about to restructure its organisation and concentrate on its core competences in medical research. Therefore the automotive filter testing is not any longer continued. This business segment has been spun off into a private company. fiatec – Filter & Aerosol Technologie GmbH has been founded by the author, who was a former employee of a major cabin air filter supplier for more than a decade and Bert Ilgen, manager of the ITA filter test lab since 1991.

As for adsorption testing the standards were open to additional agents agreed upon between customers and suppliers the regional differences in market demands mentioned above could easily be satisfied. Harmonisation discussions therefore where restricted to details like the adjustment of environmental test parameters (humidity, temperature and the tolerances achievable and required). Nitrous oxides were omitted from the German draft due to serious problems with safety and handling of the substances involved and a lack of practical relevance.

SUMMARY

The implementation of cabin air filters began in the late nineteen eighties. Within a few years the product developed a reasonable good performance level. This was achieved through the establishment of practicable test standards. Testing and specifying the products is influenced by differing market requirements world wide. After the establishment of several national standards an international working group began to work on an ISO draft in 1994.

Summarising the harmonisation efforts chances are that the work on an international standard will still go on for several years as far as cabin air particle filter testing is concerned. A recent round robin test initiated by the SAE did not provide answers to the open questions. Although, this was as much a consequence of the lack of professionally from the majority of the participating labs as it was an indication of still inherent deficiencies of the draft. Many labs failed to submit even the most fundamental data so it is impossible to analyse the results.

Though the agreement regarding international adsorption testing is very close the validity of the proposed method has to be proved in a round robin test. Results are not yet published. The author expects less problems with the findings of this test.

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