Cooking Emissions and the (Supposed) "Light Fantastic"

By F. M. (Tim) Farrell

The greasy effluent produced by commercial cooking is a significant cost for foodservice operators, as well as a growing concern for insurers and health and safety officials. Air quality regulators, code officials, and even commercial landlords, especially in California and dense urban areas, are giving these greasy emissions more attention and seeking to limit what comes out of the "tailpipes" of restaurant exhaust systems. In response, manufacturers are offering a parade of innovations to respond to the challenge, and although many of these are helpful, a few appear to be not as effective as once thought.

One attempt at innovation is inclusion of germicidal-type UV lamps in commercial kitchen exhaust hoods, with claims of near-complete oxidation of grease to CO_2 and water by UV radiation and related ozone. UV hoods command a very substantial price premium yet, after more than a decade on the market, they remain a controversial and expensive approach to grease problems. Until very recently manufacturers of these hoods could present only anecdotal evidence of effectiveness and no independently verified performance data.

As a consulting research director and chemical engineer, I was recently asked by a manufacturer of commercial kitchen ventilation (CKV) systems to provide advice on new product development. In particular, I was asked to assess whether the inclusion of UV sources in a hood will offer benefits to users. This article reports my findings and cites relevant, peer-reviewed scientific studies that demonstrate the claimed decomposition of grease does not actually happen, contrary to previous expectations. Research indicates that there are also a substantial number of actual kitchens in which UV hoods have failed to perform and have required expensive maintenance or even retrofitting.

Background

The various effluents from cooking are water vapor, grease vapor, grease droplets, solid particles of foods and char. The droplets and particles form an aerosol, i.e. matter in the liquid and solid phases, while the vapors, both condensable and non-condensable, are in the gas phase. The non-condensable vapors are called volatile organic compounds (VOCs). This state-of-matter variation is an important distinction when considering abatement techniques.

Most of the grease produced in cooking comes from meat or fish as it is being heated. Some of the grease is entrained in the plume rising from the appliance and pulled into the ventilation system. Different foods and different types of appliances produce vastly different amounts of greasy effluent and contain many chemical compounds[1, 2]. The exhaust stream is also highly dynamic, in that it is diluted and cooled by the kitchen makeup air that mixes with the cooking plume entering the hood. Grease wets virtually every surface it contacts and tends to build in thickness. Wherever grease collects, it becomes a sanitation and safety hazard.

Fire and building codes, UL standards[3,4], and lease agreements impose various performance requirements on kitchen ventilation systems. The oldest and most universal requirement is for fire safety[5]. Flare-ups from charbroilers, fryers and other appliances are common. The first line of defense is the filters or baffles in the hood; these act as flame stops to contain the spread of fire until the fire suppression system extinguishes it. U.S. Fire Administration data validates the fact that accumulation and ignition of grease are responsible for about 2/3 of kitchen fires[6]. Because of this safety concern, and the fact it is unsanitary and requires expensive cleaning, grease management gets lots of attention from foodservice operators and related equipment manufacturers and increasingly from government building, fire, health, and environmental officials.

The CKV industry has grown and innovated to serve these needs. Hood systems have improved dramatically in design and performance over the last several decades. New tools such as "Schlieren" flow visualization, emissions measurement instrumentation, aerosol science, computational fluid dynamics, etc., have been developed in the industry and borrowed from many other fields. These new technologies have advanced kitchen ventilation from an art form to a field with very capable engineering tools. It is an evolution quite comparable to the progress made decades ago to assure sanitary food handling, and high quality hoods and filters are available from many leading suppliers.

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Analysis of UV and Ozone Effectiveness Claims

Most UV systems are designed for germicidal applications in HVAC, surface sanitizing, and water purification. As a germicidal agent, UV-C (at 254 nanometers) has proven to be very effective at inactivating or "killing" microorganisms such as mold spores, bacteria, and viruses[7]. UV acts on these life-forms by breaking up their DNA; a low-energy process compared to the energy required to oxidize grease.

All hood designs include some form of primary grease filtering. UV hoods add secondary filters that capture larger-size aerosols (above 3 – 5 microns) of the grease before they enter the UV zone. This improved filtration is the primary reason for the seeming effectiveness of UV hoods, but is only a tiny fraction of the increased cost. While adding secondary filters is relatively inexpensive, they bring increased operating costs and additional challenges.

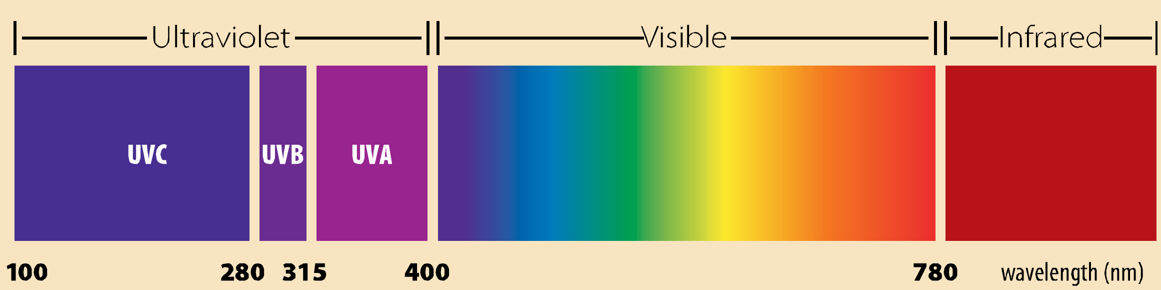
Secondary filters require more frequent cleaning or grease will build-up and reduce exhaust flow, causing the hood to spill. Added build-up is also fuel that can increase fire hazard. When secondary filters are installed incorrectly or removed, the system's design is defeated and line workers may be exposed to UV irradiation reported to be harmful[8]. Lastly, some secondary filters can be considered in violation of NFPA 96.

The claims of UV decomposing grease in kitchen exhaust systems are based on two distinct types of chemical reactions. In the first, **UV radiation** is claimed to photochemically decompose some of the grease aerosols and VOCs as they quickly pass through the lighted zone. The UV energy also is said to decompose the grease film deposited on the illuminated surfaces in the plenum to an easily-cleaned residue. UV-driven decomposition is known as photolysis.

In the second reaction, **ozone gas** (O_3) a strong oxidizing agent, is produced by the UV lamps from atmospheric oxygen (O_2) and is claimed to react with the entrained grease as it flows through the plenum and the downstream exhaust duct. This reaction is called ozonolysis. The exposure time to ozone for the exhaust stream is longer than the exposure to the UV irradiation, however in most exhaust duct systems, the time available is only seconds, at most.

The addition of UV lamps is doing nothing less than converting a hood from a simple ventilation device into a complex chemical reactor – not a trivial challenge and one that can more than double the cost of a hood. New research indicates that the chemical reactions described above do happen, but certainly not resulting in complete oxidation to CO_2 and water. The critical question is whether UV in a hood offers any real value when subjected to real-world CKV conditions, based on a rigorous engineering and economic analysis.

All chemical reactions must have starting materials (reactants) and require either an input of energy (endothermic, e.g. baking) or give off energy (exothermic, e.g. grease fire). With some reactions, a small amount of energy is input (activation) and then the reaction becomes self-sustaining and exothermic. Reaction energy is typically in the form of heat, but in the case of UV, it is high-energy light waves (photonic).



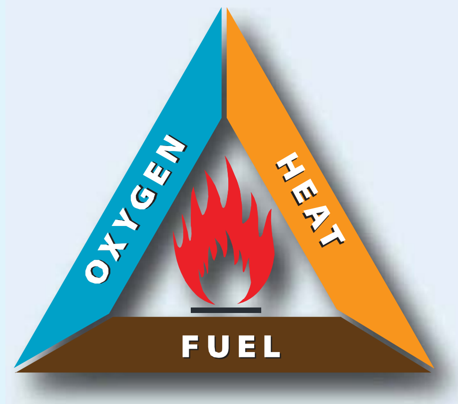
Consider fire – it is a chemical reaction which is simply very rapid oxidation. Fire requires a combination of three elements, often represented by a triangle: fuel, oxygen, and energy (heat). All three elements must be present for a fire to start and keep burning. Both prevention and extinguishing strategies involve preventing the combination or removing one of the elements. Fuel and oxygen are the reactants, while heat activates and/or sustains the reaction. Starting a fire is endothermic, but it becomes exothermic and self-sustaining due to the heat produced. Importantly, complete oxidative decomposition of grease below its flash point (~ 370–425°F in air) is exclusively endothermic – energy must continue to be added to sustain the reaction to completion.

The facts about UV and ozone reactions are these:

UV reactions in the C wavelength have received comparatively little study since UV-C is mostly blocked by the upper atmosphere. However, several studies do show that UV reactions with organic compounds break up the starting molecules into smaller ones[9], but do not drive the decomposition to CO_2 and water even with significant exposure time. In a CKV application, grease aerosols and vapor are passing through the lighted zone at 500 to over 1500 feet per minute. This allows only milliseconds of exposure for the transfer of photonic energy to drive reactions. Moreover, UV intensity is greatest at the surface of the lamp tubes; so reactions that do happen will happen there first and create a film that increases in thickness and reduces the UV energy radiating into the flowing exhaust stream.

Ozone chemistry has received a great deal of attention over the last several decades by researchers all over the world because of its role in air pollution. It is both the cause of and caused by reactions with other pollutants, mainly VOCs[10]. Many of these atmospheric reactions are photochemical, i.e. caused by light energy, specifically UV.

Grease includes many chemical compounds. In general, they are hydrocarbons and more specifically, long-chain fatty acids[11]. Beef fat, for example, is 47% oleic acid. When these compounds are completely oxidized, the final products are CO_2 and water. This is claimed to happen to most of the grease exposed to UV and ozone, resulting in clean hoods, ducts and fans. *However, there is a major flaw in this claim*. There is far too little UV energy and exposure time, and too little ozone and heat to drive



the reactions to completion. Yes, some of the grease reacts but little, if any, goes to the claimed CO_2 and water products.

Oleic acid is a molecular chain of 18 carbon atoms; there is a double bond between just two of the carbons and is said to be mono-unsaturated. Other fats are saturated, with no double bonds, while still others are unsaturated, with many double bonds. All types of fats are found in the cooking effluents of meat and fish. Double bonds are a "weak link" in all organic compounds, including grease.

The reactions that do occur in a UV hood happen at the double bonds which are the most chemically-susceptible sites for attack by an oxidizer like ozone or by UV photons. In medium and heavy duty cooking, a large quantity of grease in sub-three-micron aerosols and vapor will flow into the UV zone, regardless of any filtering ahead of the reaction zone. This flow will simply contain far too many double bonds and too little residence time for reaction. All ozone and all UV energy will be consumed before any practical amount of decomposition can happen. In other words, two sides of the reaction (fire) triangle – oxidizer & energy – are inhibited.

The net effect is that grease will continue to "plate out" onto all surfaces or be blown into the atmosphere from the exhaust system. Moreover, the reactions that do happen will create lower molecular weight compounds that do not normally occur in CKV exhausts, and may be more toxic. These new compounds, by virtue of their lower mass, have higher diffusion rates, causing a much larger fraction of them to be exhausted into the environment. This is certain to attract the attention of air quality regulators.

Notwithstanding the analysis above, at least two further questions are pertinent and

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need to be answered by further research:

- What new classes of compounds are caused by UV and ozone, and what is the toxicity of these compounds not otherwise present?
- How effective, under actual usage conditions, are UV hoods at protecting the kitchen staff from the health hazards inherent in exposure to UV-C radiation?

My foregoing technical analysis is corroborated by several case studies of ill-performing UV hood installations I have reviewed. In at least one case, filters were installed incorrectly and harmful UV-C light was visible to workers on the cooking line. In several other cases, kitchen staff have removed the secondary filters due to reduced exhaust flows and hood spillage. They then observed that grease deposited more rapidly on hoods and ducts. This behavior is consistent with the chemistry and mechanisms discussed above.

These cases all indicate that in addition to higher first costs, UV hoods impose high maintenance costs for UV lamp cleaning and replacement, replacement of UV-C degraded wiring, and little or no reduction in hood and duct cleaning costs.

Conclusion

Analysis of the underlying chemical processes and comparison between claims and actual case studies of UV hood installations now indicate that UV hoods, as currently developed, have very little practical value, and now appear to be an expensive technological dead end.

My recommendation to my client is to not add UV hoods to its product line development, and instead, provide leadership in development of less expensive, commercially viable and more effective grease filtration and pollution control technologies.

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