THE Facts Mechanical Grease

By **Andrey Livchak,** Member ASHRAE, **Derek Schrock,** Member ASHRAE, **Matti Lehtimaki,** and **Aimo Taipale**

Many kitchen hood manufacturers claim the efficiency of their grease filters is 90% or higher, and they reference several standards[1,2] to support the performance measurements. Unfortunately, none of these standards represents filter performance under cooking conditions. Grease emissions from cooking processes consist of particulate and vapor. Mechanical grease extractors are effective only at capturing particulate and are not able to extract vapor.

That is why, theoretically, the maximum grease extractor efficiency cannot exceed the mass fraction of particulates in the total cooking emissions. This maximum efficiency depends on cooking operations and ranges from 2% to 70% for electric ovens and gas broilers, respectively, based on the percentage of vapor in the emissions from cooking operations.[3]

Cooking Emissions

An ASHRAE research project, RP-745, documented emissions from different cooking processes. The results are presented in *Figures 1* and *2*. *Figure 1* shows total emissions as a function of the cooking process and *Figure 2* gives the breakdown between vapor and particulate in cooking emissions. The percentage of particulate in this figure corresponds to the theoretical maximum efficiency of a mechanical grease extractor.

Furthermore, the particulate portion of cooking emissions differs greatly in particle size as indicated in RP-745. In regards to mechanical filtration, it is easier to capture large particles than small ones. To be able to determine the actual grease extraction performance in different cooking operations, one must know the filter efficiency as a function of particle size and airflow/pressure drop across the filter.

Test Method

German standard VDI 2052[4] describes the test method that determines filter efficiency as a function of particle size. Three filters from different manufacturers were selected for testing extraction efficiency: one multicyclone filter and two commonly used baffle filters (*Figure 3*). The measurements were conducted at VTT (Technical Research Center of Finland, an independent state-owned research organization) by following the principles of the VDI 2052 standard.

Efficiency measurements were made by using DOS (di-ethyl-hexyl-sebacate) particles generated with a spinning top

aerosol generator in a particle size range of 4 – 10 µm and with a pneumatic nebulizer in the particle size range of 1 – 5 µm. Particle concentrations from the upstream and downstream of the grease filter were measured with an aerodynamic particle sizer (APS). The measured particle size distributions before and after the tested filter were used to calculate the fractional efficiency, i.e., the efficiency as a function of particle size. For each particle size (d_p), the fractional efficiency $E_f(d_p)$ was determined as follows:

$$E_f(d_p) = 100\left(1 - \frac{c_b(d_p)}{c_a(d_p)}\right) \qquad (1)$$

where $c_a(d_p)$ and $c_b(d_p)$ refer to the upstream and downstream particle concentrations.

The filters were placed in a test stand at a 45° angle. Measurements were made at three to four different flow rates for each filter. Test particles were introduced into a mixing chamber, and filtered supply air was directed into the mixing chamber and then to the test stand. The operation of the spinning top aerosol generator was controlled during the measurement so that particles up to 10 µm were generated.

Measurement Results

The results are presented in *Figure 4* for three different airflows. Each filter's performance is compared at the same airflow per linear length as if the filters were installed in the same hood to handle different cooking operations: light, medium

Research shows that multicyclone filters are most effective at removing effluents from cooking hamburgers.

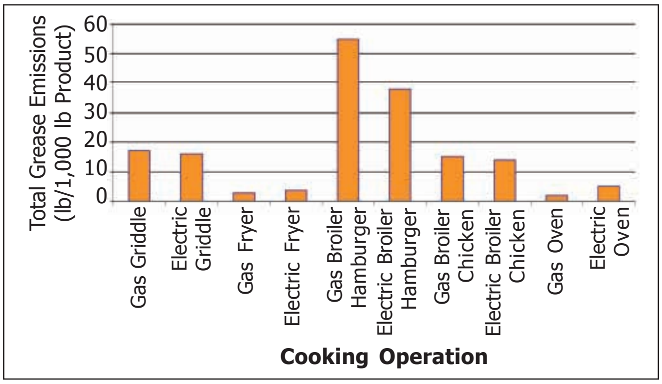

Figure 1: Cooking emissions as a function of cooking process.

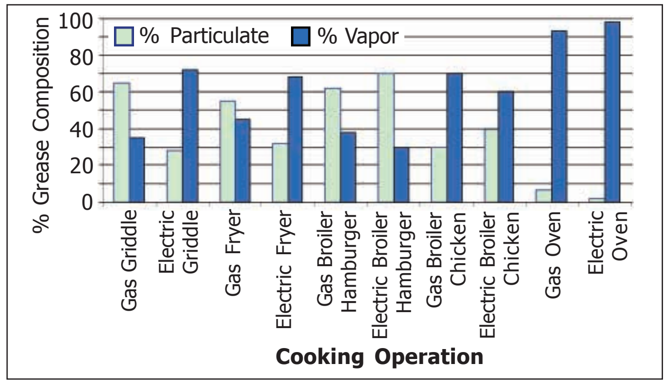

Figure 2: Vapor and particulate ratio in cooking emissions.

and heavy duty at 144, 196 and 274 cfm/ft (224, 304 and 424 L/[s·m]) accordingly. Comparing filter performance at the same airflow per filter length is the most representative method of actual filter application.

Figure 4 shows that none of the mechanical filters is effective in capturing particles less than 2.5 µm. Filtration efficiency varies significantly with filter design and manufacturer. The cyclonic filter traps at least twice the amount of grease compared to the best baffle filter in the particle range from 2.5 to 10 µm at the exhaust airflow 274 cfm/ft (424 L/[s·m]) and three times more grease at 144 cfm/ft (223 L/[s·m]) and 196 cfm/ft (303 L/[s·m]) exhaust airflow. Filtration efficiency for all filters increases with the airflow as a result of higher pressure drop across the filter.

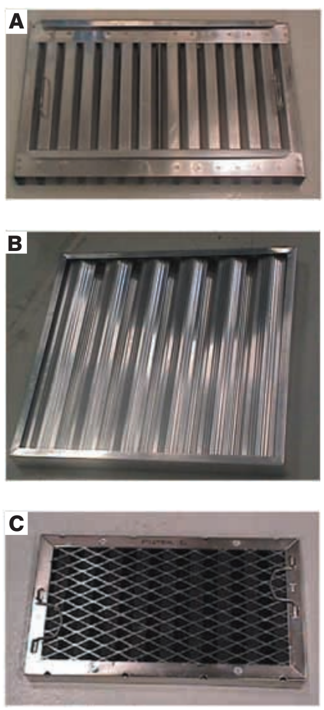

Figure 3: A — cyclonic filter; B—baffle filter I; and C—baffle filter II.

Filter Efficiency as Function of Cooking Process

By knowing the efficiency of filters as a function of particle size and particulate distribution for different cooking operations, it becomes possible to calculate filtration efficiency for different cooking operations. The method consists of three stages:

1. Determine emissions for a cooking process (vapor and particulate) including particle distribution for particulate emissions.

2. Determine filter efficiency as function of particle size and airflow range through the filter.

3. Calculate filter efficiency for the cooking process by overlaying the filter efficiency curve with the particle distribution curve for the cooking process at the design airflow (for this cooking operation) through the filter.

The benefit of this method is that Stages 1 and 2 are conducted independently. A filter efficiency test is not necessary for every cooking process providing there is adequate information on the cooking emissions (vapor, particulate and particle distribution) and the filter efficiency as function of a particle size.

The filter efficiencies as a function of cooking process are presented in *Table 1*. The table contains the data from RP-745 on cooking emissions and calculated mass efficiencies for Filters A, B and C. Two filter efficiencies are presented: total (as a ratio of grease captured to total cooking emissions) and particulate efficiency (as a ratio of grease captured to particulate emissions). Notice that the total filter efficiency, even for the best grease extractors, does not reach 90% because mechanical filters cannot trap vapor effluents.

Table 1 also presents the amount of grease captured by three filters tested in lb (kg) per 1,000 of lb (kg) of product cooked. This practical data can help a food service operator select a filter. For example, comparing the amount of grease captured by Filter A and Filter B over a gas broiler cooking hamburgers indicates that Filter A extracts twice the amount of grease from cooking effluents. That means 14.4 lb (6.5 kg) less grease in the exhaust duct and on the restaurant roof per 1,000 lb (454 kg) of hamburgers cooked for a hood equipped with Filter A.

Cooking emissions and their composition (vapor, particulate and particle size distribution), depend on many factors, such as the product being cooked, cooking process and cooking appliance. Sampling method and location of the sampling probe also affects emissions data. Exhaust airflow and the subsequent temperature of the effluents passing through a filter affects condensation of grease vapor. The higher the exhaust airflow, the lower the temperature of the effluents, and the balance vapor/particulates shifts towards particulate in the effluent composition. The higher the ratio of particulate to vapor in the emissions, the higher the overall mechanical grease extraction efficiency. However, this phenomenon should not be considered a recommendation to use hoods with higher exhaust

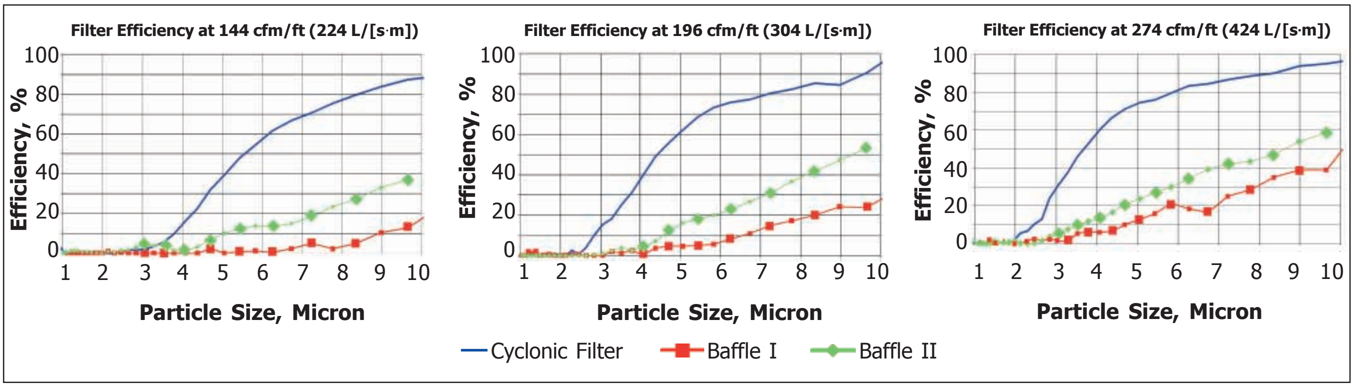

Figure 4: Filter efficiency as function of particle size for three exhaust airflows.

airflows. These hoods have high energy and air-conditioning system costs.

Conclusions

• Mechanical grease filter efficiency is a function of cooking operation and airflow (pressure drop) across the filter. The theoretical maximum total grease removal efficiency (as percentage of grease captured to the total cooking emissions including vapor and particulate) ranges from 5% to 70%.

• The efficiency of grease removal devices varies with the filter design. The cyclonic filter demonstrates at least two times higher filtration efficiency compared to the baffle filter (in the particle range from 2 to 10 μm).

• Methodology of defining filter efficiency as function of cooking process is proposed.

• A test protocol determining emissions from various cooking operations should be developed. The emissions database from various cooking processes should be created containing data on total emissions, percentage of particulates and particulate distribution.

• The test protocol to determine filter efficiency as a function of particulate size and airflow should be developed. The VDI 2052 standard can be used as a baseline.

• Prior to this testing, it was anticipated that filtration efficiency would be close to 100% for particles 10 μm and higher. This was not confirmed by the measurements, especially for baffle filters. Further measurements should be conducted with a larger range of particle sizes (from 1 to 20 μm) to determine when 100% capture occurs.

Cooking Operation	Emissions		Total Filter Efficiency			Filter Efficiency for Particulate Only			Grease Particulate Extracted lb/1,000 lb		
	Total lb/1,000 lb	% Vapor	Filter A	Filter B	Filter C	Filter A	Filter B	Filter C	Filter A	Filter B	Filter C
Gas Griddle	17	35%	60%	22%	30%	92%	33%	47%	10.17	3.68	5.15
Electric Griddle	16	72%	26%	9%	13%	92%	33%	46%	4.10	1.49	2.08
Gas Fryer	3	45%	51%	19%	26%	93%	35%	48%	1.53	0.58	0.79
Electric Fryer	4	68%	28%	8%	13%	87%	26%	41%	1.11	0.34	0.52
Gas Broiler Hamburger	55	38%	55%	28%	33%	88%	46%	54%	30.07	15.67	18.28
Electric Broiler Hamburger	38	30%	60%	31%	36%	85%	44%	52%	22.64	11.73	13.75
Gas Broiler Chicken	15	70%	20%	10%	12%	68%	34%	40%	3.05	1.52	1.80
Electric Broiler Chicken	14	60%	28%	14%	17%	71%	35%	42%	3.97	1.97	2.35
Gas Oven	2	93%	6%	1%	3%	85%	21%	37%	0.12	0.03	0.05
Electric Oven	5	98%	2%	0%	1%	81%	19%	34%	0.08	0.02	0.03

Table 1: Cooking emissions and calculated mass efficiencies for the three filters.

References

1. Underwriters Laboratories. 2000. UL 1046, *Grease Filters for Exhaust Ducts,* 3rd edition.

2. Underwriters Laboratories. 1997. ULC-S649-93, *Grease Filter for Commercial and Institutional Kitchen Exhaust Systems*.

3. Gerstler, W.D., et al.1999. "Identification and Characterization of Effluents from Various Cooking Appliances and Processes as Related to Optimum Design of Kitchen Ventilation Systems." ASHRAE 745-RP, Phase 2, Final Report.

4. VDI. VDI 2052, Part 1, "Ventilation Equipment for Kitchens. Determination of Capture Efficiency of Aerosol Separators in Kitchen Exhaust."

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