U.S. CONSUMER PRODUCT SAFETY COMMISSION
Directorate for Engineering Sciences

STAFF EVALUATION OF ELECTRIC CLOTHES DRYER FIRE CONTAINMENT REQUIREMENTS

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Introduction

In fiscal year 2019, U.S. Consumer Product Safety Commission (CPSC) Directorate for Engineering Sciences (ES) staff initiated a project to assess the effectiveness of the Fire Containment performance tests in Sections 16.6 and 16.7 of Underwriters Laboratories (UL) 2158 – Electric Clothes Dryers. This report summarizes the project team's work and recommendations.

The project's steps follow:

- Review incident data to see if it can provide any information on the efficacy of the fire containment tests.
- Examine electric clothes dryers built before and after the UL 2158 fire containment test requirements' 2013 effective date.
- Conduct a fire containment test on a new clothes dryer to gain insight on possible gaps in the test procedures.

UL 2158 Fire Containment Tests

Prior to 2002, CPSC staff, the Association of Home Appliance Manufacturers (AHAM), UL, and other interested parties discussed how to address clothes dryer fires, one of the leading causes of product-initiated fires. Late in 2002, a joint working group for gas and electric clothes dryers, consisting of representatives from UL, Canadian Standards Association (CSA), CPSC staff, and several major clothes dryer manufacturers, was formed. The group developed proposals for two performance tests to evaluate fire propagation outside a clothes dryer. The fire containment tests for electric clothes dryers were incorporated into a revised version of the second edition of UL 2158, issued in March 2009. On March 20, 2013, the fire containment performance requirements became effective, requiring all electric clothes dryers to meet the new requirements to be certified to UL 2158. The fire containment tests in UL 2158 have the potential to reduce significantly the severity of electric dryer fires, such as damage to residential property, and the likelihood of injuries and deaths.

The voluntary standard for gas clothes dryers is American National Standards Institute (ANSI) Z21.5.1/CSA 7.1 Gas Clothes Dryers Type 1 Clothes Dryers, which applies to newly produced noncommercial clothes dryers that use gas (*e.g.*, natural, manufactured, mixed gas, propane gas) as the heater fuel for the appliance. The UL 2158 Fire Containment Tests were added to the fifth edition of ANSI Z21.5.1/CSA 7.1 in January 2015, with an effective date of June 1, 2016.

In the first of these tests, the *Load Fire Containment test*, assesses the ability of a clothes dryer to withstand a fire within the drum. The dryer drum is loaded with cotton cloths with a dry weight equivalent to one pound of cloth for each cubic foot of dryer drum volume. The exterior of each sample dryer is draped with a single layer of cheesecloth, covering the top, bottom, front, back and sides of a dryer, as shown in Figure 1, to serve as an indicator that fire did not escape the dryer enclosure. Two separate tests are conducted: (a) The appliance is not started (no drum or basket motion), and (b) The appliance timer is set to the maximum time and highest heat setting. The cloths in the dryer drum are then ignited with a propane torch, the dryer door closed, and the exterior cheesecloth repositioned to ensure complete coverage of the dryer. Once the test fire is ignited, the test continues until failure, or to a maximum of 7 hours (without failure). The failure criteria for the fire tests are common to other appliance

fire containment standards in which the draped/enclosed single layer of cheesecloth covering the appliance, if ignited, indicates failure of the test.

The second test, the *Base Fire Containment test*, assesses the ability of a dryer to contain a fire that starts within the base compartment. All electrical components and connectors located in the base of the dryer are covered with eight layers of cheesecloth to simulate the accumulation of lint. Again, the exterior of each sample dryer is draped on all sides with a single layer of cheesecloth and loaded with cloths with a dry weight equivalent to one pound of cloth for each cubic foot of drum volume. Two separate tests are conducted: (a) The appliance is not started (no drum or basket motion), and (b) The appliance timer is set to the maximum time and highest heat setting. Then the internal cheesecloth in the base is ignited, and the exterior cheesecloth is repositioned to ensure complete coverage of the dryer. As in the first test, once the cheesecloth in the base is ignited, the test continues until failure, or to a maximum of 7 hours (without failure). If the exterior cheesecloth ignites, the test is considered a failure. The test is also conducted with the dryer plugged in, but not running.

Figure 1. Clothes dryer being prepared for the fire containment test

There can be many possible means for a clothes dryer to fail the fire containment tests, including the following:

- Flames escaping through the intake air louvers;
- Flames escaping through gaps in cabinet panels;
- Flames escaping through the door, due to melting of the hinge-mount or door-latch;
- Ignition of the polymeric control panel; or
- Sparks and molten metal globules created by fire attack energized conductors.

Life Expectancy of Clothes Dryers in the U.S.

According to a 2007 National Association of Home Builders (NAHB) report,[1] the average life expectancy of an electric clothes dryer is 13 years in the United States. The study was conducted in 2006, via a telephone survey. The report states that many of the people interviewed emphasized that the life expectancy of housing components is greatly affected by the quality of maintenance. They also noted that changing consumer preferences can result in products being replaced before or after the end of their practical life expectancy.

Another report states that electric and gas clothes dryers are expected to last 11 to 18 years.[2] Electric clothes dryers last, on average, a year longer than gas dryers.[3]

As of 2009, almost 80 percent of U.S. households had a clothes dryer.[4,5] The number of households with electric clothes dryers outnumbered gas (natural and propane) dryers by almost 4:1. In 2009, 71.8 million

[1] Seinders, D. et al. (February 2007), *Study of Life Expectancy of Home Components, National Association of Home Builders*, Washington DC.
[2] Robert, A.; (January 22, 2014), *When to Fix or Replace a Troublesome Appliance*, Hearst Magazine Media, viewed 4/14/2021, Good Housekeeping, California, www.goodhousekeeping.com.
[3] Threewitt, C.; (January 20, 2021), Gas vs. Electric Dryers, U.S. News 360 Reviews, viewed 4/22/2021, U.S. News, www.usnews.com.
[4] Distribution of households with clothes dryers in the United States in 2009, by energy source; (2021), Statista, viewed 4/22/2021, www.statista.com.
[5] Energy Star Market & Industry Scoping Report Residential Clothes Dryers; (November 2011), U.S. Environmental Protection Agency (EPA), viewed on 4/22/2021, http://energy.mo.gov.

U.S. households had an electric clothes dryer, versus 18.5 million (17.5 million natural and 1 million propane) households that owned a gas dryer.

Fire Losses and Reported Incidents of Clothes Dryer Fires

CPSC staff fire loss estimates covering the years 2012 to 2017 for residential structure fires attended by fire services and attributed to clothes dryers (all fuel types) are shown in Table 1.[6]

Table 1. Estimated Residential Fires for Clothes Dryers

	2012	2013	2014	2015	2016	2017
Structure fires	5,100	5,200	4,900	7,900	7,300	6,900
Injuries	180	150	160	160	210	180
Deaths	10	10	<10	10	<10	<10

Hazard Analysis staff conducted a search of the Consumer Product Safety Risk Management System (CPSRMS) database for clothes dryer fire/overheating incidents that occurred from January 1, 2000 to May 22, 2019. The search produced 1,711 reports, and three of those reports did not indicate that electric or gas clothes dryer caused the incident.

To gain insight into the causes and consequences of fire incidents, the team reviewed the reports and sorted the information by relevant parameters, such as year purchased, item that first ignited (if known), and whether the fire escaped the unit.

The dataset is not statistical and does not represent any national statistics. Thus, caution should be used in interpreting the data and graphs.

Reported Incidents Where Fire Escaped the Dryer (Electric and Gas)

Of the 1,708 reports, 318 reports contained information suggesting fire escaped the dryer (electric and gas), *i.e.*, fire damage occurred to adjacent items. Of the 318 reports where fire escaped the dryer, 103 reports stated the date the dryer was purchased, or the date of manufacture. Although the purchase date of a dryer may not be the same as the manufacture date, staff assumed that the appliance was new when purchased, and posited that the purchase date is usually within 2 years from the date of manufacture. Figure 2 shows the distribution of the 103 reported incidents, by purchase date, where the fire escaped the dryer.

[6] Miller, D. (July 2017, July 2018, July 2019, July 2020), *2012-2014, 2013-2015, 2014-2016, 2015-2017 Residential Fire Loss Estimates*, U.S. National Estimates of Fires, Deaths, Injuries, and Property Losses from Unintentional Fires, Directorate for Epidemiology, U.S. Consumer Product Safety Commission, Bethesda, MD.

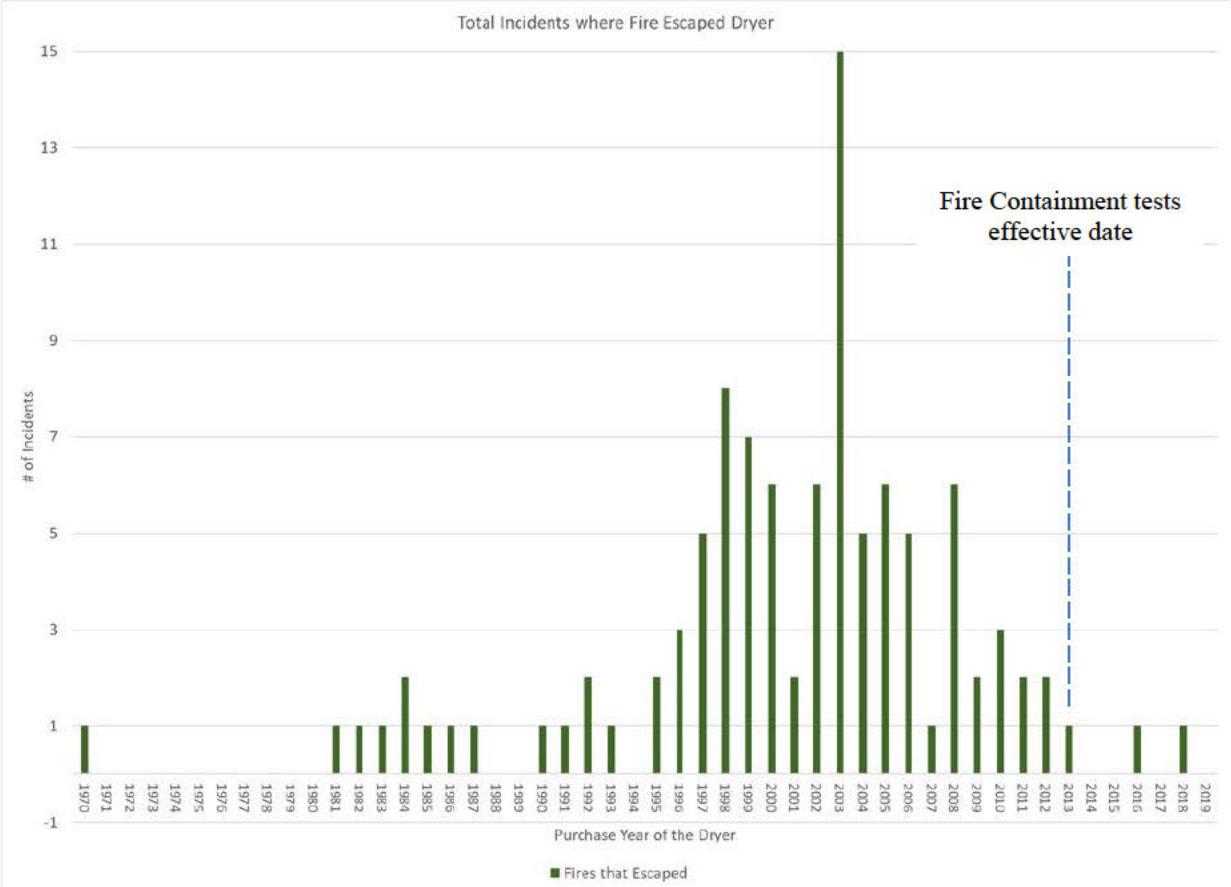


Figure 2. Reported incidents by purchase year where fire escaped the dryer (Known component and purchase date)

The incident data were refined by identifying the originating cause. Much of the dataset had insufficient information to identify the cause that initiated the incident. If a cause was identified in the report, the incident was sorted into one of 10 different categories listed in Table 2. Four of the 10 categories (electric short, load, lint, and ventilation) do not represent an actual dryer component. Two of these categories (lint and load) were mentioned often as the primary cause of the incident. Only four reports mentioned ventilation as the primary cause of the incident. If a dryer component was cited in addition to ventilation, load, lint, or electrical short (unidentified), the incident was sorted by the component.

Of the 318 reported incidents where fire escaped the dryer, only 129 reports contained known information about the first item ignited (includes purchase date unknowns). Table 2 lists the item that first ignited or was involved.

Table 2. Item First Ignited where Fire Escaped the Dryer (Includes purchase date unknowns)

First Item Ignited	Count
Electric Short (unidentified)	35
Wiring	6
Thermostat/Heater Relay	8
Control Panel/Circuit Board	4
Terminal Block	2
Load (Clothing)	21
Lint	29
Power cord	9
Motor/Blower Assembly	11
Ventilation	4
	129

Of the 129 reported incidents where fire escaped the dryer, and where there was information on the item reported to ignite first, only 35 reports contained information on the purchase date of the dryer. Table 3 lists the item first ignited or reportedly involved in the incidents with a known purchase date.
Figure 3 shows the distribution of incidents, by known purchase date, where the fire escaped the dryer and the item first ignited.

Table 3. Item First Ignited by know purchase dates, where fire escaped the dryer

First Item Ignited	Count
Electric Short (unidentified)	6
Wiring	1
Thermostat/Heater Relay	5
Control Panel/Circuit Board	3
Load (Clothing)	2
Lint	8
Motor/Blower Assembly	9
Ventilation	1
	35

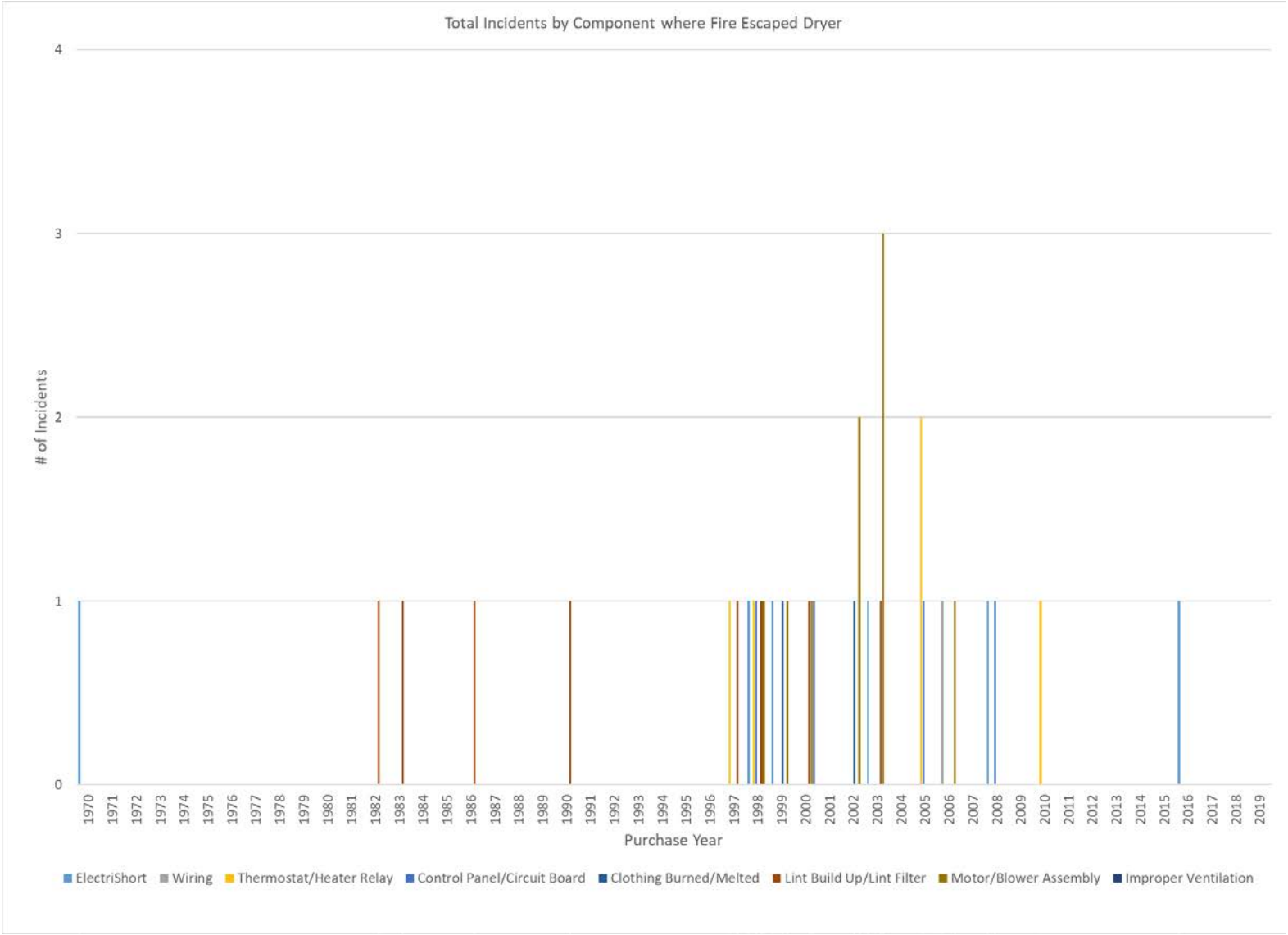


Figure 3. Reported incidents by item that was reportedly first ignited and by year of purchase

Reported Incidents Where Fire Did Not Escape the Dryer (Electric and Gas)

Of the 1,708 reports, 1,390 reports contained information suggesting that the fire did not escape the dryer (electric and gas). Of the 1,390 reports where fire did not escape the dryer, 1,143 reports contained the date the dryer was purchased. Figure 4 shows the distribution of the 1,143 reported incidents where the fire did not escape the dryer and the purchase date was known.

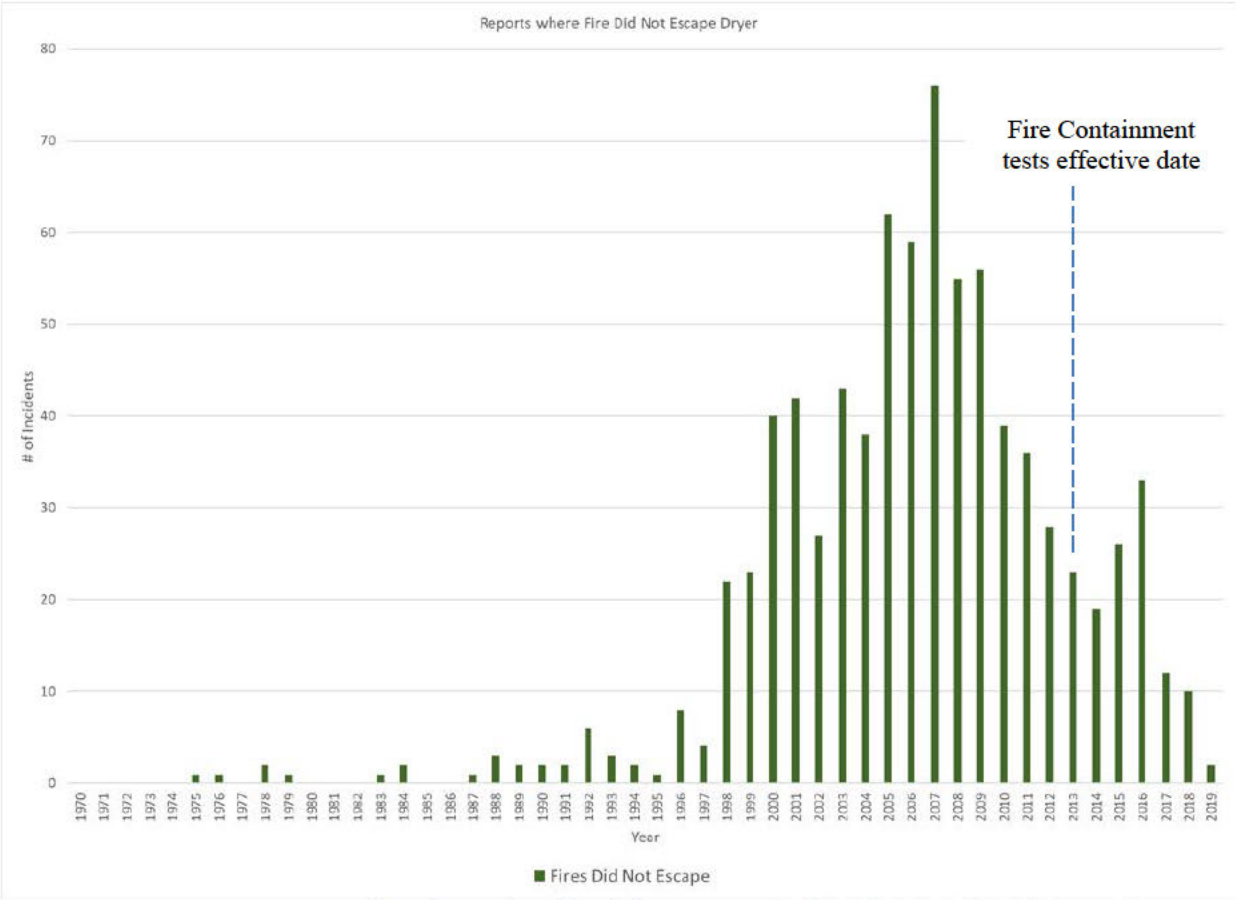


Figure 4. Reported incidents where fire did not escape the dryer by year of purchase

Of the 1,390 reports where no flames escaped the dryer, 949 reports contained information on the item that was involved in the incident. Table 4 lists the distribution of the known items first ignited or involved.

Table 4. Component First Ignited Where Fire Did Not Escape the Dryer (Includes purchase date unknowns)

First Item Ignited	Count
Electric Short (unidentified)	81
Drive belt	9
Wiring	97
Thermostat/Heater Relay	181
Control Panel/Circuit Board	212
Terminal block	21
Load (Clothing)	78
Lint	138
Power Cord	87
Motor/Blower Assembly	40
Ventilation	5
	949

Of the 949 reports, 813 reports identified the item that was reported to have been first ignited and the purchase date. Table 5 lists the item that first ignited or involved and the known purchase date. Figure 5 shows the distribution of incidents by purchase date that did not escape the dryer and item first ignited.

Table 5. Component First Ignited Where Fire Did Not Escape the Dryer for known purchase dates only

First Item Ignited	Count
Electric Short (unidentified)	64
Drive belt	7
Wiring	85
Thermostat/Heater Relay	156
Control Panel/Circuit Board	200
Terminal block	17
Load (Clothing)	52
Lint	116
Power Cord	74
Motor/Blower Assembly	37
Ventilation	5
	813

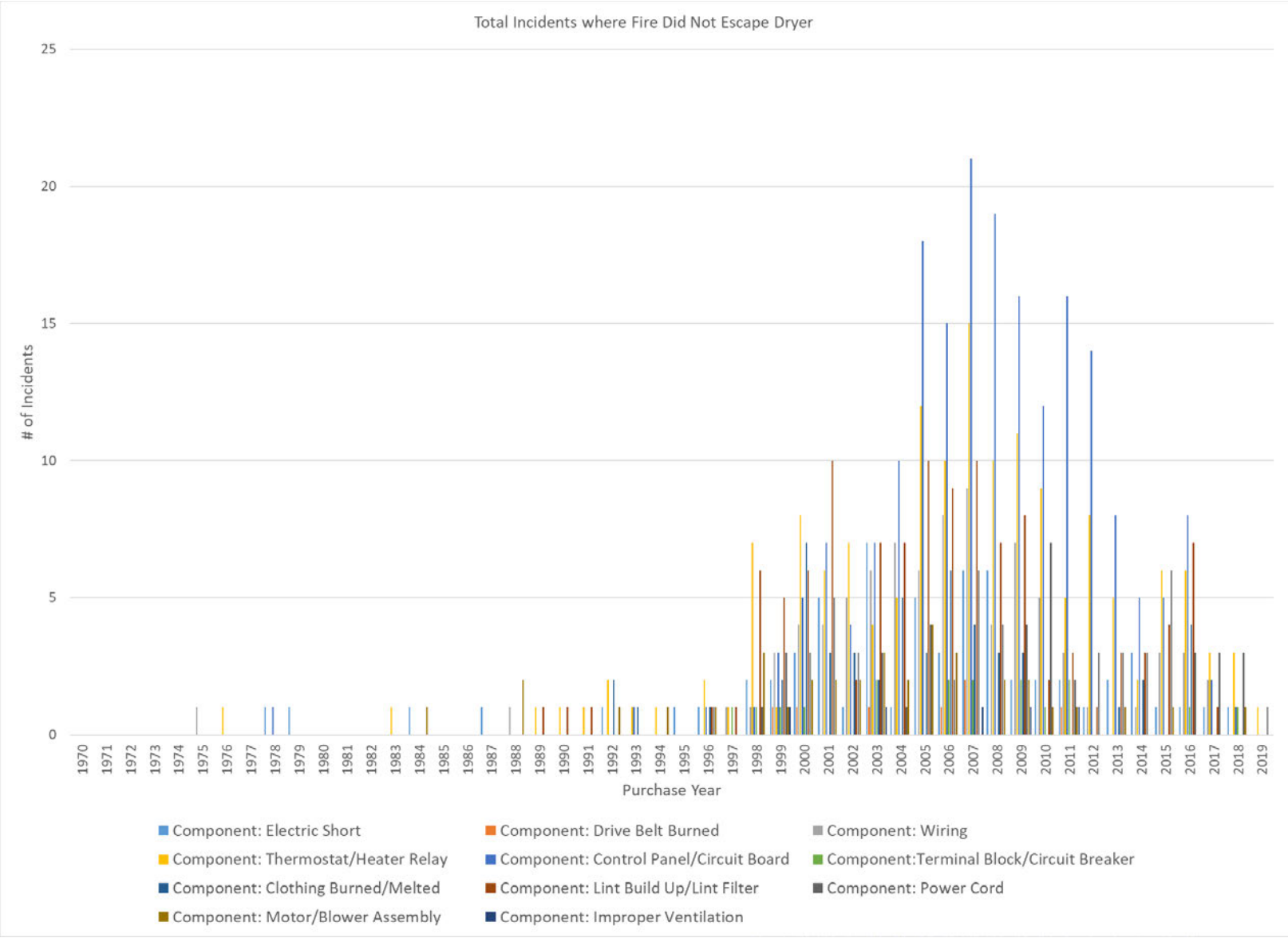


Figure 5. Reported incidents, by component and year, where the fire did not escape the dryer

Age of Dryer at Time of Incident

Of the 1,708 reports, 1,246 reports (confined and unconfined fires) contained information on the purchase date (includes unknown component). Thus, the approximate age of unit at the time of the incident was calculated from these two dates by months. Figure 6 shows the distribution of the 1,246 reported incidents indicating how long the dryer was in-service prior to the incident. The figure shows that about 32 percent of reported incidents occurred by 24 months, and about half occurred before 48 months, long before the estimated 13 year (156 month) dryer-life expectancy. One possibility is that consumers feel more compelled to report a dryer failure when the dryer is fairly new, and they perceived it to have failed prematurely. Another possibility is the percentage of households with newer clothes dryers is higher than the percentage households with older clothes dryers.

A report by the U.S. Environmental Protection Agency includes the age distribution of clothes dryers by percent total in U.S. households, as shown in Table 6.[7] The table shows that 37 percent of the clothes dryers in U.S. households are less than 4 years old, and 70 percent of the dryers in U.S. households are less than 9 years old.

Table 6. Age Distribution of Clothes Dryers in the U.S (2009)[7]

Age of Clothes Dryer	U.S. Households (millions)	Percentage of Total Households
Less than 2 Years	11.9	13%
2 to 4 Years	21.4	24%
5 to 9 Years	30.1	33%
10 to 14 Years	16.2	18%
15 to 19 Years	6.2	7%
20 Years or More	4.5	5%

[7] Energy Star Market & Industry Scoping Report Residential Clothes Dryers; (November 2011), Table 4: Age Distribution of Clothes Dryers, U.S. Environmental Protection Agency (EPA), viewed on 4/22/2021, http://energy.mo.gov.

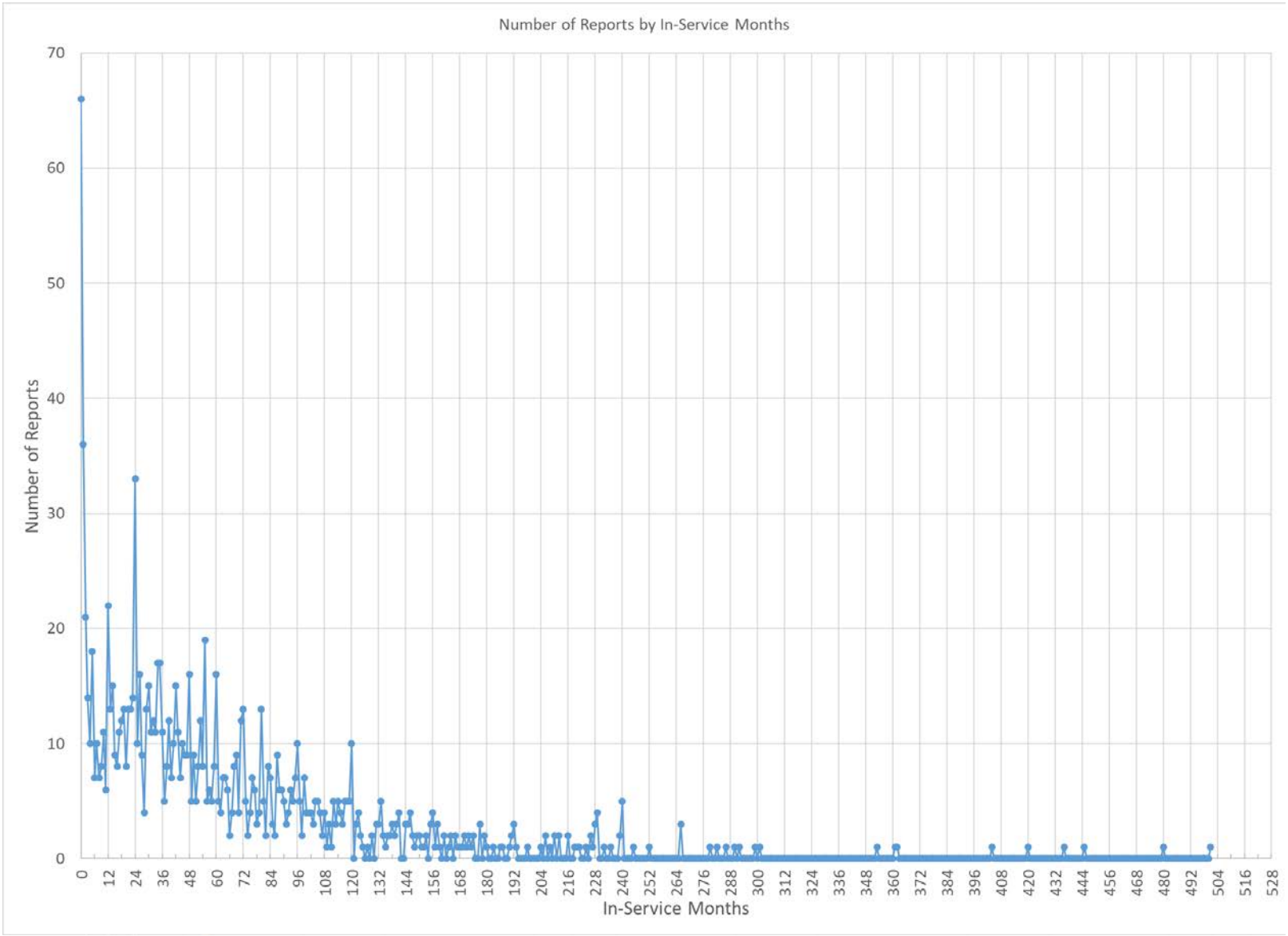


Figure 6. Number of reports by in-service years

Pre- and Post-Fire Containment Clothes Dryers

Staff purchased used electric clothes dryers manufactured before the 2013 effective date of the UL 2158 Fire Containment Performance Test requirements. Additionally, in 2019 staff purchased four new clothes dryers, manufactured after the 2013 effective date of the UL 2158 Fire Containment Performance test requirements.

The clothes dryers manufactured after 2013, contain few or no plastic components in the base compartments of the clothes dryers. The blower housing and ducting are typically constructed of metal. The air louvers in the cabinet are constructed with baffles to prevent flames from directly exiting the dryer. Figure 7 shows construction of the dryer interior components using nonflammable materials.

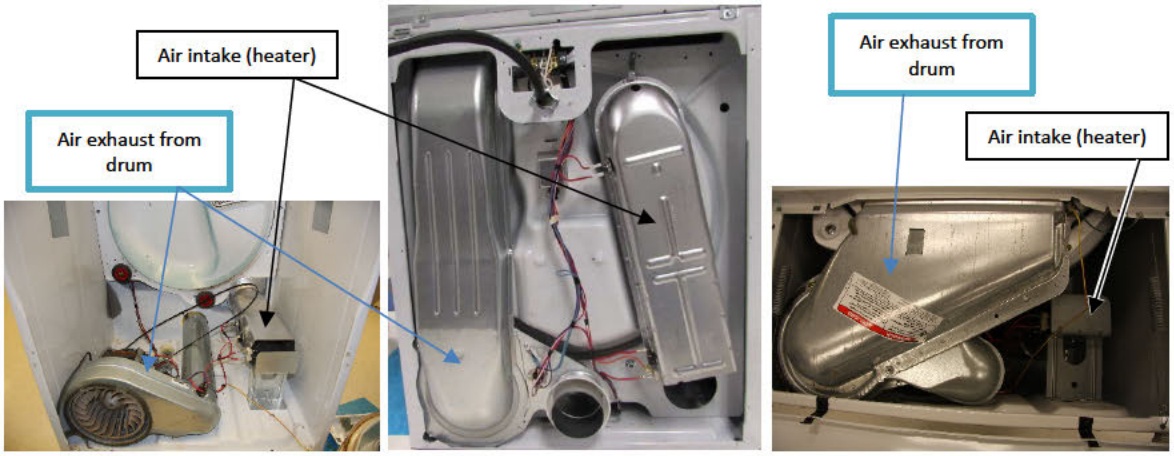
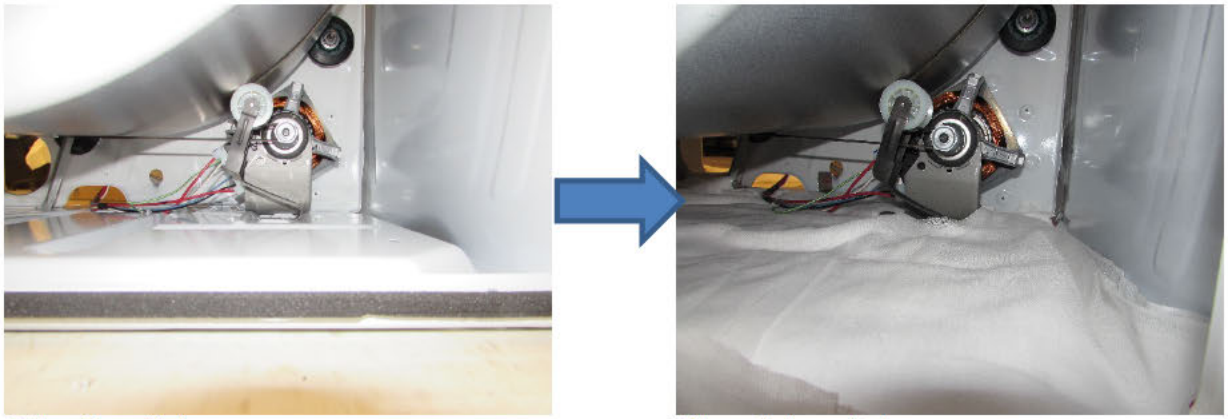


Figure 7. Examples of inside the dryer

Base Fire Containment Test on a New Clothes Dyer

The base fire containment test was conducted on one of the dryers manufactured after 2013. The bottom of the dryer housing was covered with cheesecloth, as shown in Figures 8 and 9. Cheesecloth strips were used to connect cheesecloth sections, as indicated in the standard. Small pieces of foil tape were used to ensure the strips of cheesecloth stayed in contact with the cheesecloth sections.



Before cheesecloth ***After with cheesecloth***

Figure 8. Base of dryer without and with cheesecloth

Figure 9. Various areas of the base covered with cheesecloth

The drum was loaded (dry weight of 0.016 kg/L of clothes-drum volume) with dry white cloth towels. The volume was estimated by measuring the diameter and depth of the drum. Most likely this resulted in a slightly larger volume than actual because of the paddles protruding from the sides of the drum, and the back of the drum was not flat. The dryer was draped with one layer of cheesecloth, as shown in Figure 10. The cheesecloth at the rear of the base was ignited with a butane lighter.

Shown with the door open; door was closed and covered with cheesecloth during the test (not final test set-up)

Figure 10. Cheesecloth draped over the dryer sample

Once the cheesecloth was ignited, the flame slowly crept across the bottom of the dryer. Figure 11 shows the interior cheesecloth after the test. The cloths in the drum never ignited. The cheesecloth draped over the clothes dryer never ignited, and there were no visible flames external to the clothes dryer during the test. Surfaces inside the drum were stained with smoke, as shown in Figure 12.

Figure 11. Base of the dryer after the test

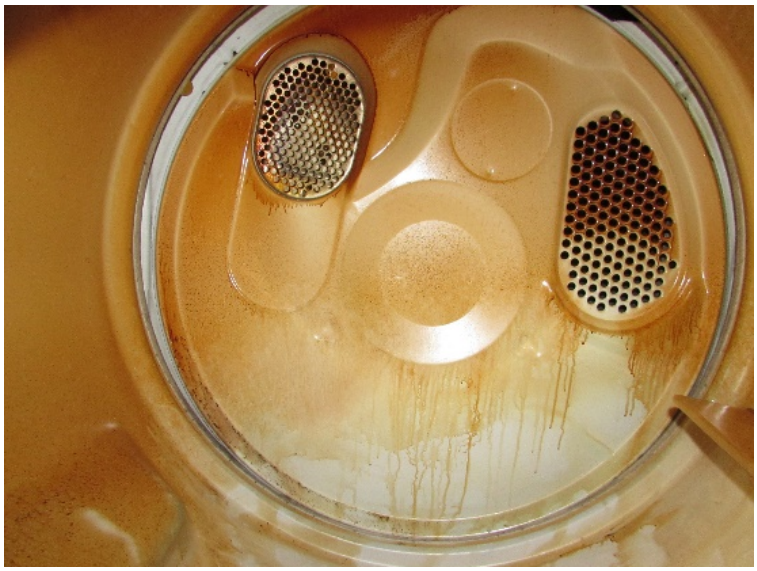


Figure 12. Inside the drum after the test

Conclusions

The fire containment tests for electric clothes dryers were incorporated into a revised version of the second edition of UL 2158, issued in March 2009. The UL 2158 Fire Containment Tests were added to the fifth edition of ANSI Z21.5.1/CSA 7.1 in January 2015. The fire containment performance requirements became effective on March 20, 2013 for UL 2158 and on June 1, 2016 for ANSI Z21.5.1/CSA 7.1, whereupon all clothes dryers must be tested to receive third party certification.

The team reviewed the reports and sorted the information by relevant parameters, such as year purchased, reported item that first ignited (if known), and whether the fire escaped the unit, for staff to gain insight into the causes and consequences of fire incidents. Specifically, looking at the purchase dates of clothes dryers from reported incidents (103) from 2000 to 2019, where fire escaped the appliance, the number of recorded incidents before the 2013 incorporation of the UL 2158 Fire Containment tests, was about 2.5 incidents per year; and for 2013 and later, the incidents were about 0.5 per year. At this time, however, no direct inference can be made regarding the impact of the 2013 Fire Containment tests in UL 2158, because the CPSRMS data are not statistically sampled, and the information in the incident reports is often incomplete (*e.g.*, a clothes dryer manufactured prior to 2013 could have been certified to the fire containment requirements). Moreover, the CPSRMS data are highly dependent upon consumer and manufacturer self-reporting of incidents.

From the review of pre- and post-2013-made clothes dryers, it appears that clothes dryer manufacturers are designing clothes dryers to contain fewer flammable plastics in locations that have potential to fuel a fire. Conducting the Fire Containment test on clothes dryers manufactured after 2013, showed that the burning cheesecloth at the bottom of the dryer chassis will burn itself out, if there is no other fuel source to ignite.

Given this information is evolving, staff will continue to monitor clothes dryer fire data. Staff recommends readdressing a detailed review in about 8 years, when a substantial number of clothes dryers in use are expected to be compliant with the UL 2158 and ANSI Z21.5.1/CSA 7.1 Fire Containment Performance tests.