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Dryer Fires: Improving Clothes Dryer Safety

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Dryer Fires: Improving Clothes Dryer Safety

An Interactive Qualifying Project Report
Submitted to the Faculty of Worcester Polytechnic Institute
In partial fulfillment of the requirements for the Degree of Bachelor of Science

In Cooperation with the U.S. Consumer Product Safety Commission



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December 13, 2012

This report is submitted in partial fulfillment of the degree requirements of Worcester Polytechnic Institute. The views and opinions expressed herein are those of the authors and do not necessarily reflect the positions or opinions of the U.S. Consumer Product Safety Commission Staff or Worcester Polytechnic Institute.

Abstract

Electric clothes dryers are responsible for approximately 4600 fire incidents annually. This project with the U.S. Consumer Product Safety Commission targeted reducing the number of clothes dryer fire incidents by amending the voluntary safety standard, UL 2158, *Electric Clothes Dryers*. We identified the major contributing factors to electric clothes dryer fires, primarily through archival research and interviews, and designed a new performance test to be added to UL 2158 to address one of the major causes of such fires.

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List of Common Acronyms and Abbreviations

CSDS- Collaborative Standards Development System
CPSC- United States Consumer Product Safety Commission
IAC- Industry Advisory Conference
IDI- In-Depth Investigation Database
IPII- Injury and Potential Injury Incidents Database
IQP- Interactive Qualifying Project
NEISS- National Electronic Injury Surveillance System
NFIRS- National Fire Incident Reporting System
NFPA- National Fire Protection Association
STP- Standards Technical Panel
UL- Underwriters Laboratories
USFA- United States Fire Administration
WPI- Worcester Polytechnic Institute

Executive Summary

Every year, approximately 4,600 fires occur in residential buildings as a result of electric clothes dryers. These fires result in an estimated 10 deaths, 140 injuries, and 63.5 million dollars in property damage annually. Because of the danger posed by electric clothes dryer fires, action should be taken to reduce their potential harm to consumers. One way to address this issue is through voluntary manufacturing standards. Currently there is an electric clothes dryer standard developed by Underwriters Laboratories (UL), an organization responsible for many successful voluntary product standards. Their standard, UL 2158, *Electric Clothes Dryers*, is followed by manufacturers when designing electric clothes dryers in order to receive UL listing for their products. Although UL 2158 requires manufacturers to satisfy numerous safety criteria and pass multiple performance tests, incidents of clothes dryer fires continue to occur. Therefore, it is possible that UL 2158 could be modified to further prevent fires.

In order to reduce the number of fires caused by electric clothes dryers, we explored a few main ideas. Our group determined where fires occur in clothes dryers, why they start, and whether there are any usage patterns responsible for a significant number of fires. This information allowed us to target the causes of clothes dryer fires, but more information is needed to figure out how to prevent them. Fire can only exist if four components are present: fuel, heat, oxygen, and an exothermic chemical chain reaction. We determined how to prevent fires by figuring out which of these components would be the most practical to eliminate. We then decided that if the voluntary standard is amended with the addition of a design requirement in an attempt to address fire incidents, manufacturers could feel restricted and could oppose the change. An alternative method of amending the standard would be to design

a performance test to be conducted before the clothes dryer can receive UL listing. We created parameters of a new performance test that addresses the heat component of clothes dryer fires. Furthermore, we worked on creating a convincing rationale in order to demonstrate the need for the amendment to UL 2158.

Our main goal was to create a proposed amendment for UL 2158. In order to identify what could be improved in UL 2158, we researched incidents of electric clothes dryer fires and identified which areas of the dryer were the most commonly reported locations of ignition. These efforts utilized data that the U.S. Consumer Product Safety Commission had archived. Using reports from the last 12 years, we were able to deduce clothes dryer components that were reported as associated with fire incidents. The majority of the fires in those reports occurred in the cabinet, the inside of the dryer that contains all of the internal components, outside of the drum. The second most commonly reported location of the fires was in the drum. Other locations included the exhaust hose, the electrical wall outlet, and the control panel. In these areas, the most reported causes of these fires were overheated clothing, accumulated lint, and electrical malfunction. We determined that some of these areas of concern were possible to address through a performance test for the voluntary standard, and that compliance would be reasonable for manufacturers to achieve. We then had the information needed to draft a proposed amendment to UL 2158, which would improve the standard and hopefully prevent fires from occurring.

After we determined some of the typical causes of clothes dryer fires, the next step was to find a way to prevent these incidents from occurring. A fire can be prevented by removing the fuel, heat, oxygen, or chemical chain reaction. While taking away any one of these factors would prevent clothes dryer fires, some factors may be more difficult to address than others.

We decided that limiting heat is the most practical in this instance because the options of preventing the fuel, oxygen, or chemical reaction are difficult due to limited technology. Heat can be removed as a component of fire by limiting the clothes dryer's cabinet temperature below the ignition temperature of lint. This should not require radical design changes or the use of high-priced materials.

Based on our decision to target the heat component of fire, we drafted language for a performance test designed to limit the internal temperatures during a typical clothes drying cycle. The temperature can be monitored during testing with thermocouples placed on surfaces inside the clothes dryer cabinet that are determined to be the hottest. It is likely that the heating element cover will have the highest temperature because it encloses the main source of thermal energy inside the clothes dryer. Manufacturers could address limiting temperature in the clothes dryer in various ways. Insulation could be added to heat sources in order to control temperatures inside the cabinet. The energy output of the heating element could also be reduced while increasing airflow. Both of these ideas have the potential to reduce temperatures throughout the clothes dryer without adversely affecting its operation. Manufacturers could determine the best way to achieve lower temperatures for their specific model and pass the performance test. If a tested clothes dryer passes this test, it can be considered for UL listing.

We recommend that the CPSC submit the language we drafted for the proposed amendment to UL 2158 to the UL Standards Technical Panel (STP) responsible for electric clothes dryers. Upon receiving this proposed amendment, the STP will evaluate our solution and hopefully update and publish a new version of UL 2158. In this way, when manufacturers create their products following the amended standard, more electric dryer fires can be prevented, which will prevent unnecessary deaths, injury, and property loss.

Chapter 1: Introduction

Many consumer products, such as major appliances, are subject to voluntary safety standards (UL, 2012b). The typical large manufacturing company often focuses on trying to create copious numbers of products while keeping production costs as low as possible, because of the highly competitive consumer products market (Lee D. R., 2006). While many considerations are taken into account during the design, manufacturing, and distribution of consumer products, one of the most important factors is safety. Deaths, injuries, and property damage have been associated with many consumer products. In order to ensure that products are as safe as possible, the U.S. Consumer Product Safety Commission (CPSC) has issued mandatory safety standards for some consumer products. Other safety standards have been created by government organizations all over the world whose goal is to create minimum design and performance levels at which products must perform, in order to protect users (Yadav & Moon, 2007). Industry committees create voluntary safety standards, which accomplish the same goal as mandatory standards but are not required by the government. Underwriters Laboratories (UL) organizes committees for a large range of voluntary safety standards; these voluntary standards are then approved as UL Standards. Compliance with the UL Standards may be necessary for major home appliances to be sold in most large US retail stores. If a product complies with the UL Standard, retailers expect the product to function properly, not cause any harm to their customers, and help maintain their reputation. Safety is an important consideration for retailers, consumer advocacy organizations, manufacturers, and governmental regulatory agencies such as the CPSC.

Safety standards are not perfect, and some products that adhere to standards may still be potentially dangerous. In the case of electric clothes dryers, the UL standard UL 2158, *Electric*

Clothes Dryers, could be improved because clothes dryers manufactured in compliance with the standard are associated with almost 4,600 annual fire incidents (Miller, 2012). Clothes dryers operate at high temperatures, and this can result in the ignition of accumulated lint and other clothing fibers. In order for electric clothes dryers to be safer and less likely to catch fire, the CPSC is working with UL to revise their standard.

One intention of the voluntary standard for electric clothes dryers, UL 2158, is to protect consumers from fires and other safety hazards. Because there are fires associated with electric clothes dryers, the standard could be improved to reduce the frequency of these incidents. Included in the standard, there are tests that must be executed to assess the performance quality of an electric clothes dryer before it can be considered for UL listing. For example, the fire containment ability of electric clothes dryers is addressed by the fire containment test, which involves wrapping a clothes dryer in cheesecloth and starting a fire inside of the dryer (UL, 2009). The clothes dryer passes the test if the exterior cheesecloth does not ignite. In addition to UL 2158, there has been a lot of work based on special features of clothes dryers that will warn users of fires, or help control them. Furthermore, causes of fires in clothes dryers are an important factor, and are recorded in reports by the National Fire Protection Association (NFPA), the United States Fire Administration (USFA), and the CPSC.

High running temperatures and lint accumulation are two main contributors to clothes dryer fires (Hall, 2012). However, there have been few studies that investigate the temperatures in specific areas of the clothes dryer and at what temperatures lint ignites. Little effort has been made to limit the spread of lint through the clothes dryer, as well as containing the lint to the air flow path (NFPA, 2012b). Alternative methods of controlling temperature inside of the clothes dryer have also not been studied. By obtaining or producing more

information on running temperatures and lint accumulation, UL 2158 could be adapted to target one or both of these specific issues.

The purpose of this project was to draft a proposed amendment to UL 2158 that improves safety in electric clothes dryers. To draft this amendment, we first determined where, how, and why clothes dryer fires occur. We determined some of the most common causes and locations of clothes dryer fires, and where lint accumulates. Finally, fire incident patterns were examined for commonality. Our group gathered this information using CPSC's In-Depth Investigation (IDI) reports and the CPSC 360 database, which includes reports on clothes dryer fires. We studied how standards like UL 2158 are created and maintained, and learned what makes a standard effective. Our goal was to make sure that manufacturers would have flexibility when creating their products; we did not want to prescribe a specific design element. Instead, we based our proposed amendment on the addition of a performance test, which focuses on limiting the clothes dryer's temperature in various locations outside of the drum. Overall, our group wanted to build a strong rationale for approval of an amendment to UL 2158. Improving the safety standard for electric clothes dryers could potentially save lives, prevent injuries, and avoid millions of dollars in property damage.

Chapter 2: Background

This chapter explains why fires occur and how they can be extinguished; provides information on electric clothes dryers including the components and features; discusses potential heat sources in a dryer; evaluates various data reporting and tracking systems; addresses the elements of clothes dryer fires; investigates actions that can be taken to address the possible fire scenarios; and reviews what actions have already been taken to address clothes dryer safety.

2.1: The Nature of Fire

Fire is not a substance (NFPA, 2012b). It is a chemical reaction, specifically an oxidation reaction, known as combustion. Because the reaction happens so quickly, heat and light are released. This section explains how fire occurs, including the components that are necessary for a fire to start, and outlines ways that a fire can be extinguished along with the principles behind each method.

2.1.1: The Fire Tetrahedron

There are several theories about the components that are necessary for combustion to occur. The theory that was widely accepted for many years is the “Fire Triangle” theory (NFPA, 2012b). This states that there are three factors that must be present in order for a fire to occur. The factors are fuel or combustible material, heat to raise the fuel to its ignition temperature, and oxygen to sustain combustion. The Fire Triangle was later replaced by another theory, the “Fire Tetrahedron,” which adds in a fourth factor, an uninhibited chemical chain reaction. This chain reaction is caused by unstable chemicals that are created when pyrolysis, the process by which the fuel is heated and vapors are released, occurs. Even if the initial source of heat is removed, the chemical chain reaction can provide the heat to maintain the tetrahedron (Safelincs Ltd, 2011). Figure 1 shows a depiction of the Fire Tetrahedron.

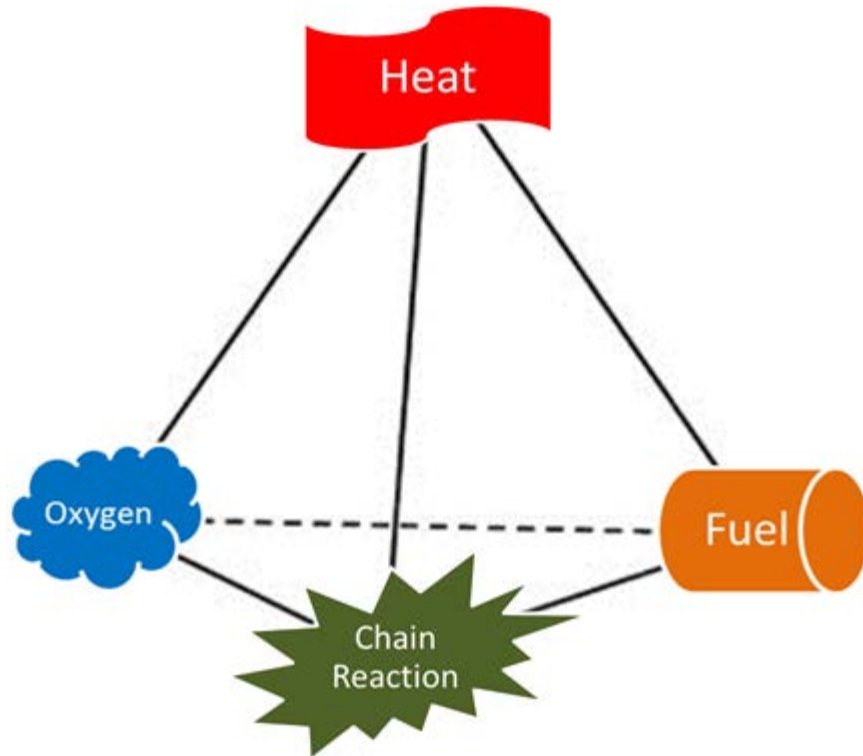


Figure 1: The Fire Tetrahedron

If one of the four components of the fire tetrahedron is removed, a fire is not possible because it cannot be sustained (NFPA, 2012b). If one of the four factors is not present, then a fire cannot start. For this reason, fire extinguishing and prevention methods are based on removing one of these factors from a fire.

2.1.2: Fire Control Methods

Fires can be prevented or extinguished by breaking a leg of the fire tetrahedron (NFPA, 2012b). One method to break the tetrahedron is to remove the fuel. For instance, in a fire caused by a flammable liquid, a powder extinguisher could be used to absorb the fuel, putting out the fire. Another method to break the Tetrahedron is to remove heat by cooling the system until it is below the fuel's ignition temperature, which is often achieved with water (Fire Sure, 2012). A fire may also be extinguished by removing oxygen from the system. By using a foam or inert gas

extinguisher, oxygen can be separated from the fuel source, preventing the possibility of oxidation. Finally, a fire can be extinguished by removing the free radicals that cause the chemical chain reaction (Safelincs Ltd, 2011). This can be done using halogen extinguishers to neutralize the radicals.

2.2: Electric Clothes Dryers

A clothes dryer is an appliance that dries wet clothes, linens, and other fabrics (Joslin & Ryherd, 1994). Eighty percent of clothes dryers in the United States are electric, while the remaining 20 percent are gas-powered (Energy Star, 2011). Electric clothes dryers have certain parts and functions that allow them to fulfill their purpose of removing moisture from textiles.

2.2.1: Components of Electric Clothes Dryers

The main components of the electric clothes dryer are an inlet for air, or air intake; the heater, or “heating element;” the drum, the cavity that holds the clothes for drying; a motor and belt, which rotate the drum; an exhaust vent; and a blower to draw the air through the clothes dryer (Joslin & Ryherd, 1994). Refer to Figure 2 for a diagram of clothes dryer parts.

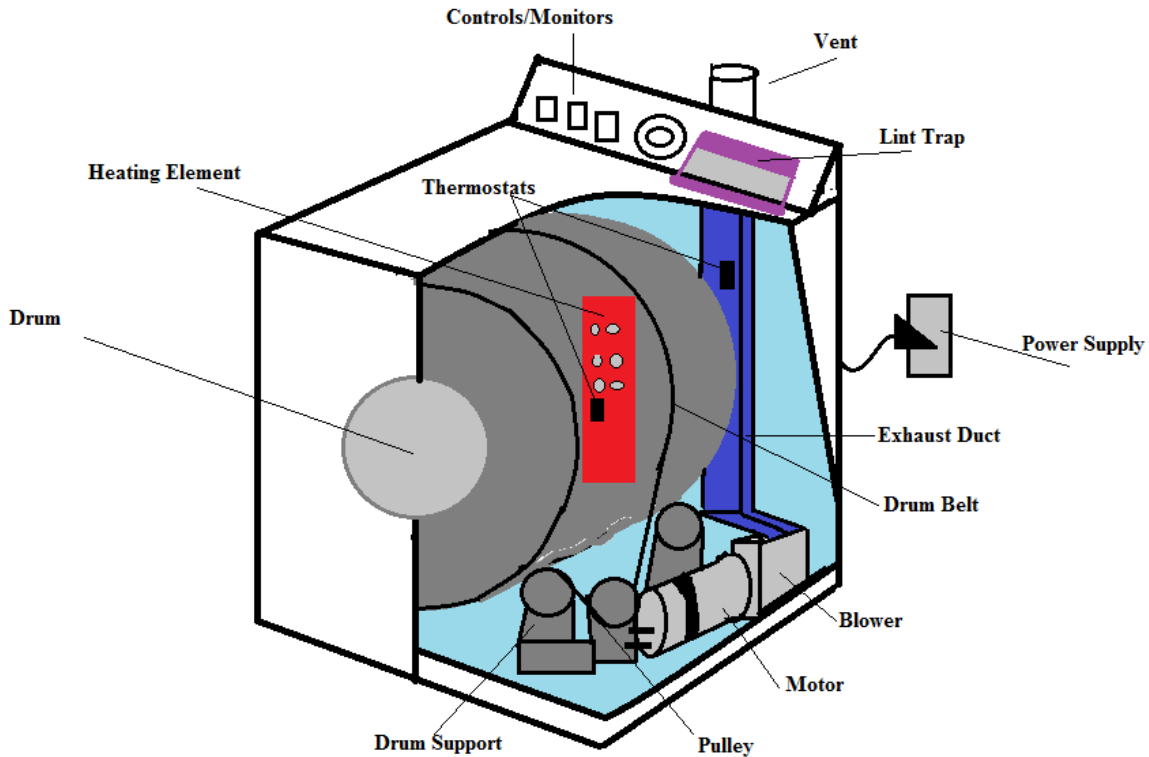


Figure 2: Diagram of a Typical Electric Clothes Dryer

The inlet for air intake is usually located either behind or underneath the clothes dryer. Domestic clothes dryers usually draw air from the room in which they are located (Narang, 1987). The air passes through the heating element to become hot enough to dry damp clothes.

Electric clothes dryers have a high-wattage heating element that is used to heat the air entering the dryer (Nice, 2000). Typical heating element temperatures can reach between 250° C and 400° C (Marks, 2012). The heating element consists of a coil of wire, whose resistance converts the electrical energy into heat. The heating element is often not insulated, and in many models of clothes dryers, all that separates the heating element and the open cabinet is a thin piece of sheet metal (Randy Butturini, personal communication, November 6, 2012). After the air passes through the heating element, it is pulled through holes in the back of the drum.

The drum is the part of the clothes dryer which holds the wet clothes. The drum is rotated within the cabinet, the area that contains the internal components of the clothes dryer, which tumbles the clothing inside to ensure that it is completely exposed to warm, drying air.

The belt and motor rotate the drum (Nice, 2000). The belt typically uses a pulley system to create the “tumbling effect” that leads to even drying. Two pulleys are generally used in the cabinet; one is to tumble the drum while the other maintains tension in the belt to keep the drum secure. The motor usually drives the smaller pulley as well as the blower, in order to maximize efficiency. Heat loss from the airflow path can cause the motor to operate in a higher temperature environment than ambient air and possibly lead to motor overheating and failure (Andrew Trotta, personal communication, November 13, 2012).

The next component in the airflow path is the lint screen. A lint screen prevents exhaust blockage by collecting excess lint before it enters the exhaust vent (Nice, 2000). Major blockages of the exhaust vent can lead to overheating and fire due to reduced air flow through the vent, trapping heat inside the clothes dryer.

Before exiting the clothes dryer, air passes through the blower. The blower in an electric clothes dryer is a centrifugal device (Nice, 2000). A centrifugal device is a cylindrical blade configuration that draws air into its center and pushes it out tangentially. The blower can become a source of heat due to restricted air flow, attributable to lint buildup (Andrew Trotta, personal communication, November 13, 2012). The blower is located towards the end of the airflow path, creating a negative pressure system to pull air through the clothes dryer (Randy Butturini, personal communication, November 1, 2012).

2.2.2: Features of Electric Clothes Dryers

Clothes dryers contain many standard features added to improve their operation, functionality, and safety. These include timers, humidity sensing, temperature controls, owner's manuals, and safety switches.

The timer on a clothes dryer indicates the length of time that the appliance will be operating (Nice, 2000). When the clothes dryer door is closed and the timer is set, the heating element activates and air begins blowing through the tumbling drum. The clothes dryer will run for the indicated time. There are also pre-programmed settings, which have different lengths of time for drying, which can vary between models. For example, a "normal dry cycle" may only take a half hour to dry, but a "delicate dry cycle" can take up to 150 minutes (Sears, 2012).

A humidity sensor detects if the humidity within the air flow path is high, which indicates that moisture is still present in the clothing. Humidity sensors prevent the clothes dryer from over-drying the contents inside the drum, which could increase the contents' flammability by causing pyrolysis (Kim, 1994). If the air inside of the drum becomes too dry, the sensor will detect this and end the cycle. If the humidity sensor wasn't included, the clothes dryer would continue to run and potentially ignite the fabrics within the drum.

The temperature control system regulates the clothes dryer based on air temperature (Butturini, 2004). This control comes pre-installed in electric clothes dryers. There are usually two of these controls located in the clothes dryer: the regulating control is located near the exhaust vent, and the overtemperature control is located near the heating element. If these controls were not included, the heating element would continue heating and fires could occur.

Each newly purchased electric clothes dryer is required to come with a safety manual (UL, 2009). These manuals include statements that warn the user of possible risk and injury, as

well as installation and maintenance care instructions. Manuals promote a proper understanding on how to maintain the electric clothes dryer. These manuals also warn users about what should not be placed in their clothes dryer, such as fabrics that were soaked in oils or greases.

Another safety feature that is included in electric clothes dryers is an automatic shut-off switch. The shut-off switch turns the clothes dryer off if the door is opened during a cycle (Sears, 2012). The clothes dryer will not turn back on unless the door is shut, and the “start” control is initiated again. Together, all of these features maintain electric clothes dryer safety and attempt to prevent injury.

2.3: Electric Clothes Dryer Fire Reports

There are several organizations in the United States that publish information on fire incidents (David Miller, personal communication, October 25, 2012). Each of these organizations uses slightly different methods, and therefore produces slightly different statistics.

2.3.1: NFPA Report

The National Fire Protection Association (NFPA) publishes yearly reports based on National Fire Incident Reporting System (NFIRS) data titled *Home Fires Involving Clothes Dryers and Washing Machines* (Hall, 2012). In 2010, the NFPA estimated that clothes washers and dryers were responsible for 4.5 percent of all reported fires. Of these fires, clothes dryers are responsible for the majority, 92 percent, and clothes washers were responsible for the remaining 8 percent. Overall, the NFPA estimates that clothes dryers were responsible for 51 deaths, 380 injuries, and 236 million dollars in property damage in 2010. In addition, the NFPA estimates lint to be the most common fuel ignited in clothes dryer fires, being responsible for 29 percent of the fire incidents associated with electric clothes dryers.

2.3.2: NFIRS Report

The United States Fire Administration (USFA) publishes National Fire Incident Reporting System (NFIRS) data. NFIRS consists of information submitted by fire departments voluntarily (David Miller, personal communication, October 25, 2012). Most fire departments in the United States submit reports to the USFA and NFIRS. NFIRS data describe the number of fires, number of injuries, and amount of property loss. NFIRS is sorted by “equipment involved with ignition,” which means that incident reports are submitted with information about what type of equipment caused each fire. Equipment refers to items such as appliances, chimneys, and lights. NFIRS incident reports can be sorted by individual equipment type. They can also be listed as “unknown equipment,” which indicates an unknown fire source, or “no equipment,” which indicates a fire source that is not considered “equipment,” such as lightning. The reports are also submitted with information about “item first ignited,” which is, in the case of electric clothes dryer fires, often lint or clothing. Later, the NFIRS product-specific data are weighted up to the NFPA number of fires to account for incidents not reported to NFIRS.

2.3.3: CPSC Report

The CPSC produces an annual report about fire loss, *Residential Fire Loss Estimates*. In the most recent report, spanning 2008-2010, the CPSC found that there was an average of 6,100 clothes dryer fires annually (Miller, 2012). For more specific information on the number of clothes dryer fires and loss from 2008-2010, see Table 1.

Table 1: Average Annual CPSC Clothes Dryer Fire Estimates

	Number	Number of Deaths	Number of Injuries	Property Loss
Clothes Dryer Fires (Gas and Electric)	6100	20	190	\$78.7 Million
Electric Clothes Dryer	4600	10	140	\$63.5 Million
% Electric Clothes Dryers	75%	50%	73.7%	81%
<i>Note: This information is an annual average of CPSC Fire Loss Statistics from 2008-2010, taken from the CPSC Residential Fire Loss Estimates (Miller, 2012)</i>				

The CPSC generates estimates for both electric and gas clothes dryers, but because electric clothes dryers are more common, they are responsible for more fires than gas clothes dryers (Energy Star, 2011). The CPSC generates their statistics using NFPA and NFIRS data by dividing the NFPA total estimates by the NFIRS total estimates. In order to produce product-specific information, the CPSC takes the “weight” from the division and multiplies it by individual product-specific NFIRS data. The CPSC estimates, however, are based only on fires where the fire department attended and reported, so they may not be completely comprehensive.

2.3.4: Comparison of Estimates

In part because the CPSC uses NFPA estimates to produce their own, the NFPA and CPSC estimates can be very different (David Miller, personal communication, October 25, 2012). These differences can be seen in Table 2.

Table 2: 2010 Estimates of Clothes Dryer Fire Damage

	Number of Fires	Number of Deaths	Number of Injuries	Property Loss
NFPA Estimate	16800	51	380	\$236 Million
CPSC Estimate	6200	10	190	\$76.4 Million
<i>Note: These estimates come from the NFPA Annual Fire Loss report, titled Home Fires Involving Clothes Dryers and Washing Machines (Hall, 2012), and the CPSC Residential Fire Loss Estimates (Miller, 2012)</i>				

Clearly, the NFPA has higher estimates than the CPSC. One of the differences in obtaining these estimates that results in differing outcomes is that the CPSC ignores intentionally

set fires, whereas the NFPA does not (David Miller, personal communication, October 25, 2012). In addition, both organizations have different methods of accounting for possibly missing data, using different statistical analysis methods (Hall, 2012). Finally and most importantly, for each “equipment involved with ignition,” the NFPA considers incidents listed in NFIRS as the equipment of interest, as well as entries listed as “no equipment”, “unknown equipment,” or entries left blank. The CPSC does not include “no equipment” in their analysis of individual “equipment involved with ignition” because they assume the information was adequately sorted by the fire departments reporting incidents (David Miller, personal communication, October 25, 2012). Because of this, the CPSC is more conservative in their estimation and the NFPA has higher estimates than the CPSC.

2.4: Factors Contributing to Clothes Dryer Fires

Typical electric clothes dryer fires are caused by a number of factors which stem from how the clothes dryer is manufactured, installed, used, and maintained (Toth, 1996). Some design choices can lead to an increased potential for fire hazards. Improper installation techniques can create unsafe conditions for consumers in their homes. The accumulation of lint, along with poor user maintenance, also has the possibility to develop into a fire hazard. All of these contributing factors could be avoidable if addressed properly.

2.4.1: Design

Safety standards ensure that manufacturers create safe products (WTO, 2012). Without them, companies could create products that would carry out their function properly, but companies wouldn't have to focus on the dangers that could potentially harm someone. Regardless of the standard criteria for products, some electric clothes dryer designs that satisfy safety standards still may not be as intrinsically safe as others. For instance, lint screens that

adhere to safety standards are designed to have holes to allow for air flow, but some lint can pass through these holes (Rooney, 2011).

2.4.2: Installation

Improper clothes dryer installation can lead to a higher risk of fire. The safest way to vent a clothes dryer exhaust hose is to the outside of the home (Rooney, 2011). Some people, however, use alternative installation methods in an attempt to save money on heating. One of these methods is to vent the clothes dryer into large buckets of water, which collect the lint from the exhaust air. The house is then heated with the warm air that bubbles up from the clothes dryer. The danger in this installation configuration is that the humid air, produced by hot air passing through water, can cause wood in the home, including the support beams, to rot and weaken.

Another method of unsafe installation is to vent the clothes dryer into a crawl space inside the home. This layout is also thought to help save on home heating costs (Rooney, 2011). This is an unsafe method of venting because it has the same danger of weakening support beams with moist air, with the added risk of lint accumulating in the crawlspace. The lint that accumulates can serve as a fire starter and can lead to devastating fires. UL 2158 includes that the user instructions must state “that the appliance shall not be exhausted into a chimney, a wall, a ceiling, an attic, a crawl space, or a concealed, space of a building” (UL, 2009, p. 30A). However, some clothes dryers are still exhausted into these areas of the home which increases the risk and severity of fires.

2.4.3: User Interaction

Along with installation and design errors, the user of the clothes dryer may also be a contributor to fires (Toth, 1996). Despite UL’s efforts to comprehensively test an electric clothes

dryer, if the user is not following the included UL 2158 mandatory instructions, safety could be compromised. UL 2158 requires that “the user-maintenance instructions shall include explicit instructions for all cleaning and servicing that is intended to be performed by the user, such as lubrication, adjustments, or removal of lint, dust, or dirt” (UL, 2009, p. 32). However, the average user does not always properly clean their clothes dryer (Hall, 2012). Figure 3 is a photograph of a lint trap that has not been cleaned, and where lint has accumulated. See Appendix C for more photographs of an electric clothes dryer that has not been properly maintained according to manufacturer’s instructions.



Figure 3: Result of Uncleared Lint Screen: Clogged Lint Area

User choice of exhaust duct material can also contribute to clothes dryer fire incidents. The safest material for a clothes dryer vent hose is a stiff metal. However, plastic and foil hoses are less expensive, and users sometimes select these options (Consumer Reports, 2004). The inexpensive hoses that many users prefer are flexible and can trap lint in their ridges and bends.

This accumulation of lint provides fuel for fires, either increasing the intensity of the fire or providing starting material (Rooney, 2011).

2.5: Actions Taken to Address Fire Incidents

Fire prevention is generally preferable to fire suppression (Randy Butturini, personal communication, September 5, 2012). Whether fire prevention is accomplished in clothes dryers by using existing solutions or innovations, further development of safety devices could improve consumer safety. There are existing methods for both suppression and prevention of clothes dryer fires, but many of the options are not in regular use.

2.5.1: CPSC Safety Bulletin

The Consumer Product Safety Commission (2012c) releases Safety Alerts, also known as Safety Bulletins. An example of a Safety Alert can be seen in Appendix D. These bulletins help to communicate the safe use of products. Each bulletin also informs consumers of product recalls, and provides a link to a website with more information on the subject. The safety bulletin for electric clothes dryers includes causes of fires and tips for preventing clothes dryer fires. These tips include cleaning the lint screen and vent, as well as recommendations on the type of duct material for venting the clothes dryer.

2.5.2: Private Services

Clothes dryer maintenance is important in preventing fires (CPSC, 2012c). Removing lint is a major factor in maintaining a safe clothes dryer. Lint is intended to remain in the airflow path of the clothes dryer because of the negative pressure system in the dryer (Randy Butturini, personal communication, November 1, 2012). Regardless of this intention, however, some lint may escape the airflow path and accumulate on internal cabinet areas. Lint can also accumulate in the clothes dryer exhaust vent. In order to address these hazards, the clothes dryer needs to be

cleaned regularly. Section 7.2.2.4 of UL 2158 includes the requirement that the instruction manual must state, “The interior of the appliance and the exhaust duct should be done periodically by a qualified service professional” (UL, 2009, p. 29). There are businesses that specialize in cleaning out clothes dryer vents and cabinets. Clothes dryer users can hire these professional services to clean their clothes dryers, which will improve clothes dryer efficiency and reduce the risk of fire. These companies typically have equipment that a user might not have access to. One company, for example, uses a rotating brush attached to a high-powered vacuum (Vent Smart, 2012). On average, a consumer will pay approximately 69 dollars to 99 dollars to have their clothes dryer vent cleaned. Hiring a cleaning company may seem inconvenient to some, but the cleaning can help prevent fires.

2.5.3: Safety Designs and Devices

Several designs and devices have been created in order to decrease the risk of clothes dryer fires and to increase safety in the event of a fire. One design is a clothes dryer that can extinguish itself (Salameh & Wheeler, 2004). These clothes dryers can sense a fire, and cool it with water before it becomes a conflagration. Another clothes dryer design protects all wires behind a fuse to limit the chance of arcing, causing ignition (Renzo, 2009). Another alternative design has a louvre cover for a clothes dryer that prevents burning debris inside the dryer from escaping and igniting combustibles outside the dryer (Prajescu, Larochelle, & Renzo, 2011). This cover is specifically designed so that air may escape, but the burning debris is contained. One safety product that has been created is a fire alarm that is placed in the exhaust vent of the clothes dryer. This alarm senses carbon monoxide (Crnkovich, 2007). It alerts the user of a fire before it becomes so large that a home fire extinguisher would not be effective. Another product is a sensor which detects lint accumulation by shining a light onto a surface where lint typically

builds up in the clothes dryer. This sensor detects whether the light is able to reflect off of that surface, in order to identify lint accumulation (Stein, Whitehead, Scholl, & Sumner, 2006).

Although there have been several designs and products invented that could be useful in reducing the number of clothes dryer fires, not all are in regular use.

2.5.4: UL 2158, *Electric Clothes Dryers*

UL 2158 represents the efforts made through the voluntary standards process to prevent injury and property damage caused by electric clothes dryers. The current voluntary standard has many specifications that clothes dryers must meet, as well as a series of performance tests that a dryer must pass before it can be listed by UL. The standard includes requirements for warnings, markings, grounding instructions, power instructions, electrical wiring, operating conditions, and mechanical strength (UL, 2009). UL 2158 intends to prevent known problems with electric clothes dryers, and addresses issues that come from manufacturing, design, and use. The standard clearly identifies issues associated with lint accumulation and how the clothes dryer should be marked to prevent it. For example, Section 7.1.2.10 of the standard requires that “an appliance that provides means for collection of dust and lint accumulation shall be plainly and permanently marked to indicate the necessity of keeping the lint trap cleaned out” (p. 23). The standard also includes a table of maximum acceptable temperature increases which are intended to make sure that a clothes dryer does not become so hot that a fire can be started.

While standards are created to protect consumers from hazardous products, standards should not limit manufacturers’ ability to create new and innovative products (Randy Butturini, personal communication, November 1, 2012). Therefore, unlike design requirements that require specific components to be included in a product, performance tests can facilitate design and manufacturing creativity, as long as the design can meet certain criteria. For example, UL 2158

currently includes a test that blocks the lint screen and exhaust. In section 19.5 of UL 2158, the blockage of lint screen and exhaust test is run to see if flame or combustion is seen under various conditions. The test is run with a lint screen blockage of 75 percent and 100 percent, and then with an exhaust blockage of 75 percent and 100 percent. The clothes dryer must not cause a fire at any of the four conditions (UL, 2009).

The STP

A Standards Technical Panel, or STP, is the specific group that is responsible for the creation and revision of voluntary standards (Joe Musso, personal communication, October 3, 2012). The STP for any given voluntary standard is comprised of engineers, consumers, commercial users, manufacturers, representatives from academia, retailers, and governmental organizations. Votes are limited so that no group has more power, and each group can equally contribute to setting the standard. The STP was created to replace the old systems of creating standards, the Industry Advisory Conference (IAC), and later, Canvas Groups. These two groups were made up of UL representatives and manufacturers. These systems were limited in regards to creating and revising standards because UL was only considering manufacturers' concerns. Therefore, the STP was introduced as a solution to the potential biases of the IAC and Canvas Groups, and is a very balanced group addressing voluntary standards.

In order to modify an Underwriters Laboratories voluntary standard, groups such as the CPSC or the National Fire Protection Association, or even individual persons, may submit their input to the STP in the form of a proposal (Joe Musso, personal communication, October 3, 2012). The STP will then analyze and vote on the proposal to decide if the change is warranted. It is helpful for the organization that submitted the proposal to gain support by submitting data and statistics about why the standard should be changed. If the STP believes the proposed

amendment of the standard is needed, the voluntary standard will be revised. If the proposed amendment fails to achieve consensus, the group that submitted the amendment has the opportunity to speak to specific members of the STP about the need for the amendment, revise their rationale, and possibly resubmit a revised proposal. Overall, the cooperation of groups such as the CPSC, the NFPA, and UL is one reason that voluntary standards are created for many products, the reason that standards are maintained, and the reason why users have greater protection than in the absence of voluntary standards.

2.6: Summary

Although voluntary safety standards attempt to reduce the risk of clothes dryer fires, approximately 4,600 electric clothes dryer fire incidents still occur each year. The property damage, injuries, and deaths that are caused by these fires should not be ignored. Something else must be done to further increase safety, such as amending UL 2158 to improve the standard's ability to address fire incidents.

Chapter 3: Methods

The goal of our project was to draft a proposed amendment to UL 2158, Underwriters Laboratories' voluntary safety standard for electric clothes dryers. In order to create a strong rationale for an amendment to UL 2158, and to ensure that the amendment is beneficial to consumers and manufacturers, we created the following objectives:

- 1: Determine where, how, and why clothes dryer fires start
 - 1.1: Determine the most common causes and locations of clothes dryer fires
 - 1.2: Determine where lint buildup occurs in clothes dryers
 - 1.3: Determine the usage patterns that could be responsible for clothes dryer fires
- 2: Determine potential ways to break the fire tetrahedron in clothes dryers
 - 2.1: Breaking the tetrahedron at the fuel leg
 - 2.2: Breaking the tetrahedron at the runaway chemical reaction leg
 - 2.3: Breaking the tetrahedron at the air leg
 - 2.4: Breaking the tetrahedron at the heat leg
- 3: Design a practical performance test, compliance to which could prevent some or all clothes dryer fires
 - 3.1: Identify features of a performance test
 - 3.2: Identify advantages of a performance test
 - 3.3: Determine performance test parameters
- 4: Provide a convincing rationale to the Standards Technical Panel for UL 2158 that would demonstrate the usefulness of an additional performance test in UL 2158

This chapter will address how we gathered the necessary information to achieve our goal and objectives, how we analyzed our results, and how we drafted a proposed amendment to UL 2158 for CPSC submission to UL for consideration by the STP.

3.1: Determine Where, How, And Why Clothes Dryer Fires Start

We determined the most common causes and locations of clothes dryer fires by reviewing and examining CPSC databases: In-Depth Investigations (IDI), Injury and Potential Injury Incident Files (IPII), and the National Electronic Injury Surveillance System (NEISS). These databases include numerous individual reports of clothes dryer-related fires and injuries. We focused mostly on the IDI reports, because the majority of these incidents were fire-related, and they contained detailed analyses of clothes dryer incidents. The IPII database consists of all

complaints about injury or potential injury related to products that are submitted to the CPSC, whether fire-related or not, so the majority of these reports were not relevant to the scope of this project. Similarly, the NEISS database consists of reports submitted by hospitals for all injuries related to consumer products. The majority of these reports pertaining to clothes dryers were for lacerations or contusions from dryer use, or back strain from lifting clothes dryers. We also reviewed reports in CPSC 360, the non-public version of SaferProducts.GOV. This is the system in which anyone can submit reports of injuries from consumer products. Users can report problems with the consumer products they have used, and while many of the complaints about clothes dryers were not applicable, some referred to fires. These reports were similar to those in the IDI database, although less detailed.

Based on our review of the databases, it was evident that the IDI reports were the most useful for this particular project. The IDI reports contained specific information about individual fires started by clothes dryers, including the location of ignition in the dryer and cause of ignition. We analyzed all of the relevant reports from 2000-2012, totaling 194 cases, and we produced data on the reported causes of the fires. Because information from the IDI reports is based on submitted accounts of individual incidents, and not that of data from all clothes dryer fire incidents, we cannot consider these reports representative of all dryer fires. The results from the IDI, however, did help highlight which areas of the clothes dryer are most often reported as the primary area of ignition. We also looked at the common causes of clothes dryer fires by using these databases. Because lint was a commonly reported cause of fire, our group was able to use the IDI and CPSC 360 reports to determine where lint builds up in clothes dryers and where it can become a fire hazard. We therefore analyzed which areas of lint accumulation were the most common and hazardous. Another aspect of clothes dryer fires that we studied was consumer use.

The IDI database and CPSC 360 were useful for this topic because if user behavior contributed to the incident, it was indicated in the report. Our team was able to determine some of the consumer behaviors that were most likely to result in a clothes dryer fire and determine whether they could be addressed through UL 2158.

We conducted an informal examination of a used clothes dryer. Our group removed the rear panel of the clothes dryer, and viewed the internal elements. We measured the distance between the heating element cover and nearby surfaces where lint could accumulate, and viewed the amount of lint accumulation in the air flow path. Our team photographed the areas inside the cabinet where lint accumulation was clearly visible. We also removed as much of the accumulated lint as possible, and conducted an impromptu experiment with the accumulated lint, observing the speed of combustion between a compacted sample and a less compacted sample. Appendix C is a detailed account of this process.

3.2: Potential Ways to Break the Fire Tetrahedron

We considered methods of breaking the fire tetrahedron on each individual leg: oxygen, heat, fuel, and runaway chemical reaction. Our team used archival research to determine how to cut off oxygen flow to dryer components, how we might prevent unwanted heat transfer, how to keep fuel (e.g. lint) away from high-risk areas, and how to prevent a runaway chain reaction. We considered each option, and analyzed which leg of the tetrahedron would be the easiest and most practical to address based on current technology and possible manufacturing limitations. We conducted this analysis by brainstorming potential methods for breaking each leg with our liaisons, and researching how these methods could be implemented. The team then discussed which option would be the easiest to achieve as well as measure in the context of a performance test.

We decided to focus on trying to break the heat leg of the fire tetrahedron, because we determined it to be the most practical option to address in a performance test. Our team was then able to consider various options in breaking the heat leg. We conducted research online, and used information from our informal case study to determine where we could address heat as a hazard in electric clothes dryers. We discussed with our liaisons what tests would be the most cohesive with the existing standard, and the least difficult for manufacturers to conduct. We used these ideas to draft the proposed amendment.

3.3: Create a Suitable Performance Test for UL 2158

We wanted the proposed amendment to UL 2158 to communicate a result, not dictate a design, to allow manufacturers freedom and creativity in creating a safer product. Our liaison wanted us to focus in this direction, because it allows for technological advancements, multiple approaches, and other innovations. To create the new test, we read through UL 2158 to learn about the existing performance tests. To gain additional insight into performance tests, we spoke to our liaison, Mr. Randy Butturini, about the significance of performance tests and how such tests should be used to produce the safest products possible. Our team used information from him to analyze UL 2158 and determine where there was room for improvement. Finally, we worked with our liaisons and decided on a temperature limit to put in the performance test, as well as considered the location for the temperature limit measurement. We determined the best wording for the proposed amendment to be as comprehensive as possible, yet flexible, by discussing different options with all of our liaisons, who have experience in this area.

To decide which of the options we created to propose to UL, we spoke primarily with Mr. Randy Butturini and Dr. Jonathan Midgett. We discussed the pros and cons of each of our ideas,

and determined which would be the best option to address high temperatures in electric clothes dryers.

3.4: Provide a Compelling Rationale

Our first priority in creating a rationale to convince the UL STP of the need for an amendment to UL 2158 was to demonstrate that there is room for improvement. We interviewed Mr. David Miller, a mathematical statistician who works with fire data at the CPSC, about the prevalence of clothes dryer fires and the damage they cause. He gave us information about why the CPSC, NFPA, and USFA all produce significantly different estimates for the number of clothes dryer fires each year. We intended to use the statistics for the number of clothes dryer fire incidents and the damage they cause to provide evidence of the severity of the problem.

Our team wanted to determine the best limiting temperature for the new performance test. We spoke to Ms. Jacqueline Campbell, a textile technologist, to get information on the ignition temperatures of different clothing materials. We also considered the ignition temperatures of non-textile materials that users could be putting through their clothes dryers, whether unintentionally or intentionally. We found these ignition temperatures through archival research online and in reference books.

We wanted to ensure that the standard amendment that we created was the best option for improving consumer safety. We created alternative ideas for improving electric clothes dryer safety, and determined the relative advantages and disadvantages of these alternative methods. Determining which option was better led us to the eventual proposed amendment to UL 2158. Overall, our goal in establishing a rationale for an amendment to UL 2158 was to demonstrate

the need for more appropriate temperature restrictions in electric clothes dryers. The next chapter discusses our findings, including ideas we pursued and alternative methods.

Chapter 4: Results and Analysis

In this section, we discuss our findings about the main causes and locations of first ignition of clothes dryer fires. We address potential means of breaking the fire tetrahedron in electric clothes dryers. We also explain the proposed performance test that we created to improve clothes dryer safety. Finally, we discuss alternative approaches for improving clothes dryer safety.

4.1: Common Clothes Dryer Fire Causes

We determined that the main causes of clothes dryer fires are: the overheating of clothing in the drum; electrical components igniting wiring insulation, clothing, or accumulated lint; and the overheating of accumulated lint in the cabinet.

From the IDI incident reports, we determined some of the major causes of clothes dryer fires, focusing on 194 reports from 2000-2012. Although this represents a small number of the clothes dryer fire incidents that are estimated to have occurred, the data are useful in determining commonalities among clothes dryer fires. Figure 4 shows the common causes of clothes dryer fires, based on data we collected from the IDI reports. Figure 5 displays the major locations of ignition based on information from the same reports.

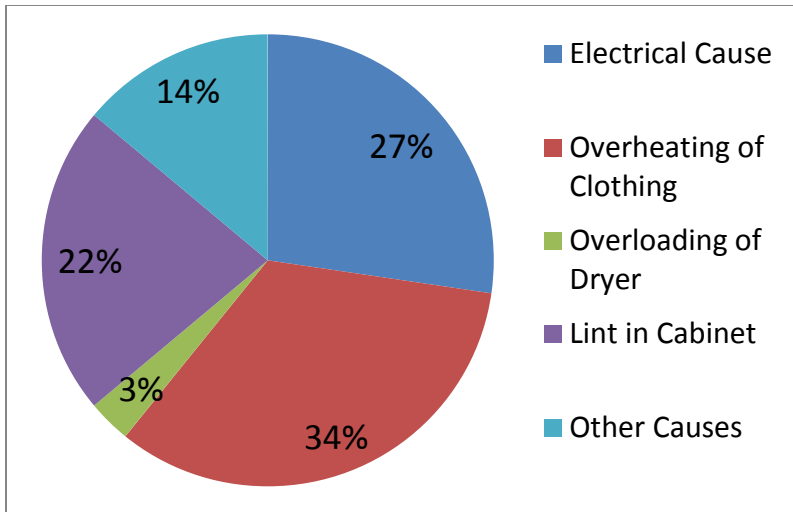


Figure 4: Major Causes of Clothes Dryer Fires

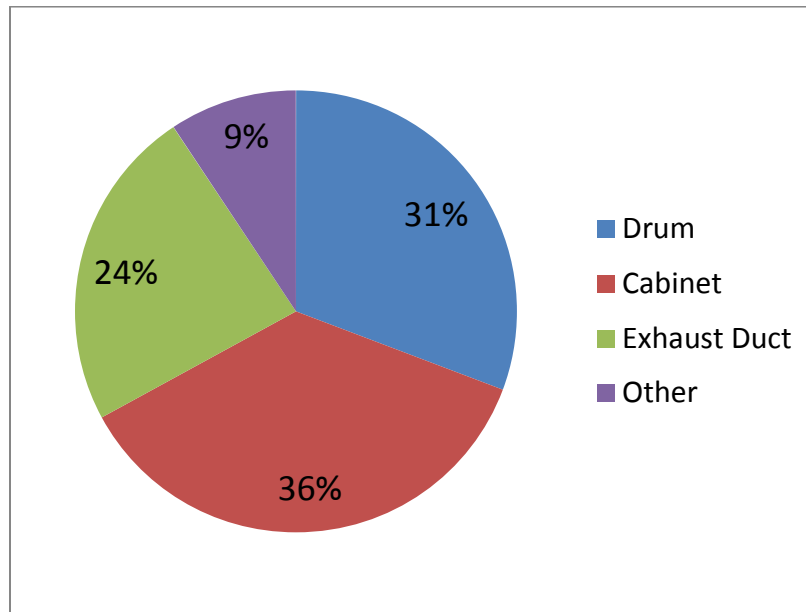


Figure 5: Major Locations of Clothes Dryer Fires

The overheating of lint is a major cause of fires according to the reports in the IDI database, and these data are consistent with NFPA estimates of the item first ignited in electric clothes dryer fires. In addition, the cabinet was the most common area where initial combustion occurred. Therefore, we focused primarily on the issue of accumulated lint overheating in the cabinet when we created the proposed amendment to UL 2158.

4.2: Breaking the Fire Tetrahedron

We studied how we could disrupt the fire tetrahedron on each of its legs to prevent clothes dryer fires. We decided that the heat leg was the most practical to focus on, because high temperatures are a major contributor to clothes dryer fire incidents, and temperature is a measurable quality. In addition, the other legs of the fire tetrahedron appeared more difficult to break.

When considering the oxygen leg of the tetrahedron, we determined that it is impractical to try to remove oxygen as a factor in causing fires. It would be costly and difficult to maintain an anaerobic environment inside the clothes dryer, especially for its long life in a household setting. Anaerobic chambers are not widely available, and although the technology exists, it is costly in some installations (Shel Lab, 2012).

We decided not to try to address the runaway chemical reaction leg because with current technologies, this would not be realistic. Fire extinguishers that address this leg are no longer made (H3R Clean Agents, 2012). They contain Halon 1211 or Halon 1301, which are chlorofluorocarbons. These chemicals have damaging effects on the ozone layer of the atmosphere, and therefore, production was stopped due to the Clean Air Act.

Because there is no technology available to eliminate lint from a clothes dryer, we decided not to attempt to break the fuel leg of the tetrahedron. In part because of the impracticalities of addressing the other legs of the fire tetrahedron, it became clear that our best option to reduce the probability of electric clothes dryer incidents was to break the heat leg.

4.2.1: Heat Sources in the Clothes Dryer Cabinet

There are several sources of heat in an electric clothes dryer, with the heating element being the major source of heat. The heating element and the spaces around it can become coated with a layer of lint after long-term use. This can become a fire hazard because the heating element can reach temperatures between 250°C and 400°C, and its cover may not be an adequate thermal insulator (Marks, 2012). If the cover becomes hot enough, it can ignite accumulated lint in the cabinet. The motor is also a potential heat source. This is because during mechanical operation, heat is a byproduct of energy use (George Mason University, 2012). In the electric clothes dryer we examined, there was nothing protecting the motor from lint buildup on the dryer's base. The motor could produce enough heat to ignite this lint. We focused on these areas when designing our performance test.

4.3: The Performance Test

Although there are design options that could be mandated to reduce the risk of clothes dryer fires, it would be restrictive to require manufacturers to use a specific design. Our group decided that a better approach would be a performance test, to allow flexibility for manufacturers to solve the problem in their own ways because there are many potential design solutions, and innovation would then be possible.

4.3.1: Constraints

Many constraints must be considered while trying to improve a safety standard such as UL 2158. Any suggested change to the voluntary standard will be voted on by the STP, which includes the manufacturers, allowing them to have input on requirements. Cost is always a major concern. It would be ideal to require manufacturers to have every clothes dryer's internal components thermally insulated so there is no chance of lint ignition. However, this would likely

be expensive and manufacturers may not support such a requirement. To put the limitation for cost into perspective, in the United States there are approximately 5.2 million electric clothes dryers sold each year (Energy Star, 2011). Based on reports from the CPSC about fire incidents, 63.5 million dollars in property damage occurs from electric clothes dryer fires annually (see Table 1). Because the NFPA estimates that 29 percent of fires in electric clothes dryers are started due to lint ignition, we can assume that 29 percent of the 63.5 million dollars in property damage is caused by this ignition, which is 18.4 million dollars (Hall, 2012). If we take the 18.4 million dollars and divide by the 5.2 million electric clothes dryers sold per year, we come up with about 3.5 dollars per dryer. This means that on average, there is about 3.5 dollars of societal cost associated with each electric clothes dryer. Although no price can be put on the safety of consumers, one measure of the practicality of a proposed change to clothes dryer design is that the additional cost to each dryer should not exceed 3.5 dollars. It would not be a net benefit for manufacturers to increase their production costs beyond the cost of damages resulting from electric clothes dryer fire incidents. Therefore, any addition to the standard must be effective, yet remain possible for manufacturers to implement within an estimated maximum of 3.5 dollars per clothes dryer.

Manufacturers comply with UL's voluntary standard in order have their designs listed by UL, even though electric clothes dryer designs have a lot of variation (Randy Butturini, personal communication, November 9, 2012). In order to be applicable to each manufacturer's design, a performance test cannot be dependent on the specific structure of the dryer; instead, it must focus on the components and conditions inside the dryer. For example, a performance test cannot assume that an electric clothes dryer component would be in a specific location inside the cabinet. A performance test must be applicable to all conditions and possible configurations of

electric clothes dryers' components. Otherwise, manufacturers would experience difficulty when satisfying the standard, and UL testers would probably have difficulty when assessing a dryer.

4.3.2: Test Options

We decided that temperatures inside the cabinet should be limited in order to reduce the probability of electric clothes dryer fires. That way, if lint builds up inside the cabinet, it is less likely to catch fire. An added performance test could ensure that temperatures do not become high enough in the cabinet to lead to combustion. In order to prevent combustion of built-up lint inside the clothes dryer cabinet, a test that measures and limits temperatures would be effective. UL testers would locate the highest temperature inside the clothes dryer cabinet during operation. Then, a thermocouple would be attached to this identified area to measure temperature. A thermocouple is a simple sensor that is used to measure temperature (Omega, 2012). It is comprised of two dissimilar metals welded together at one end, and linked to a voltage meter at the other. The difference in voltage is used to calculate temperature. With a thermocouple attached, the clothes dryer would then be run through a normal cycle several times, to achieve a total run time of seven hours, duplicating the conditions used by other performance tests in UL 2158. If the temperature of the hottest area exceeds the predetermined safety temperature, the electric clothes dryer is considered to have failed the test.

Another way to determine if temperatures inside the cabinet have the potential to ignite lint is through the use of cheesecloth as a fuel surrogate. Components inside the clothes dryer would be wrapped in cheesecloth while the dryer is run through a normal cycle for seven hours. Because cheesecloth simulates the characteristics of lint, if the cheesecloth caught fire during the testing, the clothes dryer would fail the test (Randy Butturini, personal communication, November 7, 2012).

4.3.3: Performance Test Decision and Supporting Argument

Our group decided to focus on the thermocouple temperature performance test. Both of the proposed tests described in section 4.3.2 have the potential to reduce the number of electric clothes dryer fire incidents, but the thermocouple test is more comprehensive and easier to implement. This test addresses the problem areas inside the clothes dryer cabinet. Cheesecloth and thermocouples are both readily available to UL testers because they are used in different tests in the standard, so neither test would require much additional expense. However, attaching thermocouples to various positions inside the clothes dryer cabinet would be easier than wrapping every component inside the cabinet with cheesecloth. Also, by wrapping the internal clothes dryer components with cheesecloth, the tester would receive limited data that focuses solely on whether internal components can produce enough heat to ignite lint, rather than measurements of temperature. In addition, cheesecloth heated in a clothes dryer for only 7 hours does not take into account the potential for lowered ignition temperature due to repeated heating over time.

The thermocouple test would also be easy to implement because it could be run in accordance with a performance test already present in the standard. The thermocouple test would require no additional service by the UL inspector other than the attaching of thermocouples and recording of temperatures at various locations. Extreme temperatures are already produced in the clothes dryer during the “Blockage of lint screen and exhaust” performance test in section 19.5 of UL 2158. This test blocks the exhaust and lint screen individually at levels of 75 and 100 percent to produce the characteristics of lint buildup (UL, 2009, section 19.5). The clothes dryer is then run to see if the load inside the drum will catch fire. While the “Blockage of lint screen and exhaust” test currently only focuses on temperatures inside the drum, it causes the clothes

dryer to become very hot inside the cabinet, creating the ideal conditions for our group's suggested thermocouple test. Therefore, it would be easy to carry out this proposed performance test at the same time as another test already in the standard. Our suggested thermocouple test would require little change to UL's system for testing electric clothes dryers, which could reduce the amount of unnecessary property damage and possibly save lives.

4.3.4: Technical Details of Selected Test

The thermocouple test must adhere to specific criteria to be effective at preventing fires stemming from lint buildup inside the cabinet. As stated before, this test would have a specific safe temperature that no area inside the clothes dryer cabinet must exceed. Cotton fibers are the primary component of lint. The ignition temperature of cotton fibers is 266°C (Wakelyn, et al., 2007). However, there are other materials that may frequently be included in lint. One such material is paper. Paper has an ignition temperature of approximately 232°C, which is likely the lowest ignition temperature of any material that may find its way into a dryer (Randy Butturini, personal communication, December 4, 2012). It is necessary to consider paper when setting a maximum temperature because if paper catches fire in lint, cotton fibers may also be ignited. Pyrolysis is another factor that must be considered when setting an allowable maximum temperature. When a material such as lint is superheated, as it may be if it accumulates in a dryer cabinet and is then heated repeatedly, the chemical bonds in the material begin to break down, lowering the temperature needed to cause ignition. Therefore, the highest temperature allowable in the clothes dryer must be safely below 232°C. We have set the maximum temperature for this performance test at 200°C, which means that no location inside the cabinet can achieve this temperature throughout the seven hours of performance testing.

When UL is identifying an electric clothes dryer's location of highest temperature, it is possible that there may be more than one area that is suspected to exceed 200°C. Before testing, UL will need to determine which areas could yield the highest temperatures. Our group expects that the hottest location in the dryer cabinet will occur on the heating element's cover, because the heating element is the main source of heat in the dryer. However, it may be necessary to attach more than one thermocouple to the inside of the clothes dryer cabinet because other areas, in addition to the heating element, could display high temperatures. If any thermocouple measures a value over 200°C, the manufacturer would have to make changes to their electric clothes dryer before it could be listed by UL as compliant with the voluntary standard.

4.3.5: Possible Ways to Fulfill Test Requirements

In order to pass our group's proposed performance test, one engineering consideration could be to lower the temperature of the heating element. Doing so would make it more difficult for built-up lint to ignite, but decreasing the temperature of the heating element would reduce the clothes dryer's efficiency. Lowering the temperature would result in the need for either longer drying times or multiple drying cycles. Therefore, other actions would have to be taken in order to maintain clothes dryer performance (Randy Butturini, personal communication, November 8, 2012). If the heating element temperature decreases, electric clothes dryers would need to have increased airflow, larger drums, or other means to achieve a high evaporation rate and maintain current drying times. Another way to pass our group's proposed performance test is to add insulation. Because we expect the heating element to be the source of highest temperatures in the clothes dryer cabinet, our group determined some potential insulation designs for insulating the heating element cover. This could potentially reduce the surface temperature of the heating element cover, so that if lint did accumulate around the heating element, it would not be able to

ignite. Insulation could be added in the form of a ceramic material that would surround the heating element cover, or double-walled sheet metal to reduce the thermal conductivity from the heating element to the outer cover. Other insulation materials or designs could also be possible. Refer to Figures 6 and 7 for images of possible insulation solutions.

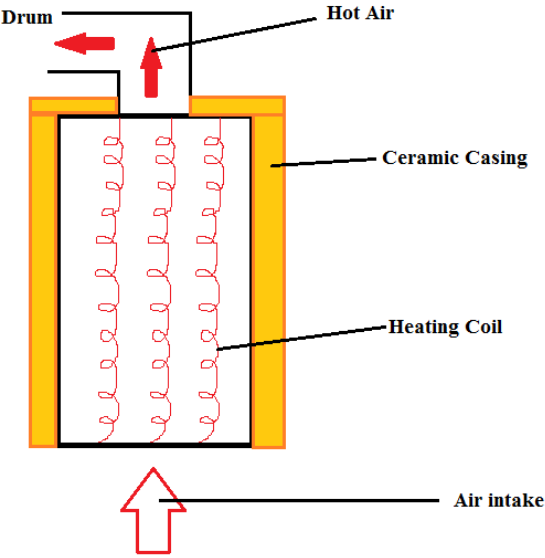


Figure 6: Ceramic Insulation Design

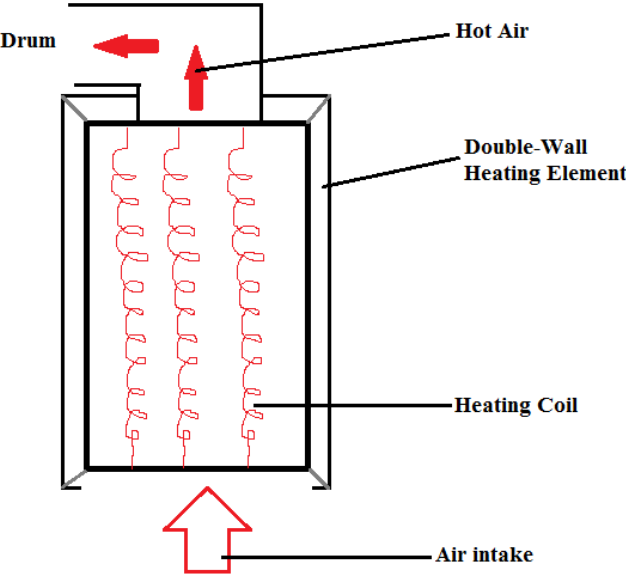


Figure 7: Sheet Metal Insulation Design

4.3.6: Test Details Left to Determine or Establish with Future Work

While this performance test has the potential to decrease the number of incidents associated with electric clothes dryer fires, it may not be the ideal solution. It is possible that there is a better way to test the temperatures of components inside the clothes dryer cabinet, but these methods are outside the scope of this project. For example, there may be a better way to measure heat at various locations inside the clothes dryer cabinet, which would include using some form of heat sensitive paper or spray (Randy Butturini, personal communication, November 16, 2012). It is also possible that other methods could be created that would better address clothes dryer fire incidents.

4.4: Alternative Approaches

Although this performance test has the potential to reduce the number of electric clothes dryer fire incidents, there are alternative approaches. Lint could be prevented from accumulating in the cabinet, the heating element could be replaced with a dehumidifier, and air pressure could be lowered to increase evaporation. While there are other alternative solutions, these are the approaches that our group considered.

4.4.1: Preventing Lint from Accumulating In Cabinet

Because lint is a major contributor to clothes dryer fire incidents, an alternative solution is to prevent lint from accumulating in the cabinet. However, it is impossible to remove all lint from clothes dryers. Lint is created when fibers are separated from articles of clothing or fabric (Randy Butturini, personal communication, October 31, 2012). This occurs during the wash cycle when the washing machine's agitation function grinds fabrics together and against the sides of the machine. When clothing is then dried in the clothes dryer, the lint separates from the clothing. It is intended for lint to remain in the airflow path, but not all of the lint is contained

within the drum, lint screen, or exhaust vent (Rooney, 2011). It is not known exactly where or how the lint escapes into the cabinet. Therefore, it would not be possible to solve this problem without further research being conducted. In addition, it is difficult to test for a clothes dryer's ability to prevent lint accumulation. A performance test could not accurately simulate lint accumulation over the dryer's lifetime, because it is a long and slow process. In addition, amount of lint accumulation is not an easily measured parameter. For these reasons, our group decided to not use this approach.

4.4.2: Replace Heating Element with Dehumidifier

Another alternative approach is to replace the heating element with a dehumidifier. This would reduce the chance of fires, as there would be less heat in the system. However, this is not a practical solution. It would require a redesign of the entire clothes dryer and would likely be much more difficult to implement than reducing temperatures on the outer surface of the heating element cover. In addition, because this is a design requirement, manufacturers would be restricted in their innovation process. Consequently, we discarded this idea for this a proposed amendment to UL 2158.

4.4.3: Lower Air Pressure to Increase Evaporation

Another solution is to lower the air pressure inside the clothes dryer to increase the rate of evaporation. This would require a tight seal on the drum, and a vacuum pump to create lower pressure inside (Randy Butturini, personal communication, November 19, 2012). In low-pressure situations, more water can be evaporated into the air because of the lower vapor pressure of water under partial vacuum conditions. Therefore, water from clothing would evaporate more quickly into the air, so temperatures could be reduced without affecting drying time. However, if this solution were required, it would become a design requirement, limiting a manufacturers'

freedom of design, which is something we tried to avoid. This idea was therefore discarded for the proposed amendment to UL 2158.

4.5: Limitations

There are limitations to our findings. For instance, the fire statistics used to estimate several factors, such as main areas of ignition in clothes dryers and the expected success of the amendment to UL 2158, are based only on information from fires that fire departments were dispatched to. It is possible that there have been more electric clothes dryer fires annually, but fire departments were not always notified. Therefore, our estimates could be incomplete.

Another limitation is the assumption that all electric clothes dryers are equally likely to be involved with fire incidents. Of the 71.8 million electric clothes dryers in regular use in the United States, some may be more likely to be sources of fires than others. Older clothes dryers with outdated designs could be less safe than newer clothes dryers with modern designs.

Although these factors could affect the quality of our data, we believe the performance test we created to be a necessary addition to UL 2158.

Chapter 5: Conclusions and Recommendations

This chapter reviews our conclusions and recommendations for the CPSC. We discuss the wording for our proposed performance test, as well as the projected impact and time frame of its effect.

5.1: Performance Test to Measure Temperatures Outside of the Drum

The new performance test will be easy to implement. UL already uses thermocouples for clothes dryer testing, so UL employees who would normally be testing the clothes dryers would need no additional training to run this test. The other benefit to this additional performance test is that it has a clear indication of whether the electric clothes dryer passes or fails. The new test requires that no temperature inside the clothes dryer cabinet exceed the safety level of 200°C. This is a quantitative, measureable test with little room for confusion or misinterpretation.

5.1.1: Proposed Wording

Because UL uses specific wording for their standards, it is imperative that the phrasing of this additional performance test be similar and consistent with that of the existing standard. If our proposed amendment does not follow the writing style that UL 2158 uses, this performance test would need revision of the technical wording before being brought to a vote. This would delay the consideration of the proposed amendment. In order to maintain a cohesive standard that UL can continue to use with ease, our proposed wording for the new performance test follows the general format of the rest of UL 2158, and it references conditions that are already defined in the standard. For example, the proposed test refers to the simulated installation process that is described for electric clothes dryers, which is defined in the standard. Refer to Appendix B for the group's proposed wording for the amendment.

5.2: Expected Impact on Clothes Dryer Fire Incidents

If the performance test proposed for the standard is implemented, it should reduce the number of clothes dryer fire incidents. The majority of lint-fueled fire incidents should not occur, because the test will require all new electric clothes dryers to operate with surface temperatures in the cabinet below the ignition temperature of lint. In the 194 IDI reports, lint was one of the most commonly reported causes of electric clothes dryer fires. According to estimates by the NFPA, 29 percent of clothes dryer fires are started because lint is ignited (Hall, 2012). Based on NFPA and CPSC estimates, the implementation of this performance test could prevent up to approximately 29 percent of clothes dryer fire incidents. At full implementation, it is possible that the number of incidents could be reduced by approximately 1300 fires per year, with an annual reduction of 3 deaths, 41 injuries, and 18.4 million dollars in property damage .

The average mechanical life of a clothes dryer ranges from 12 to 16 years (Energy Star, 2011). For this reason, the effects of the added performance test may not be seen for many years after it is implemented. New clothes dryers will be produced according to the amended standard, but old dryers will still be in use. Therefore, it could be up to 16 years before the full impact of the change is seen. However, over time, as new clothes dryers replace the installed base, the number of fire incidents due to clothes dryers should decrease.

5.3: Recommendations

Our group recommends that the CPSC submit to UL STP 2157 the proposed wording for an amendment to UL 2158, as seen in Appendix B. We also recommend that further research be conducted to identify how lint escapes the airflow path and accumulates in the clothes dryer cabinet. Breaking other legs of the fire tetrahedron could allow manufacturers the ability to choose which to focus on in their individual designs. Another avenue for research is in

improving the effectiveness of insulation. New insulation materials could be developed specifically for a clothes dryer environment, or new insulation layouts in electric clothes dryers could be applied. It should be determined how to better communicate to users the importance of reading their manuals and maintaining their clothes dryers. The hazards associated with not properly cleaning electric clothes dryers could be better impressed upon owners so that they better understand the hazards associated with improper maintenance. It is also possible that electric clothes dryers be sold with a service and cleaning contract. In addition, research could be done on clothes dryer efficiency, and how better insulation could reduce heat loss and improve performance. Finally, more research should be conducted to determine if this proposed amendment is useful and easy to comply to. More research conducted in these areas could provide avenues for further clothes dryer safety improvements.

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Appendices

Appendix A: Sponsor Description

According to the website of the U.S. Consumer Product Safety Commission (2012), the CPSC is a government-funded, independent federal regulatory agency. Because they are independent, they essentially run themselves and do not report to other government groups. The CPSC is responsible for finding issues with consumer products that could pose a safety risk to users. Their mission is to keep the public safe from unnecessary injury due to potential dangers of thousands of types of products, excluding only products such as automobiles, tires, food, beverages, tobacco, and cosmetics. The CPSC develops both mandatory and voluntary safety standards for products, issues recalls on products found to be unsafe or have unsafe parts, and educates the public on product safety.

Though the Consumer Product Safety Commission is now a vital component of public safety, it is a relatively modern innovation. The Consumer Product Safety Act founded the CPSC in 1972, and the agency began functioning the next year (CPSC, 2012a).

The Consumer Product Safety Commission has an annual budget of approximately 65 billion dollars (CPSC, 2012a). This money comes from Congress, and pays for every aspect of the organization's function. The majority goes towards salaries and general office fees.

The agency has a functional organizational structure. There are five Commissioners of the agency, appointed by the President of the United States (CPSC, 2012b). The commissioners have seven-year terms, which are staggered to prevent complete turnover and maintain consistency. There are approximately 500 total employees. The CPSC has six offices directly under the Chairman. These are the offices of Communication, Legislative Affairs, the Inspector General, the Executive Director, the General Council, and Equal Employment Opportunity and

Minority Enterprise. The Office of the Executive Director has eight offices beneath it, and these are the offices of Hazard Identification and Reduction, Import Surveillance, Compliance and Field Operations, Facilities Services, Human Resources Management, Information and Technology Services, Education, Global Outreach, and Small Business Ombudsman, and the Office of Financial Management, Planning, and Evaluation. This particular research project will be conducted for the Office of Hazard Identification and Reduction. Refer to the CPSC Organizational Chart, Figure A-1, for more information on the organizational structure.

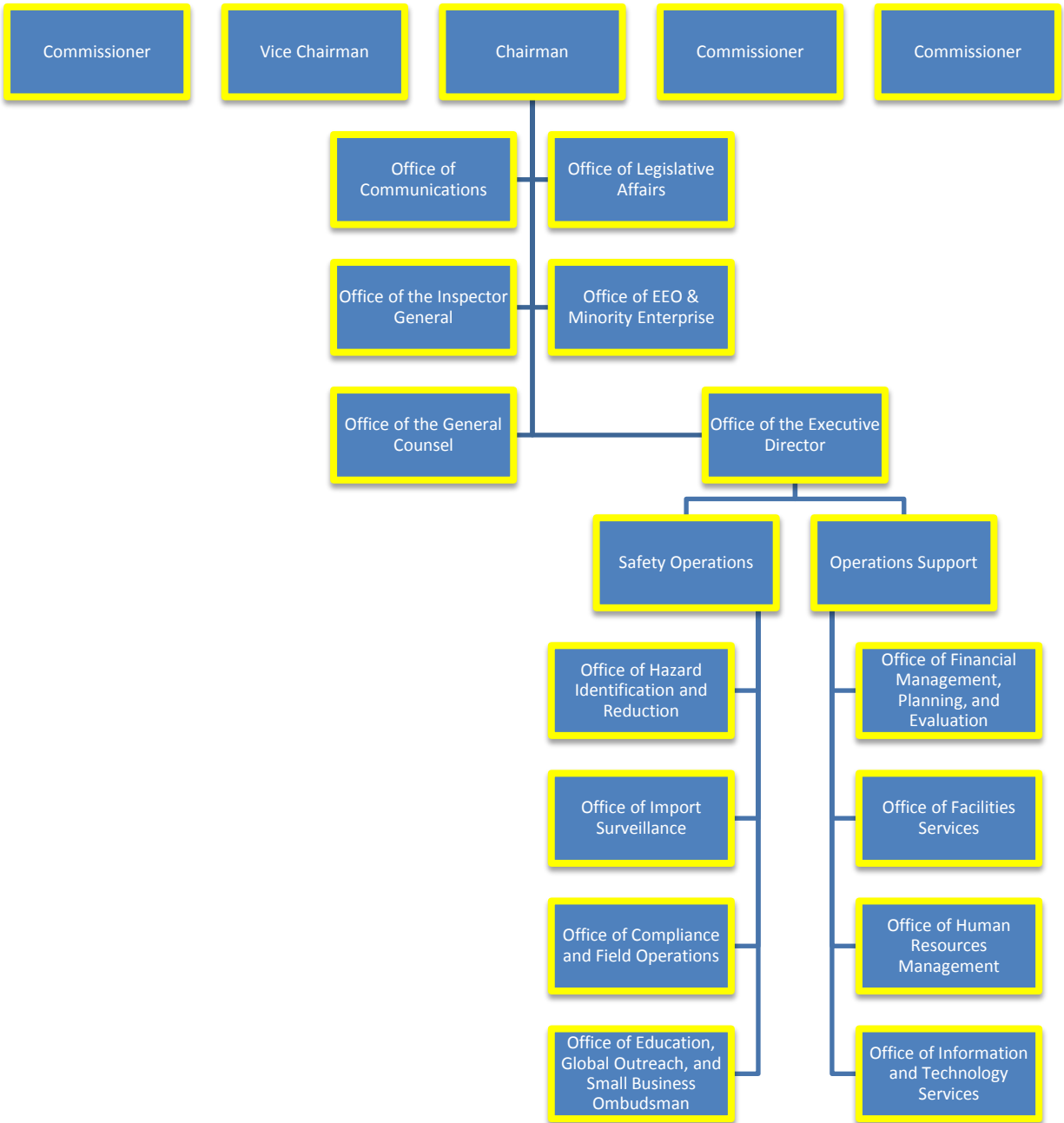


Figure A- 1: CPSC Organizational Chart (Adapted From CPSC, 2012b)

The CPSC has access to some information that they do not release to the public (Randy Butturini, personal communication September 5, 2012) . This includes specific incident reports,

safety reports involving law enforcement, and documents that include trade secrets. This information will be useful in our project research.

Another organization that works towards clothes dryer safety is the National Fire Protection Association. The NFPA focuses on tips for users to keep clothes dryers clean, in order to prevent lint fires (NFPA, 2012). This organization also develops standards for safety. The NFPA is an independent agency. They are not a direct partner or competitor to the CPSC, but they work toward a common goal of public safety.

Underwriters Laboratories (UL) is also an organization that works toward protecting consumers (ULLC, 2012). Unlike the CPSC, Underwriters Laboratories is responsible for giving their approval to products that pass their list of standards, declaring that the product works effectively and won't cause damage to the user. The reason that manufacturers want the UL mark of approval is because since 1894, UL has been serving the population by holding companies to certain voluntary standards. Over one hundred years later, retailers are looking to purchase and resell products that will work effectively, not harm the user, and bring their company more business; therefore, in order for manufactured items to be bought, most must carry the UL mark.

Appendix B: Wording of Proposed Standard Amendment

This performance test would be inserted into UL 2158 as 19.5, altering the existing numbering for section 19. The current 19.5 would become 19.6, 19.6 would become 19.7, and 19.7 would become 19.8. This wording refers to the proposed renumbering for UL 2158.

19.5 Dryer Cabinet Temperatures

19.5.1 A household appliance shall be tested as described in Clauses 19.7.2 to 19.7.11, and there shall be no:

- a. temperature reading inside the dryer cabinet that is of greater than 200 °C; or
- b. activation of any temperature-limiting control.

19.5.2 The appliance shall be installed as described in Clauses 11.7 to 11.9.

19.5.3 The drum shall be loaded with cloths that have dry weight as specified in Clause 4.2.

19.5.4 Determine area inside the cabinet with the highest surface temperature under normal operating conditions. Connect a thermocouple to this area so that maximum temperatures during use can be recorded.

Note: The positions for the most extreme temperatures will most likely be located on or nearby the heating element cover. The location of the highest temperature is dependent upon the geometry of the heating element and its cover. It is presumed that the location of highest temperatures will be somewhere between the middle of the cover and the air exit of the heating element enclosure. The middle of the cover has heating element coils on both sides, and is likely subject to the greatest amount of radiant heat. The exit of the heating element is going to be the last possible position where the air is heated before it exits to the drum. Because this area will most likely have the highest temperatures, careful consideration should be taken to this portion of the heating element cover when administering this performance test.

19.5.5 The test shall be continued for multiple dryer cycles of maximum length as dictated by the timer. The number of cycles should add up to a total drying time of 7 h.

Appendix C: Clothes Dryer Deconstruction Procedure

Location of Clothes Dryer

The electric clothes dryer that our group deconstructed to observe was installed in a closet in the basement of a home. We disconnected the clothes dryer and moved it to a more open space in the home.



Figure C- 1: Electric Clothes Dryer



Figure C- 2: Back of Electric Clothes Dryer

Viewing the Cabinet

We removed the back of the clothes dryer to reveal the cabinet. The lint collection area, drum, heating element, wiring, and exhaust duct can be seen. There is lint accumulation on horizontal surfaces and wiring.



Figure C- 3: Electric Clothes Dryer with Back Panel Removed



Figure C- 4: Base of Cabinet with Lint Accumulation

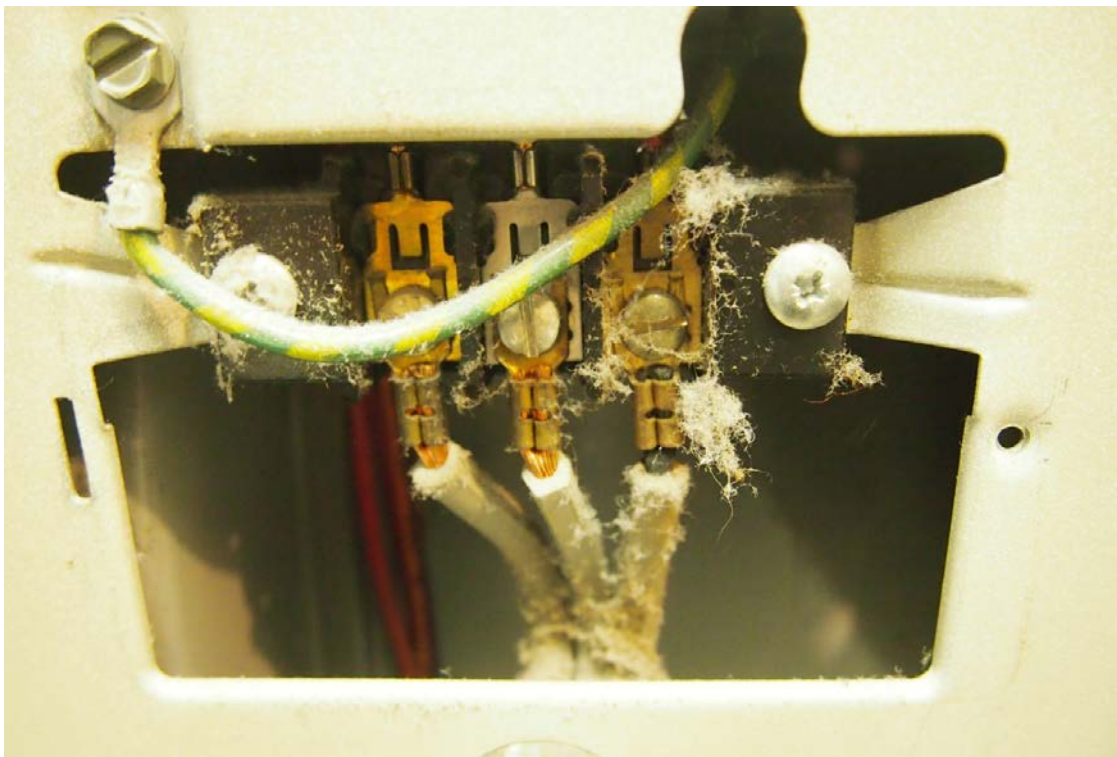


Figure C- 5: Wiring in Cabinet with Lint Accumulation

Lint Screen Area

The lint screen on this model was located in the back of the clothes dryer. This particular dryer was not properly maintained, and the lint screen had never been properly cleaned. Lint was heavily accumulated in the region of the lint screen; our group removed as much lint as possible.



Figure C- 6: Process of Removing Lint from Clothes Dryer



Figure C- 7: Lint Screen and Compacted Lint Removed from Screen Area

Opening the Lid

Our group next opened the lid of the clothes dryer. This allowed us to see the drum as well as observe the other side of the cabinet that was blocked from view from the back.

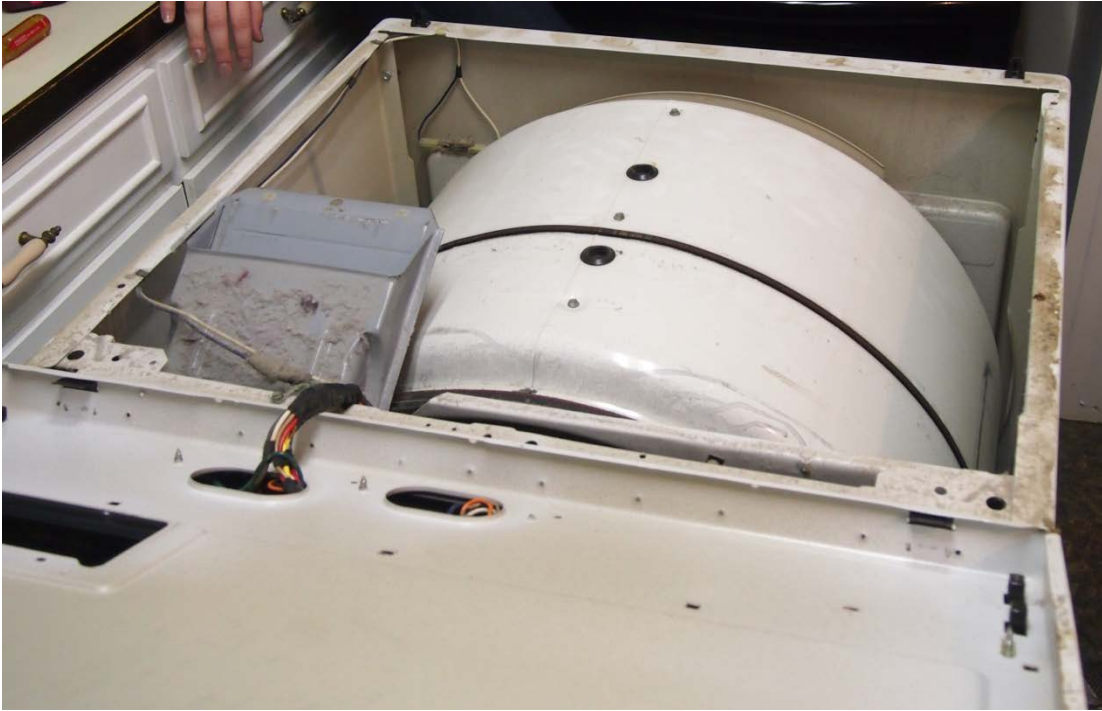


Figure C- 8: Cabinet of Clothes Dryer, Top View

Appendix D: CPSC Safety Alert



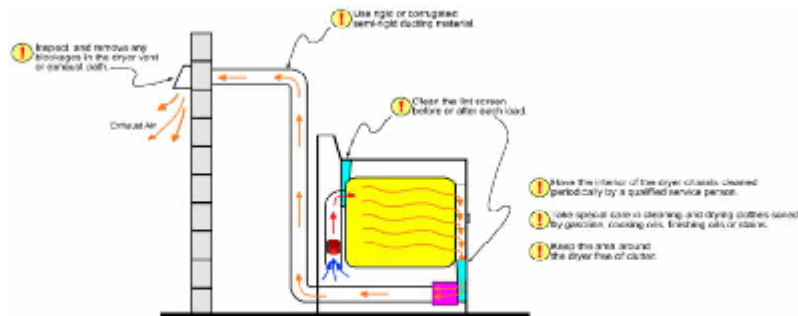
CPSC Safety Alert

Overheated Clothes Dryers Can Cause Fires

Fires can occur when lint builds up in the dryer or in the exhaust duct. Lint can block the flow of air, cause excessive heat build-up, and result in a fire in some dryers.

To help prevent fires:

- **Clean the lint screen/filter before or after drying each load of clothes.** If clothing is still damp at the end of a typical drying cycle or drying requires longer times than normal, this may be a sign that the lint screen or the exhaust duct is blocked.
- **Clean the dryer vent and exhaust duct periodically.** Check the outside dryer vent while the dryer is operating to make sure exhaust air is escaping. If it is not, the vent or the exhaust duct may be blocked. To remove a blockage in the exhaust path, it may be necessary to disconnect the exhaust duct from the dryer. Remember to reconnect the ducting to the dryer and outside vent before using the dryer again.
- **Clean behind the dryer, where lint can build up.** Have a qualified service person clean the interior of the dryer chassis periodically to minimize the amount of lint accumulation. Keep the area around the dryer clean and free of clutter.
- **Replace plastic or foil, accordion-type ducting material with rigid or corrugated semi-rigid metal duct.** Most manufacturers specify the use of a rigid or corrugated semi-rigid metal duct, which provides maximum airflow. The flexible plastic or foil type duct can more easily trap lint and is more susceptible to kinks or crushing, which can greatly reduce the airflow.
- **Take special care when drying clothes that have been soiled with volatile chemicals** such as gasoline, cooking oils, cleaning agents, or finishing oils and stains. If possible, wash the clothing more than once to minimize the amount of volatile chemicals on the clothes and, preferably, hang the clothes to dry. If using a dryer, use the lowest heat setting and a drying cycle that has a cool-down period at the end of the cycle. To prevent clothes from igniting after drying, do not leave the dried clothes in the dryer or piled in a laundry basket.



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Appendix E: Interview Notes, Richard Hooker

Interview with Richard Hooker: Summary Notes

Conducted by Scott Gould and Kyle Bonaccorso on September 23rd, 2012

Conducted at Massachusetts Delta Chapter House of Sigma Alpha Epsilon Fraternity

1. What are the codes that are related to electric clothes dryers?

-NFPA 70 (national electric code), NFPA 101 (life safety code), and NFPA 220

2. How does the NFPA communicate with the CPSC and UL?

“The only time you get in contact with them (CPSC, UL, and NFPA) is when you want to have a product manufactured and certified but still there is almost continuous contact between each group (NFPA, UL, and CPSC).”

3. How would people find out about the wiring for dryers?

“Talking about dryers, paperwork for dryers will tell you about wiring, amps, voltage, etc.”

“Best way is to look at the data sheet that comes with the appliance you are dealing with”

-Old houses aren't wired for these new appliances. You need the house to be rewired for the house to support the electric grid.

“Can't put a 220 watt appliance in a plug that only supports half that.”

“Need a certified electrician to see if the houses wiring can support it”

-Most people will try and get around this. This will lead to fire. NFPA 70 – overloading of circuits and wiring

“If it is not installed properly, the wiring to dryer from wall can cause a fire.”

“Can't overload wires”

“Wiring within the machine itself causes the problem.”

“You want to have some kind of a checklist.” (for wires, etc.)

-Calrod Unit – wiring: make sure it is intact

“Have a certified electrician certify it and ok it”

-Dealing with a second hand passed down dryer that doesn't have the original paperwork being installed.

“I would do that without hesitation at all.”

4. In your opinion, and from what you have seen, what do you think is the main cause of a dryer fire?

“Principle fire from a dryer is lint. That has to do with housekeeping – cleaning up the lint trap.”

“Lint is like a fuse.”

“Source of ignition comes from back of dryer with exposed wires.”

“90% of the problem is wiring not in proper condition (exposed wiring, something that can cause a spark) and lint accumulation.”

“The dryer is supposed to be insulated.”

5. Do you have any tips for us, or where we should get started once we get to Washington, D.C.?

-We need to know exactly what we are doing with what specific machine, then he can help us solve it. We need the specs for every part of the machine

“Write to them, tell them (UL) what we are doing, or where we are stuck, they direct us. What the necessary procedures are to submit the project for approval”

-led to interview with Joe Musso

-Maybe have a different kind of lint trap, maybe different placement of Calrod Unit.

“Take the dryer apart, show the parts, wiring diagrams, etc., and tell them where the changes need to be made (whether it’s 200rpm or 250rpm rather than 190 or so and so).”

“Calrod Units vary by size, placement, and each of those make a difference.”

Appendix F: Interview Notes, John Hall

Interview Notes with Dr. John Hall, the Division director for fire protection and analysis at the NFPA

Interview Conducted September 26, 9 am over the phone, by Kyle Bonaccorso, Mariah Eldredge, Scott Gould, Cameron Mills

1. Are you familiar with NFPA regulations on dryers?

-NFPA has no regulations on dryers, except for installation requirements—for standards on insulation and operation/maintenance of products they defer to CPSC: “has standards for maintenance of products”

“usually defer clothes dryer standards to CPSC”

“Wiring is not the dominant problem. The main problem is the ignition of the things inside.”

2. How does the NFPA interact with UL and CPSC?

-Interaction with CPSC: legally defined mission to protect consumers, NFPA standards focus on other areas than homes, lets CPSC focus on consumers – other entities are involved, UL gives mark of approval, indicating safety – doing reasonable job protecting people, NFPA doesn’t need to get involved: “CPSC has a legally defined mission to protect consumers. They deal with things in the home where the NFPA deals with other places people congregate.”

“UL puts a mark on many products that indicate these products have met performance requirements.” “We often work together. We have statistics they don’t have. They do more lab research. We interact all the time at all different levels. We work together towards better.”

-When NFPA becomes involved, they try to track size, characteristics of specific cases – tries to give all people taking actions to try and let organizations operate better – NFPA does depth of analysis of specific cases; research section gets involved when necessary, and advised from rest of NFPA – stove top fire protection standards, had project to improve ability to evaluate technologies like these – another project is the fire safe project – CPSC can NOT do anything about cigarettes and firearms – went out to every 50 states to get them to approve own regulations – could not be done by national legislature: “I track the size and characteristics of fire problems.”

“The next group that may be involved is our research foundation.”

“Starting projects to evaluate technologies.”

-Other product restrictions – some advocates feel that CPSC needed to act better (kerosene, fireworks): “CPSC is legally prohibited from doing anything about cigarettes. It is blocked from their jurisdiction.”

-Often work with UL – UL doesn’t have as much data as NFPA so NFPA gives UL data because they do more intensive research on specific products

3. Do you think people could do anything differently to prevent their dryers from catching on fire?

-“The short answer I don’t.”

-“The ignition of built-up lint. Need some sort of system that reminds people about lint buildup.”

-“There are people who use the dryer for storage, and turn it on without remembering those things are in there. People also use it to heat their house. Basic misuse of equipment.”

“Short circuits within the dryer.”

-“Look at what fraction of the fires are occurring under which circumstances.”

4. What do you feel is the main cause of dryer fires?

-Clothes dryer fires usually due to ignition of built-up lint – better system that causes people to remove lint along filter or through cut, or out of the dryer completely, would be safest – dryer was being used to heat space in house – user errors

–Short circuits inside the dryer- interior works might fail, create heat source and ignite combustible materials – heat coming out of the back or the side being ignited by intense heat – need to go through and find out what kinds of fires are happening under certain circumstances

-Wire issues or high temperatures – if you go through NFPA statistics where appliance housing is first ignited (not dominant problem) – problem that things inside the dryer being ignited is main issue

Appendix G: Interview Notes, Michelle Andersen

Interview Notes with Michelle Andersen, a principal engineer at UL

Interview Conducted October 5, 9 am over the phone, by Kyle Bonaccorso, Mariah Eldredge, Scott Gould, Cameron Mills

1. How long have you worked for Underwriters Laboratories?

- 20 years this month

2. What exactly do you do for Underwriters Laboratories?

- Principle engineer for kitchen and laundry machines

“I am in the principal engineer for kitchen and laundry machines. I am responsible for a number of food preparing machines such as blenders, and laundry equipment. I am responsible also for the international requirements, energy efficiency, and safety requirements.”

-“maintaining consistency for standards”

-“What I do is really very broad”

3. How often are individual standards reviewed by UL to make sure that they are sufficient?

- Her standards are on an “as needed” basis

-“Its really an ongoing process. Some standards have revisions cycles that they put through every so many years. The ones I deal with do not”

-“UL 2158 is a bi-national standard, it’s a US and Canadian Standard.”

4. How often are products rejected for approval by Underwriters Laboratories?

- It varies

-“A new product coming in from a new client that hasn’t worked with UL in the past would be more likely to have issues rather than big manufacturing companies who have worked with UL before.”

-“A lot of those companies have test labs of their own”

-“Dryer fire containment test added to Standard in 2009. It will become effective March, 2013”

5. Why do you or why don’t you believe that UL 2158 is sufficient?

-“I believe UL 2158 is sufficient. From a standard’s perspective”

- “You can never write a safety standard to provide absolute safety, it’s always a level of safety”

-The process is working

6. How does UL communicate with groups like the CPSC? Is it a personal interaction or is it done over the phone or through mail? How often do groups like the CPSC submit feedback to UL?

-A number of levels

- Communicate at a very high level, try to stay connected
- Participate in many STP groups
- Work in 'working groups' as well: Currently one for 'status indicators'--Industry people, CPSC, UL
- Involved when there are recalls
- "More of an 'as needed' basis rather than an annual basis"

7. Are you familiar with any tests conducted to determine the safety of dryers?

- Dryer containment test: If fire does occur, it shouldn't spread outside the dryer cabinet
- Many are related to risk of fire
- Abnormal tests: fail thermostat and ensure backup device works; blocked lint screen, 100% and 75% blocked

---Any other major tests when looking in to the standard?

- "many are related to the risk of fire. Lint screen and black exhaust testing [75% exhaust block]"
- "tests to see if the fire won't spread outside of the dryer cabinet."

Appendix H: Interview Notes, Joe Musso

Interview With Joe Musso, we asked the following questions and received the following results.

Interview Notes with Joe Musso, the STP Chair of UL

Interview Conducted October 3, 9 am, over the phone, by Kyle Bonaccorso, Mariah Eldredge, Scott Gould, Cameron Mills

1. What's an STP?

-It is considered the consensus body/committee responsible for maintenance and development of UL standards

-Review developed material, proposals, drafts of standards; vote on standards

- "Balanced committee" made up of manufacturers, academia, retailers, consumers, government organizations, commercial users, and more

- "Umbrella STPs" cover multiple standards

- "STP is considered the consensus body that is responsible for the development and maintenance of 1 or more UL standards"

- "They review new drafts of standards, and do the actual voting."

- "Some are testing, some are authorities having jurisdiction (inspectors), supply chain folks, consumers, government organization"

- "There are close to 400 UL STP's"

- "Many STP's responsible for more than one standard. We call these umbrellas"

2. What purpose does it serve (other than revisions/creating new standards)?

-It exists for open participation in the standards development process: You don't have to be on committee to submit a proposal or comment on proposal

-People not on committee don't have a vote, but anyone in the world can comment

- "You do not have to be on the committee to submit a proposal. The standard process is open to anyone in the world."

- "The key is that it is an open process. There is open participation for/from anyone."

3. What system was in place before the STP was created?

-Two old systems: Up to mid/late 90s, closed committees, IAC (Industry Advisory Conference): UL would call meeting with manufacturers, technical topics, and 'open discussion,' UL would use input and decide on standard

-Canvas group mailings replaced this: they were more open, but eventually became STP in the early 2000s

a. What was the situation with the old system that prompted the implementation of STP?

-Process was too dominated by large manufacturers and UL, it was too closed

-“Old-school” manufacturers don’t always like STP, because anyone can comment, regardless of experience and expertise

-UL only has one vote now, which prevents them from having supreme power

-Basically, there has been a shift from UL and industry-dominated panel to an open and equal process

-“Agenda of technical topics and go through a discussion with manufactures, and then UL would take that input into account and decide what goes into the standard.” [IAC]

-“Now we have one vote just like everyone else.”

-“Anyone can submit a proposal, not just UL.”

-“it is an open process that is not just dominated by UL”

4. What process is used to convert an idea for an amendment to a voluntary standard into a ballot measure?

-If a need becomes evident (based on recalls, a trend of recalls, etc.), UL would draft proposed change and rationale, submit to CSDS (Collaborative Standards Development System), UL admin staff “cleans up” draft, STP reviews draft, anyone can review and comment, then the voting members vote

-Anyone can submit a proposal

5. What sorts of actions do supporters of a ballot take to encourage support?

-A strong rationale is very helpful, it can include testing results and strong data

-Submitter can comment themselves on their own proposal, which can encourage others to follow

-It is possible to lobby STP members through email or phone calls

-Discussion/meeting with STP is possible, and the proposal developer could come and present and run discussion

-Proposal may be radical or technical, the submitter can ask the STP chair to get a group of focused technical people to fine-tune and clarify proposal (Working Group): CPSC has done this, proposals for clothes dryers about status indicators, such as lint screen cleaning alerts, formed working group

-People can also lobby/work against proposals-some people feel very strongly about proposals

-“There are times when a proposal is so significant, and so long, so what they’ll do is when they submit proposals is form a sub-group of the STP and review/revise the proposal ahead of time before it gets to the entire STP. It is an informal subgroup. Some are STP members, some are not.”

6. What actions are taken if a ballot measure fails to reach consensus? If the sponsor still thinks it's a good idea, what actions can they take?

-Consensus: 50+% must return ballot, $\frac{2}{3}$ must be positive: If only the 50% returned item is met, submission can be recirculated (submitter could change based on negative comments), then a revote takes place

-If there is a complete failure, it is closed, but the proposer could rewrite and try again: it is important to explain the changes in the rationale; could try to submit without changes, but STP chair will request not wasting everyone's time

7. How many issues, percentage-wise, pass on the first attempt?

-No statistics, but based on his experiences with appliances, electric tools, etc.: probably about 75% pass the first time, but definitely more pass than fail

-STP chair will do pre-work (discussion with stakeholders) if they sense that people won't like the proposal

8. How often does STP 2157 meet during the regular year?

-Varies; case-dependent: in general, some STPs meet regularly, typically once a year, some STPs don't meet at all (high travel costs mean tend towards web-meetings)

-2157 has not met in the last 10 years or so, there hasn't been a need (they co-publish standards with CSA (Canadian UL), therefore usually conduct discussions online)

-“Some STP's meet on a regular basis, most typically meet once a year, some STP's don't meet at all.”

-“There have been revisions, but the standards under STP 2157 are bi-national standards. This means they are parallel with Canadian standards, meaning the US and Canada share the same standard. Canada, however, has its own standard committee process.”

9. How many STPs are you the chair of?

-Approximately 60 STPs, which cover probably 150 standards, but some are umbrella standards (electric tools STP covers about 50)

-There are four other full-time STP Chairs at UL with similar job, but different STPs

Appendix I: Interview Notes, David Miller

Interview Notes with David Miller, Directorate for Epidemiology at CPSC

Interview conducted October 25, 2 pm by Kyle Bonaccorso, Mariah Eldredge, Scott Gould, and Cameron Mills

1. How does the CPSC collect data for Residential Fire Loss Estimates?

-The CPSC uses two sources, NFIRS data and NFPA data

-NFIRS is a reporting system by the United States Fire Administration, and many fire departments submit reports

-The NFPA does an annual survey of number of fires, number of deaths, number of injuries, and amount of property loss

-The CPSC uses these two sources to create a weight for their own numbers, to account for unreported or misreported fires caused by clothes dryers

2. Are you familiar with how the NFPA collects this information?

-Yes

3. Why do you think the estimates differ?

-The CPSC excludes intentionally set fires

-CPSC and NFPA use different statistical tools to account for missing data: CPSC uses “raking,” a more complicated tool than the NFPA

-The NFPA also counts dryers for incidents reported as “no equipment,” “unknown equipment,” and blank fields as to the cause of the fire, whereas the CPSC ignores “no equipment”

-Something else to consider is that the results for number of dryer fires may be slightly, the CPSC report is based only on fires that the fire department attends. Therefore, the CPSC tends to be aware of fewer but more severe fires.