How standards can better reflect consumer relevance on the example of range hoods

Arno Knieschewski
Bundesanstalt für Materialforschung und -prüfung (BAM)
Unter den Eichen 87
12205 Berlin
Germany
Arno.Knieschewski@bam.de

Dr. Moritz-Caspar Schlegel
Bundesanstalt für Materialforschung und -prüfung (BAM)
Unter den Eichen 87
12205 Berlin
Germany

Dr. Floris Akkerman
Bundesanstalt für Materialforschung und -prüfung (BAM)
Unter den Eichen 87
12205 Berlin
Germany

Prof. Rainer Stamminger
University of Bonn
Nußallee 5
53115 Bonn
Germany

Dr. Anne Simo
Bundesanstalt für Materialforschung und -prüfung (BAM)
Unter den Eichen 87
12205 Berlin
Germany
Anne.Simo@bam.de

Keywords

Energy Labelling Directive, efficiency classification, standards, domestic appliances, testing, range hoods

Abstract

The EU's Ecodesign and Energy Labelling Regulations for domestic cooking appliances became legally binding in 2015. To determine the classes on the energy label, the regulations refer to the European Standard for performance measurements of range hoods EN 61591. The standard EN 61591 has been analysed and evaluated within the National Action Plan on Energy Efficiency (NAPE), a government programme that aims to increase the energy efficiency in Germany. The analysis revealed several drawbacks of the test standard. The standard used for the evaluation of range hoods is composed of methods for determining: (i) volumetric airflow, (ii) odour extraction, (iii) effectiveness of the lighting system and (iv) grease absorption. Currently, the grease absorption class is obtained by heating up oil and water in a pot, which creates vapour and splashes of grease. In this paper different alternative methods for the evaluation of the grease absorption efficiency will be discussed. In the proposed test method an atomizer nozzle is used. Consequently, the exact amount of atomized oil is known and the ratio of filtered to atomized oil can be measured. Thereby the proposed new method is able to take into account aerodynamic designs and leaks. Furthermore, it enables to alter the classification guideline of the energy label to give more significant and consumer relevant declarations. It allows manufacturers to develop innovative grease absorption methods with little airflow. This study revealed that it can be beneficial to review more of the existing standards in the light of improving their consumer relevance.

Introduction

In the European Union the first energy label appeared on the public market in 1995[1, 2, 3]. It is mandatory for selected products and has the purpose to illustrate how efficiently the products operate. During the last years the energy label has been introduced for many new product groups. To determine the energy class, the regulations refer to the European standards for performance measurements that were developed over several years and already existed prior to the regulations. Serving as reference for the regulations increases the importance of well-developed standards and justifies their review in the light of the EU Ecodesign and Labelling regulations. In this study, a review was performed on range hoods. A round robin test (RRT) has been initiated within Europe, to be followed by performance tests of several different models. First data suggest that the grease absorption measurement of range hoods needs a redesign in order to give reliable and relevant results. Hence, a modified grease absorption measurement is suggested in this paper. The

1. Council Directive 92/75/EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances. ELI: http://data.europa.eu/eli/dir/1992/75/oj.

2. Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products (Text with EEA relevance). ELI: http://data.europa.eu/eli/dir/2010/30/oj.

3. Commission Directive 94/2/EC of 21 January 1994 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations. ELI: http://data.europa.eu/eli/dir/1994/2/oj.

modified test method would enable a new approach for calculating the Energy Efficiency Index (EEI) that is able to better reflect the consumer use.

Current test standard

The regulation (EU) No 65/2014[4] for range hoods refers to the standard EN 61591 that is composed of test methods regarding: (i) volumetric airflow, (ii) odour extraction, (iii) effectiveness of the lighting system and (iv) grease absorption. The EEI for range hoods is defined in the regulation and is calculated on the basis of the volumetric airflow and the power consumption used for the ventilation and the lighting. The lighting efficiency is obtained by dividing the average illumination through the nominal electric power input of the lighting system. The efficiency of the volumetric airflow is defined by the Fluid Dynamic Efficiency (FDE) which is a parameter calculated with a formula that was proposed in the preparatory study on residential ventilation[5]:

$$FDE = \frac{Q_{BEP} \cdot P_{BEP}}{W_{BEP}} \cdot 100 \quad (1)$$

with Q_{BEP} as the flow rate of the domestic range hood at the best efficiency point, P_{BEP} as the static pressure difference of the domestic range hood at the best efficiency point and W_{BEP} as the electric power input of the domestic range hood at the best efficiency point.

Initially range hoods were supposed to have the same kind of energy label as all residential ventilation systems. However, this idea was discarded later on when the differences between range hoods and regular ventilation systems were considered to be too significant. Nonetheless, some parts of their common preparatory study, such as the formula for the FDE, were adopted.

The grease absorption has no influence on the EEI, but it is stated on the energy label separately in a pictogram. The purpose of the grease absorption test is to detect how much of the oil mist stays in the grease filter and how much passes it unfiltered. During the test, oil and water are dropped into a hot pot that has a temperature of 250 °C. As a consequence of the rapid water evaporation, nearby oil is dispersed in the air. A part of the dispersed oil stays in the air as atomized oil mist and another part is deposited in the environment as larger oil drops. In practice the created oil mist is directed to the range hood by placing walls around the test procedure. When entering the range hood, a part of the oil mist stays in the grease filter. Non-filtered oil will deposit in the interior of the range hood, its ducting or finally in an absolute filter that is installed especially for this measurement. After weighing all parts of the setup, the deposited oil in each part is known and the grease absorption factor g_f is calculated as follows:

$$g_f = \frac{w_g}{w_r + w_t + w_g} \cdot 100 \quad (2)$$

where w_g is the mass of oil in the grease filter, w_r is the mass of oil retained in the airways and w_t is the mass of oil retained in the absolute filter. In the regulation (EU) No 65/2014 the grease absorption factor is called 'Grease Filtering Efficiency' and has the variable GFE_{hood}. The physical meaning of g_f of the standard and GFE_{hood} of the regulation is identical. In the following the Grease Filtering Efficiency will be referred to as grease absorption factor in order to achieve a consistent terminology.

The standardized test method for the odour extraction is currently not considered in the regulation and therefore is not discussed in this study.

DEVIATION IN MEASUREMENTS

The above-mentioned RRT involves five independent and accredited laboratories. Each laboratory carries out four repetitive measurements according to the standard EN 61591 on two selected range hoods. According to EN 61591 the grease absorption measurement is performed twice and g_f is averaged over the two measurements. Hence, each laboratory carries out eight repetitive measurements of the grease absorption. The tested range hoods are passed from laboratory to laboratory. From the results the intra-laboratory repeatability and inter-laboratory reproducibility can be assessed. So far two laboratories completed their measurements of the ongoing RRT. The results of laboratory 1 and laboratory 2 revealed large deviations for g_f. In Figure 1, it can be seen that the difference between the four measured values of g_f of the first laboratory that participated in the RRT is more than twice as large as the verification tolerance of 5 % as stated in the regulation. Laboratory 2 showed a better repeatability for g_f, but the average value of all four measurements is 12 % higher than the average g_f of laboratory 1. This indicates a poor reproducibility.

In addition, the total amount of captured and deposited grease ($w_g + w_r + w_t$) shows immense differences between measurements as depicted in Figure 2. The data used for Figure 1 and Figure 2 origin from the same measurements.

These findings suggest that the testing procedure for g_f is not accurate enough for the demanded tolerance of the regulation. As a consequence there is an increased chance that the information on the label is not true.

Definition of energy efficiency

The energy label has the purpose to illustrate the efficiency of products. Hence the measured performance is related to the measured energy consumption. The mathematical expression is the ratio of performance to consumed energy. This ratio should be the foundation for any formula that calculates an EEI. It is easily feasible to accurately determine the 'consumed energy'. However, to create a formula and a measuring process for the 'performance' that enable reproducible and meaningful results is more challenging. Another aspect is that the costs and time of the measuring process have to stay within a reasonable frame.

Range hoods have many functions, such as lighting, grease absorption and odour extraction. When used in extraction mode, range hoods also remove water vapour and smoke. Of these functions, the grease absorption can be considered as a main function of a range hood, since not filtered oil mist poses health

4. Commission Delegated Regulation (EU) No 65/2014 of 1 October 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of domestic ovens and range hoods Text with EEA relevance. ELI: http://data.europa.eu/eli/reg_del/2014/65/oj.

5. Riviere P. et al. (2009) ECODESIGN Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation) Study on residential ventilation – Final report, February, 2009.

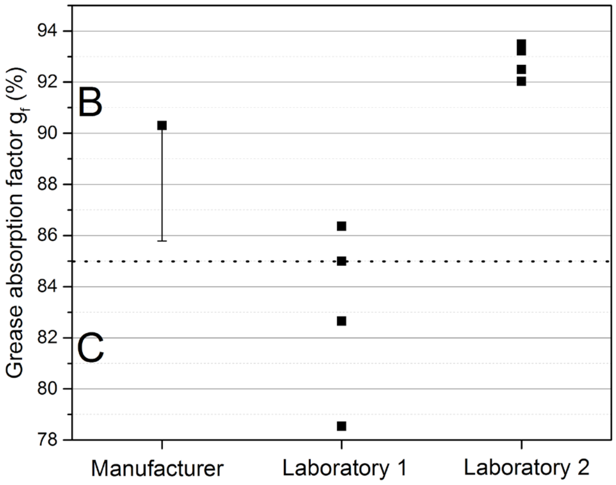

Figure 1. The left data point is the declared grease absorption factor of the manufacturer with the given tolerance according to the regulation. The grease absorption factor of the same range hood was measured four times by each of the independent laboratories 1 and 2. The letters B and C show the grease absorption class that is stated on the energy label. The dotted line represents the border between class C and class B.

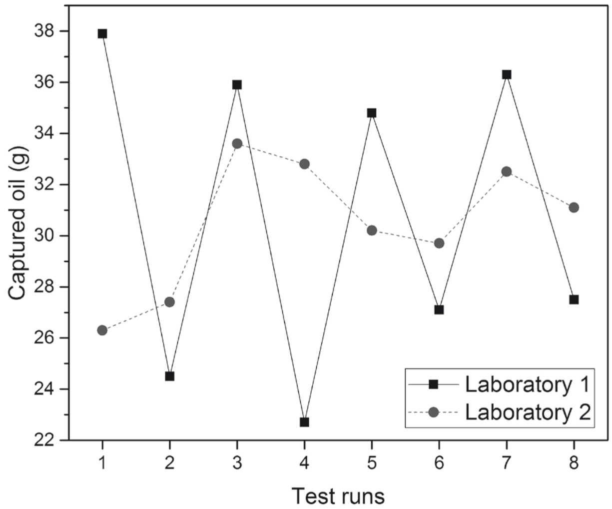

Figure 2. Total amount of captured oil ($w_g + w_{r+} w_t$) for eight examinations of the grease absorption factor of laboratory 1 and laboratory 2, respectively.

risks like asthma and lipid pneumonia[6,7,8]. In addition, the kitchen becomes sticky and demands intense cleaning if the oil mist is not filtered. Nevertheless, the grease absorption is only indirectly considered in the calculations of the EEI by the assumption that a higher volumetric airflow leads to a higher percentage of filtered oil. The amount of oil mist drawn into the range hood by the suction of the airflow is referred to as captured oil. The idea behind the current EEI is that a higher airflow is more likely to draw oil mist into the range hood than a lower airflow and that a larger amount of captured oil mist leads to a larger amount of filtered oil. This idea has two disadvantages. First of all it might be true that a higher airflow captures more oil mist when the same range hood is operated at different airflows, but it is not a valid assumption when different types are compared. In order to capture the same amount of oil, wall-mounted range hoods, which are installed close to the hob, need a lower airflow than ceiling range hoods, which are installed at a larger distance. Also downdraft systems, which are located closest to the hob and create a downward airflow, will differ in their ability to capture oil mist while operating at the same airflow. Another disadvantage of only considering the airflow for the EEI is that a range hood can theoretically obtain the best energy efficiency class without extracting any oil out of the air. This circumstance is particularly unfortunate when the range hood is used in recirculation mode and parts of the captured oil are returned to the kitchen. Range hoods that can only operate in recirculation mode are currently excluded from the energy label, but most range hoods offer the possibility to switch between extraction and recirculation mode. As a result many consumers find an energy label when looking for a range hood with recirculation mode. If the consumer wants to ensure that the oil mist is filtered, he would have to compare the EEI and g_f for each model, which is unlikely to happen in practice. It can be assumed, that the pictogram for g_f receives much less attention than the efficiency scale, as it is known from other product groups[9].

As a conclusion, the airflow has only limited significance for the evaluation of a range hood's energy efficiency, while the airflow itself is not even desired and rather annoying. Therefore, the airflow should not be used as the range hood's 'performance'. The problem can be solved by incorporating the grease absorption factor in the EEI instead of the FDE. In order to replace the FDE, the grease absorption measurement needs to be modified to assess the capture of oil in terms of absolute values.

Modified grease absorption

The current formula for g_f only describes the ratio of filtered to captured oil. But the consumer is also interested in the ratio of captured oil to produced oil mist. If it is not necessarily needed to know each of the two ratios, they can be multiplied to analyse directly the amount of extracted oil out of the air:

$$g_{f\ \mathrm{new}} = \frac{\text{filtered oil}}{\text{captured oil}} \cdot \frac{\text{captured oil}}{\text{produced oil mist}} \cdot 100$$

$$= \frac{\text{filtered oil}}{\text{produced oil mist}} \cdot 100 \qquad (3)$$

6. Svendsen, K. et al. (2002) Exposure to cooking fumes in restaurant kitchens in Norway. Ann Occup Hyg, 46 (4), pp. 395–400. doi: 10.1093/annhyg/mef045.

7. Robertson, A.S. et al. (1988) Occupational asthma due to oil mist. Thorax, 43 (3), pp. 200–205. doi: 10.1136/thx.43.3.200.

8. Oldenburger, D. et al (1972) Inhalation lipoid pneumonia from burning fats – newly recognized industrial hazard. Jama, 222 (10), pp. 1288–1289. doi: 10.1001/jama.222.10.1288.

9. Dünnhoff E., Palm A. (2014) Comprehensibility of the EU Energy Label – Results of two focus groups and a representative consumer survey.

With w_m as the mass of the produced oil mist, equation (3) can be written as:

$$g_{f\text{ new}} = \frac{w_g}{w_r+w_t+w_g} \cdot \frac{w_r+w_t+w_g}{w_m} \cdot 100 = \frac{w_g}{w_m} \cdot 100 \quad (4)$$

Hence only w_g and w_m have to be determined in order to calculate $g_{f\text{new}}$. The mass of filtered oil w_g can be obtained by weighing the grease filter as it was already done before. The mass of the produced oil mist w_m, however, cannot be measured with the current test method. The mass of the oil dropped into the 250 °C hot pot is known. But the ratio of created oil mist to splashes of oil is unknown and varies randomly from test to test. Moreover it is virtually impossible to weigh all surroundings of the pot to receive the combined weight of all splashes.

Therefore a procedure has to be found which creates an oil mist without sprinkling drops into the surroundings. In the following, three examples of altered setups for the grease absorption measurement are presented: a) in a vessel with an orifice, b) passing water vapour into oil and c) using an atomizer nozzle.

In a) oil and water are mixed in a closed vessel with an orifice where the water vapour and oil mist can escape as presented in Figure 3a. Splashes are kept within the vessel by an obstacle which is in between the orifice (triangle in Figure 3a) and the point where oil and water are heated. The oil mist will still move past the obstacle to the highest point due to buoyancy. This promising idea has some disadvantages though. During application, much of the water vapour and oil mist condense on the walls during their way to the orifice. When accumulated to larger amounts, the condensed water and oil flow back to the original starting point where the water vaporizes again and the cycle repeats. Continuously a little water vapour and oil mist leave the vessel. Unfortunately, the escaped fraction is so small that this procedure takes too long to test a range hood in a reasonable amount of time. Increasing the size of the whole object would not allow accurate measurements of the weight. Transferring more heat to the upper part of the vessel would only make the condensed water evaporate and lead to the decomposition of the deposited oil without a significant increase of the yield.

In b) water vapour passes through a beaker filled with oil at 120 °C. In this setup the water already evaporated before coming in contact with the oil and does not create any splashes. As illustrated in Figure 3b) a closed beaker filled with water is heated up to produce water vapour that passes through the oil. The idea was that the water vapour lifts some oil out of the beaker and into the air. However, during application it was observed that no oil left the beaker even after running the procedure for hours. Thus it can be concluded that the rapid water evaporation needs to happen adjacent to the oil in order to create the oil mist which can be observed in the kitchen.

The most promising experiment c) was to utilize an atomizer nozzle for the creation of oil mist. The impact of the compressed air atomizes small amounts of oil at the tip of the atomizer nozzle. This technique creates appropriate amounts of oil mist necessary for testing range hoods in little periods of time and without any splashes. Therefore the input of oil, which can be easily measured, equals w_m and allows for calculating $g_{f\text{new}}$. Another possible advantage is that using an atomizer nozzle might decrease time and cost compared to the current grease absorption test. When using an atomizer nozzle there is no time needed to wait for the setup to heat up to a temperature of 250 °C. Also the cleaning of burned oil becomes no longer necessary which saves working time and thus personnel costs.

Conclusion and recommendations

In this paper the test standard EN 61591 is analysed. It is found that the grease absorption measurement reveals considerable drawbacks. The experimental results of independent and accredited laboratories indicate a poor repeatability and reproducibility of the method used to determine the grease absorption factor. The setup involves heating up oil and water in a pot that leads to random amounts of splashes of grease and thus a poor repeatability. As another disadvantage of the setup it is pointed out that the total amount of produced oil mist cannot be measured. Hence, different alternative methods for the evaluation of the grease absorption factor are pro-

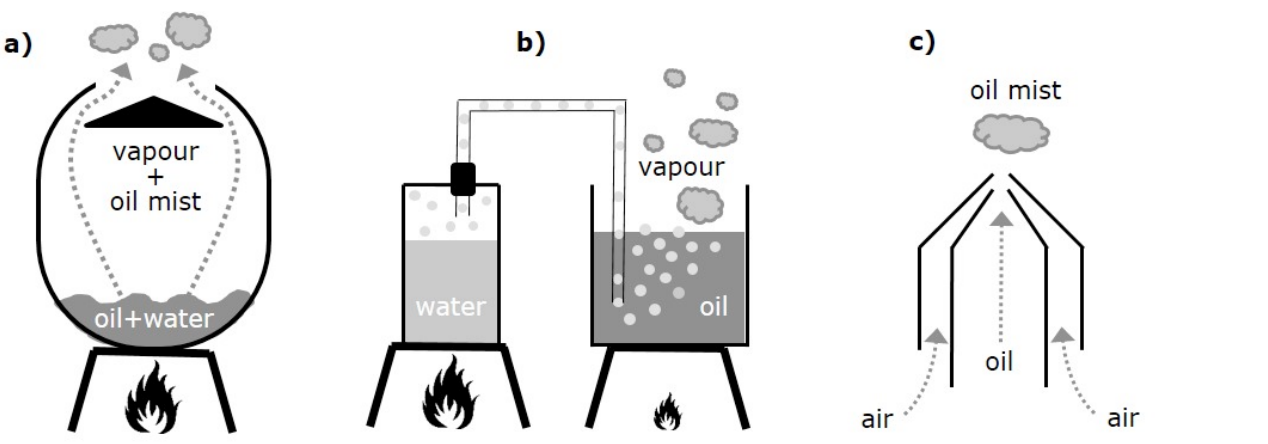

Figure 3. a) A vessel is heated up to 250 °C and filled with water and oil. The water evaporates and creates oil mist and splashes. Due to buoyancy the steam and oil mist leave the vessel, while splashes stay inside. b) Evaporated water is conducted through a beaker filled with oil. c) Utilization of an atomizer nozzle: Compressed air is directed onto small droplets of oil. The impact of the air turns the drops into mist.

posed. The most prospective technique involves an atomizer nozzle which enables the determination of the exact amount of created oil mist.

With the implementation of an atomizer nozzle the repeatability and reproducibility of the grease absorption measurement can be increased. Furthermore, bad aerodynamic designs and leaked oil mist can be taken into account.

Finally, the proposed new method extends the grease absorption test by the evaluation of the range hood's ability of capturing oil. The capture of oil is currently covered by the volumetric airflow. However, the airflow itself is not desired and involves several problems when used for the assessment of range hoods. With the modified grease absorption being considered in the Energy Efficiency Index, manufacturers have more freedom in designing their product and are rewarded for innovative operating principles that capture oil mist with little airflow and thus less energy consumption. Consequently, the proposed method introduced a promising basis for a revision of the EEI towards more significant and consumer relevant declarations which will be subject of future work.

Acknowledgements

This project is financed as part of the National Action Plan on Energy Efficiency (NAPE) of the Federal Ministry for Economic Affairs and Energy.