TESTING OF COMBUSTIBLES ON THE HEATER HOUSINGS USED IN ELECTRIC CLOTHES DRYERS

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DIRECTORATE FOR ENGINEERING SCIENCES

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COMBUSTIBLES ON THE HEATER HOUSINGS

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The information presented in this report reflects the time the report was written

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The experiments described in this research report were undertaken to support future advances in safety of clothes dryers. This report should not be used to suggest that current clothes dryers are unsafe or defective.

The views expressed in this report are those of the CPSC staff and have not been reviewed or approved by, and may not necessarily reflect the views of, the Commission.

Executive Summary

In 2002, the U.S. Consumer Product Safety Commission (CPSC) staff initiated a project to investigate possible conditions that may lead to clothes dryer fires, in particular, ignition of lint. The results from this test program demonstrated that with a blocked exhaust, some areas of the dryer run cooler than normal, and other areas run hotter.[1] Testing also showed that lint could ignite on the heater housing under certain conditions. In these tests, the heater housing was tested outside the dryer so that the results could be generalized across many dryer designs. The test results indicated that lint would ignite only if the airflow through the heater housing was blocked and the high-limit thermostat was bypassed (simulating a temperature-regulating thermostat that failed to open). These tests were not conducted in actual clothes dryers, and a one-shot thermal limiter (a safety device found in most dryers today) was not evaluated as a means to prevent combustibles on the heater housing from igniting.

This report discusses a series of tests that were conducted to determine if combustibles on the heater housing of electric clothes dryers could ignite before a safety device–a one-shot thermal limiter–would disconnect power from the heating element. The one-shot thermal limiter (a manual, nonresettable temperature-limiting device) is used to disconnect power to the heating element if: (1) the air temperature near the heater becomes elevated well above the value necessary to activate the high-limit thermostat, and (2) the high-limit thermostat fails to activate. In this report, the one-shot thermal limiter may be referred to as a one-shot.

Heater housings from four electric clothes dryer designs were used in this series of testing. For these tests, the heater housings were wrapped with cheesecloth, a common fire indicator. The cheesecloth simulates combustibles, such as lint, that may accumulate on the heater housing. Two sets of tests were conducted. For the first set, the high-limit thermostat was bypassed (simulating a thermostat that failed to open) and the exhaust duct was 100 percent blocked. Neither the one-shot thermal limiter, nor the primary thermostat was removed from the circuit, unless stated. In the second set of tests, in addition to bypassing the high-limit thermostat and blocking the exhaust duct 100 percent, the one-shot thermal limiter was bypassed.

Even though these tests used only one type and thickness of combustible material, the selected temperature "trip" points of the one-shot thermal limiters partially determined whether combustibles on the heater housing would ignite before disconnecting power from the heater element. In some of the tests, the cheesecloth ignited before the one-shot thermal limiter would have activated. In some cases, the time between combustible ignition and activation of the one-shot was very close. Changing some of the test parameters (airflow or blockage level, combustible material type and amount) may lead to the ignition and activation times to be even closer or further apart, or change in order of occurrence.

[1] U.S. Consumer Product Safety Commission. May 2003. *Final Report on Electric Clothes Dryers and Lint Ignition Characteristics*. Prepared by Lee, A. Division of Electrical Engineering. Directorate for Engineering Sciences. Washington DC.

The specifications for and locations of the one-shot thermal limiters in clothes dryers may not have been designed initially to prevent ignition of combustibles on the heater housing. It is clear that the one-shot thermal limiter is used to help prevent the interior of the clothes dryer from “getting too hot” if the primary and high-limit thermostats do not regulate the temperature; but it is also clear that careful selection of the “trip” temperature and location of the one-shot thermal limiter play an important role in determining the likelihood of combustible ignition on the heater housing.

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1.0 BACKGROUND

Over the years, the number of safety devices included in clothes dryers to reduce the incidence of fire has increased. The increased safety of dryers has likely contributed to the slowed growth rate in dryer fires. However, with more than 80 million clothes dryers (electric and gas) in U.S. households today, there were an estimated 14,600 clothes dryer fires resulting in 300 injuries, $86.8 million in property damage, and fewer than 10 deaths in 1999.[2]

The National Fire Protection Association (NFPA) annual report, *The U.S. Home Product Report, January 2002,* states that the leading cause of dryer fires was lack of maintenance (30 percent).[3] The report states that the second leading cause was part failure, leak, or break (10 percent), followed closely by short circuit or ground fault. Clothing not on a person was the leading form of material first ignited (32 percent), followed by dust, fiber, or lint (28 percent).

In 1998, the U.S. Consumer Product Safety Commission (CPSC) staff began an evaluation of clothes dryers. The results of the tests conducted during that evaluation showed that, when the dryer exhaust was blocked, some areas of the dryer would run cooler than normal, and other areas would run hotter. CPSC staff believed that long-term operation of a dryer under conditions of restricted airflow, such as that caused by lint accumulation in the exhaust duct, could eventually lead to premature failure of components; and that condition might result in a fire incident.[4]

In 2002, the CPSC staff initiated a project to investigate possible conditions that may lead to dryer fires–in particular, ignition of lint. The results from this test program were similar to the findings in the 1998 testing.[5] Testing also showed that lint could ignite on the heater housing under certain conditions. In these tests, the heater housing was tested outside the dryer so that the results could be generalized across many dryer designs. The test results indicated that lint would ignite only if the airflow through the heater housing was blocked and the high-limit thermostat was bypassed (simulating a thermostat that failed to open). The one-shot thermal limiter (a safety device found in most dryers today) was not evaluated as a means to prevent combustibles on the heater housing from igniting.

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[2] U.S. Consumer Product Safety Commission. November 2003. *1999 Residential Fire Loss Estimates*. Prepared by Miller, D. Division of Hazard Analysis. Directorate for Epidemiology. Washington D.C. [The most recent NFIRS 3-year average data is for 2008 – 2010. It estimates an annual average of 6,100 clothes dryer fires causing 20 deaths, 190 injuries, and $79 million in property loss.]

[3] National Fire Protection Association. January 2002. *The U.S. Home Product report (Appliances and Equipment Involved in Fires).* Prepared by Rohr, K. Fire Analysis and Research Division. Quincy, MA.

[4] U.S. Consumer Product Safety Commission. 2000. *Final Report on Electric and Gas Clothes Dryers.* Prepared by Kadambi, S. Division of Electrical Engineering. Directorate for Engineering Sciences. Washington D.C.

[5] U.S. Consumer Product Safety Commission. May 2003. *Final Report on Electric Clothes Dryers and Lint Ignition Characteristics*. Prepared by Lee, A. Division of Electrical Engineering. Directorate for Engineering Sciences. Washington DC.

2.0 INTRODUCTION

The heater component of a clothes dryer produces the hottest air and surface temperatures inside the appliance. The data presented in this report were collected to determine if combustibles on the heater housing would ignite before the safety device–a one-shot thermal limiter–would disconnect power from the heating element. The one-shot thermal limiter (a nonresettable temperature-limiting device) is used to disconnect power to the heating element if: (1) the air temperature near the heater becomes elevated well above the value necessary to activate the high-limit thermostat, and (2) the high-limit thermostat fails to activate.

The voluntary standard for electric clothes dryers is Underwriters Laboratories (UL) Standard for Safety 2158, *Electric Clothes Dryers.* In the standard, Section 19.5, *Blockage of Lint Screen and Exhaust* includes tests on the clothes dryer under the conditions of a 75 percent or 100 percent blocked lint screen or a 75 percent or 100 percent blocked exhaust. The testing is conducted with all temperature-regulating and temperature-limiting devices defeated or bypassed. A manual- resettable or nonresettable temperature-limiting device does not have to be bypassed for the testing. According to the standard (Section 24.12.8), the manual temperature-limiting device must:

a) be manual-reset or nonresettable type and inaccessible to the user without the use of tools; or
b) de-energize both the heating element and the drum-driving force (motor) and necessitate that the appliance be manually restarted.

These tests are conducted on new appliances that do not contain any accumulation of lint inside or outside the clothes dryer. During these tests, the appliance cannot have:

a) emission of flame or molten metal;
b) glowing or flaming of combustible material outside the appliance; or
c) indication of flame or glowing embers in the load, either before or after the access door is opened.

Although there are no tests in the voluntary standard that test for the ignition of lint near or on the heater, the voluntary standard requires that clothes dryers be permanently marked according to Section 7.1.2.13, which states: “An appliance shall be permanently marked in accordance with Table 1.” The “Caution” markings listed in Table 1 contain the statement: “A clothes dryer produces combustible lint.”

Previous CPSC staff testing demonstrated that a functional high-limit thermostat would most likely prevent combustibles, such as lint, from igniting on the heater

housing.[6] The purpose of the testing conducted for this report was to determine if the one-shot thermal limiter can prevent ignition of combustibles on the heater housing with the high-limit thermostat bypassed (simulating a failed thermostat in the closed position) and with the airflow in the exhaust duct 100 percent blocked. The voluntary standard does not evaulate the ability of the one-shot thermal limiter to prevent ignition of combustibles on the heater housing.

Four electric clothes dryer designs were used in this testing. For these tests, the heater housing was wrapped with cheesecloth, a common fire indicator. The cheesecloth simulates combustibles, such as lint, that may accumulate on the heater housing. Two sets of tests were conducted.

The first set of tests simulated a 100 percent blocked exhaust and a failed high-limit thermostat. Incidents involving a blocked exhaust is a common failure mode for a dryer not running effcienctly. A blocked exhaust would result in the high limit thermostat operating more frequently, which can result in a failed thermostat. This was observed in the 2003 clothes dryer testing by CPSC staff. Neither the one-shot, nor the primary thermostat was removed from the circuit, unless stated. In the second set of tests, in addition to bypassing the high-limit thermostat and blocking the exhaust duct 100 percent, the one-shot was bypassed. These tests were to determine the time to ignition of the cheesecloth on the heater housing. Figure 1 shows illustrations of the four dryer designs used in the testing.[7]

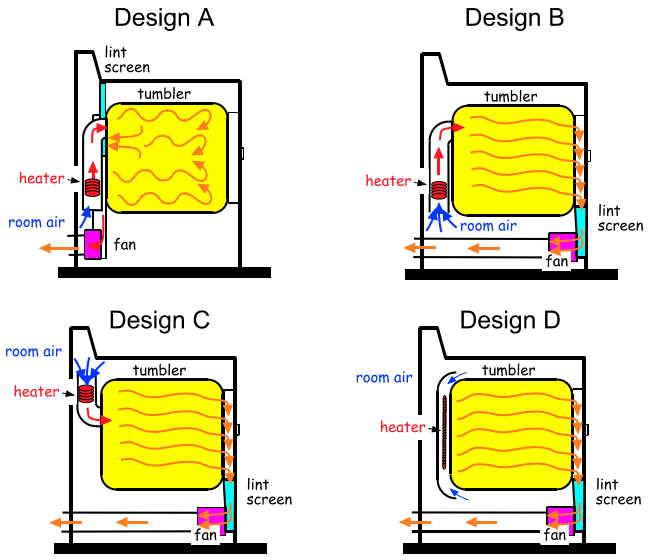


Figure 1. Four different dryer designs were tested. The location of the heater, lint screen, and air entering and exiting the drum varied among the dryer designs.

[6] U.S. Consumer Product Safety Commission. May 2003. *Final Report on Electric Clothes Dryers and Lint Ignition Characteristics*. Prepared by Lee, A. Division of Electrical Engineering. Directorate for Engineering Sciences. Washington DC.

[7] The same four dryer designs used in the 2002 testing were also used in this testing.

All four dryer designs tested have the same basic airflow path. Air is pulled into the dryer through gaps in the dryer housing, particularly through rear vents. Air is drawn over the heater, which warms the air, and the air then enters the tumbler. The air exits the tumbler and is directed through a lint screen. The air then passes through a duct and into the fan. The fan forces the air through an exiting duct to the rear of the dryer. The main differences in these dryers is the heater design (housing and element) and location, as well as the lint screen size and location.

All four dryers use a centrifugal-type fan. A centrifugal fan draws air through the center and forces it outward. The fan creates negative pressure in the drum and blows air into the exhaust duct.

The general locations of the temperature control devices on the dryers are similar. All four dryers have a minimum of two temperature control devices (primary and high-limit thermostat). One temperature switch (the primary, or operating, thermostat) is located after the lint screen and near the blower air intake. The second temperature switch (the high-limit thermostat) is located near the heater air intake. Each of the dryer designs also has a safety device, a one-shot thermal limiter, which is located in different places for each of the dryer designs, but generally, in close proximity to the heater element.

The cheesecloth used for testing has specifications of approximately 28−30 m^2/kg cotton, a thread count of 13 threads per cm in one direction and 11 threads per cm in the other direction. These specifications are similar to the cheesecloth requirements in UL 2158, Section 4.6, *Cheesecloth for heating and abnormal tests*.

3.0 TESTING

3.1 Test Parameters and Setup

A single K-type thermocouple was placed as close as possible to the front face of the one-shot thermal limiter, without contacting the thermal limiter for all the tests. The thermocouple was sampled at a rate of 100 samples per second with a computer-controlled data acquisition system.

The dryers were tested on the highest heat setting and with no clothes in the drum.

A 3.5-foot straight duct was connected to the exhaust of the dryer. A blast plate was placed at the end of the exhaust duct to create a 100 percent blocked exhaust. The connections between the exhaust duct and the dryers were press-fitted and clamped.

Three layers of cheesecloth were wrapped on the heater housing for all the tests. Three layers of cheesecloth were used to achieve approximately 0.3 grams in a 2" x 2" area. A weight of 0.3 grams in a 2" x 2" area was selected because it was similar to the

sample lint weight used in previous testing.[8] The weight does not necessarily represent typical lint accumulation in actual clothes dryers. Binder clips were used to hold the cheesecloth to the heater housing.

Data collection was started approximately 30 seconds before the clothes dryer was started. A video recorder with a timer was used to record the events and to determine the elapsed time from the start of the dryer to any events.

The purpose of this testing was to determine if the one-shot thermal limiter would activate before the combustible cheesecloth on the heater housing would ignite when the high-limit thermostat was bypassed and the exhaust duct was 100 percent blocked. The primary thermostat was not removed from the circuit, unless otherwise noted. (In the 2002 CPSC staff testing, it was noted that the temperature near the primary thermostat was below its set trip point because of the reduced airflow caused by a blocked exhaust. Therefore, the primary thermostat would be expected to have no effect on ignition of the fire indicator at the heater housing.)

In the first set of tests, the one-shot thermal limiter was included in the circuit. If the one-shot activated before the cheesecloth ignited, a second test was run with the one-shot bypassed. This was done to determine when the cheesecloth would have ignited had the one-shot not intervened to cut electric power to the heater. If in the first test the one-shot did not activate and the cheesecloth ignited, the second test was run without cheesecloth to determine how long it would take for the one-shot to activate.

Thermostat activation and cheesecloth ignition times recorded on videotape have a ¼-second resolution. The times listed in the report are rounded down to the nearest second.

3.2 Test Limitations

The tests were conducted using three layers of cheesecloth. Different results may be produced with other thicknesses of cheesecloth or different combustible materials.

The tests were conducted with the blockage at 3.5 feet from the dryer exhaust connection. Different results may be achieved with a partial blockage, a blockage in a different location, or with different configurations of exhaust ducting.

The dryers were tested with either the top of the dryer partially opened, the top cover removed, the rear cover removed, or the front bottom kick panel removed. This allowed monitoring of the cheesecloth and access to extinguish a fire, if needed. It is unknown if these configurations dramatically affected the times of one-shot activation or

[8] U.S. Consumer Product Safety Commission. May 2003. *Final Report on Electric Clothes Dryers and Lint Ignition Characteristics-Task 4 Lint Ignition Characteristics*. Prepared by Lee, A. Division of Electrical Engineering. Directorate for Engineering Sciences. Washington DC.,

ignition of the cheesecloth; but it is believed that the test results would have been unaffected or very similar since the proximity of the cheesecloth to the source of the heat was small and the temperature gradiant was high.

The ignition times are reported from the time the dryer was started to when flames first appeared in the video. The first ignition of the cheesecloth may not have been in direct view of the video camera, and therefore, the actual ignition time may have been slightly earlier.

3.3 Test Data

The test results are presented in the order in which the dryers were tested.

3.3.1 Dryer Design C Testing

In Dryer Design C, the clothes dryer heater is located behind the drum near the top of the dryer. The intake air is taken from the top of the dryer interior (outside the drum) and directed downward into the heater. The distance between the heater element and the intake into the tumbler is only a few inches. The heater housing contains louvers on the rear side of the housing to allow air into the dryer interior.

The cheesecloth was wrapped on three sides of the heater housing, as shown in Figure 2. The fourth side of the heater housing was up against the air intake grill for the drum. The one-shot thermal limiter is located on the side of the heater housing adjacent to the heating element. The thermocouple was placed in front of the one-shot thermal limiter.

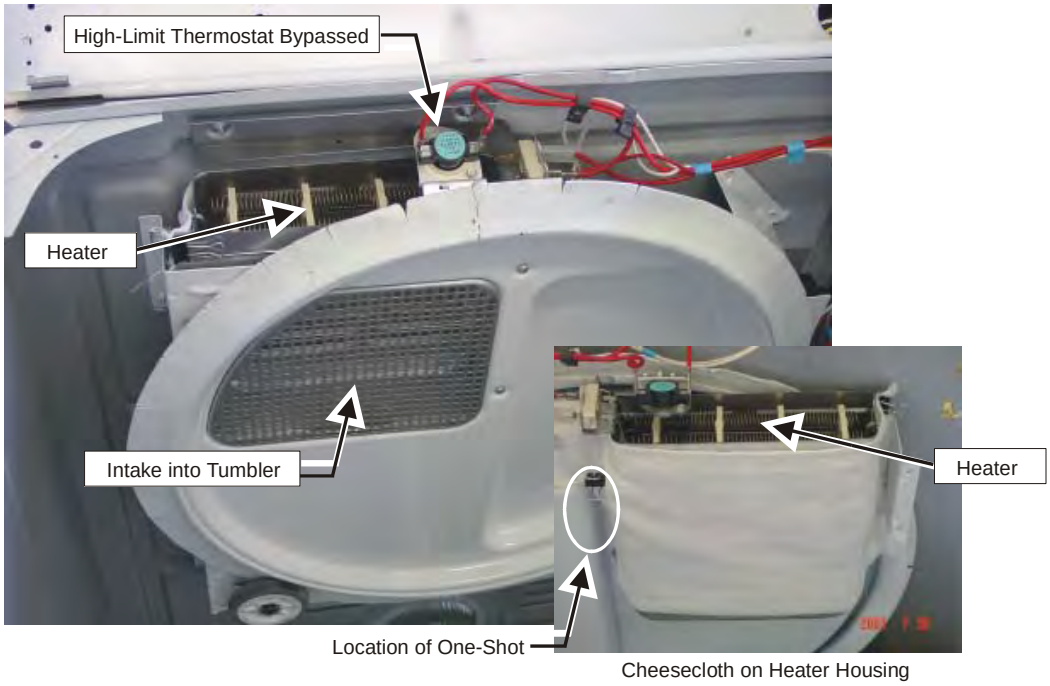
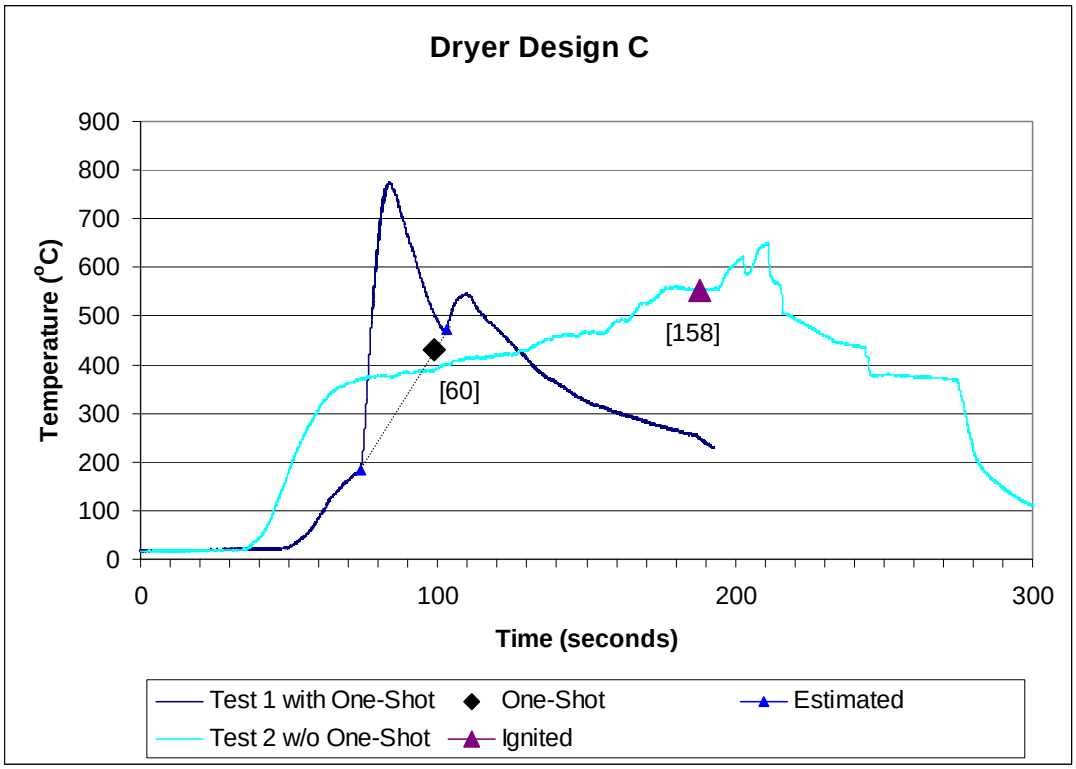


Figure 2. Dryer Design C setup with the cheesecloth on the heater housing. Cheesecloth was wrapped on three sides of the heater housing. The fourth side contained louvers to allow air to enter the drum.

The first test was conducted with the one-shot thermal limiter in the circuit and with cheesecloth wrapped around the heater housing. The one-shot thermal limiter activated approximately 60 seconds after the dryer was started, as shown in Figure 3. (A small piece of fiberglass tape on the thermocouple ignited around 43 seconds after the dryer was started; it began to extinguish around 56 seconds after the dryer was started.) It is unlikely that the flame from the burning tape would have altered the activation time of the one-shot because the flame was away from and above the location of the one-shot thermostat.

In the second test, the one-shot was bypassed to determine how long it would take the cheesecloth to ignite. The cheesecloth ignited approximately 158 seconds after the dryer was started, as shown in Figure 3. During the setup for the second test, the thermocouple shifted slightly when the one-shot was being bypassed. It can be seen that even the slightest movement of the thermocouple causes the temperature profile to change because of the close proximity of the thermocouple to the heating element.



Times in [ ] are from the video and represent elapsed time from when the clothes dryer was started. The x-axis time scale represents the elapsed time when the data acquisition system was started.

Figure 3. Activation times of the one-shot and ignition of the cheesecloth are shown for Tests 1 and 2. The sudden increase in temperature in Test 1 was a result of fiberglass tape igniting.

Figure 4 shows photos of cheesecloth ignition during the second test of Dryer Design C. Ignition occurred at the rear of the heater housing.

Start of the Dryer

Flames First Appear

11 seconds after first flames

Figure 4. The cheesecloth ignited approximately 158 seconds after the dryer was started with the one-shot bypassed. The circle in frame 2 indicates where flames were first noticed.

3.3.2 Dryer Design B Testing

In Dryer Design B, the clothes dryer heater is located behind the tumbler near the bottom of the dryer. The intake air is taken from the bottom and directed upward into the heater. The heater housing contains cutouts for ceramic clips on the front side of the heater housing, which are used to hold the heating element.

Cheesecloth was wrapped on all four sides of the heater housing, as shown in Figure 5. The one-shot thermal limiter is located on the side of the heater housing (as viewed from the rear) adjacent to the heating element. A thermocouple was placed in front of the one-shot thermal limiter.

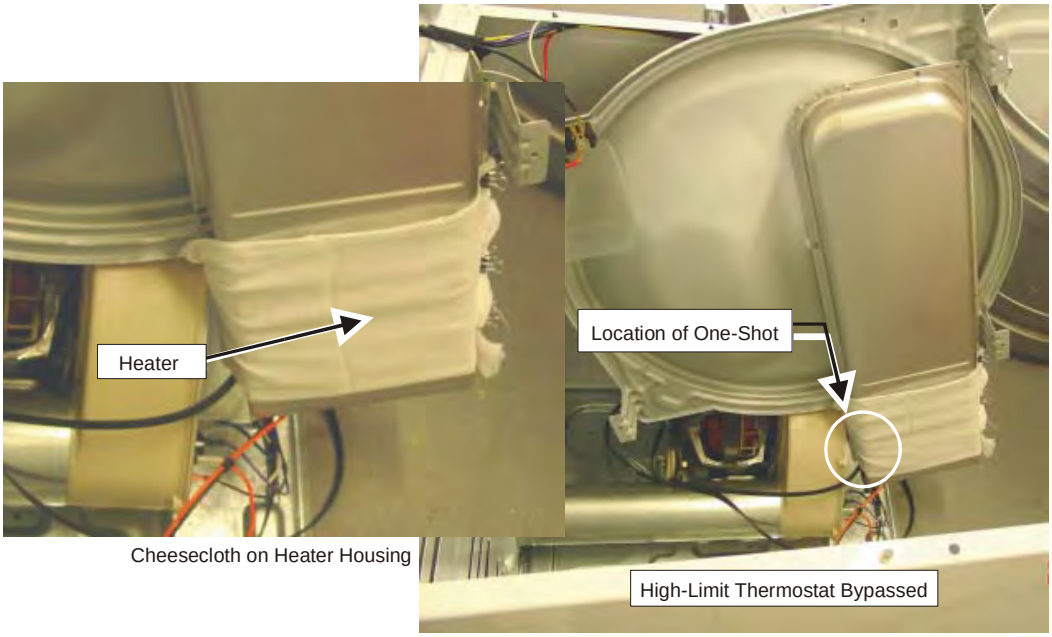
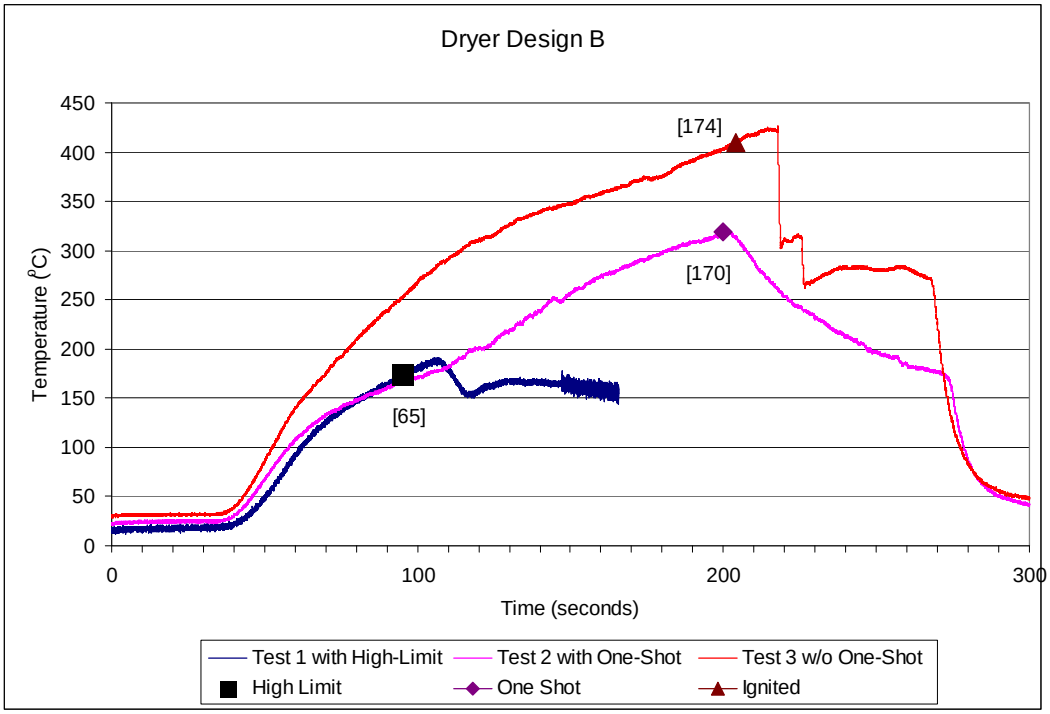


Figure 5. Dryer Design B setup with the cheesecloth on the heater housing. Cheesecloth was wrapped on all sides of the heater housing.

In the first test, inadvertently, the high-limit thermostat had not been bypassed. The high-limit thermostat activated at approximately 65 seconds after the dryer was started, as shown in Figure 6. Since the high-limit thermostat activated in a relatively short period of time, and there were no signs of smoldering or other thermal degradation, the same cheesecloth was used in the second test.

After the high-limit thermostat was bypassed, the second test was conducted with the one-shot thermal limiter in the circuit and with cheesecloth on the heater housing. The one-shot activated approximately 170 seconds after the dryer was started, also shown in Figure 6.

A third test was conducted in which the one-shot was bypassed to determine when the cheesecloth would ignite. A new piece of cheesecloth was installed on the heater housing. The cheesecloth ignited approximately 174 seconds after the dryer was started, as shown in Figure 6. During setup for the third test, the thermocouple shifted slightly when the one-shot thermal limiter was being bypassed and the cheesecloth was installed.



Times in [ ] are from the video and represent elapsed time from when the clothes dryer was started. The x-axis time scale represents the elapsed time when the data acquisition system was started.

Figure 6. Activation times of the high-limit thermostat, one-shot, and ignition of the cheesecloth are shown for Test 1, 2, and 3. The one-shot and ignition of the cheesecloth occurred approximately the same time.

Figure 7 shows when the cheesecloth ignited during the third test. The camera was oriented 90 degrees counterclockwise of the dryer orientation. The figure shows the dryer oriented with the bottom of the dryer on the left and the top of the dryer to the right. Ignition occurred on the rear side of the heater housing.

Start of the Dryer

Flames First Appear

Figure 7. The cheesecloth ignited approximately 174 seconds after the dryer was started with the one-shot bypassed. The circle in frame 2 indicates where flames were first noticed.

3.3.3 Dryer Design A Testing

In Dryer Design A, the clothes dryer heater is located behind the tumbler near the bottom of the dryer, similar to Dryer Design B. The intake air is taken from the bottom and directed upward into the heater. The side of the heater housing contains cutouts for metal tabs. A metal plate with tabs is located inside the heater housing. The metal plate is used to hold the ceramic clips that support the heating element.

Cheesecloth was wrapped on all four sides of the heater housing, as shown in Figure 8. The one-shot thermal limiter is located on the side of the heater housing close to the air intake for the tumbler. A thermocouple was placed in front of the one-shot thermal limiter.

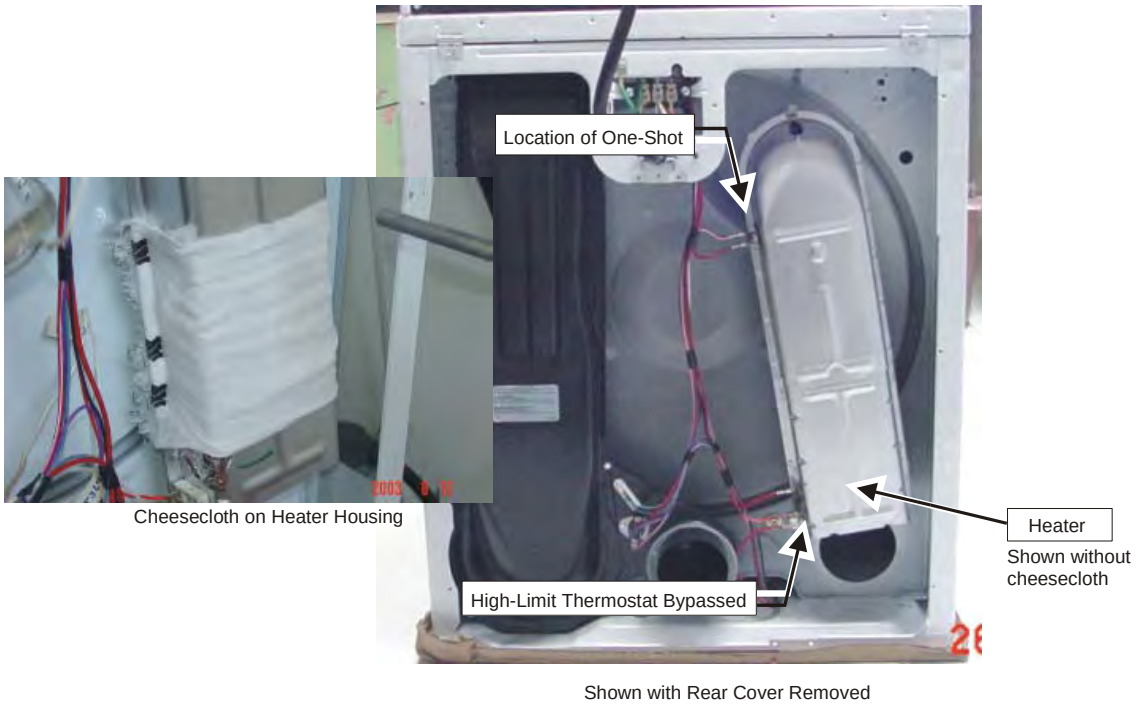
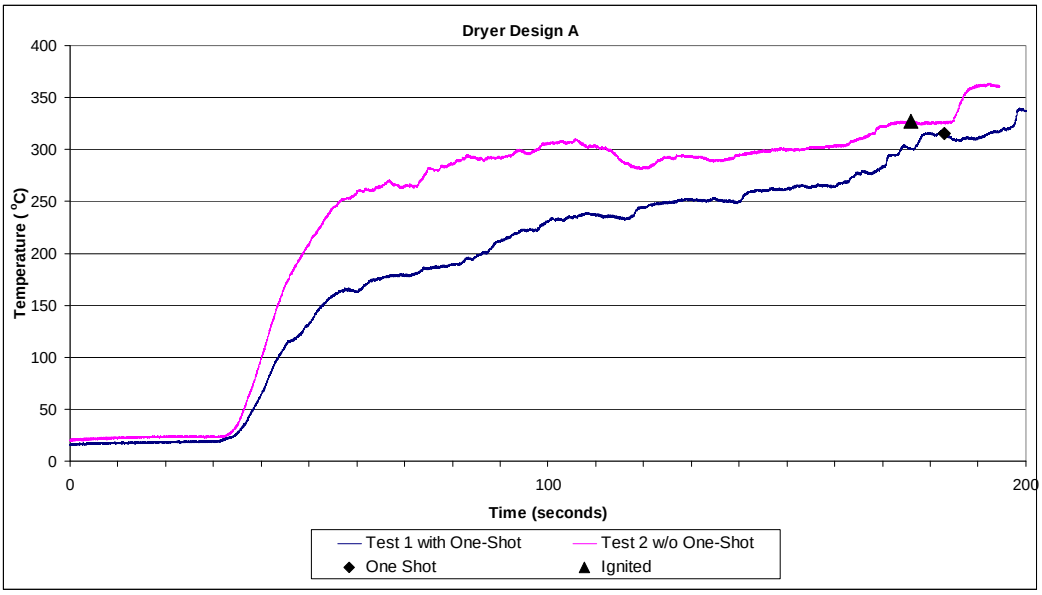


Figure 8. Dryer Design A setup with the cheesecloth on the heater housing. Cheesecloth was wrapped on all sides of the heater housing.

The first test was conducted with the one-shot thermal limiter in the circuit and with cheesecloth wrapped on the heater housing. The one-shot activated approximately 153 seconds after the dryer was started, as shown in Figure 9.

In the second test, the one-shot was bypassed to determine when the cheesecloth would ignite. The cheesecloth ignited approximately 146 seconds after the dryer was started, as shown in Figure 9. In this series of tests, ignition of the cheesecloth occurred in slightly less time than it took for the one-shot to activate. It is probable that variations in wrapping the cheesecloth can cause slight changes in the time to ignite the cheesecloth. During the setup of the second test, the thermocouple shifted slightly when the one-shot thermal limiter was being bypassed.



Times in [ ] are from the video and represent elapsed time from when the clothes dryer was started. The x-axis time scale represents the elapsed time when the data acquisition system was started.

Figure 9. Activation times of the one-shot and ignition of the cheesecloth are shown for Test 1 and 2. The one-shot and ignition of the cheesecloth occurred at approximately the same time.

Figure 10 shows when the cheesecloth ignited during the second test. Ignition occurred at the rear of the heater housing.

Figure 10. The cheesecloth ignited approximately 146 seconds after the dryer was started (without the one-shot bypassed). The circle in frame 3 indicates where flames were first noticed.

3.3.4 Dryer Design D Testing

In Dryer Design D, the clothes dryer heater is located behind the tumbler in a circular configuration, as shown in Figure 11. The intake air is pulled in from 360 degrees and directed into the heater to the back of the drum. The heater housing also contains circular cutouts on the rear side of the heater housing for additional airflow into the heater.

The cheesecloth was wrapped around the heater housing, as shown in Figure 11. The one-shot thermal limiter is located on the dryer chassis rear wall, near the top of the chassis. A thermocouple was placed in front of the one-shot thermal limiter.

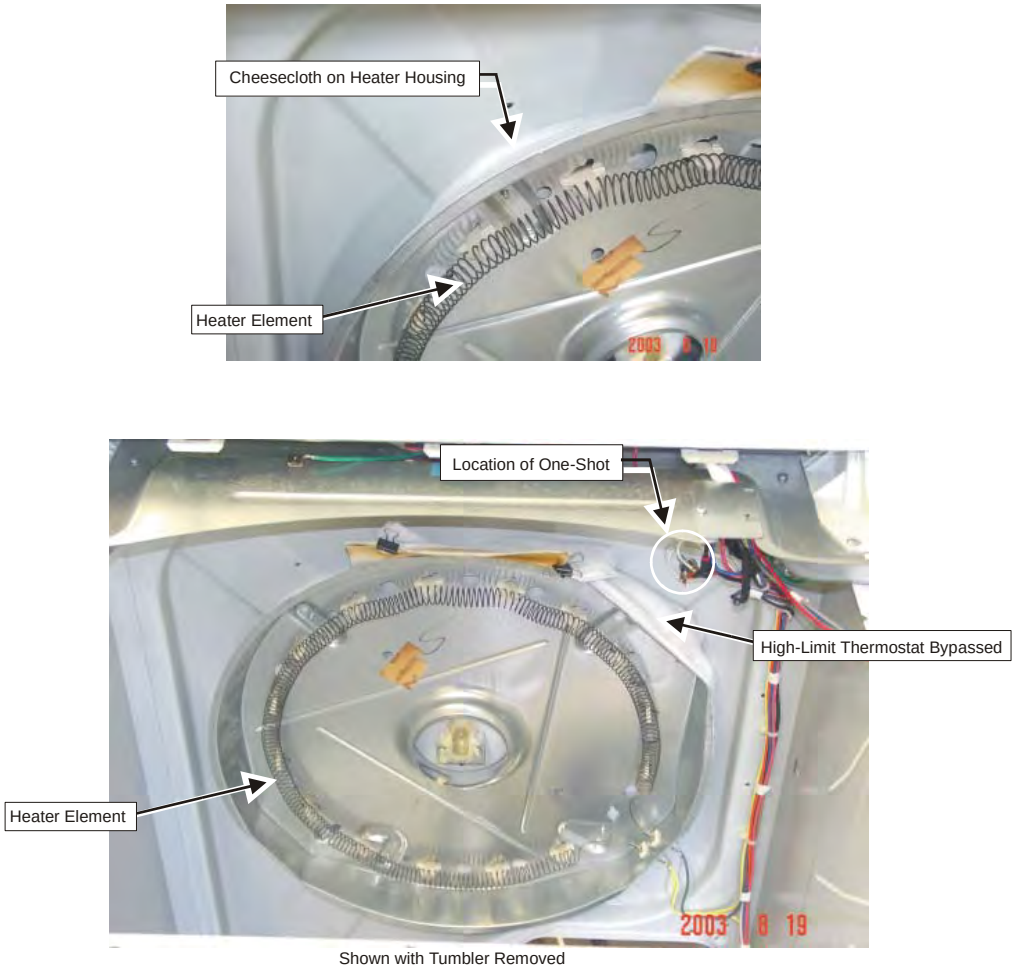
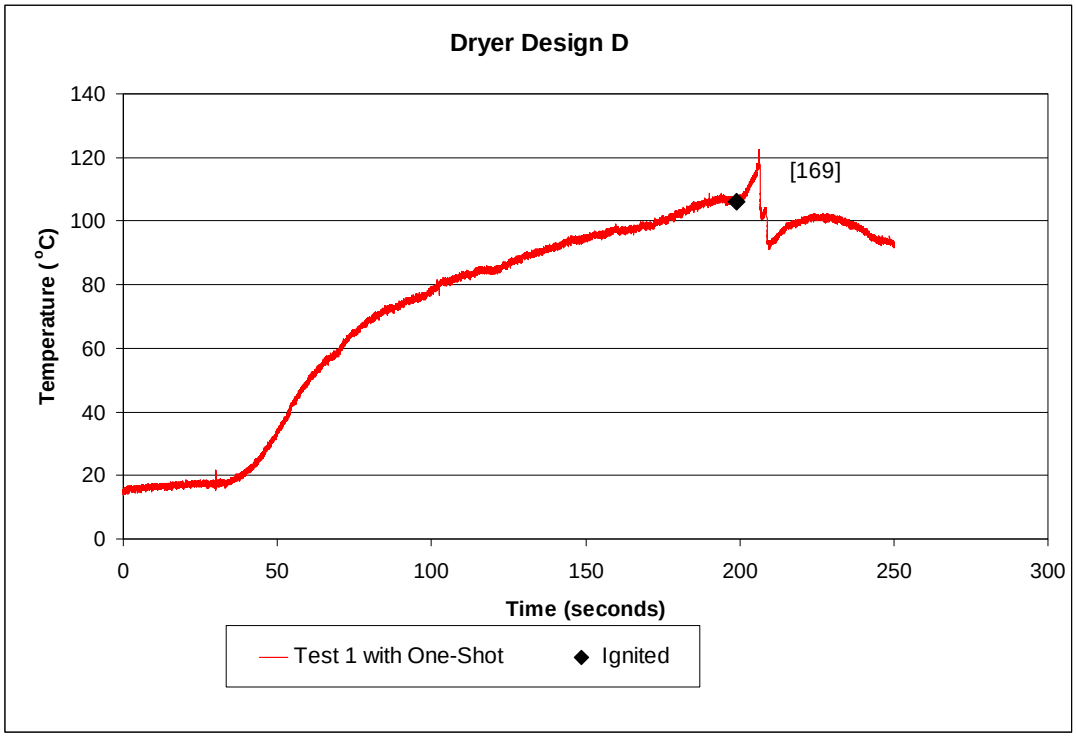


Figure 11. Dryer Design D setup with the cheesecloth on the heater housing. Cheesecloth was wrapped around the circular heater housing.

The first test was conducted with the one-shot thermal limiter in the circuit and with cheesecloth on the heater housing. The cheesecloth ignited approximately 169 seconds after the dryer was started, as shown in Figure 12. Figure 13 shows when flames first appeared. Upon inspection, it was observed that the cheesecloth ignited at a location where there were cutouts in the heater housing, as shown in Figure 14. Covering the

cutouts with cheesecloth may have prevented convective heat from the heating element from traveling to the one-shot thermal limiter, affecting its activation time.



Times in [ ] are from the video and represent elapsed time from when the clothes dryer was started. The x-axis time scale represents the elapsed time when the data acquisition system was started.

Figure 12. Ignition time of the cheesecloth is shown for Test 1. The cheesecloth ignited before the one-shot activated.

Start of the Dryer

Flames First Appear

Figure 13. The cheesecloth ignited approximately 169 seconds after the dryer was started (without the one-shot bypassed). Flames appear near the top right, as shown in frame 2.

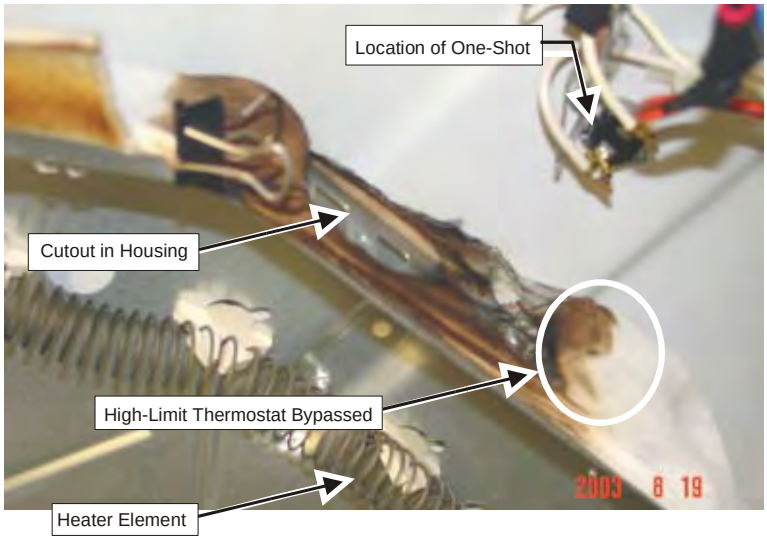


Figure 14. The cheesecloth ignited at a location where there was a cut-out in the housing.

For the second test, the cheesecloth was not placed over the cutout, as shown in Figure 15. The one-shot thermal limiter activated approximately 333 seconds after the dryer was started, as shown in Figure 16. In this test, the cheesecloth did not ignite.

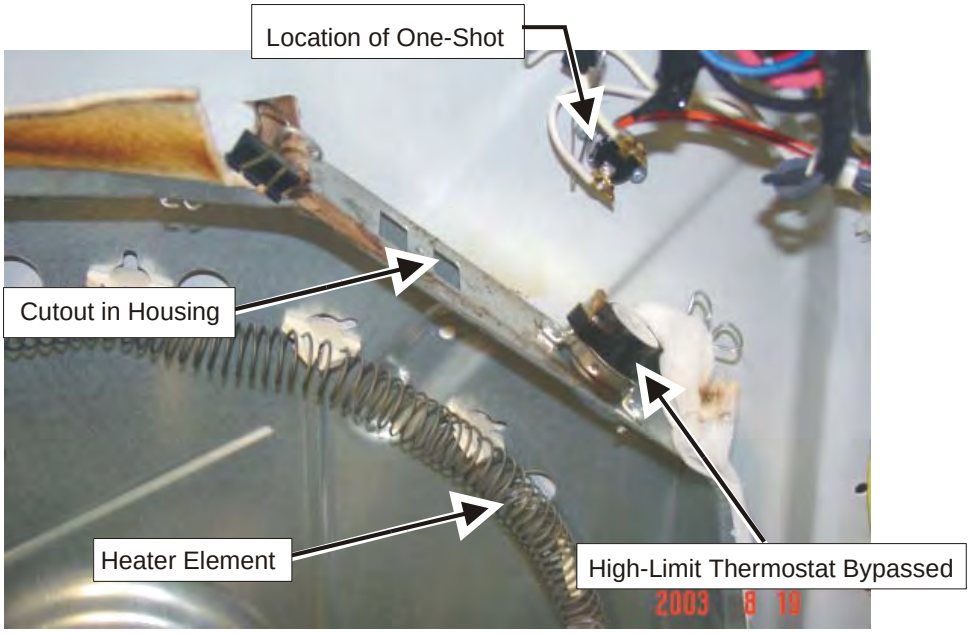
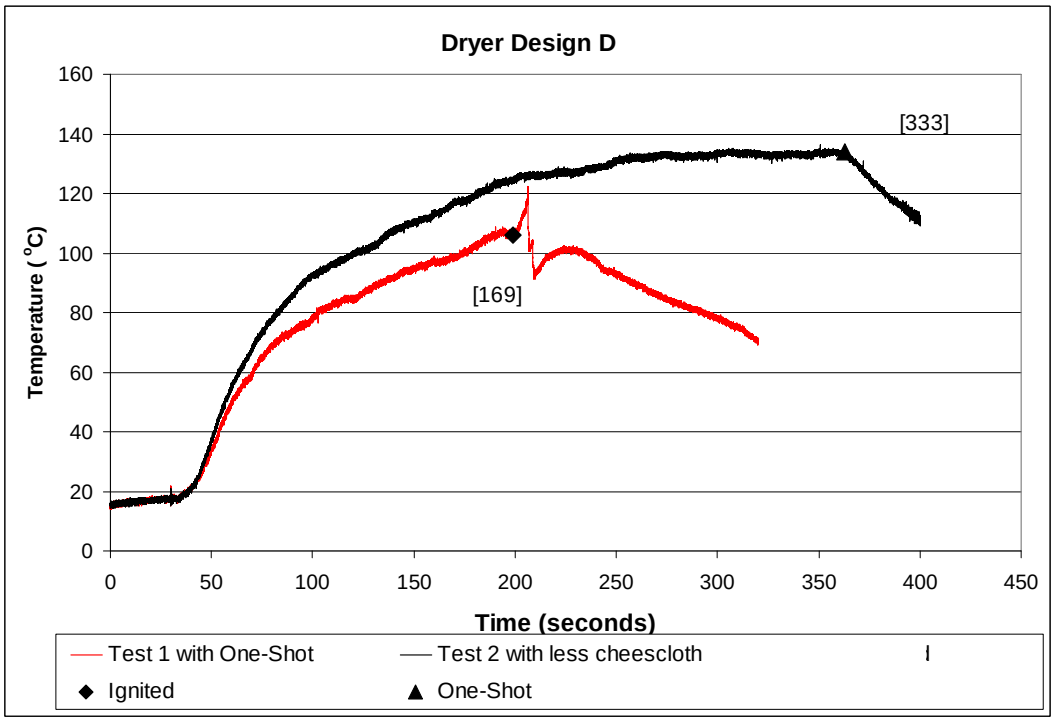


Figure 15. For test 2, cheesecloth was not placed over the housing cut-out.

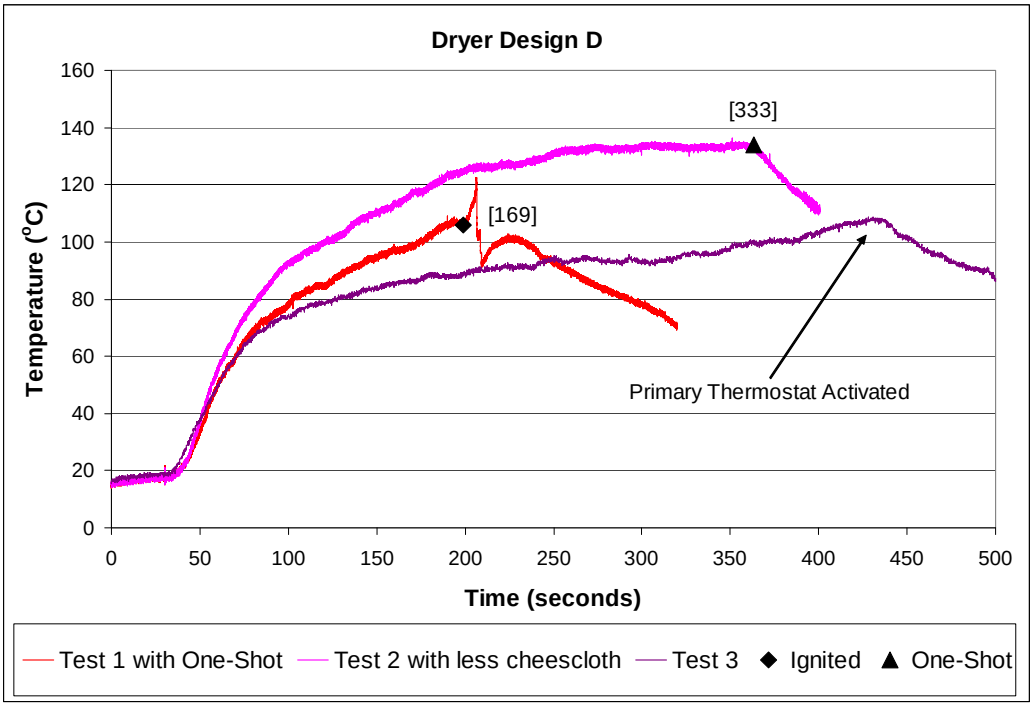


Times in [ ] are from the video and represent elapsed time from when the clothes dryer was started. The x-axis time scale represents the elapsed time when the data acquisition system was started.

Figure 16. Test 2 -the one shot activated 333 seconds after the dryer was started. Tests 1 and 2 plotted on the same graph.

In the third test, the one-shot was bypassed to determine when the cheesecloth would ignite. The primary thermostat activated around 400 seconds after the dryer was

started, as shown in Figure 17. It is suspected that sufficient heat from the heating element was able to travel to the primary thermostat, located after the blower, and cause its activation.



Times in [ ] are from the video and represent elapsed time from when the clothes dryer was started. The x-axis time scale represents the elapsed time when the data acquisition system was started.

Figure 17. For test 3, the primary thermostat activated before the cheesecloth ignited. The elevated temperatures in the dryer had migrated to the primary thermostat to cause it to activate. Tests 1, 2 and 3 plotted on the same graph.

In the fourth test, the primary thermostat was removed from the ducting and placed in the dryer chassis to prevent activation, as shown in Figure 18. Again, the purpose of the test was to determine when or if the cheesecloth would ignite. The primary thermostat activated around 800 seconds after the dryer was started, as shown in Figure 19. The interior heating of the dryer chassis was sufficient to cause the primary thermostat to activate. It is also suspected that the cheesecloth would not have ignited at this point. The amount of smoldering had begun to decrease significantly when the thermostat activated.

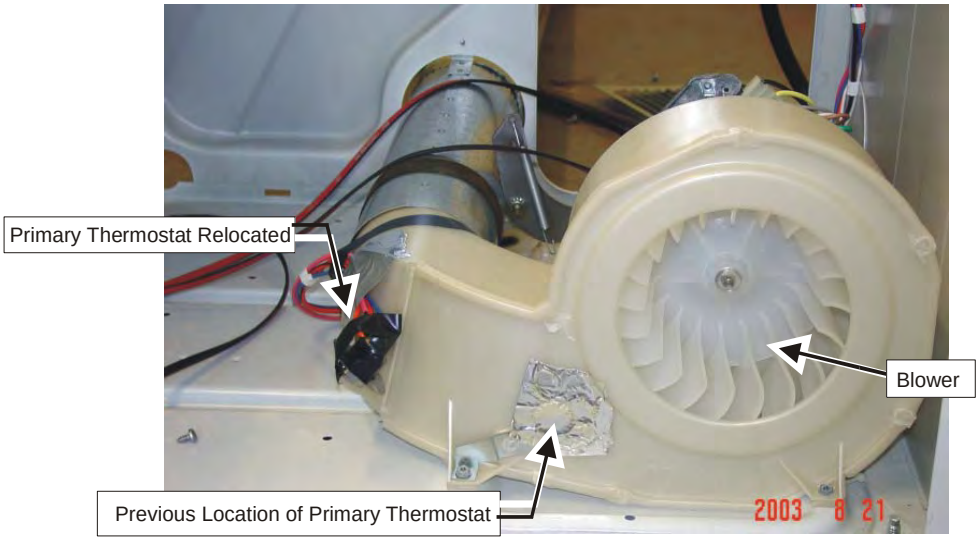
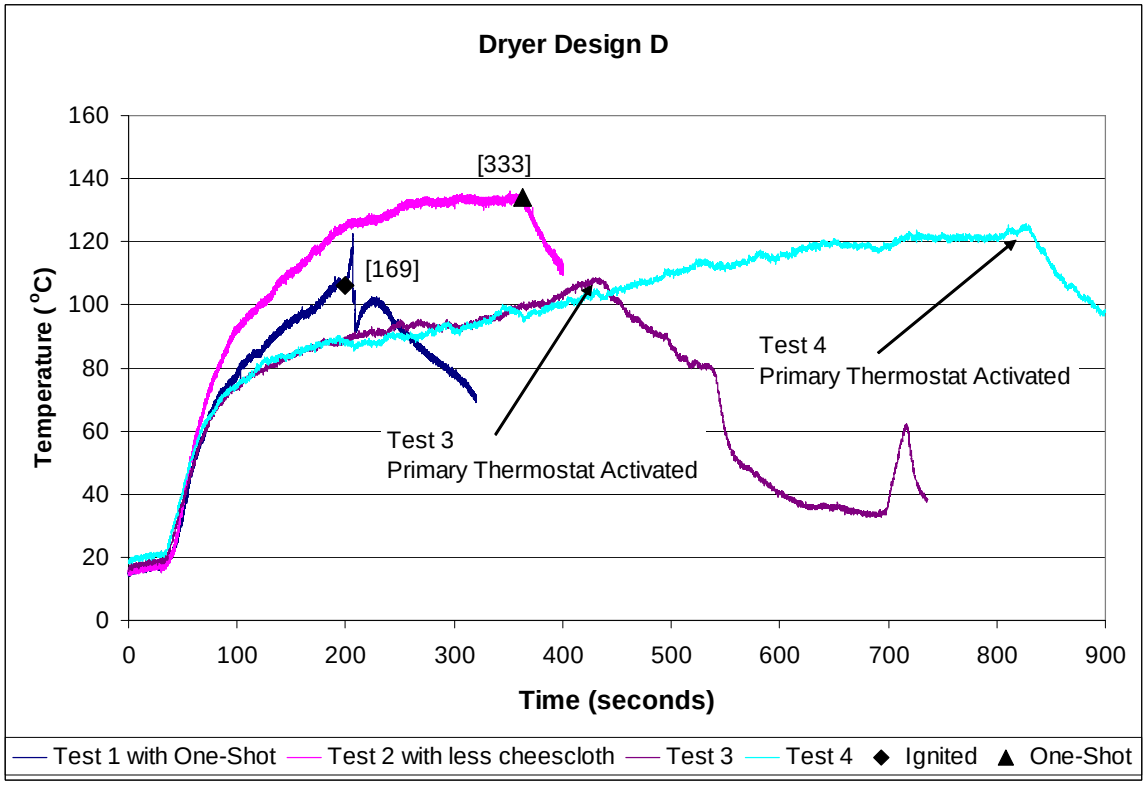


Figure 18. For test 4, the primary thermostat was removed to help prevent it from activating. The test was to determine when the cheesecloth would ignite without a one-shot thermal limiter.



Times in [ ] are from the video and represent elapsed time from when the clothes dryer was started. The x-axis time scale represents the elapsed time when the data acquisition system was started.

Figure 19. For test 4, the primary thermostat activated again before the cheesecloth ignited. The elevated temperatures in the dryer had migrated to the primary thermostat to cause it to activate. The cheesecloth would not likely have ignited if the primary thermostat had not activated. Tests 1, 2, 3, and 4 plotted on the same graph.

4.0 DISCUSSION

The CPSC staff conducted tests on four electric clothes dryers to determine if combustibles on the heater housing would ignite before a safety device–a one-shot thermal limiter–would disconnect power from the heating element. The tests were conducted using a combustible material cheesecloth on the heater housings, under conditions where the high-limit thermostat was bypassed and the exhaust was 100 percent blocked. Multiple tests were conducted to evalaute the characteristics between the one-shot activation and ignition of the cheesecloth. The CPSC staff observed the following:

- In Dryer Design C, the time for the one-shot thermal limiter to activate was 98 seconds less than the time it took for the cheesecloth to ignite. In these tests, the one-shot limiter would have prevented any combustibles contacting the heater's external housing from igniting.

- In Dryer Designs A and B, the cheesecloth ignited close to the same time that the one-shot activated. Because of testing variations, the order of events could sway either way. For Design A, the cheesecloth ignited 7 seconds before the one-shot activated, whereas for Design B, the time for the cheesecloth to ignite was 4 seconds longer than activation of the one-shot.

- In Dryer Design D, the cheesecloth ignited 164 seconds before the one-shot thermal limiter activated. This occurred at a cut-out in the heater housing, where the combustible material becomes exposed to higher temperatures. When retested with no cheesecloth on a portion of the heater housing located at the cut-out, the following was observed:

    - The one-shot activated before ignition of the cheesecloth.
    - The cheesecloth did not ignite with the one-shot bypassed.
    - The primary thermostat activated in two cases.

The thickness and the composition of the accumulated combustibles on the heater housing would determine likelihood of the material igniting. Design of the heater housing, such as cut-outs, distance to the heating coil, and thickness of the metal, would also have an effect on the ignition time of combustibles. Even though these tests used only one type and thickness of combustible material, the selected temperature "trip" points of the one-shot thermal limiters partially determined whether combustibles on the heater housing would ignite before the limiter disconnected power from the heater element. In some of the tests, the time between combustible ignition and activation of the one-shot was very close. Changing some of the test parameters (airflow or blockage level, combustible material type and amount) may cause the ignition and activation times to be closer or further apart, or change in order of occurrence.

The specifications for and location of the one-shot thermal limiters in clothes dryers may not have been designed initially to prevent ignition of combustibles on the heater housing. The one-shot thermal limiter is used to help prevent the interior of the

clothes dryer from “getting too hot” if the primary and high-limit thermostats do not regulate the temperature. But the careful selection of the “trip” temperature and location of the one-shot thermal limiter play an important role in determining if combustibles on the heater housing can ignite.