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Arno Knieschewski

**Energy efficiency rating of
cooking fume extractors based
on captured and filtered oil mist**

Energy efficiency rating of cooking fume extractors based on captured and filtered oil mist

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Abstract

The energy efficiency rating on the European Union energy label for cooking fume extractors is based on measurements of the flow rate and static pressure difference within the duct behind the cooking fume extractor according to standard EN 61591:1997/A12:2015 and regulation (EU) No 65/2014. These measurements do not enable a definite conclusion about the cooking fume extractor's air purification performance. Measurements which evaluate the air purification performance directly would be more valuable for consumers.

In this thesis, a test method was developed that enables the energy efficiency rating of cooking fume extractors based on a direct measurement of the air purification by measuring the captured and filtered oil mist. The test method also enables the rating of cooking fume extractors that operate in recirculation mode, which is not possible using the current standard EN 61591:1997/A12:2015.

The performance rating based on removed oil mist requires a reproducible generation of oil mist. Furthermore, the generated oil mist should resemble the oil mist from common cooking scenarios to give meaningful performance ratings. The oil mist from the grease absorption test according to standard EN 61591:1997/A12:2015 was taken as a reference oil mist for common cooking scenarios. A round robin test revealed that the oil mist generation with the grease absorption test from the standard is not reproducible enough for performance tests. The oil mist generation with atomizer nozzles was found more suitable for the reproducible generation of an oil mist.

Two different atomizers were analyzed by measuring the properties of generated oil mist and by applying them in performance tests on cooking fume extractors. One "mantled atomizer" was bought from the market and one "open atomizer" was developed specifically for the test of cooking fume extractors.

It was found that an oil mist with similar properties compared to the reference oil mist can be generated with the design of the open atomizer. The proposed test method using the open atomizer led to a better repeatability compared to the grease absorption tests according to the current standard and has the potential to improve the reproducibility. The results suggest that the proposed test method could be used for standardized testing which would enable more meaningful energy efficiency ratings and the rating of cooking fume extractors that operate in recirculation mode.

Zusammenfassung

Die Energieverbrauchskennzeichnung der Europäischen Union von Dunstabzugshauben basiert auf den Messungen des Volumenstroms und der statischen Druckdifferenz im Abluftrohr hinter der Dunstabzugshaube gemäß der Norm EN 61591:1997/A12:2015 und Verordnung (EU) No 65/2014. Diese Messungen erlauben keine eindeutigen Rückschlüsse auf die Luftreinigungsfunktion der Dunstabzugshaube. Eine Energieeffizienzbewertung, welche auf Messungen beruht, die die Luftreinigungsfunktion direkt messen, hätte einen größeren Nutzen für die Verbraucher.

In dieser Arbeit wird eine Prüfmethode vorgestellt, welche die Energieeffizienzbewertung von Dunstabzugshauben durch eine direkte Messung der Luftreinigungsfunktion ermöglicht, indem die Masse eines eingefangenen und gefilterten Ölnebels ausgewertet wird. Die Prüfmethode erlaubt außerdem die Bewertung von Umlufthauben, was mit der jetzigen Prüfnorm EN 61591:1997/A12:2015 nicht möglich ist.

Die Leistungsbewertung bezogen auf entfernte Öltropfen benötigt eine reproduzierbare Ölnebelproduktion. Des Weiteren soll der produzierte Ölnebel dem Ölnebel von typischen Kochvorgängen ähneln, um eine aussagekräftige Energieverbrauchskennzeichnung zu ermöglichen. Der Ölnebel vom Fettabscheidegradtest der Norm EN 61591:1997/A12:2015 wurde als Referenz für typische Kochvorgänge genommen. Ein Ringversuch hat ergeben, dass die Ölnebelproduktion vom Fettabscheidegradtest nicht reproduzierbar genug ist, um die Leistung von Dunstabzugshauben zu bewerten. Eine zuverlässigere Ölnebelproduktion konnte mit Zerstäuberdüsen erreicht werden.

Zwei verschiedene Zerstäuber wurden analysiert, indem der produzierte Ölnebel vermessen wurde und die Zerstäuber in Leistungsprüfungen von Dunstabzugshauben eingesetzt wurden. Ein „verhüllter Zerstäuber“ wurde gekauft und ein „offener Zerstäuber“ wurde speziell für den Test von Dunstabzugshauben entwickelt.

Der offene Zerstäuber konnte einen Ölnebel erzeugen, welcher ähnliche Eigenschaften hatte wie der Referenzölnebel. Die vorgeschlagene Prüfmethode zeigte mit dem offenen Zerstäuber eine bessere Wiederholbarkeit als der Fettabscheidegradtest der derzeitigen Prüfnorm. Die Ergebnisse zeigen, dass die vorgeschlagene Prüfmethode als Prüfnorm genutzt werden könnte, um die Aussagekraft der Energieverbrauchskennzeichnung zu erhöhen und die Bewertung von Umlufthauben zu ermöglichen.

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List of acronyms

AC – Alternating Current

AEC – Annual Energy Consumption

AMK – Arbeitsgemeinschaft Die Moderne Küche e.V.

BEP – Best Efficiency Point

CFE – Cooking Fume Extractor

DC – Direct Current

EEI – Energy Efficiency Index

FDE – Fluid Dynamic Efficiency

LE – Lighting Efficiency

LED – light-emitting diode

MEES – Minimum Energy Efficiency Standards

MEK – Methyl-Ethyl Ketone

RRT – Round Robin Test

SAEC – Standard Annual Energy Consumption

WP – Working Point

List of symbols

Latin symbols

A_i – average cross-sectional area of installed air ducts

A_o – cross section of air outlet

c – isobaric specific heat capacity

c_1 – concentration of MEK in room air without CFE

c_2 – concentration of MEK in room air with CFE

d – diameter

$d_{d,s}$ – diameter of the smaller droplet in a collision

E_a – air tempering energy

E_{CFE} – annual energy consumption of a cooking fume extractor

E_L – average illumination of the lighting system with a maximum of 1000 lux

E_{middle} – average illumination of the lighting system

E_{tot} – total annual energy consumption

f – time increase factor

f_a – air tempering factor

FDE_{hood} – fluid dynamic efficiency at the best efficiency point

g – gravitational field strength

g_f – grease absorption factor

h_1 – height 1: 33 cm above the cooktop

h_2 – height 2: 50 cm above the cooktop

m – mass

m_c – mass of captured oil

m_e – mass of emitted oil

m_f – mass of filtered oil

O_f – odor reduction factor

Oh – Ohnesorge number

p – pressure

p_c – pressure of compressed air

P_{BEP} – static pressure difference at the best efficiency point

P_{el} – electric power input

P_L – electric power input of the lighting system

P_O – electric power input in off-mode

P_S – electric power input in standby mode

P_{WP} – electric power input at the working point

Q – volumetric flow rate

Q_{BEP} – volumetric flow rate at the best efficiency point

Q_h – heat

Q_{max} – maximum volumetric flow rate at highest speed setting

Re_p – particle Reynolds number

$s_{r,rel}$ – repeatability standard deviation relative to the mean

$s_{R,rel}$ – reproducibility standard deviation relative to the mean

t_H – 60 min, average running time per day of CFEs

t_L – 120 min, average lighting time per day of CFEs

v – velocity

$v_{a,max}$ – maximum airflow velocity

$v_{d,av}$ – vertical component of the average droplet velocity

$v_{d,col}$ – relative velocity of colliding droplets

W_{BEP} – electric power input at the best efficiency point

We – Weber number

We_c – critical Weber number

We_{col} – collision Weber number

w_g – mass of oil in grease filter

W_L – electric power input of the lighting system

w_T – mass of oil retained in airways

w_t – mass of oil retained in absolute filter

Greek symbols

Δp – static pressure difference

ΔT – temperature difference

ζ – pressure loss coefficient

η_c – capture efficiency

η_f – filter efficiency

η_r – removal efficiency

κ – heat capacity ratio

μ – dynamic viscosity

ρ – mass density

ρ_c – density of compressed air

σ – surface tension

τ_p – particle relaxation time

Multiply used unique indices

a – air

d – droplet

WP – working point

BEP – best efficiency point