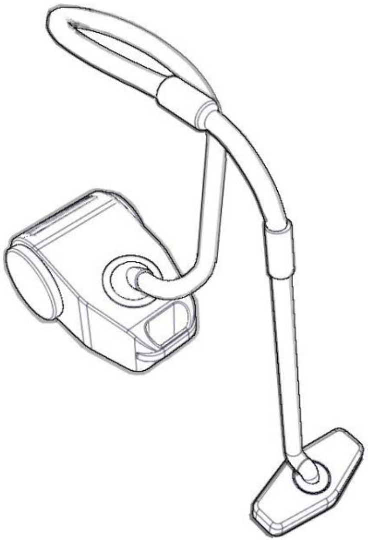
European Commission

Special review study on durability tests

According to Article 7(2) of Commission Regulation (EU) No 666/2013 with regard to **ecodesign requirements for vacuum cleaners**



INTERIM REPORT

Prepared by

VHK for the European Commission

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Energy

Prepared by

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Cover: Cylinder vacuum cleaner [picture VHK 2016].

This study was ordered and paid for by the European Commission, Directorate-General for Energy.

Acronyms, units and symbols

Acronyms

a	annum (year)
avg.	average
BAT	Best Available Technology
BAU, BaU	Business-as-Usual (baseline without measures)
BC, BaseCase	the average appliance on the market (per category)
BNAT	Best Not yet Available Technology
CECED	European Committee of Domestic Equipment Manufacturers
CEN	European Committee for Standardization
CLC, Cenelec	European Committee for Electro-technical Standardization
DG	Directorate-General (of the EC)
EC	European Commission
EN	European Norm
EoL	End-of-Life
eq	Suffix, means 'equivalent'
EU	European Union
ICSMS	Information and Communication System on Market Surveillance
IEC	International Electro-technical Committee
MEErP	Methodology for Ecodesign of Energy-related products
MEPS	Minimum Efficiency Performance Standard
NGO	Non-Governmental Organization
SME	Small and Medium-sized Enterprise
StiWa	Stiftung Warentest (German consumer association)
TC	Technical Committee (in ISO, CEN, CLC, etc.)
TR	Technical Report
VHK	Van Holsteijn en Kemna, NL (author)
WEEE	Waste of electrical and electronic equipment (directive)
WG	Working Group (of a TC)
WG6	CLC TC59X/WG6 (working group dealing with the relevant standard)
Which?	UK consumer association
yr	annum (year)

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1 Introduction

1.1 Assignment

This special review study follows Article 7(2) of Commission Regulation (EU) No 666/2013 on Ecodesign requirements for vacuum cleaners[1] (hereafter the Regulation), which specifies that the durability requirements on hose (at least 40 000 oscillations) and motors (at least 500 hours at half-loaded receptacle) shall be reviewed. The study started in December 2015. This interim report is published in March 2016, followed by a stakeholder meeting 25 April 2016. The final study report is foreseen for the end of June and the presentation to the Consultation Forum must take place before 1 September 2016.

1.2 Timing: Shorter deadline

The special review study is closely linked to the efforts of Cenelec TC59X/WG6 (hereafter 'WG6') to produce a harmonised standard before the durability requirements will be implemented by the 1st of September 2017. The WG6 is currently engaged in the amendment of the standard EN 60312-1 via a so-called Unique Acceptance Procedure (UAP). This is a fast-track option that is allowed if there are no major technical changes. In order to meet the deadlines for that UAP, the working group has to hand in the final text by the 19tht of May 2016. Allowing also some time for internal editing, this means that **any feedback or changes would need to be introduced by the beginning of May 2016.**

If that deadline is met, the amended EN-standard could be published –assuming that the internal voting procedure within Cenelec runs smoothly—in March 2017 and could then be harmonised by the Commission immediately after. If the deadline is missed, the durability requirements in the Regulation would not be covered by a harmonised standard. It also means that any feedback the Consultation Forum might give e.g. in August 2016 may contribute to a long-term vision but will not solve the immediate problem.

In order to solve the timing problem it was thus decided, in consultation with the Commission Services, to try to synchronise the review study with the time schedule of Cenelec WG6. **This means that in fact the stakeholder meeting in April, and any written comments beforehand, will *de facto* have a decisive impact on the way forward with the durability requirements.** The Consultation Forum will then have to confirm that decision.

1.3 Tasks

The activities follow stipulations as set out in:

- the Specifications of the Framework Contract, specifically points I.1, 2 and 4, and
- the methodology described in the Contractor's Technical Proposal of the Framework Contract, which amongst others takes into account relevant parts of the Directive 2009/125/EC (recast) of 21 October 2009 establishing a framework for the setting of ecodesign-requirements of energy-related products;

[1] Commission Regulation (EU) No 666/2013 of 8 July 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for vacuum cleaners, OJ L 192, 13.7.2013, p. 24–34

The following activities are proposed:

Task 1

Determining whether the existing methods for determining the durability of the hose and the operational motor lifetime are appropriate.

The existing test methods are described in

- EN 60312-1:2013 - Vacuum cleaners for household use - Part 1: Dry vacuum cleaners Methods for measuring the performance, point 6.9 includes a test methodology for determining the durability of the hose by its repeated bending.

- EN 60312-1:2013 - Vacuum cleaners for household use - Part 1: Dry vacuum cleaners- Methods for measuring the performance, point 6.10 includes a methodology for determining the operational motor lifetime of the motor.

The consortium shall evaluate the test methods and gather information on their practical application by discussing them with the relevant standardisation technical committees and working groups, industry, test laboratories and consumer or environmental organisations.

Task 2

Determining whether the existing methods for determining the durability of the hose and the operational motor lifetime could be simplified.

The consortium shall evaluate if the methods described in EN 60312-1:2013 could be simplified while maintaining an appropriate accuracy level.

The contractor shall evaluate any alternative test methods for durability of the hose and the operational motor lifetime applied by industry, test laboratories and consumer or environmental organisations.

1.4 Consultation and other activities

The study began 14 December 2015.

The project website www.ia-vc-art7.eu, intended to register and inform interested stakeholders of context, planning, documents and meetings, was launched January 2016[2]. The members of the Consultation Forum will be informed in due time by the Commission services on the existence of the project website and the launch of the study.

Specifically regarding the relevant industry stakeholders, the contractor met with CLC TC59X/WG 6 in December 2015, to explain purpose and timing of the assignment and learn about activities related to durability testing within this standardisation working group. The German consumer association *Stiftung Warentest* was contacted through ANEC/BEUC. The UK consumer association *Which?* was contacted directly.

[2] The project website is not part of the assignment, but it was agreed during the kick-off meeting that communication and logistics of the project would benefit from such a site. The text for the website was approved by the Commission services.

The kick-off meeting between contractor and representatives of DG ENER, DG GROW and JRC-IES took place 29 January 2016. JRC-IES is author of a recent durability case study of vacuum cleaners and provided valuable input, e.g. regarding the importance to maintain the switching sequence as proposed in the Regulation.

Also in February, the Commission services and contractor met with a delegation of CLC TC59X/WG6 to have a better understanding of problems and possible solutions related to the assignment.

Apart from the above consultations, the contractor engaged in desk-research of standards and other technical data, also building on the 2009 preparatory study, the 2013 impact assessment accompanying the measure, latest draft legislation concerning verification tolerances and specific (JRC-IES) or generic (AEA-Ricardo) studies on durability testing.

1.5 Methodology

The assignment specifies two tasks, but already during the kick-off meeting it became clear that the issues and options relating to the review of durability test can be combined. In fact, the possible solutions elaborated by CLC TC59X/WG6 already aim at simplification as well as accurate, reliable and reproducible test methods.

It was decided that the contractor was to follow a pragmatic course and try to solve the issues within the available (shorter) time-frame (see section 1.2).

2 Durability testing of the hose

2.1 Introduction

The current test set-up and test-procedure in Clause 6.9, ‘Repeated bending of hose’ in the harmonised standard EN 60312-1 (see Annex I) has been used for many years by industry and consumer associations and is in principle unproblematic.

For the durability test of the hoses the problem lies with the definition of the hoses: Which hoses (primary, secondary) of which types of vacuum cleaners (cylinder, upright) will need to be subject to the test. There are 3 options:

1. The durability test is applied to the primary hose of a cylinder type vacuum cleaner. The convenor has prepared a text to that effect. The test itself, which has been around and proven for many years, does not pose a problem. The test would cover 95% of all household vacuum cleaners in the EU.
2. The same test would also be applied to the secondary hose of an upright vacuum cleaner. Upright vacuum cleaners represent 40% of the UK market, meaning 5% of the EU-market. The secondary hose is used for ‘above the floor’ cleaning, i.e. of curtains, stairs, furniture, etc. and is a standard accessory of almost all upright cleaners. The preparatory study has found, and new research in this special review study has confirmed, that the secondary hose is one of the major causes of repairs (13% of repairs amongst *Which?* members in 2015) for upright vacuum cleaners.[3] Applying the same test would not constitute a major technical change in the standard and can thus be realised within the timeframe of the UAP but consensus is needed in order not to jeopardise the whole UAP.
3. A different test method for the secondary hoses of upright vacuum cleaners should be developed. The secondary hoses of upright vacuum cleaners are completely different from the hoses that are used in cylinder vacuum cleaners. They are highly flexible and –above all—they are made to be extended roughly twice their original length. There are no specific tests for these hoses but it is expected that most of the damage comes from prolonging/contracting/pulling the hose, rather than –as is the case with cylinder vacuum cleaner hoses—from bending. In other words, the bending test might be useless in predicting the actual durability of this secondary hose. The solution could be, also subject to the opinion of stakeholders, to develop a dedicated test for the secondary hose of an upright vacuum cleaner (i.e. test with 'repeated stretching' instead of 'repeated bending'), if stakeholders find it worthwhile for such a relatively small market segment. Developing the test will anyway take several years and, because it will contain technical novelties, will not be included in the UAP.

Option 1 can be seen as the easiest and fastest to implement though it would not be technology neutral and 5% of the market would not be covered. Option 2, introducing a possibly futile test, seems not a good idea unless one of the stakeholders has new information on the bending test for secondary hoses of upright cleaners. Option 3 appears to be the most complete one but also the most controversial for getting stakeholders acceptance and the slowest to be implemented.

-> Stakeholders reaction is required.

[33] Pers. comm. Mr. Matthew Knight, *Which?* (UK consumer association)

2.2 Background: Upright and cylinder vacuum cleaner hoses.

Both upright and cylinder vacuum cleaners are, for the purpose of the current Regulation, dry vacuum cleaners.
Section 3 of the harmonised standard EN 60312-1:2013 defines dry vacuum cleaners and upright cleaners as follows:

3.1
dry vacuum cleaner
electrically operated appliance that removes dry material (e. g. dust, fibre, threads) from the surface to be cleaned by an airflow created by a vacuum developed within the unit, the removed material being separated in the appliance and the cleaned suction air being returned to the ambient
3.2
upright cleaner
self-standing and floor-supported vacuum cleaner with the cleaning head forming an integral part of or permanently connected to the cleaner housing, the cleaning head normally being provided with an agitation device to assist dirt removal and the complete cleaner housing being moved over the surface to be cleaned by means of an attached handle.

A definition of cylinder vacuum cleaners is given in the draft standards FDIS IEC 62885-2 (Clause 3.21) as follows:

3.21
Cylinder vacuum cleaner.
A portable, dry vacuum cleaner, having a nozzle separated from the cleaner housing by a hose. In use, only the nozzle is guided over the surface area to be cleaned.

NOTE 1 These dry vacuum cleaners are generally floor-supported.
NOTE 2 The dry vacuum cleaner may have detachable nozzles, attachments, and tubes for both floor and above the floor cleaning.
NOTE 3 The nozzle may employ a driven rotating brush to assist in cleaning.

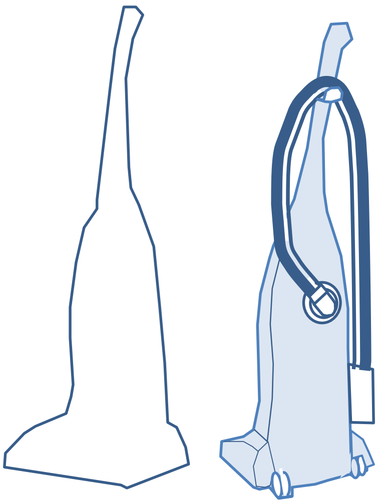


Figure 1. Upright vacuum cleaner with secondary hose
(contour front and back)

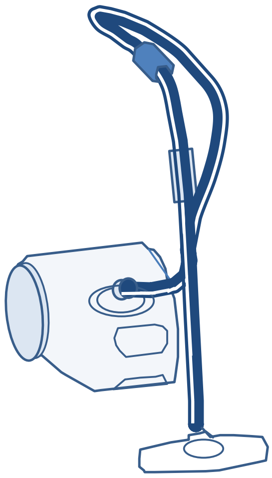


Figure 2. Cylinder vacuum cleaner with primary hose

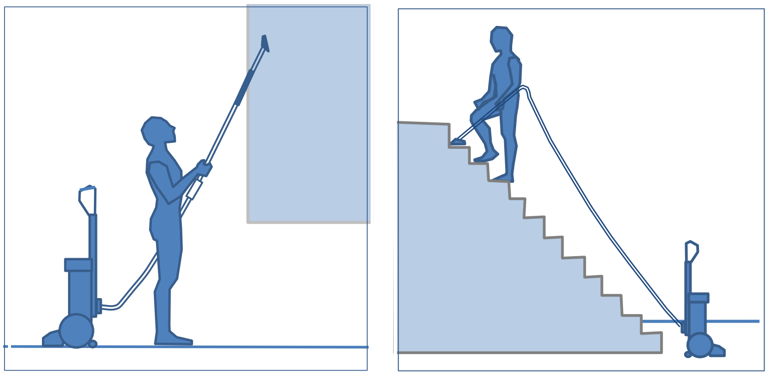


Figure 3. Upright vacuum cleaner with secondary hose used for curtains (left) and stairs (right).

2.3 Background: *Which?* survey

The *Which?* survey showed that defective hoses are a major source for complaints of upright vacuum cleaners.

The 'population' of the survey is only *Which?* members and it comes from an annual reliability survey which covers 11 large domestic appliance categories including upright, cylinder and cordless vacuum cleaners.

Fieldwork took place in the period 28 August - 15 September 2015. The overall sample size is 9055. The total sample (population) sizes for upright vacuum cleaners are 1042, for cylinders 1304 and for cordless 965.

In terms of faults, 350 respondents reported one or more faults from the uprights sample, 287 from the cylinders sample and 198 from the cordless sample. There is no targeting of specific brands in this survey, it merely represents the vacuum cleaners that our members own.

A 'split hose' accounts for 13.7% of the faults recorded for upright vacuum cleaners and only 7.7% of the faults for cylinder vacuum cleaners (see table). Further to this, *Which?* also records how each respondent in the survey classifies the severity of the fault (minor, major or catastrophic). Out of total 350 repairs of upright cleaners 48 concerned a split hose (24 minor, 17 major, 7 catastrophic repairs); 22 out of total 287 repairs of cylinder vacuum cleaners concerned a split hose (9 minor, 9 major and 4 catastrophic repairs).

Which? mentions that 45%% of its members own an upright vacuum cleaner. Ownership of uprights in continental Europe is negligible, implying that uprights constitute around 5% of vacuum cleaners in the EU.

Table 1. *Which?* fault reports for upright and cylinder vacuum cleaners

Upright vacuum cleaners, Faults experienced *(source: Which? 2015)*	
Suction deteriorated	24.3%
Blocked filters	21.7%
Belt broken (drive-belt rotating brush)**	16.9%
Split hose	13.7%
Motor broken	13.4%
Brush not working properly	12.0%
No suction	10.0%
Brush not working at all	9.4%
Casing cracked/chipped/broken	8.9%
Other	8.6%
Broken accessories	8.3%
Overheating	6.3%
Power cable faulty	5.1%
Wheels/castors broken	4.9%
Handle broken	4.6%
Power not working at all	3.7%
Power cutting out	3.1%
Handle loose	2.3%
Controls broken	.6%
Total	**177.7%**

**=77.7% with multiple faults, n=350*
***=maintenance issue; belt costs 2-5 euros*

Cylinder vacuum cleaners, Faults experienced *(source: Which? 2015)*	
Suction deteriorated	19.5%
Blocked filters	17.8%
Other	15.7%
Broken accessories	12.2%
Brush not working properly	10.8%
Casing cracked/chipped/broken	10.1%
Overheating	8.7%
Split hose	7.7%
Motor broken	6.6%
Power cutting out	5.2%
Power cable faulty	5.2%
No suction	5.2%
Brush not working at all	4.9%
Handle broken	3.8%
Power not working at all	3.8%
Controls broken	2.4%
Wheels/castors broken	2.4%
Belt broken (drive-belt rotating brush)	2.1%
Handle loose	1.7%
Total*	**146.0%**

**=46% with multiple faults, n=287*

3 Durability test of motors

3.1 Initial options

The current harmonised standard EN 60312-1:2013 says in its Clause 6.10 on life test related to the determination of the ability of the vacuum cleaner to maintain its air flow performance that both the suction motor and the motor of the agitation device (e.g. rotating brush) should be subject to the durability test.

A dispute regards the durability tests with a half-loaded receptacle, where again there are three initial options:

1. Keep the test at minimum 500 hours and half-loaded receptacle, as described explicitly in the Regulation. Industry (and apparently also the market surveillance authorities) is against this option because the reproducibility is reported to be bad and very well trained personnel would be required to do the test. An industry argumentation to this issue is added in the Annex II. In addition it can be mentioned that, as 'half-loaded' means 50% of 'fully loaded', the determination of 'fully loaded' is complex and potentially adds to uncertainty. For instance, the maximum volume of the receptacle is not clearly defined for bagless vacuum cleaners. Air data measurement using expensive DMT 8 test dust is needed for bagged vacuum cleaners. [4]
2. Perform the test with an empty bag at minimum 500 hours. The industry is in favour of option 2, but for non-experts it is peculiar that a test with an empty bag would be equivalent to a test with a half-loaded bag at the same amount of hours.
3. Perform the test with an empty bag and more hours e.g. 600 hours. Option 3 makes more sense for a non-expert, i.e. that the test is at 600 hours and not at 500 hours to compensate for the fact that the bag is empty. The industry mentions that *Stiftung Warentest* (StiWa) testing up to 600 hours but that this is just to get a verdict of 'Sehr Gut'; they think that for a minimum requirement at entry level this is too harsh and that it should be lower.

In that sense it is plausible that testing with a half-loaded receptacle gives problems with reproducibility and/or requires highly trained personnel that works with high precision.

Furthermore, also consumer associations perform durability tests with an empty receptacle and find enough discrimination between the models.

Finally, as indicated in Annex III, also some market surveillance authorities seem to prefer testing at empty receptacle as a simple and robust option.

3.2 Solution with least administrative burden

The problem is that Annex II of the Regulation is very explicit that the operational motor life-time test should be done with a '*half-loaded receptacle'* and for at least 500 hours and a maximum of 600 hours.

To change the wording in the Regulation from '*half-loaded'* to *'empty'* would require a very tiresome and lengthy amendment procedure.

Ideally, to avoid such a procedure, the best option seems to mention in the standard and possibly in a transitory method that the vacuum cleaner durability test at empty receptacle at **X** hours is equivalent to a test of 500 hours at half-loaded receptacle.

[4] chapter 5.9 of EN IEC 60312-1. DMT Type 8 ('DMT8')is a synthetic vacuum cleaner test dust to simulate certain characteristics of real house test. It consists of mineral powder (Dolomite), cellulose particles and cotton fibers.

The 'only' problem would then be to find an agreement on the value of **X.**

3.3 Industry position

The reason why probably, as mentioned in option 2, the industry believes that the equivalent number of testing hours should also be 500 hours lies amongst others in the type of motor that is used in the household vacuum cleaner (see also Annex IV). This is in most cases a *universal motor*, meaning it is suitable for *AC/DC* operation (although it is usually operated at AC input). This type is low-cost, lightweight, can meet the high speed requirement (8000 rpm and above), delivers high torque at low speed (relevant for start-up) and is easy to regulate (thyristor or 'TRIAC', working on the phase angle). It is used in vacuum cleaners, power tools and blenders, i.e. applications where it is not supposed to run continuously. The disadvantages of this motor type are that it has low-efficiency (20-30% being a typical value), makes a lot of noise, uses a commutator with carbon brushes and can be critical when operating at no load, i.e. the speed goes over the top and the large heat dissipation causes the motor to burn. For that reason, there are safety measures that ensure that the motor is always subject to an external load. From that background it may be plausible that, unlike with other types of motors, the durability of the motor at half-load can be higher than at a low (empty receptacle) load.

Nonetheless, this begs the question why the requirement of a half-load receptacle was introduced in the standard EN 60312-1 in the first place. Industry's answer is that the purpose of the test in Clause 6.10, which was the inspiration of the receptacle being half loaded at the time, is not to test the durability of the motor, but –as mentioned in Clause 6.10.1—*"The purpose of this test is to determine the ability of the vacuum cleaner to maintain its air flow performance with a partly filled dust receptacle, representative of normal household use and household dust."* From that perspective the use of a half-loaded receptacle makes sense.

3.4 Long term perspective

However, the question is how long universal motors will still be used. In that context it is relevant that universal motors were previously used in washing machines, but today's washing machines are using predominantly *BrushLess DC motors (BLDC)* or sometimes *Switched Reluctance motors (SR motors)*. Motor controller manufacturers like Texas Instruments[5] are making the case to use BLDC motors also in vacuum cleaners, because they are more energy efficient, better to (speed) control, much less noisy and have a product life of 10 000 hours or more. The high reliability, moderately priced speed control (compared to an AC motor with variable frequency drive) and low-noise are also important reasons why BLDC motors are now used in (variable speed controlled) hermetic compressors for household refrigerators, ventilation fans and many other applications.

It would stand to reason that manufacturers using these BLDC motors would like the durability tests to show the extra quality and life expectancy. Running the test at 600 hours instead of 500 hours would probably help to accomplish that. The big question is, whether the fall-out under universal motors –that are dominating the current vacuum cleaner market—is acceptable at this moment in time or whether it is more prudent to wait for a full review of the Regulation.

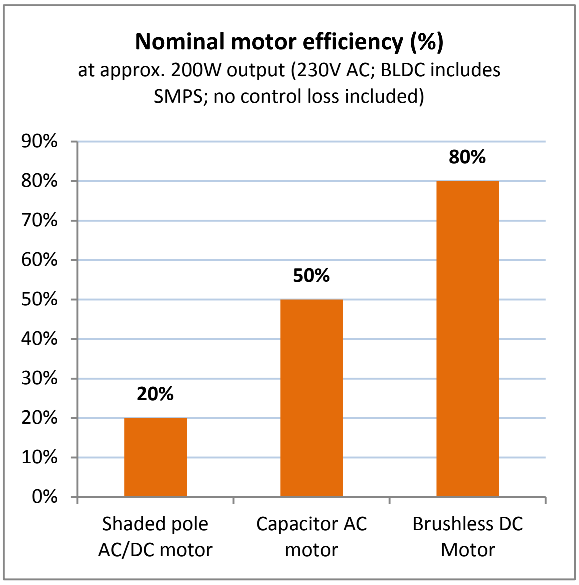
In that sense it is also relevant that there is a downside to the use of BLDC motors: They use permanent magnets, which contain Neodymium (20-30 wt.%). Neodymium is identified by the Commission as a 'critical raw material' (CRM), meaning that it is not only relatively scarce but most of its production is in the hands of China, who is using

[5] Texas Instruments, Hardware Design Considerations for an Efficient Vacuum Cleaner Using a BLDC Motor, Application Report SLVA654-June 2014-Revised July 2015.

this ‘monopoly’ to its advantage. This means it is hard to come by in Europe without a Chinese ‘connection’. This situation may change in the coming years because considerable quantities of Neodymium and other rare earth materials have been found in Greenland and will probably be commercially exploited in the near future (if permits are granted). The situation may also change because European motor manufacturers, faced with the Neodymium scarcity, have made in recent years much progress in SR motors, which do not contain permanent magnets but shown many of the good performance characteristics of BLDC motors.

For these and cost reasons, BLDC motors being an expensive solution, an AC motor (3-speed) with capacitor may be an intermediate proposition. In the consultation on the fan-Regulation leading EU-fan producer *Ebmpapst* proposed the efficiency level of ‘AC motor with capacitor’ as the minimum efficiency level that is attainable and economical for small fans (<125W). It is cheaper than the BLDC-level, 50% more efficient than universal motors (45% instead of 30% efficiency) and life expectancy is much higher e.g. because it has no carbon brushes. Sellers guarantee minimum life of 3000 h.

Figure 5 gives an overview of indicative efficiencies and OEM-prices for motors with a power output of 200W. Naturally these prices (and efficiencies) vary over a broad range and in time, but it gives a first impression.[6] Note that between OEM-prices and consumer prices (incl. VAT) a factor 5 is typical. This means e.g. that a BLDC motor of € 36 – without the rest of the vacuum cleaner—translates into a consumer price of € 180. For a (low quality) universal motor this value is € 20 and for an AC motor with capacitor this value becomes € 50.



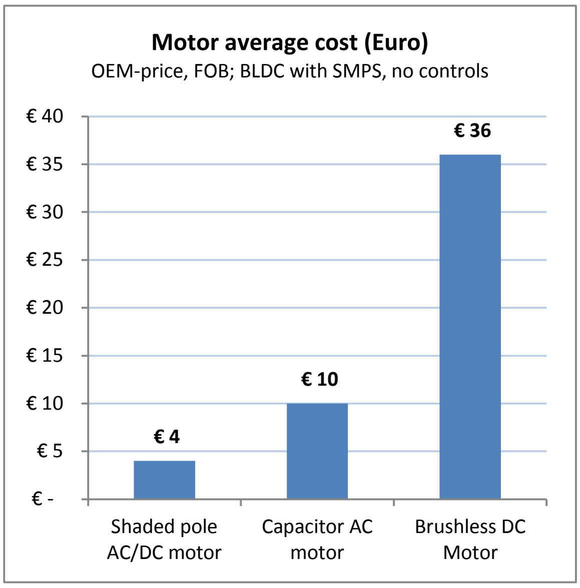


Figure 4. Motor 200W output; nominal efficiency and average OEM costs (source: VHK 2016, based on publicly available prices and declared efficiencies)

For a vacuum cleaner, an appliance that is used only 50 hours per year, no economic calculation is needed to show that a transition from universal AC/DC motors to more efficient types is not economical and thus cannot be enforced through minimum Ecodesign requirements. However, using the energy label Regulation, a considerable part

[6] EbmPapst position paper on small fans, 2015. Download from www.fanreview.eu

of the consumers may want to choose for the more efficient and more durable motor solution if they were made aware in an appropriate way.

This could be done in various ways, but introducing a durability test of thousands of hours does not seem the most appropriate for effective market surveillance. As e.g. the experience with light sources has shown, It takes too long and by the time that the testing is done, the container full of cheap vacuum cleaners that was investigated may be long sold out and the importer untraceable.

3.5 Recommendation for a short term solution

The previous section indicates that the full review of especially the Energy Label Regulation (EU) No 665/2013 for vacuum cleaners, due before 2 August 2018, will be very interesting and it will be a challenge to shape the measures in a way that facilitates the market transition towards much more durable and efficient vacuum cleaners for at least the top-range of the vacuum cleaners.

In the meanwhile, the long term perspective also indicates that –whatever solution will be chosen for the short term problem of a minimum durability requirement for motors— its importance for market transition will be relative. For that reason it is recommended to find a quick and pragmatic solution.

WG6, with many members also active at IEC level, informs that at the moment the global FDIS IEC 62885-2 is at IEC Central Office (IEC CO) for the final editing and the French translation before being circulated for voting in March. The text on motor durability testing is given below:

6.17 Operational motor life-time test

6.17.1 Purpose

The purpose of this test is to determine the stationary operational life-time of a **dry vacuum cleaner** suction motor.

6.17.2 Test method

The **dry vacuum cleaner**, equipped as in its normal operation with empty dust receptacle, hose and **tube** (if applicable) and nozzle, is allowed to run intermittently with periods of 14 min 30 s on and 30 s off. If the **dry vacuum cleaner** is provided with an agitation device it shall be running.

The tube grip of **dry vacuum cleaners** with suction hose or the handle of other **dry vacuum cleaners** shall be held as for normal operation at a height of (800 ± 50) mm above the test floor.

The nozzle shall be energized and not be in contact with the floor, but lifted 1 cm off the floor.

End of life is reached when the suction motor stops operating.

NOTE The 30 second off period is not included in the calculation of overall motor life.

This text seems compatible with Annex II, point 8 on 'Operational motor life-time' of the Regulation. It is also in line with the motor durability testing by *Stiftung Warentest*.[7] What is missing is an indication of minimum or maximum number of hours for the test.

The natural way forward is that the text of Clause 6.17 of FDIS IEC 62885-2 will be transposed to the new EN 60312-1 in the UAP, but amended for the missing parts mentioned on the number of hours for the test. In order to be flexible with regard to

[7] Pers. Comm. Elke Gehrke (*Stiftung Warentest*)

future requirements, it is not needed to set an explicit (minimum/maximum) number of hours in the new EN 60312-1. The minimum/maximum number of hours is already in the Regulation.

It would be enough, in the new EN 60312-1, to add a sentence regarding the equivalence of half-loaded versus empty receptacle testing. E.g. *"Where testing is done with half-loaded receptacle, it is considered that the operational motor life in hours is equivalent to the operational motor life in hours at empty receptacle plus X %"*. If indeed 600 hours (500h + X=20%) is considered too ambitious then a compromise solution could e.g. be 550 hours (500h + X=10%). [8]This is up to the stakeholders to indicate a preference. The important issue is that there is a difference and thus an equivalence statement is required.

The German consumer association *Stiftung Warentest* has performed a test with empty receptacle at 600 hours (or until failure), using the switching times as indicated in the Regulation, since 2003. Over the period 2003-2015 the motor durability of in total 190 vacuum cleaners was tested. *Stiftung Warentest* has shared these data with the study team, showing that 170 of 190 vacuum cleaners (89%) reached the limit of 600 hours. This percentage is largely --up to a price of € 400-- independent of the purchase price, as is shown in the table and figure below. It also seems to be fairly constant in time, i.e. the percentage that failed was similar in the period 2003-2008 to that in the period 2009-2015.

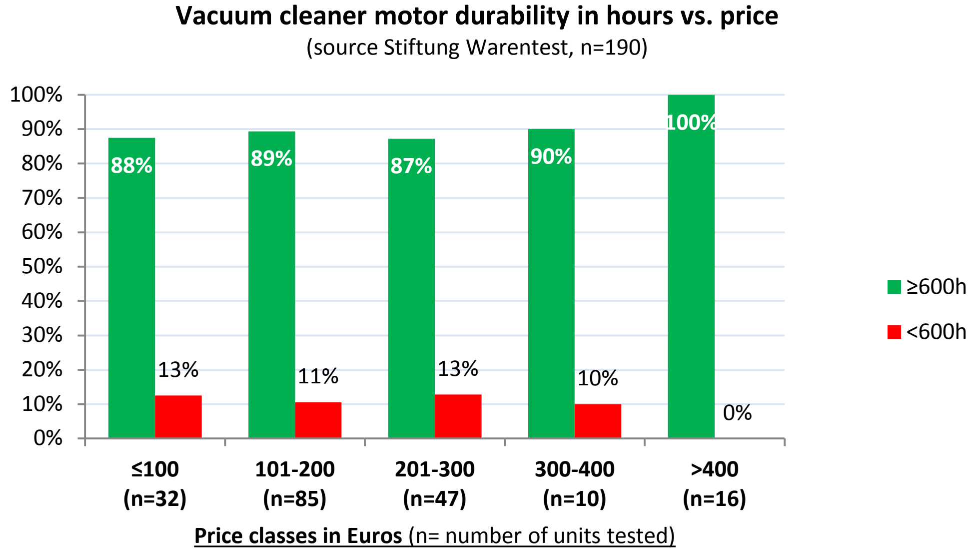


Figure 5 Vacuum cleaner motor durability in hours versus price (source: *Stiftung Warentest*, March 2016; test results 2003-2015 for in total 190 products)

[8] This 550 hours is the 'Working Assumption' in the Ricardo-AEA report on Durability of Products (2015) although it does not specify whether it applies to an empty or half-loaded receptacle.

Table 2. Vacuum cleaner motor durability test (*Stiftung Warentest*, 2016)

	number of units tested			percentage	
Price (Euro)	**total**	**≥600h**	**<600h**	**≥600h**	**<600h**
≤100 (n=32)	32	28	4	87.5%	12.5%
101-200 (n=85)	85	76	9	89.4%	10.6%
201-300 (n=47)	47	41	6	87.2%	12.8%
300-400 (n=10)	10	9	1	90.0%	10.0%
>400 (n=16)	16	16	0	100.0%	0.0%
Total	**190**	**170**	**20**	**89%**	**11%**

The test results for the 20 products that failed to reach the 600h motor life suggest that lowering the threshold to e.g. 550h does not make much of difference. Instead of 20 products (10.5%), 17 products would have failed (8.95%).

Table 3. Failed vacuum cleaners (*Stiftung Warentest*, 2016)

Hours to failure	**nr.**	**average price**
≤100	3	169
101-200	1	50
201-300	2	155
300-400	4	143
400-500	3	117
500-550	4	245
550-599	3	190
Total	**20**	**166**

Stiftung Warentest mentions that its focus is on products that claim a low energy consumption and that could thus be relatively more expensive than the market average. However, the average price of the 190 vacuum cleaners tested is € 221,-, which is very close to the average mentioned in the Impact Assessment report that accompanied the Regulation, i.e. € 225,-.[9] The 170 products that passed the 600h test cost on average € 227,-. As is shown in the table, the 20 products that failed cost on average € 166,- , but there is also a model of € 340,- that failed.

[9] EC, Vacuum cleaner IA report, SWD 2013/0240.

Note that *Stiftung Warentest* typically tests only one unit.

In case of conformity assessment for the vacuum cleaner Ecodesign Regulation, if one unit fails, three additional units are tested. According to the latest Draft Regulation on verification tolerances[10], "*the model shall be considered to comply with the applicable requirements if, for these three units, the arithmetical mean of the values of the relevant parameters as measured in testing and the values calculated from these measurements are within the respective verification tolerances.* " For motor durability testing a verification tolerance of 5% applies.

Stakeholder reaction on the way forward is requested.

[10] Draft COMMISSION REGULATION (EU) …/…, amending Regulations (EC) No 1275/2008, (EC) No 107/2009, (EC) No 278/2009, (EC) No 640/2009, (EC) No 641/2009, (EC) No 42/2009, (EC) No 643/2009, (EU) No 1015/2010, (EU) No 1016/2010, (EU) No 327/2011, (EU) No 206/2012, (EU) No 547/2011, (EU) No 932/2012, (EU) No 617/2013, (EU) No 666/2013, (EU) No 813/2013, (EU) No 814/2013, (EU) No 66/2014, (EU) No 548/2014, (EU) No 1253/2014, (EU) 2015/1095, (EU) 2015/1185, (EU) 2015/1188, (EU) 2015/1189 and (EU) 2016/XXX, [Air heating/cooling and chillers Number of the Regulation to be inserted before publication in the OJ] with regard to the use of tolerances in verification procedures. Brussels, 4 Feb. 2016.

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http://www.fanreview.eu/downloads/Nicotra%20An%20analysis%20of%20the%20efficiency%20of%20centrfugal%20fans_R13-1.pdf

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Draft COMMISSION REGULATION (EU) …/…, amending Regulations (EC) No 1275/2008, (EC) No 107/2009, (EC) No 278/2009, (EC) No 640/2009, (EC) No 641/2009, (EC) No 42/2009, (EC) No 643/2009, (EU) No 1015/2010, (EU) No 1016/2010, (EU) No 327/2011, (EU) No 206/2012, (EU) No 547/2011, (EU) No 932/2012, (EU) No 617/2013, (EU) No 666/2013, (EU) No 813/2013, (EU) No 814/2013, (EU) No 66/2014, (EU) No 548/2014, (EU) No 1253/2014, (EU) 2015/1095, (EU) 2015/1185, (EU) 2015/1188, (EU) 2015/1189 and (EU) 2016/XXX, [Air heating/cooling and chillers Number of the Regulation to be inserted before publication in the OJ] with regard to the use of tolerances in verification procedures. Brussels, 4 Feb. 2016.

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FDIS IEC 62885-2, Surface cleaning appliances - Part 2: Dry vacuum cleaners for household and similar use - Methods for measuring the performance, Draft for vote, 2016.

Patent application EP2641523 A1 of Eurofilters Holding N.V. (publication date 25.9.2013).

Pers. comm. Mr. Matthew Knight, *Which?* (UK consumer association)

Pers. comm. Ms. Elke Gehrke, *Stiftung Warentest* (German consumer association)

Ricardo AEA, The Durability of Products --Standard assessment for the circular economy under the Eco-Innovation Action Plan, Report for the European Commission DG Environment, August 2015.

Annex I. Hose durability, standard text

Repeated bending of the hose

From published IEC 60312-1 and EN 60312-1:2013 (harmonised) respectively:

6.9 Repeated bending of the hose

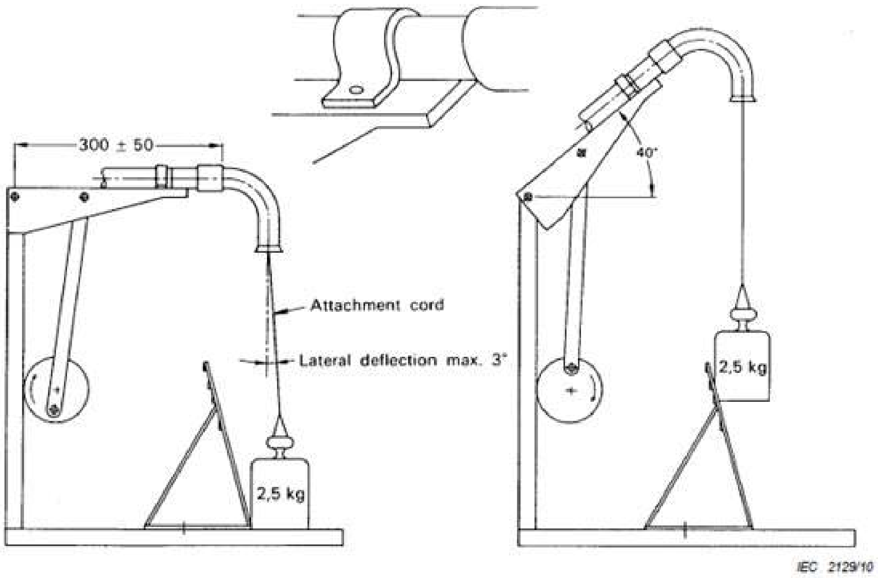
6.9.1 Purpose

The purpose of this test is to determine the ability of the hose to be repeatedly bent, as in normal use of the vacuum cleaner, before damage causes leakage affecting the performance of the cleaner.

NOTE Standard atmospheric conditions according to 4.1 not required.

6.9.2 Test equipment

The test equipment, in accordance with Figure 17, consists of a pivoting lever with a clamping device for the attachment of the hose connector. The lever is operated by means of an oscillator, for instance the crank mechanism shown, to perform a raising and lowering movement with a frequency of (10 ± 1) periods per minute. The initial position of the lever is its horizontal position from which it is raised to form an angle of 40° ± 1° with the horizontal plane.



Dimensions in millimetres

Figure 17 – Equipment for repeated bending of hoses

6.9.3 **Test method**

The hose connector is clamped to the lever so that the distance between the pivot point of the lever and the hose fitting end of the connector is 300 mm ± 50 mm.

A weight of 2,5 kg is attached to the pendent part of the hose in such a way that, during the oscillation period, it is lifted to a height of 100 mm ± 10 mm above the mounting plate and, during the remainder of the period, rests on the mounting plate to unload the hose completely. To accomplish this movement, the hose may need to be shortened to a length of about 300 mm.

In order to avoid pendulation of the weight loading the hose, it is given a lateral deflection of maximum 3° by means of an adjustable deflection plate.

The number of oscillations performed until the hose is damaged to the extent that it is deemed unusable is recorded.

NOTE It is recommended that the test is discontinued after 40 000 oscillations.

According to decisions made within WG 6 the following additions might be made for the next edition of EN 60312-1 via the UAP:

- new text:
  "This test is applicable to the hose of a cylinder vacuum cleaner. Secondary hoses such as in certain upright cleaners for above-the-floor cleaning, hoses inside nozzles or other attachments and accessory hoses are not subject to this test."

- additional note:

  Another note should be added defining the weight applied to the hose: 2.5kg is the total of the weight, the attachment cord and its attachment to the hose.

The definition from the FDIS IEC 62885-2 could be added for the sake of consistency and clarity:

3.21
cylinder vacuum cleaner
a portable, **dry vacuum cleaner**, having a nozzle separated from the cleaner housing by a hose. In use, only the nozzle is guided over the surface area to be cleaned.

NOTE 1 These dry **vacuum** cleaners are generally floor-supported.
NOTE 2 The dry vacuum **cleaner** may have detachable nozzles, attachments, and **tubes** for both floor and above the floor cleaning.
NOTE 3 The nozzle may employ a driven rotating brush to assist in cleaning.

The above text was supplied by the convenor of the CLC TC59X/WG6, Mr Bernard Scheuren.

Annex II. Operational motor life-time

This is from the draft document FDIS IEC 62885-2 which is at IEC CO for the final editing and the French translation before being circulated for voting. In principle, this test could be included in the UAP for the next version of EN 60312-1, but with the additions as discussed.

6.17 Operational motor life-time test

6.17.1 Purpose

The purpose of this test is to determine the stationary operational life-time of a **dry vacuum cleaner** suction motor.

6.17.2 Test method

The **dry vacuum cleaner**, equipped as in its normal operation with empty dust receptacle, hose and **tube** (if applicable) and nozzle, is allowed to run intermittently with periods of 14 min 30 s on and 30 s off. If the **dry vacuum cleaner** is provided with an agitation device it shall be running.

The tube grip of **dry vacuum cleaners** with suction hose or the handle of other **dry vacuum cleaners** shall be held as for normal operation at a height of (800 ± 50) mm above the test floor.

The nozzle shall be energized and not be in contact with the floor, but lifted 1 cm off the floor.

End of life is reached when the suction motor stops operating.

NOTE The 30 second off period is not included in the calculation of overall motor life.

Annex III. Motor durability text, MSA experience in Germany

MSAs (Market Surveillance Authorities) need a reliable, not too time-consuming, and not too complex test in order to be able to perform e.g. the test at their own test facilities or at third parties without having any doubt regarding the test results. Baden-Wuerttemberg could perform this e.g. at the LUBW, Landesanstalt für Umwelt, Messungen und Naturschutz if tested in-house.

Baden-Wuerttemberg has within the Federal Republic of Germany a deep focus on testing the energy label and eco-design requirements of vacuum cleaners and performed in December 2014 tests on 20 different vacuum cleaners.

Issue: Measurements had to be given out to third party testing due to complexity and cost intensive test equipment, plus it is necessary to be very familiar with the test ("best lab practise"). The MSAs need of course a tool that help them conduct their work and not make it more difficult.

One solution: The operational motor lifetime could be tested e.g. in-house to have at least the chance to see whether there are issues on the market and then give testing out to third party rather than spending each time ~5000 € to test ONE vacuum cleaner.

Issue here: Half-loaded dust receptacle. How is that measured. You take a full dust bag weigh it and then fill one with 50 % of the weight; or do you take the volume and mark half. What do you do with bagless systems? This shows that the half-loaded dust receptacle adds an uncertainty to the system.

Therefore, an automated measurement with an empty dust receptacle would be an additional powerful tool to help screening the market for "black sheep".

The study team is invited to discuss this further with the MSA Baden-Wuerttemberg and LUBW in Stuttgart/Karlsruhe if needed.

Charalambos Freed
Head of Standardization and Compliance
IEC Secretary SC 61J
IEC Convenor SC 61J JWG 1
IEC Convenor SC 59F WG 6
CLC Convenor TC 61 WG 10
Issue Manager EN 60335-2-67, EN 60335-2-68, EN 60335-2-69, EN 60335-2-72, EN 60335-2-79

Annex IV. Theoretical background: Reduced air flow and longer motor life

During the consultation process, vacuum cleaner industry experts claimed that the reduced air flow due to a half-loaded receptacle versus an empty receptacle leads to a longer product life. This technical annex intends to put more nuance to this statement.

Fan basics

In reality, the relationship between motor life and air flow is more complex, as mentioned e.g. in the Ecodesign regulations of fans[11] and the regulation on ventilation units[12]. With an ideal gas, the output (gas) power P_u (in W) of a motor depends, with an ideal gas, on two parameters, i.e. multiplication of air flow q_v (in m/s) and pressure difference Δp (in Pa)[13].

In formula:

$$P_u = q_v \cdot \Delta p$$

This means that when the pressure Δp goes up, e.g. because of a half-loaded receptacle instead of an empty receptacle, the air flow becomes lower at the same power output. In other words, the motor has to work just as hard and in principle there should be no beneficial effect on the motor life.

Rather, it can be expected that there is a negative effect on the motor life from this shift in operating point. It can be assumed that the motor is designed for an ideal operating point (best efficiency point) when the receptacle is empty. The isochoric fan efficiency is defined as $\eta_{fan}=P_u/P_e$, where P_e is the electricity input power (in W).

This best efficiency point (bep) is thus the point with the least heat dissipation, because all energy that is not used for output power is –in some form—waste heat. When you deviate from bep at an empty receptacle, the efficiency becomes worse. Thus the heat goes up and in principle shortens the motor-life. On the other hand, if you choose the bep at a half-loaded receptacle, the efficiency increases when you move from an empty receptacle to a half-loaded receptacle.

Vacuum cleaner fans

A vacuum cleaner fan is not a normal fan. It is a so-called 'blower' or High Pressure, Low Volume (HPLV) fan designed for volume flows in the range of up to 40-50 litres per second (0.04 m^3/s) and a high pressure difference in the range of up to 17500 Pa (for top models)[14]. For comparison: A central ventilation fan for a dwelling has a volume flow of 300 m^3/h (83 litres per second, 0.083 m^3/s) and a pressure difference of 200 Pa.

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[11] Commission Regulation (EU) No 327/2011 of 30 March 2011 implementing Directive 2009/125/EC of the European Parliament and of the Council on fans driven by motors with an electric input power between 125W and 500 kW, OJ L 90, 6.4.2011, p. 8.

[12] Commission Regulation (EU) No 1253/2014 of 7 July 2014 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for ventilation units, OJ L 337, 25.11.2004, p. 8.

[13] The pressure difference relates to the difference in pressure between inlet and outlet. On the inlet side there is a normal atmospheric pressure (ca. 1 bar=10^5Pa=100 kPa= 100 000 bar)

[14] E.g. topmodel: max. 41 l/s, max 175 hPa, max motor output power 260W (empty receptacle) at 800W motor input (32% efficiency). Speed: nominal 60 000 rpm. Note that a pressure difference above 100 kPa would qualify the fan as a vacuum pump or compressor.

In a vacuum cleaner the HPLV-performance is typically realised with a thin[15] centrifugal fan rotating at very high speed: from 5000 to 20 000 rpm for fans with universal motors; up to 60 000 rpm with e.g. switched reluctance motors. At these conditions, the air is no longer an ideal, incompressible gas but compressibility phenomena start to occur and friction losses are high. As a result, the impeller efficiency[16] is considerably lower than that of a 'normal' fan. This is, for instance, an important reason why vacuum cleaner fans ('fans with speed >8000 rpm') are exempted from the fan regulation.

A characteristic parameter for HPLV-fans is e.g. the 'specific speed' [17].

A definition of specific speed at bep σ_{bep} is

$$\sigma_{bep} = n \cdot \frac{2 \cdot \sqrt{\pi \cdot q_{v,bep}}}{\left(2 \cdot \frac{p_{f,bep}}{\rho}\right)^{0,75}}$$

where

- σ_{bep} is specific speed (-);
- n is fan speed in rounds per second (rps);
- ρ is air density 1.2 kg/m³;
- $q_{v,bep}$ is volume flow rate at bep, in m³/s;
- $p_{f,bep}$ is total fan pressure at bep, in Pa;
- π is the number pi (3.14…).

The limit between a HPLV-fan and a normal fan is around $\sigma_{bep} < 0.12$. If it is lower it is a HPLV fan[18].

Because of the compressibility phenomena at nominal speed it is fairly unpredictable, i.e. depends on the design details, how the efficiency curve will behave over the full range of operating points. It could well be, depending on motor- and impeller design, that the vacuum cleaner fan starts to behave more like a 'normal' fan, i.e. with relatively higher efficiency than expected, when the air flow is reduced.

Vacuum cleaner motor

Another reason why the efficiency, and thereby the heat dissipation of a vacuum cleaner fan may behave differently from e.g. standard ventilation fans is the motor. Whereas standard fans for continuous operation use AC motors or (brushless) DC motors, most vacuum cleaners in the low- and medium market segment use universal (AC/DC) motors.

As mentioned in the main report, these motors have considerable economical and operational advantages, but they are not energy-efficient (meaning they dissipate considerable heat)and they have a limited lifespan. One of the main factors limiting the life span is wear of the carbon brushes in the commutator, but for our problem –i.e. whether an empty or half-loaded receptacle gives a shorter motor life—the heat dissipation is more relevant.

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[15] Meaning a small distance between front and backplate, leaving a very narrow air passages. The geometry, in connection with the rpm speed, is characterised by 'specific speed'.
[16] Ratio between power output (in W) and shaft power input (=output of the motor in W). Efficiencies
[17] There are several possible definitions. This definition is the one proposed by German HPLV-fan industry for the new fan regulation (corrected by VHK for units) for centrifugal fans <10 kW, test categories B and D (Total efficiency). References: Bohl, W. (1982). Strömungsmaschinen. Würzburg: Vogel Verlag (Seiten 42ff.) and Bommes, L.; Fricke, J.; Grundmann, R. (2003). Ventilatoren. Essen: Vulkan-Verlag (Seiten 30ff.). Other definitions, using angular speed ω (in rad/s), can be found in Dixon, S.L., Hall, A.C, Fluid Mechanics and Thermodynamics of Turbomachinery, 7th edition, Elsevier, 2014.
[18] Industry proposal for the review of the fan regulation.

In that sense, the part-load efficiency curve of a universal motor –in combination with the blade design—is more relevant. On that subject, Dario Brivio, expert of Nicotra-Gebhardt, although recognizing the disadvantage, lists a number of advantages of 'high-slip' motors like AC and universal motors e.g. in combination with forward-curved centrifugal impellers[19]. The 'slip' is the difference between the actual rotor speed and the synchronous speed that fits the AC-frequency. 'High-slip' motors are much more 'tolerant' than the 'low-slip' motors like brushless DC motors. Whereas with brushless DC or SR motors the motor speed is maintained with increased torque, the speed (rpm) of universal motors decreases considerably with increased load/torque (e.g. loading of the receptacle). Depending on where the bep lies, this usually results in lower efficiency and thus more heat dissipation.

Other influences

Some manufacturers of bagless vacuum cleaners claim that the pressure-drop and air-flow is independent of how full the receptacle is because the load does not block the airflow. In that case it would hardly matter for motor life how 'full' the receptacle is.

Other influences concern the quality of the filter/bag and in some cases how the cooling of the motor is conceived. E.g. for some motors it is reported that some of the suction air of the vacuum cleaner by-passes the receptacle/filter to cool the motor.

The following graphs were taken from Patent application EP2641523 A1 of Eurofilters Holding N.V. (publication date 25.9.2013), showing pressure difference ('Unterdruck' in kPa), air flow ('Luftstrom' in l/s or dm^3/s), electric input ('Aufnahmeleistung' in W) and gas power output ('Luftleistung' in W) of some vacuum cleaners, with various filters and possibly in dependence of the receptacle-load ('Staubmenge' in g of test-dust DMT8). The tests were performed in accordance with test standard **EN 60312**. The main claim of the inventor is that with their filterbag design the airflow is reduced by only 5-15% in a partly loaded receptacle.

Note: The graphs are only shown as an illustration of the influence of the filter and typical efficiency curves and no conclusions regarding the merits of the patent application nor the quality of the tests are intended.

Conclusion

It is not a universal truth that a fan producing a lower air flow will thus have a longer motor-life. For a 'normal fan' even the reverse would be true. For a vacuum cleaner fan, with its specific characteristics, the statement might be true but it depends very much on the design-choices that were made regarding a multitude of parameters.

[19] Dario Brivio, An analysis of the efficiency of centrifugal fans, Nicotra Gebhardt, input consultation review of fan regulation (EU) 327/2011, 2015. http://www.fanreview.eu/downloads/Nicotra%20An%20analysis%20of%20the%20efficiency%20of%20centrfugal%20fans_R13-1.pdf

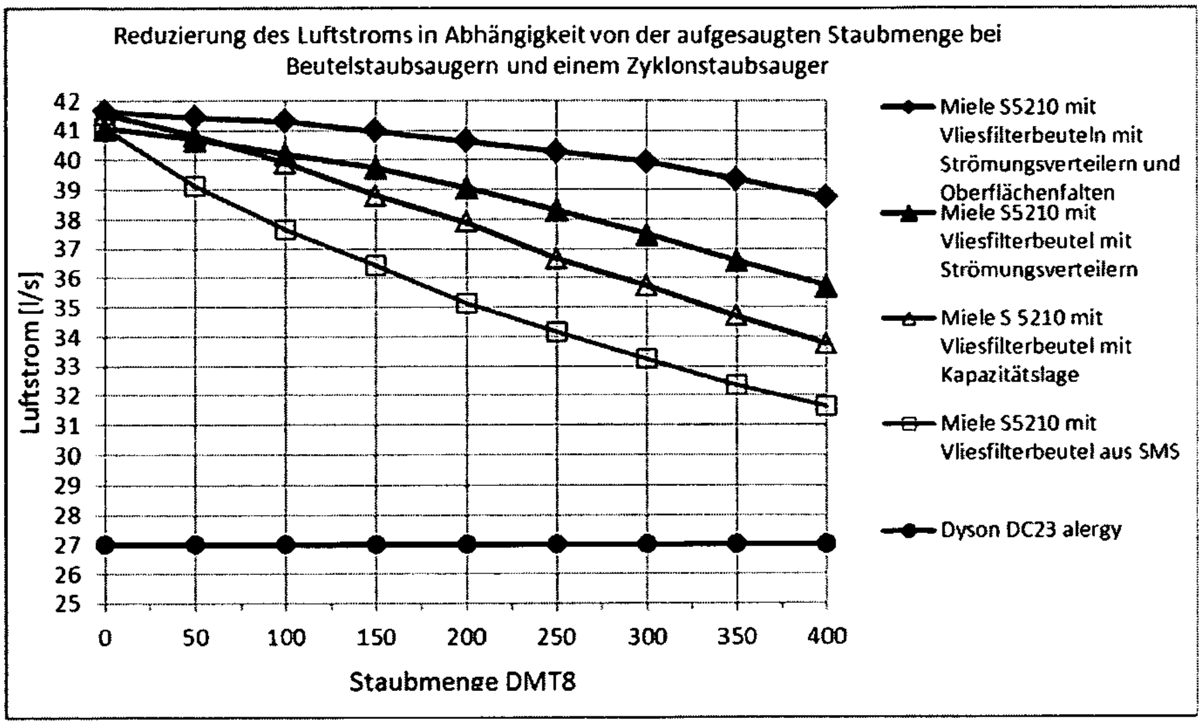

Fig. 3: Reduzierung des Luftstroms beim Aufsaugen von 400 g DMT8 Prüfstaub in Anlehnung an EN 60312 bei einer Aufnahmeleistung von 2200 W (Miele S5210) und 1400 W (Dyson DC23 alergy)

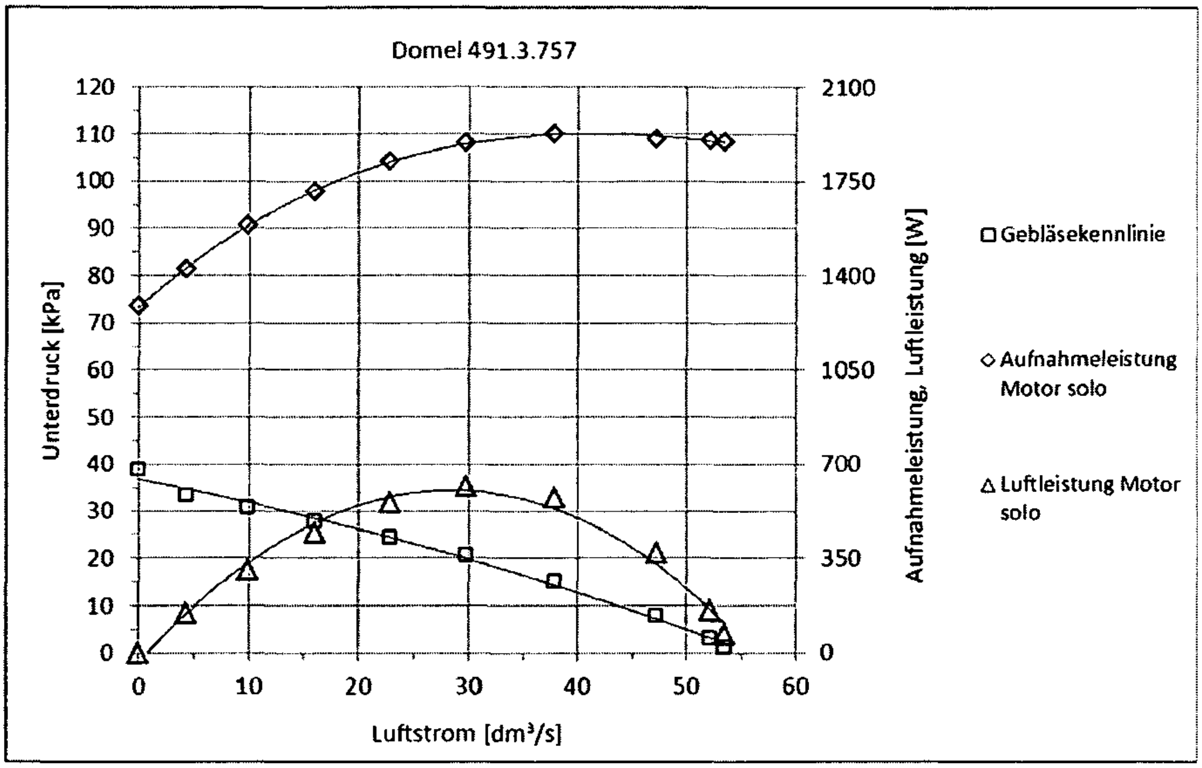

Fig. 4: Luftkenndaten einer Motor-Gebläseeinheit mit hoher Aufnahmeleistung

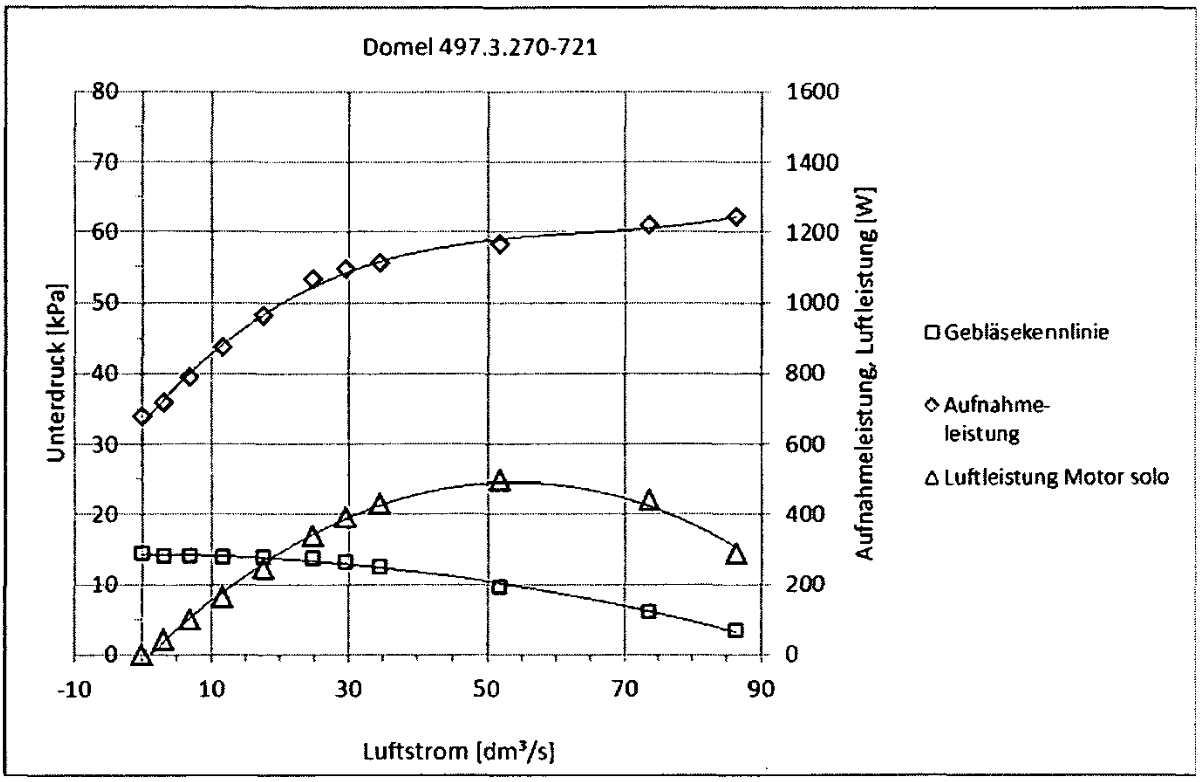

Fig. 5: Luftkenndaten einer Motor-Gebläseeinheit zur Verwendung gemäß einer bevorzugten Ausführung der vorliegenden Erfindung

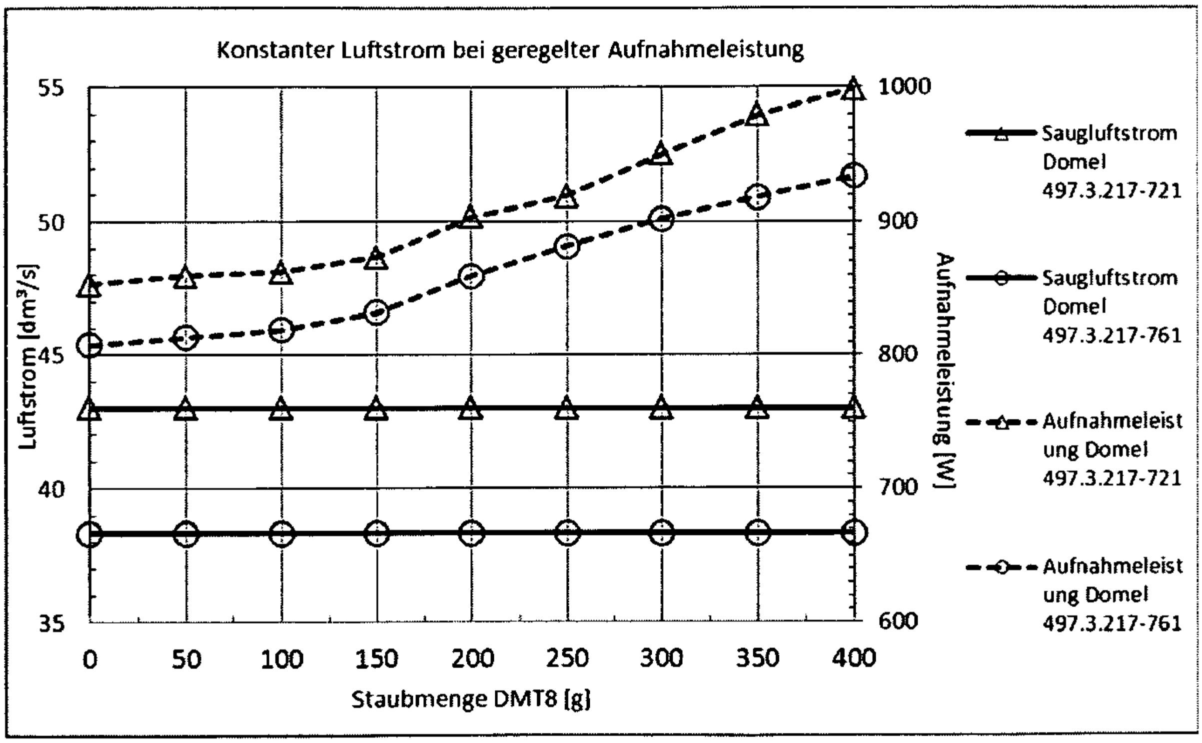

Fig. 6: Staubsauger mit konstant hoher Saugleistung und einer Aufnahmeleistung von unter 1000 W