Evidence Against Routine Cooking Flare-Ups as a Valid Ignition Source for Range-Hood Fires

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Background

- Momentary flare-ups from restaurant grills and ranges are common
- Investigators often believe brief flame impingement on grease-laden filters provides a competent ignition source
- Flare-up duration and size are important factors in heating grease up to its smoke point

Hood Filter Heat Flux

- Flame heights computed: $L_f = 1.3\ m$
- Using flare-up fuel estimates from prior slide, SFPE Handbook Fig. 2-14.14 and Eq. 15 (p.2-277) give:

$$q''_{lard} = 24.6\ \frac{kW}{m^2}$$

$$q''_{alcohol} = 17.2\ \frac{kW}{m^2}$$

- SFPE Handbook cites asymptotic maximum observed heat flux (10 experiments) from buoyant fire plumes:

$$q''_{max} \approx 90\frac{kW}{m^2}$$

Results Summary

- For moderate initial grease temperature ($T_{init} = 50°C = 122°F$) and moderate heat flux $\left(q'' \approx 20\frac{kW}{m^2}\right)$ the time for the grease surface to reach it's smoke temperature exceeds $t = 60\ sec$
- For momentary flare-ups ($t < 4.0\ sec$) ignition of grease does not occur unless initial temperature is very high ($T_{init} > 75°C$)and flare heat flux is very high $\left(q'' > 80\frac{kW}{m^2}\right)$.
- High initial temperature could result from exhaust fan failure.
- High heat flux occurs when the pool fire grows and both the diameter and height of the fire are larger
- UL 1046 testing requires "no flame extension" with a 70 kW pilot flame for 3 min (180 sec)

Flare-up Fuels

- Char-Broiler – Lard:
  $\Delta H_{HHV} = 43{,}500\frac{kJ}{kg}$
  $D = 5.0\ cm\ \ (2.0\ inch)$
  $\dot{V} = 10\ mL\ (in\ 4.0\ sec)$
  $\dot{Q} = 94.2\ kW$

- Flambé pan - Alcohol:
  $\Delta H_{HHV} = 30{,}000\frac{kJ}{kg}$
  $D = 28.\ cm\ \ (11.0\ inch)$
  $\dot{V} = 3\ fl.oz\ (in\ 25\ sec)$
  $\dot{Q} = 92.2\ kW$

- UL 1094 Test Flame:
  $No\ flame\ extension$
  $(in\ 180\ sec)$
  $\dot{Q} = 70.2$ kW

Grease Layer Details

- Smoke point of lard: $T_{smoke} = 182°C$
- Thermal conductivity of lard: $k = 0.57\ \frac{W}{m \cdot K}$
- Assume grease layer on filter is a semi-infinite medium (for the duration of the flare-up)
  - This assumption is conservative because aluminum (or stainless steel) filters have higher thermal diffusivity than grease and would draw more heat away than grease alone.

$$\alpha_{grease} = 0.158 \times 10^{-6}\frac{m^2}{2}$$

$$\alpha_{stainless\ steel} = 3.48 \times 10^{-6}\frac{m^2}{2}$$

$$\alpha_{aluminum} = 73.0 \times 10^{-6}\frac{m^2}{2}$$

Conclusions

- Momentary grill or cooking pan flare-ups are rarely (if ever) capable of initiating fires in range hood grease filters
- A hostile fire (long duration, large diameter/height) originating at the cooking surface is a far more likely ignition source for a range hood fire than a routine, short-duration flare-up
- Grease filter design (i.e., listing to UL 1094) inhibits ignition of grease on filters by momentary flare-ups.
- Restaurant flare-ups should be studied and testing should be performed to better characterize grease layers, heat fluxes, and ignition conditions

Hood Details

NFPA 96 (2011) Section 6.2.1.2:

- Where grease removal devices are used in conjunction with charcoal or charcoal-type broilers, including gas or electrically heated charbroilers, a minimum vertical distance of 1.22 m (4 ft) shall be maintained between the lower edge of the grease removal device and the cooking surface.

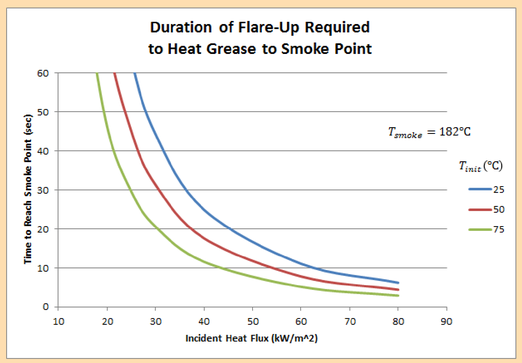
Semi-Infinite Medium

- For a specified Heat Flux $q'' = 20 - 90\ \frac{kW}{m^2}$, use Cengel Eq. 4-46:

$$T(x,t) = T_{init} + \frac{\dot{q}}{k}\left[\sqrt{\frac{4\alpha t}{\pi}exp\left(\frac{-x^2}{4\alpha t}\right)} - x \cdot erfc\left(\frac{x}{2\sqrt{\alpha t}}\right)\right]$$

- Solving for time t to reach T_{smoke} for lard at surface of grease filter ($x = 0.0\ m$), assuming $T_{init} = 60°C = 140°F$:

$$t = \frac{\pi}{4\alpha}\left(\frac{k}{q''_{flare}}[T_{smoke} - T_{init}]\right)^2$$



Citations

- UL 1046 (2012) "Grease Filters for Exhaust Ducts"
- NFPA 96 (2011) "Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations"
- Cengel, Y.A. and Ghajar, A.J.; (2011) "Heat and Mass Transfer – Fundamentals & Applications"; McGraw-Hill
- "SFPE Handbook of Fire Protection Engineering -3rd Edition"; (2002); National Fire Protection Association
- Cooper, L.Y.; (1982); "Heat Transfer from a Buoyant Plume to an Unconfined Ceiling"; ASME J. Heat Transfer; Vol. 104; P. 446
- http://www.cookingforengineers.com/article/50/Smoke-Points-of-Various-Fats