
GAI
ENGINEERS
Thermo
OFF
Heat

Cooking Oil Ignition Study

Issued:
December 21, 2019

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GAI ENGINEERS

GAI Engineers is a forensic engineering firm specializing in origin and cause investigation, failure analysis, accident reconstruction, damage assessments, and other technical support for insurance companies, law firms, fire investigators, manufacturers and private parties throughout New England. Since our founding in 1934, GAI has investigated and resolved thousands of cases involving property loss, premise liability, personal injury, and product liability.

At GAI, our mission is clear: Through rigorous investigation, objective analysis, reliable reporting, accurate assessment, and unassailable expert testimony —we assist each client to understand and solve complex technical problems, resolve claims and litigation, and mitigate or eliminate loss. Working on behalf of insureds, claimants, plaintiffs, and defendants, GAI understands that client needs usually stem from the demands of an insurance contract or legal dispute. Our engineers have helped countless clients achieve cost-effective resolution of claims, maximum recovery from subrogation, strong defense on insured liability, and favorable settlements on behalf of private parties.

Experienced in litigation, GAI professionals provide legal support and expert testimony for prosecutors, plaintiffs and defendants, product manufacturers, utilities, and insurers. Our engineers assist as non-testifying experts in preparing and reviewing depositions, and evaluating technical documents obtained through discovery. We also help determine the underlying cause of a loss, and whether a reasonable basis for subrogation exists. As testifying witnesses, GAI effectively renders opinions on topics ranging from electrical and mechanical engineering issues, to electrical fires, gas explosions, and product design, manufacture, service, and installation. With valid scientific methodology our hallmark, we successfully withstand Daubert motions and consistently qualify as expert witnesses in state and federal courts on civil and criminal matters.

Since our inception, GAI has been continuously operated and locally owned by only two families — a system that has ensured reliability, quality, and continuity of service for our clients. Today, under the direction of Andrew J. Williams, P.E., GAI continues a longstanding tradition of responsive service, accurate analysis, thorough reporting, and defensible presentation of findings and opinions for insurers, attorneys, and private parties throughout New England and beyond.

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INTRODUCTION

Cooking fires continue to be a leading cause of fires in the United States. Per the 2018 National Fire Protection Association (NFA) report, *Home Cooking Fires*, from 2012-2016, there were an average of about 113,000 cooking fire per year in the country. In that timeframe, there were 560 deaths associated with cooking fires. The leading failure mode of these fires is unattended cooking, accounting for about 32% of all fires and 45% of all deaths. Of the first materials ignited in these fires, cooking oils accounted for about 35,000 fires per year on average.

The challenge to the fire investigation community is that many homeowners are reluctant to admit to an unattended cooking fire. Many incorrectly fear that such a fire will not be covered under a homeowner's insurance policy. Homeowner's evasiveness, and sometimes outright deceit, only raises the suspicions of fire investigators, resulting in further investigation that is many times unneeded.

Fire investigators and forensic engineers have many tools to determine the origin and cause of a cooking fire using the methodology outlined in the *Guide to Fire and Explosion Investigations* (NFPA 921). Using this methodology, even with unreliable witness statements, assists fire investigators to determine fire origins at cooking appliances such range-ovens, cooktops, and the like. Experienced and well-trained forensic engineers can use their expertise in arc-mapping, appliance operating controls and ignition mechanisms to assist fire investigators in determining 1) if a cooking appliance was operating at the time of fire and 2) if the heat source had sufficient temperature and energy to ignite the fuel source.

GAI set out to understand how cooking oils react during an unattended cooking scenario, up to ignition. A test protocol was developed to encompass a variety of cooking oils. The time to smoke showing, simulated smoke alarm activation, and auto-ignition was recorded.

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PROTOCOL

1.0	**PROTOCOL TITLE:**	Cooking Oil Ignition Study
2.0	**PROTOCOL LOCATION(S):**	GAI Engineers 378 Page Street – Building 10 Stoughton, MA
3.0	**PROTOCOL DATE & TIME:**	To Be Determined
4.0	**ORIGINATOR(S):**	Andrew J Williams, P.E.
5.0	**ORIGINATION DATE:**	August 27, 2019

6.0 PURPOSE/SCOPE:

The purpose of this protocol is to study the conditions relative to ignition of cooking oils. Various cooking oils will be used.

7.0 TOOLS/ EQUIPMENT:

7.1 Hot Plate, Thermo-Scientific, SP195025
7.2 GAI Non-Combustible Test Box, 3'x3'x3'
7.3 Radio Shack, Digital Weathermeter, 63-1032
7.4 Two-Channel Digital Thermometer, Extech 421502
7.5 Bead-Style Thermocouples, Omega, 5SC-TT-J-30-36
7.6 Infrared Thermometer, Extech 42545 or equivalent

8.0 MATERIALS:

8.1 Stainless Steel Beaker, 600ml
8.2 Smoke Alarm, Photo-Electric & Ionization, First Alert, Pi9010
8.3 Cooking Oil, Canola, Wesson, as needed
8.4 Cooking Oil, Corn, Mazola, as needed
8.5 Cooking Oil, Extra-Virgin Olive, Bertolli, as needed
8.6 Cooking Oil, Peanut, Great Value, as needed
8.7 Cooking Oil, Soybean, Nutrioli, as needed
8.8 Cooking Oil, Vegetable, Smart Balance, as needed

9.0 PROCEDURE:

9.1 Photograph each Cooking Oil, including sides and labels.
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9.2 Install Smoke Alarm in GAI Non-Combustible Box at top side, along front edge. Install Hot Plate in GAI Non-Combustible Box along rear edge.

9.3 Photograph test set-up, including all tools/equipment and materials.

9.4 Record ambient temperature and relative humidity using Digital Weathermeter and Data Sheet.

9.5 Pour 1/2 Cup (125 ml) of first Cooking Oil sample in Stainless Steel Beaker.

9.6 Set Heat Plate to highest setting (10). Allow Heat Plate surface temperature to reach 950°F using Infrared Thermometer.

9.7 Place Stainless Steel Beaker on Heat Plate. Place Thermocouple in Cooking Oil, centered within the Cooking Oil and Beaker.

9.8 Record time and temperature when smoke is first visible above Beaker.

9.9 Record time and temperature when Smoke Alarm activates.

9.10 Record time and temperature when ignition occurs.

9.11 Repeat Steps 9.4 through 9.10 for four (4) more runs.

9.12 Repeat Steps 9.4 through 9.11 for five (5) other Cooking Oils.

10.0 ENCLOSURES:

10.1 Protocol Data Sheet.

Cooking Oil Ignition Study - Data

Run Number	Cooking Oil	Ambient Temperature (deg. F)	Ambient Humidity (% RH)	Smoke Showing Time (Min:Sec)	Smoke Showing Temperature (deg. F)	Smoke Alarm Time (Min:Sec)	Smoke Alarm Temperature (deg. F)	Ignition Time (Min:Sec)	Ignition Temperature (deg. F)
1	Canola								
2	Canola								
3	Canola								
4	Canola								
5	Canola								
6	Corn								
7	Corn								
8	Corn								
9	Corn								
10	Corn								
11	Extra-Virgin Oil								
12	Extra-Virgin Oil								
13	Extra-Virgin Oil								
14	Extra-Virgin Oil								
15	Extra-Virgin Oil								

Cooking Oil Ignition Study - Data

Run Number	Cooking Oil	Ambient Temperature (deg. F)	Ambient Humidity (% RH)	Smoke Showing Time (Min:Sec)	Smoke Showing Temperature (deg. F)	Smoke Alarm Time (Min:Sec)	Smoke Alarm Temperature (deg. F)	Ignition Time (Min:Sec)	Ignition Temperature (deg. F)
16	Peanut								
17	Peanut								
18	Peanut								
19	Peanut								
20	Peanut								
21	Soybean								
22	Soybean								
23	Soybean								
24	Soybean								
25	Soybean								
26	Vegetable								
27	Vegetable								
28	Vegetable								
29	Vegetable								
30	Vegetable								

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STUDY SET-UP PHOTOGRAPHS

1. GAI Laboratory, showing Test Materials.

2. Test Materials, showing Olive Oil Container. (NOTE: Side view)

STUDY SET-UP PHOTOGRAPHS

3. Test Materials, showing Vegetable Oil Container. (NOTE: Side view)

4. Test Materials, showing Corn Oil Container. (NOTE: Side view)

STUDY SET-UP PHOTOGRAPHS

5. Test Materials, showing Canola Oil Container. (NOTE: Side view)

6. Test Materials, showing Soybean Oil Container. (NOTE: Side view)

STUDY SET-UP PHOTOGRAPHS

7. Test Materials, showing Peanut Oil Container. (NOTE: Side view)

8. Test Materials, showing Smoke Alarm.

STUDY SET-UP PHOTOGRAPHS

9. Smoke Alarm, showing Bottom Side.

10. GAI Laboratory, showing Smoke Hood.

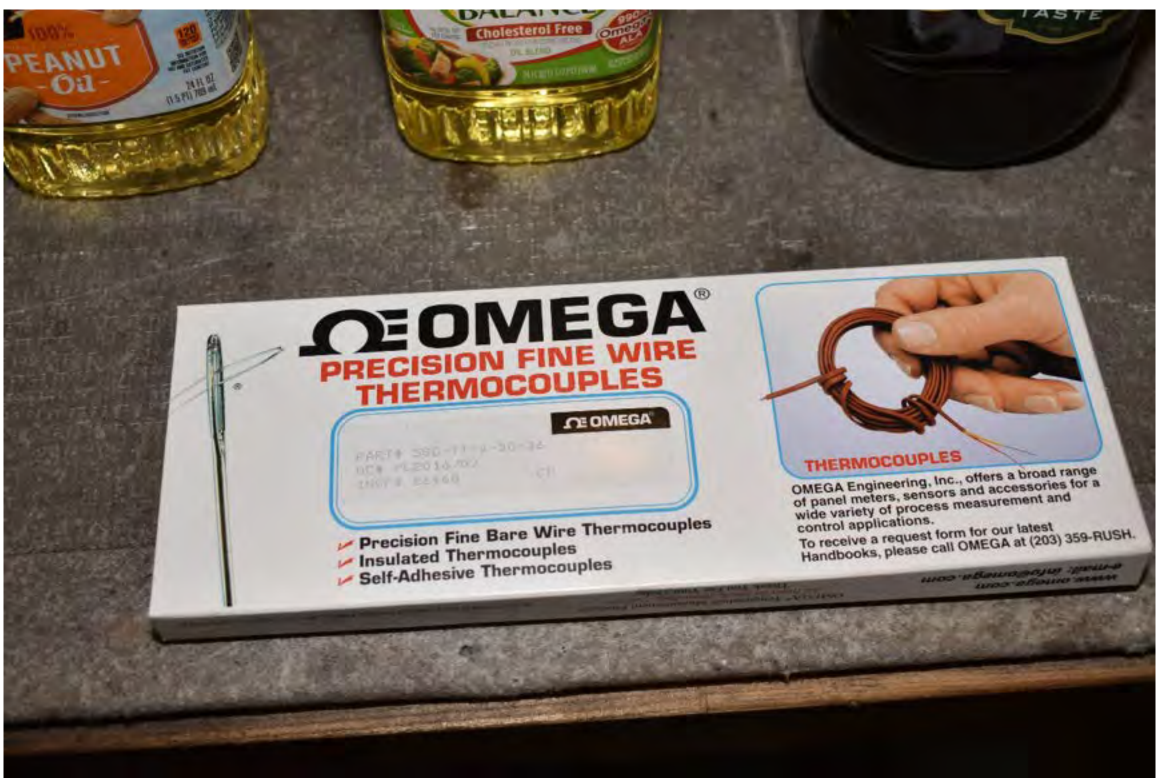
STUDY SET-UP PHOTOGRAPHS

11. Smoke Hood, showing GAI Non Combustible Test Box, Test Equipment and Test Materials.

12. Test Materials & Equipment, showing Stainless Steel Beaker and Hot Plate.

STUDY SET-UP PHOTOGRAPHS

13. Test Materials & Equipment, showing Digital Thermometer.



14. Test Materials & Equipment, showing Thermocouples.

STUDY SET-UP PHOTOGRAPHS

15. Test Materials & Equipment, showing Infrared Thermometer.

16. Test Materials & Equipment, showing Digital Weathermeter.

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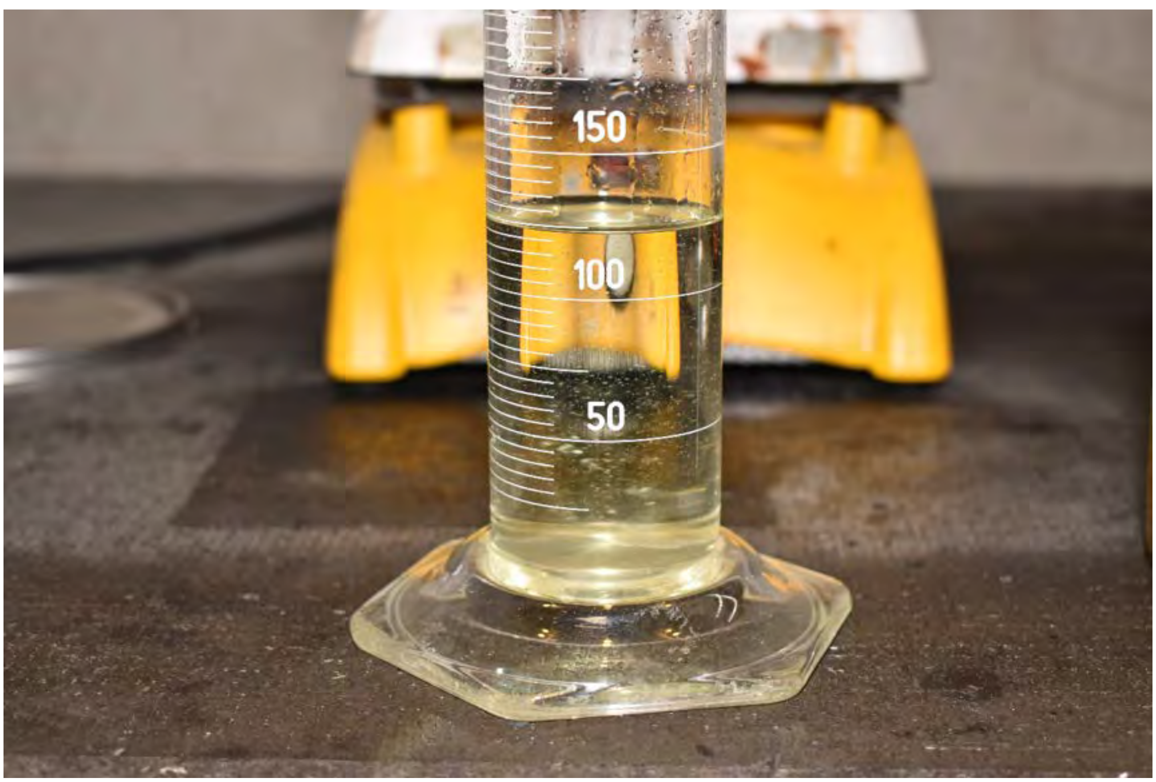
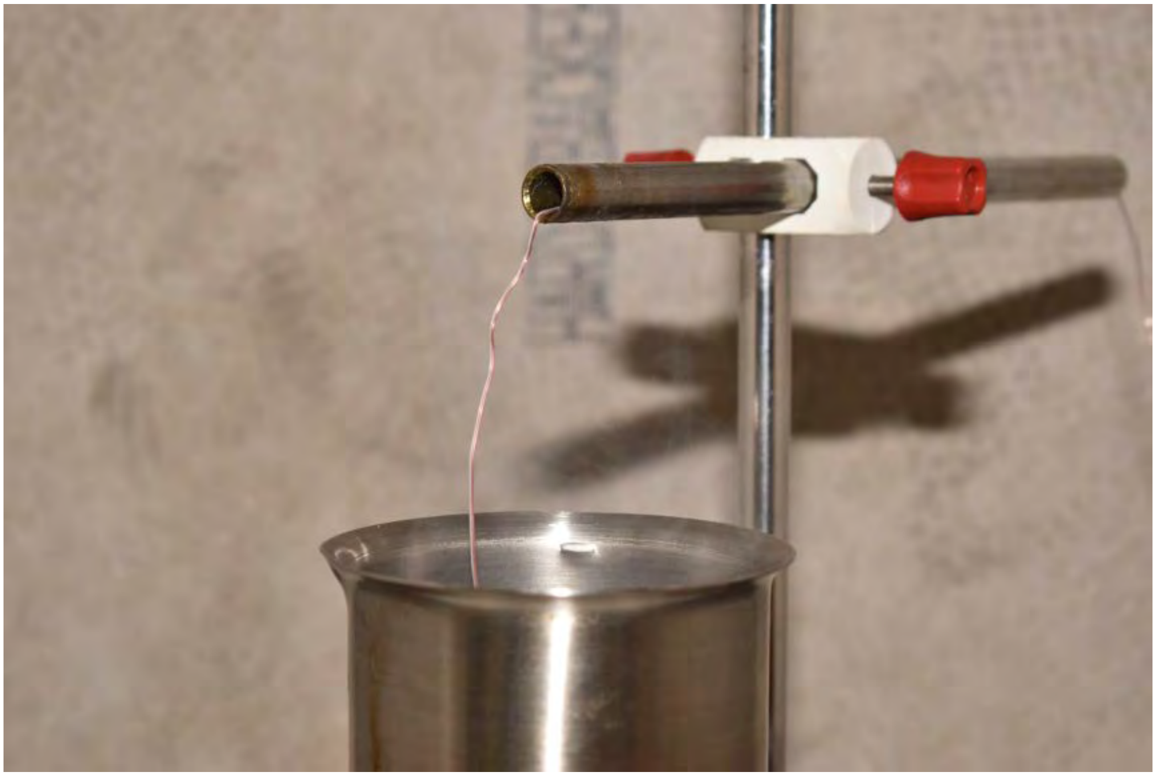
STUDY RUNS PHOTOGRAPHS

1. Run #1, showing Test Materials and Equipment.

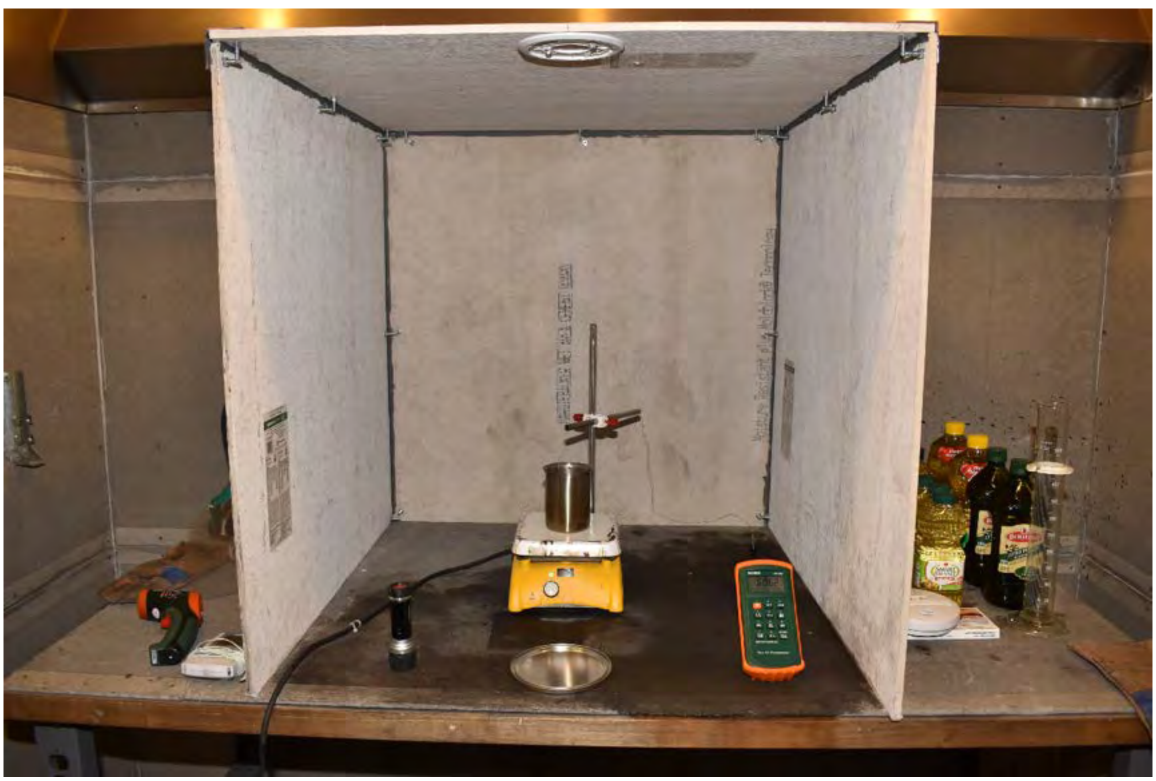


2. Run #1, showing Cooking Oil Volume.

STUDY RUNS PHOTOGRAPHS



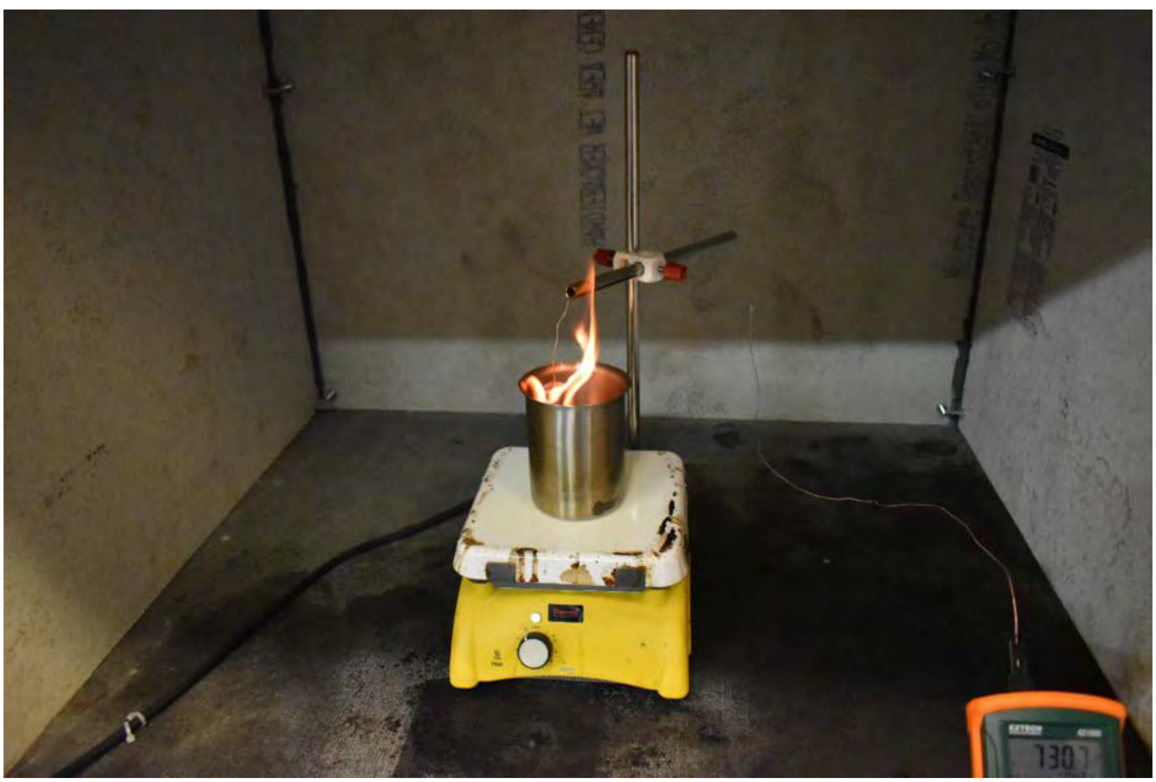
3. Run #1, showing Initial Smoke Showing.



4. Run #1, showing Smoke at Smoke alarm Activation.

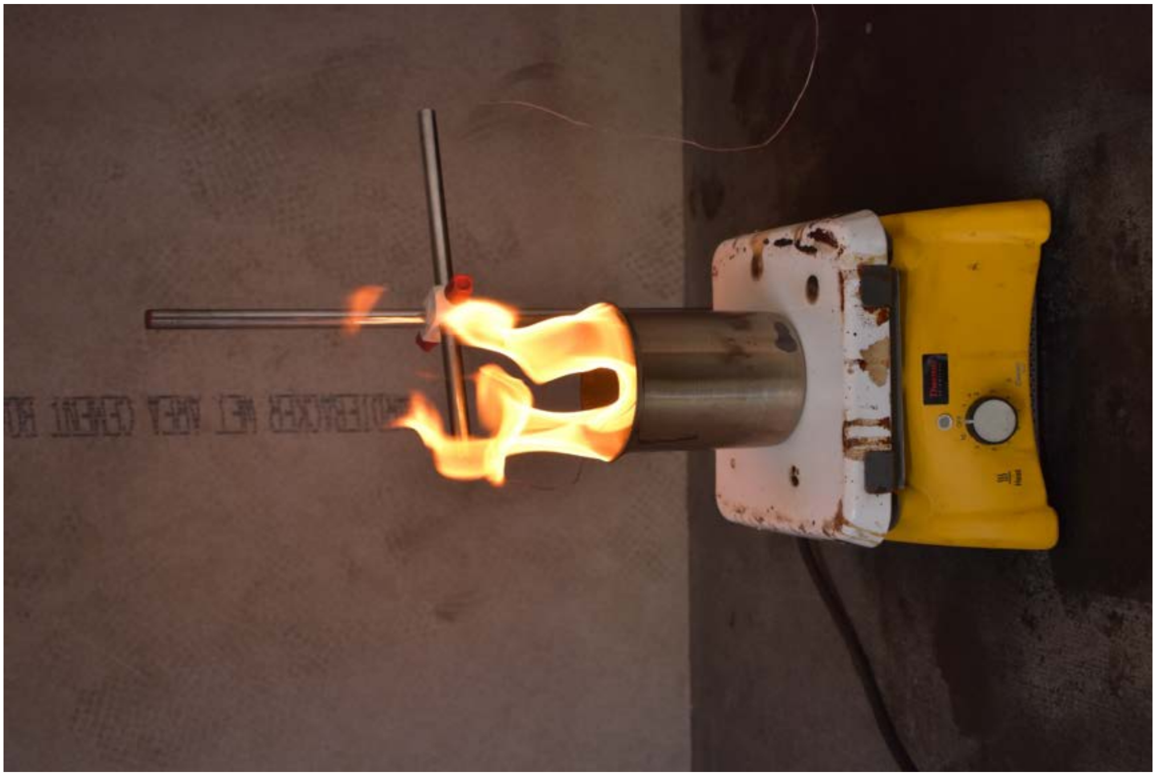
STUDY RUNS PHOTOGRAPHS

5. Run #1, showing Initial Auto-Ignition.



6. Run #1, showing Fire Development.

STUDY RUNS PHOTOGRAPHS



7. Run #1, showing Fire Development. (NOTE: Side view)

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Cooking Oil Ignition Study - Results

Run Number	Cooking Oil	Ambient Temperature (deg. F)	Ambient Humidity (% RH)	Smoke Point Time (Min:Sec)	Smoke Point Temperature (deg. F)	Smoke Alarm Time (Min:Sec)	Smoke Alarm Temperature (deg. F)	Ignition Time (Min:Sec)	Ignition Temperature (deg. F)
1	Canola	71	48%	4:26	429	8:00	554	15:10	721
2	Canola	74	59%	4:30	440	8:00	540	15:12	730
3	Canola	74	41%	4:00	430	8:10	550	14:57	715
4	Canola	74	39%	4:37	423	8:08	558	15:17	723
5	Canola	74	41%	4:20	432	8:15	539	15:22	728
				Mean:	**431**			**Mean:**	**723**
				Standard Deviation:	**6**			**Standard Deviation:**	**6**
				Minimum:	**423**			**Minimum:**	**715**
				Maximum:	**440**			**Maximum:**	**730**
6	Corn	75	60%	5:00	444	7:24	534	15:05	725
7	Corn	75	61%	4:58	421	7:05	520	15:13	719
8	Corn	76	62%	4:30	435	6:45	535	15:00	720
9	Corn	75	64%	4:50	441	7:30	540	15:04	722
10	Corn	75	65%	4:34	420	8:10	529	15:11	721
				Mean:	**432**			**Mean:**	**721**
				Standard Deviation:	**11**			**Standard Deviation:**	**2**
				Minimum:	**420**			**Minimum:**	**719**
				Maximum:	**444**			**Maximum:**	**725**

Cooking Oil Ignition Study - Results

Run Number	Cooking Oil	Ambient Temperature (deg. F)	Ambient Humidity (% RH)	Smoke Point Time (Min:Sec)	Smoke Point Temperature (deg. F)	Smoke Alarm Time (Min:Sec)	Smoke Alarm Temperature (deg. F)	Ignition Time (Min:Sec)	Ignition Temperature (deg. F)
11	Extra-Virgin Oil	74	66%	4:00	360	6:40	481	16:04	729
12	Extra-Virgin Oil	76	63%	3:49	356	6:00	463	15:20	729
13	Extra-Virgin Oil	77	62%	4:02	372	6:19	483	15:20	728
14	Extra-Virgin Oil	77	62%	4:15	385	5:55	466	15:30	730
15	Extra-Virgin Oil	78	59%	4:10	369	6:04	470	15:20	728
				Mean:	**368**			**Mean:**	**729**
				Standard Deviation:	**11**			**Standard Deviation:**	**1**
				Minimum:	**356**			**Minimum:**	**728**
				Maximum:	**385**			**Maximum:**	**730**
16	Peanut	78	59%	4:20	360	5:50	420	15:50	720
17	Peanut	73	56%	4:30	359	5:10	430	15:12	720
18	Peanut	73	55%	4:28	349	6:05	400	14:55	728
19	Peanut	74	54%	4:00	353	5:40	430	15:17	697
20	Peanut	75	53%	4:20	339	6:00	450	15:00	730
				Mean:	**352**			**Mean:**	**719**
				Standard Deviation:	**9**			**Standard Deviation:**	**13**
				Minimum:	**339**			**Minimum:**	**697**
				Maximum:	**360**			**Maximum:**	**730**

Cooking Oil Ignition Study - Results

Run Number	Cooking Oil	Ambient Temperature (deg. F)	Ambient Humidity (% RH)	Smoke Point Time (Min:Sec)	Smoke Point Temperature (deg. F)	Smoke Alarm Time (Min:Sec)	Smoke Alarm Temperature (deg. F)	Ignition Time (Min:Sec)	Ignition Temperature (deg. F)
21	Soybean	77	50%	4:25	400	5:30	459	14:07	758
22	Soybean	78	54%	4:40	400	5:50	480	13:45	726
23	Soybean	76	52%	4:20	406	6:20	506	14:00	730
24	Soybean	77	51%	4:20	380	5:51	470	14:30	720
25	Soybean	78	59%	4:30	400	6:00	465	14:00	730
				Mean:	**397**			**Mean:**	**733**
				Standard Deviation:	**10**			**Standard Deviation:**	**15**
				Minimum:	**380**			**Minimum:**	**720**
				Maximum:	**406**			**Maximum:**	**758**
26	Vegetable	73	57%	4:40	410	5:52	450	14:50	720
27	Vegetable	74	54%	4:40	420	6:00	480	15:00	710
28	Vegetable	76	58%	4:30	406	6:05	465	14:43	730
29	Vegetable	77	59%	4:27	410	5:51	470	14:51	722
30	Vegetable	78	50%	4:25	422	6:03	445	14:30	730
				Mean:	**414**			**Mean:**	**722**
				Standard Deviation:	**7**			**Standard Deviation:**	**8**
				Minimum:	**406**			**Minimum:**	**710**
				Maximum:	**422**			**Maximum:**	**730**

Cooking Oil Ignition Study - Results

Run Number	Cooking Oil	Ambient Temperature (deg. F)	Ambient Humidity (% RH)	Smoke Point Time (Min:Sec)	Smoke Point Temperature (deg. F)	Smoke Alarm Time (Min:Sec)	Smoke Alarm Temperature (deg. F)	Ignition Time (Min:Sec)	Ignition Temperature (deg. F)
				POPULATION MEAN:	399			POPULATION MEAN:	725
				POPULATION STANDARD DEVIATION:	32			POPULATION STANDARD DEVIATION:	10
				POPULATION MINIMUM:	339			POPULATION MINIMUM:	697
				POPULATION MAXIMUM:	444			POPULATION MAXIMUM:	758

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CONCLUSIONS

The results of the smoke point and auto-ignition of cooking oils yields similar results to other published references and studies.

Regarding smoke point, the temperature of the population of cooking oils ranged from 339 °F to 444 °F, with a mean of about 399 °F. There was little variation within runs of the same cooking oil. The extra-virgin olive oil smoke point mean was about 368 °F, well below the population mean. The canola oil smoke point mean was about 431 °F, well above the population mean.

Regarding auto-ignition, the temperature of the entire population of cooking oils ranged from 697 °F to 758 °F, with a mean of about 725 °F. There was very little variation throughout the runs of the population of cooking oils, regardless of composition.

The timeframe from the smoke point to auto-ignition of the population of cooking oils was in the range of roughly 10-11 Minutes. It should be noted this data is based on 1/2 Cup of cooking oil on a 1,100 Watt hot plate with a starting surface temperature of about 950 °F. If one was to extrapolate using a quart of cooking oil, in a sauce pan, on a small heating element (1,500 Watt), at a medium heat setting, at room temperature on an electric range oven, this timeframe would be much longer.

On many cooking oil fires that GAI has investigated, occupants have stated they left a range-oven unattended "for a minute", and the heating cooking oil went from no smoke showing to auto-ignition. The testing shows this timeframe is unrealistic – there would be actually be an extended period of time.

In summary, this study has established some initial results to provide clarity on both the temperatures and timeframes regarding the smoke point and auto-ignition of various cooking oils. A further study using actual range-ovens and cookware would provide further useful data to fire investigators and forensic engineers.

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REFERENCES

1. Ahrens, Marty, *Home Cooking Fires*, National Fire Protection Association, Quincy, Massachusetts, 2018.

2. NFPA 921, *Guide for Fire and Explosion Investigations*, National Fire Protection Association, Quincy, Massachusetts, 2017.

3. Buda-Ortins, Krystyna, *Auto-Ignition of Cooking Oils*, University of Maryland, College Park, Maryland, 2010.

4. *Smoke Point of Oils*, The Vegetarian Health Institute, Wilmington, Delaware, Unknown Date.

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