

A PRELIMINARY ANALYSIS OF  
HYPERTHERMIA DEATHS ASSOCIATED WITH  
ELECTRIC ROOM/SPACE HEATERS

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**U.S. CONSUMER PRODUCT SAFETY COMMISSION**  
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DIRECTORATE FOR ENGINEERING SCIENCES



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*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.*

## Abstract

Electric space/room heaters can heat a specific room or space independently of other areas in an occupancy. They can be used for or with a central heating system. The voluntary standard for room heaters addresses the risk of ignition, but not the risk of overheated rooms. A room in which a heater is located, depending on the room and the heater output, could sustain temperatures exceeding 100° F (38° C). If an individual is exposed to above-normal core temperatures for an extended period of time, the individual could experience hyperthermia and die.

CPSC staff conducted a data search for heater-related deaths that occurred from January 1, 2008 to August 31, 2018. CPSC identified hyperthermia deaths that involved four children and one adult caused from room heaters. Staff evaluated these incidents, conducted sample testing, and reviewed voluntary standards. Staff's review revealed that room heaters may present an unaddressed hazard to consumers, especially to young children. Staff's review further concluded that children, people with disabilities, and senior citizens may be more susceptible to this hazard because of their limited ability to take action or react to the elevated ambient temperature.

According to staff's preliminary analysis, certain steps could reduce the risk of overheated rooms from room heaters. For example, educating consumers about the hidden hazard and providing guidance on safely operating a room heater in a small room could help consumers prevent room temperatures from rising above safe levels. In addition, staff suggests, standards could be developed to address heater function. Manufacturers could incorporate sensors into heaters sensors that will accurately monitor the room temperature to prevent room temperatures from reaching an unsafe level.

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# 1.0 INTRODUCTION

## 1.1 Background

Most room or space heaters incorporate a regulating or control thermostat that allows the user to set the desired temperature level for the heater to maintain. Room heaters allow a specific room or space to be heated independently of other areas in an occupancy. They can be portable or fixed-in-place heaters. Portable heaters are versatile and can be moved from one room or space to another area that needs heating. In contrast, fixed heaters are permanent and are intended for zone heating, rather than a central heating system, or to supplement heat in a specific room.

“Hyperthermia” is defined as a failure of the heat-regulating mechanisms of the body to deal with the heat coming from the environment, which results in an abnormally high body temperature.<sup>1</sup> CPSC staff analyzed hyperthermia deaths associated with portable and fixed room heaters. Staff not only reviewed the incidents, but also examined the voluntary standards to understand the hazard scenarios associated with space heaters. This report summarizes staff’s preliminary assessment.

## 1.2 Objective

Staff’s objective in conducting this preliminary assessment was to consider potential actions to reduce the hazards associated with hyperthermia deaths from consumer’s use of electric room/space heaters.

# 2.0 INCIDENTS

## 2.1 Review of Reported Incidents

The CPSC Injury and Potential Injury Incident (IPII) data system includes online reports, consumer letters, CPSC Hotline complaints, newspaper clippings, and medical examiner reports. CPSC field investigators may follow up on selected incidents after reviewing collected death certificates, conducting In-Depth Investigations (IDIs) that may include interviews with the victim, witnesses, and conferring with responding emergency personnel. CPSC field investigators may also collect samples that they send to technical staff to evaluate. These samples might be the actual products involved in the incident, or they may be exemplars of the incident sample.

CPSC staff searched the CPSC IPII database for all incidents related to hyperthermia deaths and all types of heaters. The dates CPSC searched covered

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<sup>1</sup> *Hyperthermia: too hot for your health* (June 27, 2012), National Institutes of Health. <https://www.nih.gov/news-events/news-releases/hyperthermia-too-hot-your-health-1>

January 1, 2008 to August 31, 2018.<sup>2</sup> The search revealed 15 deaths within the search period. The incidents involved seven child deaths and eight older adult deaths, as shown in Figure 2.1. The age range of the victims was less than 3 years of age to more than 50 years of age.

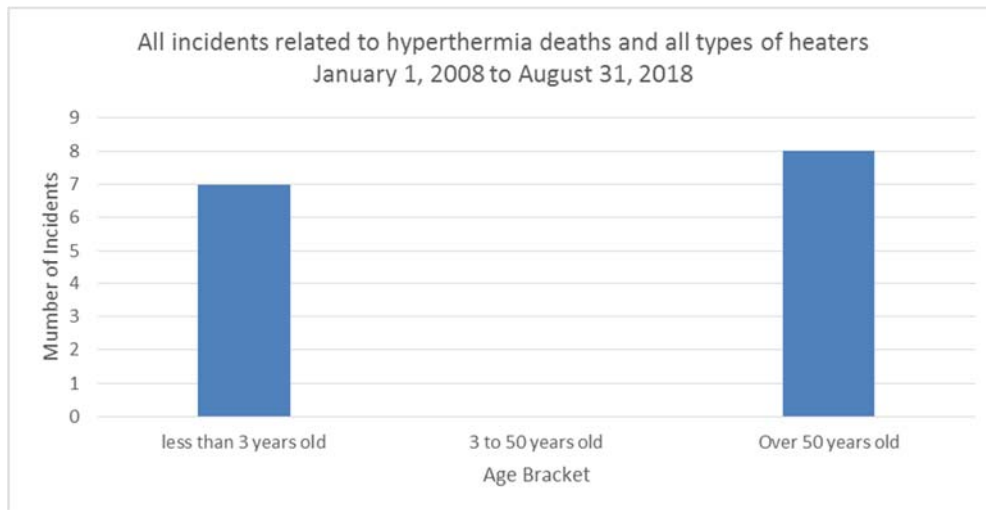


Figure 2.1. Number of hyperthermia deaths related to heaters

### Incidents Involving Adults Deaths

Staff reviewed the eight adult deaths to determine whether the incidents resulted in hyperthermia caused by heating products. The incidents all involved heating systems, but not space or room heaters. Five of the eight deaths (4 of 7 incidents) appeared to be unrelated to a faulty or malfunctioning heating system, such as a central furnace that sends heated air or water through the building using vents or pipes and radiators. (See the appendix for summaries of these four incidents.)

### Incidents Involving Children

In reviewing the incident reports of the seven child deaths, staff sought to determine whether the deaths were related to hyperthermia caused by heating systems or space/room heaters. In one incident, which resulted in an asphyxiation, a room heater was present, but was not the cause of the death. In a second incident, a malfunctioning heating system was involved. Another incident contained a room heater in the room that was reported the heater was off. The coroner determined the death was caused by dehydration due to exogenous hyperthermia. The remaining four incidents involved space or room heaters with hyperthermia reported as the cause of death. The four space/room heater incidents involved victims with ages ranging from 12 months to 2 years old. For two of the incidents, there were IDI reports, but the other two incidents only included information provided in medical examiner reports.

<sup>2</sup> Product code search 310, 311, 318, 322, 384, 309, 312, 365, 388, 348, 391, 392, 393, 381, 340, 367, 399, 394, 119, 236, 118, 242, 133, and 134. NEISS Coding Manual, January 2017, U.S. Consumer Product Safety Commission. Retrieved on November 10, 2018 from cpsc.gov

For the two incidents that did not include an IDI, the summaries, detailed below, state that the children died from hyperthermia associated with the use of a room or space heater:

Database Narrative – “Decedent is a one year old male. Decedent placed to sleep by his father at 2200 hours on 4/14/09 in bedroom. Father turned on space heater in decedent’s bedroom because heater was not working and closed the bedroom door. Decedent was heard crying at 0300 hours on 4/15/09 by mother. Grandmother lives at residence and cares for child during the day. Grandmother went to check on decedent at 1300 hours 4/15/09 and found him unresponsive and unplugged the space heater at that time. Upon our arrival, the temperature of the bedroom was 97 degrees F [36.1° C]. Upon arrival of paramedics, the decedent had a rectal temperature of 107 degrees F [41.7° C].” Cause of death: Exogenous hyperthermia.

Database Narrative – “2 yr. old female left in bedroom with {deleted} heater that was allegedly set to fan. Found in morning unresponsive in bed suffering from acute hyperthermia (108F) [42.2° C]. Resuscitation [sic] was unsuccessful. Victim was pronounced DOA in the Emergency room. Firefighters find [sic] the heater heating the room severely. The bedroom window was however believed to have been closed also, perhaps for security reasons.” Cause of death: Exogenous hyperthermia.

The three IDI reports provided additional details on the products and the incident scenarios.

#### Summary of an incident involving a 29-month-old female

In 2017, a mother brought her 29-month-old daughter to her bedroom after her bath and turned on the heater’s thermostat until the click sound was heard. The built-in wall heater provided heat in the girl’s bedroom. The mother put her daughter in her crib for the night and left a crack in the bedroom door. During the night, the mother heard her daughter crying and fussing but did not check on her.

The next morning, the father went to check on his daughter. When he entered the bedroom, he found her unresponsive and called “9-1-1.” Fire and emergency personnel arrived and noted that the child’s bedroom was extremely warm, and the heater was on. They turned off the heater and opened a window in the room. The medics noticed her body was hot. The coroner’s office ruled the cause of death from hyperthermia.

#### Summary of an incident involving a 17-month-old female

In 2018, a mother of a 17-month-old girl went to check on her daughter in late morning. The mother discovered the girl unresponsive. When police and emergency medical services (EMS) responders arrived on the scene, they immediately noticed how unusually warm the girl’s

bedroom was, compared to the rest of the house. EMS turned off the heater that was on in the room. Later, EMS personnel measured the temperature in the bedroom to be 95° F (35° C). The coroner's office ruled that the cause of death was consistent with hyperthermia.

### 3.0 SPACE/ROOM HEATERS

In five of the fatal incidents (4 children and 1 adult), the heat source that caused the hyperthermia was a room or space heater that appeared to be functioning normally, but apparently overheated a room. The remainder of this report focuses on room/space type heaters.

#### 3.1 Description of Space and Room Heaters

Space or room heater designs can be portable or fixed in place. Portable heaters are versatile and can be moved to heat different spaces within a structure. Fixed heaters are intended for zone heating in place of a central heating system, or to provide supplemental heat for a specific room. Baseboard heaters are unique because of their dimensional requirements. A "baseboard heater," by definition, must have the following dimensions: the length-to-height ratio of the heater must be more than 2:1, and the depth of the heater must be less than 6 inches. Figure 3.1 shows examples of three different types of room heaters.



Portable room heater   Built-in fixed room heater

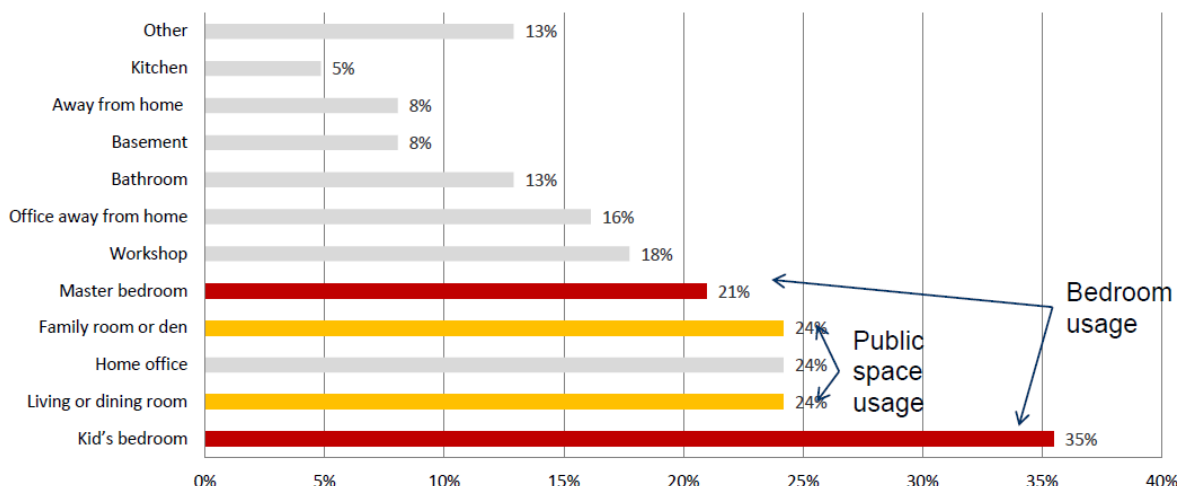


Portable baseboard room heater

Figure 3.1. Some of the types of room heaters

#### 3.2 Usage Location Information for Portable Heaters

According to a Riedel Marketing Group study<sup>3</sup> from 2013, 35 percent of respondents indicated they use a portable heater mostly in children's bedrooms, as shown in Figure 3.2.<sup>4</sup> An additional 21 percent of respondents indicated that they use a portable heater in the master bedroom.



Graph reprinted with permission.

Figure 3.2. Where owners use portable electric heaters

## 4.0 TESTING OF ROOM/SPACE HEATERS

To understand how hyperthermia deaths occur as documented in the IDI reports, CPSC staff examined and tested two types of room heaters collected from two incidents. One sample collected was a small portable heater, and the other sample collected was a built-in wall heater that uses a separate thermostat.

### 4.1 Small Portable Heater

The small portable heater from one incident did not show any signs of physical damage or overheating, such as melting of the enclosure. There were two control knobs on top of the heater. One knob controls the power and heat output (“OFF”, ☼ symbol for fan only, “○” white circle for low heat, “◐” half-filled circle for medium heat, “●” black circle for high heat). The other knob controls the regulating thermostat, marked “MIN” and “MAX,” with no temperature indication between the words. A red light illuminates when the unit is plugged into an energized receptacle. A tipover switch was located on the bottom of the heater. The entry for the permanently attached power supply cord with a polarized plug was on the back of the heater. The heater was listed to UL1278, *Movable and Wall- or Ceiling- Hung Electric Room Heaters*.

<sup>3</sup> Riedel, A.J., (May 2013) *2013 U.S. Portable Heater Market Report*, Riedel Marketing Company, Phoenix AZ

<sup>4</sup> The survey sampling was 64 participants.

Figure 4.1 shows the various components of the heater with the rear enclosure removed. Inside the unit are the regulating thermostat, temperature-limiting control (TLC) device, heater output switch, heating element, tip-over micro switch, LED indicator light, and fan motor and metal impeller.

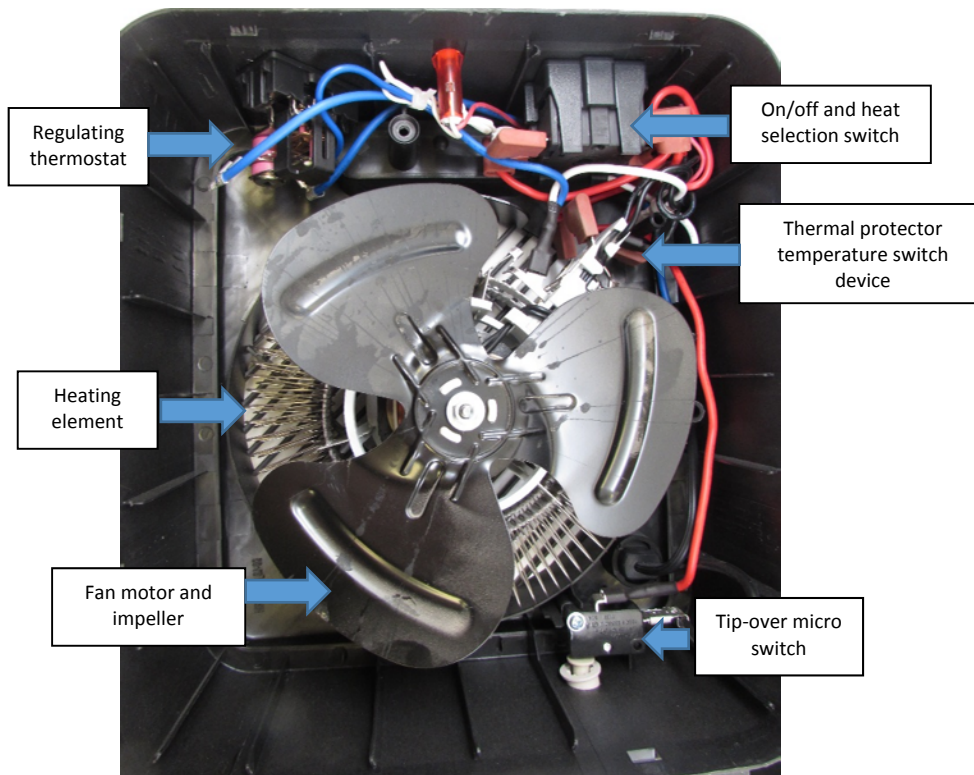


Figure 4.1 Components within the heater

The regulating thermostat is the automatic temperature-setting control for the heater. The TLC is the limiting control, which is located near the heating element and is intended to prevent the unit from overheating. The TLC is a self-hold type, meaning that when it reaches its set temperature, it will disconnect power from the heating element and fan motor until the user acts. When the TLC contacts are open, a temperature-sensitive bimetal holds the contacts in an open state until power is removed and sufficient time allows the TLC to cool and reset.

An x-ray of the regulating thermostat, as shown in Figure 4.2, illustrates the contacts opened (set at MIN) and closed (set at MAX) when the knob is rotated from one end to the other end of the dial. At about 1/3 of the turn from the MIN setting, the thermostat's contacts could be heard clicking on and off, depending on whether the knob was turned clockwise toward MAX, or counterclockwise toward MIN. The lab room temperature was about 75° F (24° C).

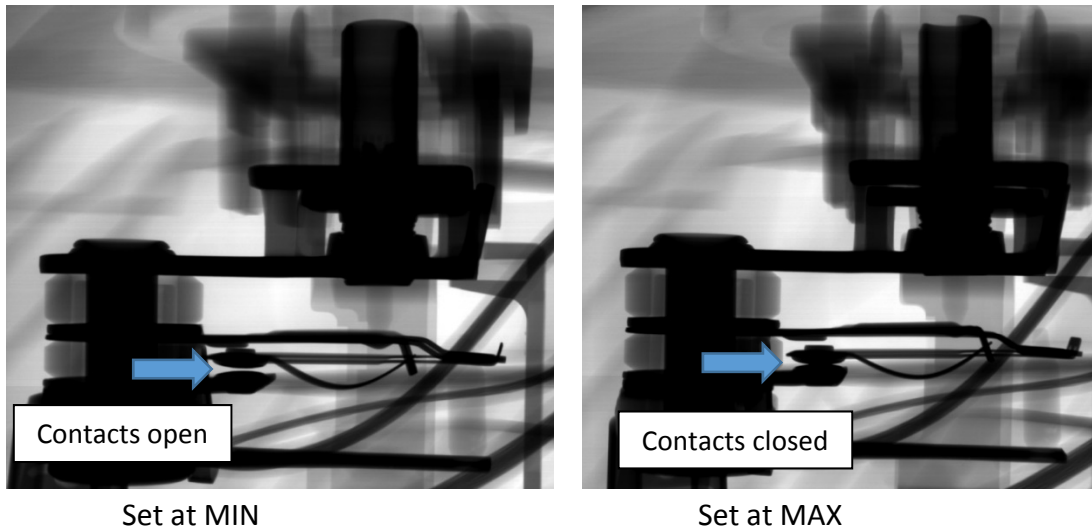


Figure 4.2. X-rays of the thermostat at MIN and MAX at room temperature

Because the incident involved a hyperthermia death, the testing focused on the ambient temperatures relative to thermostat setting and TLC trip points. Staff conducted four tests inside a conditioning oven to evaluate the response of the heater's thermal devices. The tests were designed to demonstrate various conditions that could occur around the heater for different scenarios. The interior of the conditioning oven measures about 25 inches (64 cm) x 25 inches (64 cm) x 25 inches (64 cm) or about 9 cubic-feet (0.25 m<sup>3</sup>). For Test 1, the oven's heating feature was used to generate heat within the oven and the heater sample was off during the test. For Tests 2 through 4, the oven's heating feature was not on for these tests. The heater was the source of the ambient heating. Staff conducted the following four tests:

Test 1 – Heater off and conditioning oven temperature increased gradually. This test was to evaluate the trip temperatures for the thermostats within the heater.

Test 2 – Heater energized at maximum settings in a closed, sealed space (conditioning oven door closed and oven off). This test was to evaluate the heater's heat output in tripping the heater's thermostats within a closed space.

Test 3 – Heater energized at maximum settings in a partially closed space (conditioning oven door partially opened and oven off). This test was to evaluate the maximum temperature of the air flowing into the heater without tripping the thermostat.

Test 4 – Test 3 repeated with a different thermostat dial setting (conditioning oven door partially opened and oven off). This test was to evaluate the relationship between the thermostat dial setting and temperature of the air flowing into the heater.

### Test 1. Non-energized heater in the conditioning oven

The non-energized heater was placed within the conditioning oven, as shown in Figure 4.3. Two thermocouples were placed on the heater. Thermocouple 1 measured the air temperature at the front of the heater, and Thermocouple 2 measured the air temperature at the back of the heater. The continuity between the neutral and hot-plug terminals was monitored with a digital multi-meter to determine when the regulating thermostat or the TLC activated, *i.e.*, the meter indicated an open circuit.



Figure 4.3. Heater inside the conditioning oven

The regulating thermostat was set at maximum heat (MAX), and the heat setting was set at the highest heat output (●), although any non-off setting is sufficient for this test because the heater was not energized during this test. The oven door was closed. Starting at room temperature 75° F (24° C), the oven temperature was increased about 1.8° F every 2 minutes. The test was terminated when the oven temperature reached 122° F (50° C). Neither the regulating thermostat, nor the TLC device activated during the test period.

### Test 2 – Heater energized at maximum settings in a closed sealed conditioning oven chamber

After the previous test, the oven and heater self-cooled to almost room temperature before staff started Test 2. The thermostat was set at maximum heat (MAX), and the heat setting was on the highest heat output (●). After the oven door was closed, the heater was plugged into a 120 V receptacle. Thermocouple 1 measured the air temperature exiting the front of the heater, and Thermocouple 2 measured the air temperature drawn into the heater, as illustrated in Figure 4.4.

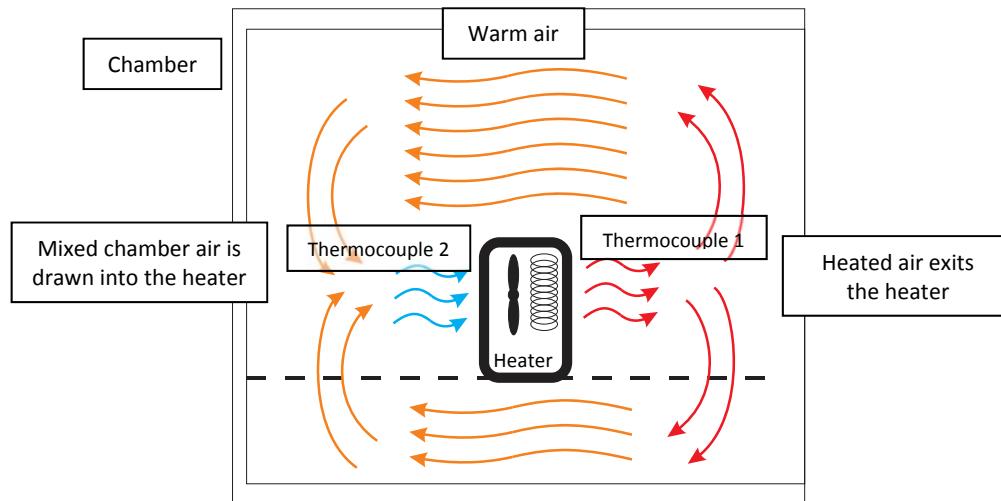


Figure 4.4. Air flow inside the conditioning oven (heater running, oven off)

The temperatures on the heater rose quickly, as shown in Figure 4.5, because of the small chamber volume. When the rear of the heater reached about 118° F (48° C), the TLC activated, which de-energized the heater and caused the temperature to drop momentarily. After the heating element shut off and the fan stopped rotating, there was no airflow passing over Thermocouple 2, which caused the temperature to rise temporarily from residual heat from within the heater.

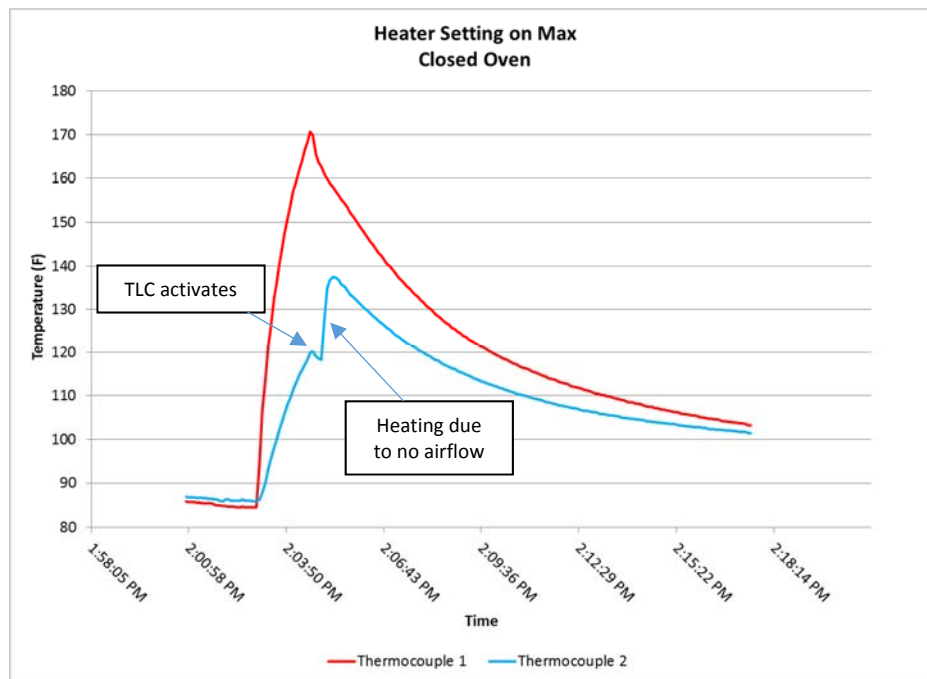


Figure 4.5. Thermocouple measurements during Test 2

### Test 3 – Heater energized at maximum settings in a partially closed conditioning oven

After the previous test, the oven and heater self-cooled to almost room temperature before staff started Test 3. For this test, the chamber door was partially opened approximately 9 inches (23 cm), as shown in Figure 4.6. The partially opened oven door allowed some of the heated air to exit and some of the cooler room air to enter the chamber, as illustrated in Figure 4.7. The thermostat was set at maximum heat (MAX) and the heat setting was on the highest heat output (●). Thermocouple 1 measured the front of the heater or the airflow exiting the heater, and Thermocouple 2 measured the rear of the heater, or the airflow entering the heater.



Figure 4.6. Oven chamber door partially opened about 9 inches (23 cm)

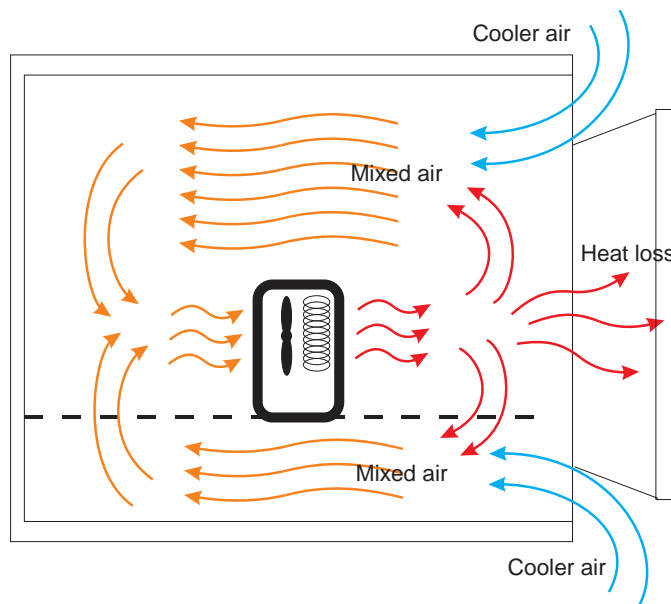


Figure 4.7. Airflow with partially opened door

The heater was plugged into a 120 V receptacle. The temperatures on the heater still rose quickly. When the rear of the heater measured about 118.4° F (48° C), the TLC activated, which de-energized the heater, as shown in Figure 4.8, from the start of the data through approximately 3:30 p.m., as shown in the graph. The heater was allowed to cool and the TLC was reset by

unplugging the heater, as shown in Figure 4.8, through approximately 3:40 p.m., as shown in the graph below.

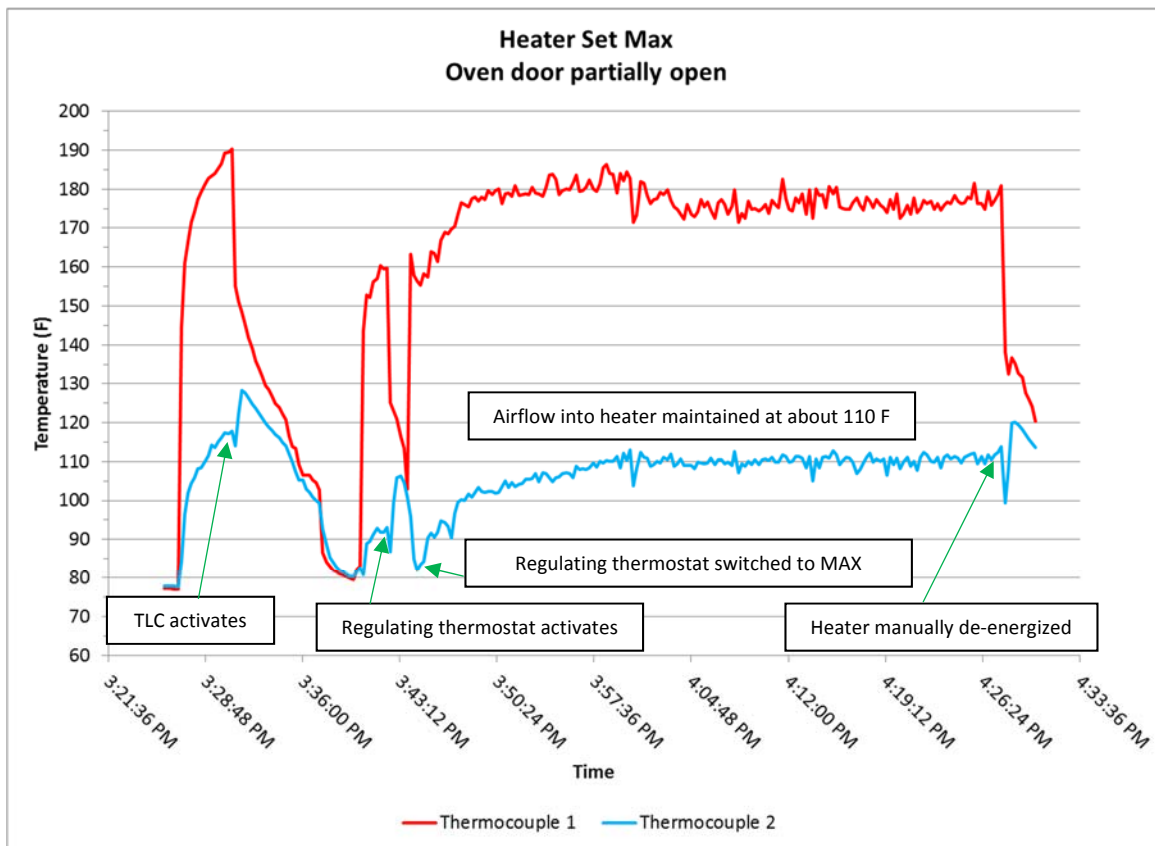


Figure 4.8. Thermocouple measurements during Test 3

The heater's regulating thermostat knob was set halfway between the MIN and MAX. At this setting, the regulating thermostat contacts were still closed. The heater was plugged into the receptacle. Once the temperature on the back of the heater rose to about 93.2° F (34° C), the regulating thermostat activated (opened) and de-energized the heater at approximately 3:43 p.m., as shown in the graph above.

The regulating thermostat was changed to MAX, which caused the heater to energize from approximately 3:45 p.m. to the end of the test, as shown in the graph. To prevent the chamber from heating too quickly, an external fan was placed on the floor outside the oven chamber to remove additional heat from the chamber. This setup allowed the air that was entering the back of the heater to maintain a constant temperature of about 110° F (43° C), without causing the regulating thermostat or the TLC device to activate. The temperature stayed at about 110° F (43° C) for 30 minutes, until the test was manually terminated.

Theoretically, this temperature state of 110° F (43° C), which represents the mixed room air temperature being drawn into the heater, could be maintained for an extended period until some environmental factor, such as a change in heat loss, altered the parameters.

#### Test 4 – Test 3 repeated (conditioning oven door partially opened)

As with the previous test, the oven and heater self-cooled to almost room temperature before staff started Test 4. The same setup as Test 3 was performed with the chamber door partially opened approximately 9 inches (23 cm), except the external fan was used at the beginning of testing. The thermostat was set to maximum (MAX), and the heat setting was on the highest heat output (●). Thermocouple 1 measured the front of the heater or the airflow exiting the heater, and Thermocouple 2 measured the rear of the heater or the airflow entering the heater.

Once the heater was energized, the temperature stabilized around 110° F (43° C) for Thermocouple 2, as shown in Figure 4.9. Neither the regulating thermostat nor the TLC activated after 2 hours. After about 2 hours into the testing, the oven chamber door was closed until there was about a 5-inch (13-cm) opening. The temperature jumped up to around 118° F (48° C) for Thermocouple 2, then gradually continued to increase until the temperature rose to 122° F (50° C), which caused the TLC device to activate, as shown in the graph below.

The heater was unplugged to reset the TLC, then the heater was re-energized. The heater's regulating thermostat knob was set in the middle, between the MIN and MAX settings, which caused the heater's regulating thermostat to switch off and back on when the airflow at the back of the heater measured around 108° F (42° C) and 90° F (32° C).

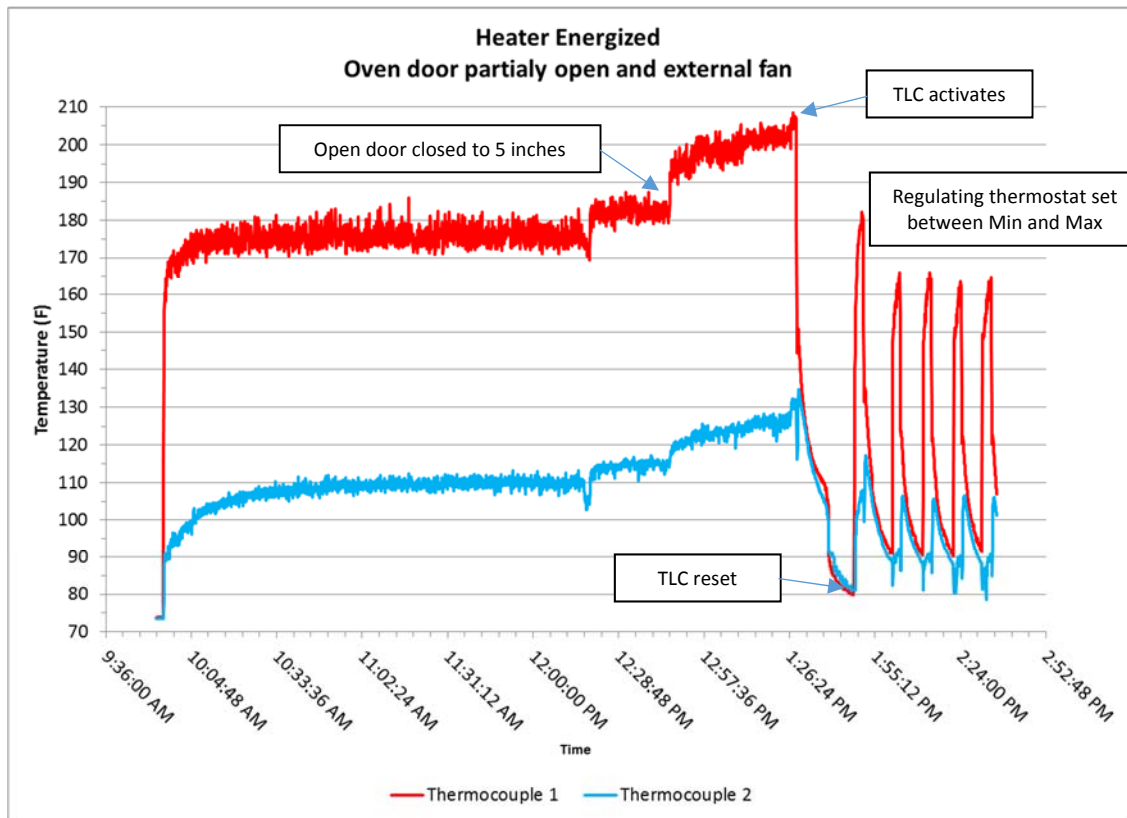


Figure 4.9. Thermocouple measurements during Test 4

## 4.2 Control Thermostat for Built-in Wall Heater

The sample used for testing was a built-in wall heater (fan/heater) that uses a separate control thermostat typically mounted on a wall. The thermostat is wired in series with one of the conductors for the heater, as illustrated in Figure 4.10. The heater unit relies on the external thermostat for regulating its output. The thermostat is a thermal-mechanical type, which uses a bi-metal element to control the switch contacts. The thermostat dial contains numbers and markings that would suggest the units are in degrees Fahrenheit, even though the units were not labeled on the dial.

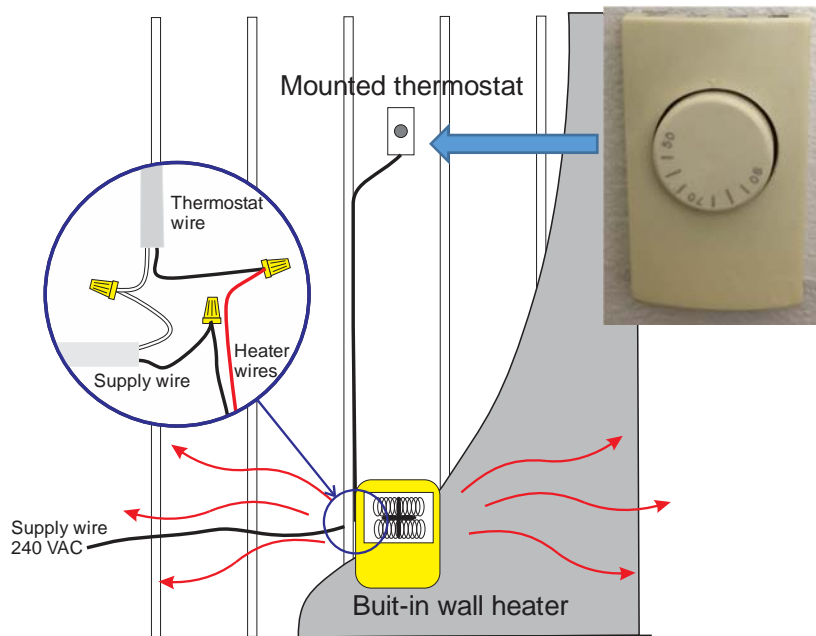


Figure 4.10. Illustration of wiring for a built-in wall heater and thermostat

Two thermostats were tested individually, by placing each thermostat in a conditioning oven, as shown in Figure 4.11, and controlling the same heater outside the conditioning oven. The thermostat was mounted inside a single-gang plastic electrical box. Five thermocouples measured the temperature inside the oven. Four of the five thermocouples were placed inside the electrical box and one thermocouple outside the electrical box. The conditioning oven's temperature was programmed to increase 1.8°F every 2 minutes.



Figure 4.11. Thermostat in the conditioning oven

### Thermostat 1 Testing

Even before the test started, turning the temperature setting dial from its minimum setting produced an “off” click below 50 on the thermostat dial. This revealed that the set/operating point was not accurate because the lab room temperature was not below 50° F (10° C). Ideally, when the thermostat’s dial is turned slightly above 70, a clicking (contacts closing and opening) sound should be heard because the room temperature was 72° F (22° C).

For the testing, the dial was set at each of the display marks 50, 55, 60, 70, 80, and 90. When the thermostat dial was set at 50, the thermostat opened when the oven temperature reached 91° F (33° C). When the thermostat dial was set at 90, the thermostat did not open until the oven temperature reached 177° F (81° C). The test results graphed in Figure 4.12 show the actual thermostat response was consistently higher than the ideal response of the thermostat. On average, the thermostat activated and de-energized the heater at about 60° F (16° C), higher than the dial setting.

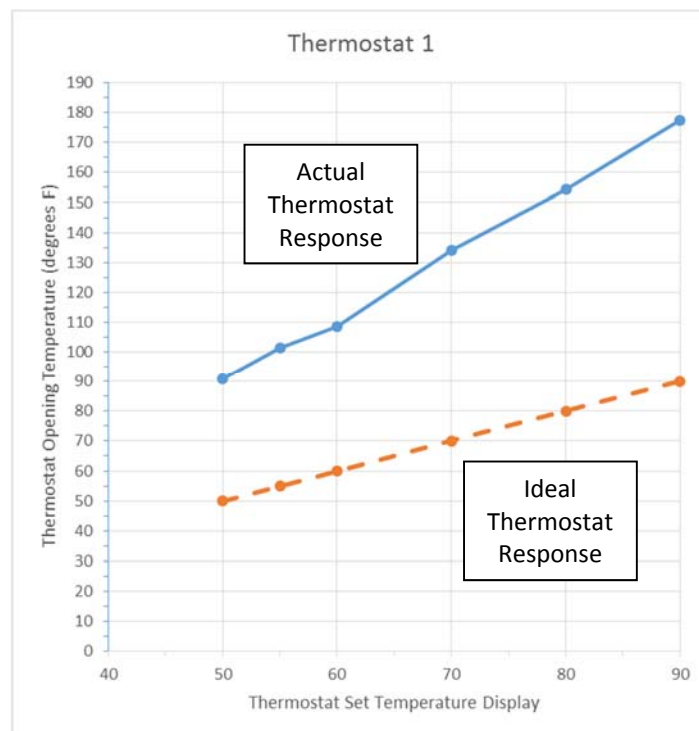


Figure 4.12. Thermostat 1 conditioning oven results plot

### Thermostat 2 Testing

Turning the temperature setting dial before starting the testing revealed that the setting/operating point differences were off, but not as far as for Thermostat 1. The switch clicking could be heard between 80 and 85 mark on the dial display, and the room temperature was about 72° F (22° C). For this testing, the dial could only be set at around the 83, 85, and 90 mark because the thermostat would only begin to turn on above 80 on the dial. When the thermostat dial was set at around 83, the thermostat opened when the conditioning oven

temperature reached 94° F (34° C). When the thermostat dial was set at 90, the thermostat did not open until the conditioning oven temperature reached 109° F (43° C). The graphing of the test results in Figure 4.13 shows the actual thermostat response was higher than the ideal response of the thermostat, but the shift was not as pronounced as Thermostat 1. On average, the thermostat activated and de-energized the heater about 14° F higher than the dial setting.

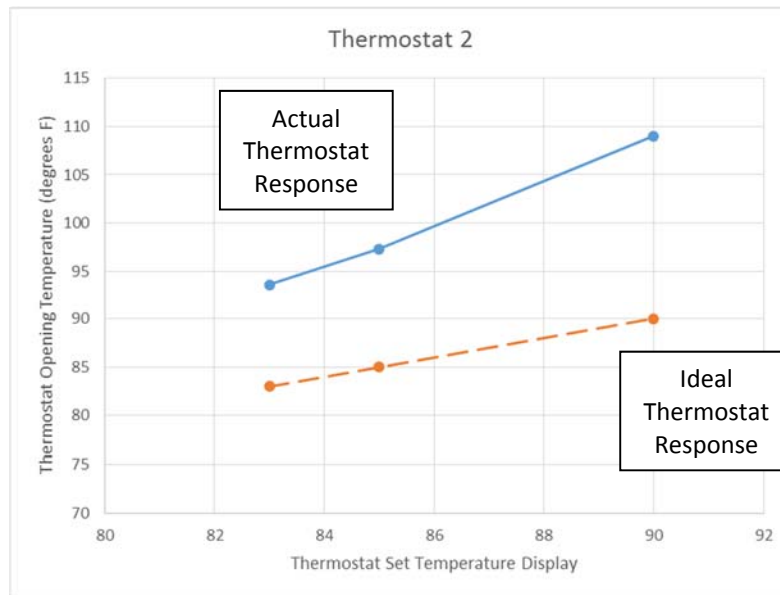


Figure 4.13. Thermostat 2 conditioning oven results plot

In both of the thermostats tested, the calibration of the thermostats appeared to be shifted higher than the dial display. The inaccurate calibration of the thermostats could result in the room achieving a higher temperature than what the occupant may have intended, if the occupant was relying on the thermostat's dial display as the set-desired room temperature. For Thermostat 1, if the dial is set at the 55 mark or above, the heater would operate until the room temperature is 100° F (37.8° C) or greater. For Thermostat 2, if the dial is set around 86 or above, the heater would operate until the room temperature is 100° F (37.8° C) or greater.

## 5.0 VOLUNTARY STANDARDS FOR SPACE OR ROOM HEATERS (PORTABLE AND FIXED)

The voluntary standard for portable heaters is *Underwriters Laboratories (UL) 1278 Movable and Wall- or Ceiling-Hung Electric Room Heaters, Edition 4*. The scope of this standard covers movable and wall- or ceiling-hung electric room-heating equipment rated 600 volts or less to be used in ordinary locations in accordance with the *National Electrical Code*, ANSI/NFPA 70 (NEC).

The voluntary standard for fixed heaters is *UL 2021 Fixed and Location-Dedicated*

*Electric Room Heaters, Edition 4.* The scope of this standard covers fixed and location-dedicated electric room heating equipment rated 600 volts or less to be used in ordinary locations in accordance with the *NEC*.

The voluntary standard for baseboard heaters is *UL 1042 Electric Baseboard Heating Equipment, Edition 5*. The scope of this standard covers portable and fixed electric baseboard heating equipment rated at 600 volts or less, to be used in ordinary locations in accordance with the *NEC*.

*UL 873 Temperature-Indicating and -Regulating Equipment, Edition 12* applies to thermostats built in or external to the heating appliance's electrical equipment for control of heating appliances rated 600 volts or less, to be used in ordinary locations in accordance with the *NEC*. The standard covers general-use equipment for field-installation and controls intended to be factory installed on or in certain appliances as safety, limiting, or operating controls. These controls respond directly or indirectly to changes in temperature, humidity, or pressure to control the equipment or appliance's operation.

The construction and performance requirements in UL 1278, UL 2021 and UL 1042 address the risks of electric shock and fire. Addressing fire risk is understandable because heaters are one of the leading appliances known to cause household fires. The CPSC staff report, *2013-2015 Residential Fire Loss Estimates*, indicates that portable and fixed (non-central) heaters accounted for an annual average of 4,500 structure fires from 2013 to 2015.<sup>5</sup>

## **5.1 Voluntary Standards for Room or Space Heaters**

The normal operation performance tests in UL 1278, UL 2021, and UL 1042 limit the maximum temperature to 117 degrees F (47.2° C) for surfaces adjacent to the heater, which is intended to prevent nearby combustibles from igniting.<sup>6</sup> The standards specify that the “temperature-regulating thermostat is one that functions only to regulate the temperature of the heater under intended conditions of use, and whose malfunction would not result in risk of fire.” The standard does not address excessive temperatures within the space that would pose a risk of hyperthermia to an occupant. The standard specifies further that a safety control or a temperature-limiting control (one designed to prevent unsafe operation of a heater) shall interrupt power (to a sufficient number of heating elements) to reduce temperature as not to exceed 347° F, obviously intended to prevent the risk of fire.

## **5.2 Voluntary Standard for Thermostats for Heaters**

*UL 873, Temperature-Indicating and -Regulating Equipment, Edition 12*, applies to thermostats separate from or integral to a heater. Residential Operating Controls, such as room thermostats, are subjected to performance testing to ensure that operation does not pose a risk of fire or cause damage to any materials used in the equipment. The standard does not

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<sup>5</sup> Miller, D. (July 2018) *2013-2015 Residential Fire Estimates, U.S. National Estimates of Fires, Deaths, Injuries, and Property Losses from Unintentional Fires*; U.S. Consumer Product Safety Commission, Bethesda, MD

<sup>6</sup> *UL 1042 Electric Baseboard Heating Equipment, UL 1278 Movable and Wall- or Ceiling-Hung Electric Room Heaters, UL 2021 Fixed and Location-Dedicated Electric Heaters*, Underwriters Laboratories, Northbrook, IL

address evaluating the temperature-indicating or -regulating equipment allowing excessive temperatures that would pose a risk of hyperthermia to the occupant within a space. The standard does not require calibration verification for heater thermostats, but it does have calibration verification for water-heaters and electric range-controls.

## 6.0 DISCUSSION

Heat can enter the room from a room heater through convection. The room and the air within the room absorb the heat, but heat is also lost by conduction through the walls, windows, doors, floor, and ceiling. As the heat is lost in the room, there is a demand from the heater to produce heat to reach the set temperature. There may be parameters where the heat lost in the room, room volume, and heater output allow the room temperature to be maintained at a stabilized temperature that is below the set point of the heater's thermostat, but is high enough to pose a risk to some occupants, if exposed for an extended period of time, particularly for occupants whose age or disabilities might limit their ability to respond to the elevated temperature.

In the incidents, a space/room heater appeared to elevate the temperatures within the room to a level that was fatal for a toddler. Staff evaluated the conditions that would be required to elevate the room temperature to such a level. The simplified illustration shown in Figure 6.1 indicates that the room temperature is determined by the amount of heat gain, minus heat loss. By considering various room sizes and starting temperatures, but keeping all other parameters the same, it is possible to illustrate that a typical room heater output may raise room temperatures to 100° F. This section examines the main variables, such as heat losses, starting temperature, and room size, to determine the room heater needed to raise the temperature to 100° F.

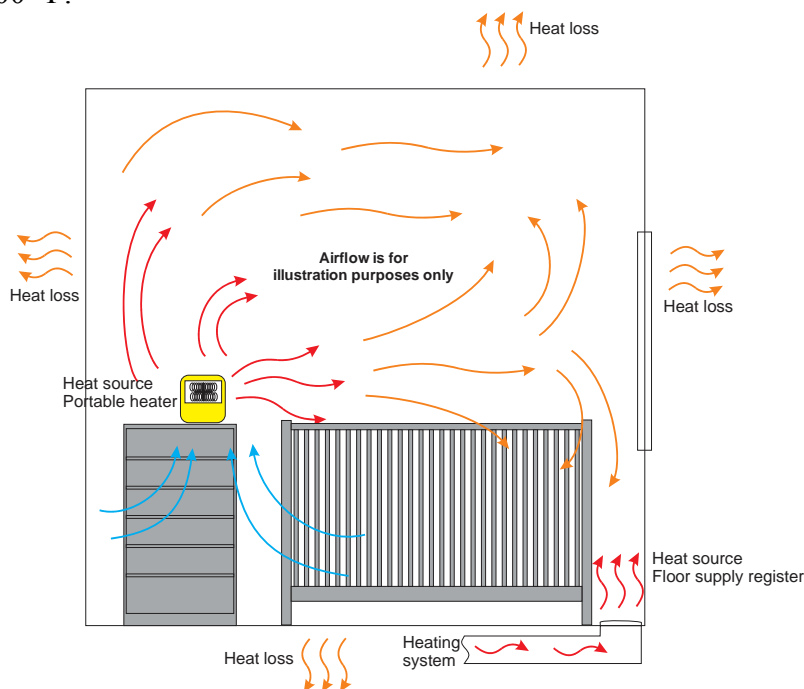


Figure 6.1. Illustration of heat losses and gains in a room

## 6.1 Evaluating Changes to Start Temperature and Room Size on Heating Requirements

The calculations were based on using variables from a hyperthermia incident in which some of the information for room size, room layout, and room construction were known. For the unknowns, industry construction standards were used.

Heat losses, which have a specific R-Value, occur through the walls, ceiling, floor, windows, and door. R-values are used in describing effectiveness of insulation and in analysis of heat flow across assemblies (such as walls, roofs, and windows) under steady-state conditions. If given the R-Value, area affected, and temperature difference, the amount of heat loss in an hour can be calculated by the equation:

$$\text{Heat Loss} \left( \frac{\text{BTUs}}{h} \right) = \frac{\text{Area}(\text{ft}^2) \times \text{Temp. Difference } (^\circ\text{F})}{\text{R-Value} \frac{\text{ft}^2 \cdot ^\circ\text{F} \cdot h}{\text{BTU}}}$$

To evaluate the impact of room sizes on the heating requirement, the analysis will use three different room sizes. The first bedroom size is the minimum bedroom, as required by the International Residential Code (IRC), and that would be defined as “habitable.” The IRC specifies the minimum bedroom must have a minimum floor area of 70 square-feet with a minimum of 7 foot ceilings, which equates to 490 cubic feet.<sup>7</sup> The second bedroom size is an incident bedroom, which is 10 feet x 10 feet with 8 foot ceilings and equates to about 800 cubic feet. The third bedroom for the analysis is a bedroom that is 1 foot larger in length and width than the second bedroom. The room’s dimensions are 11 feet x 11 feet with 8 foot ceilings and equates to 968 cubic feet. All other parameters, such as the number and type of windows, number and type of interior door, and wall, floor, and ceiling construction stayed fixed for each room size.

In addition to the room size changing in the calculations, another key variable that determines the heating requirement is the starting temperature, which can be the outside temperature or HVAC set temperature. Because the analysis calculated the heater watts needed to raise the room temperature to 100° F, the starting temperature would be a factor in the heater output. For example, if the outside temperature was very cold, the delta between the starting temperature and 100° F would be greater than if the outside temperature was not as cold. A sample calculation is located in the appendix that was used for the analysis. The plots shown in Figure 6.2 demonstrate that, depending on room size and starting temperature, a 1,500 watt heater is capable of elevating the room temperature to 100° F. For example, a 1,500-watt heater can raise the room temperature of an 800 cubic-foot room from 61° F (16° C) to 100° F (38° C) or a 968 cubic-foot room from 65° F (18° C) to 100° F (38° C).

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<sup>7</sup> 2018 International Residential Code for One- and Two-Family Dwellings, International Code Council (ICC).

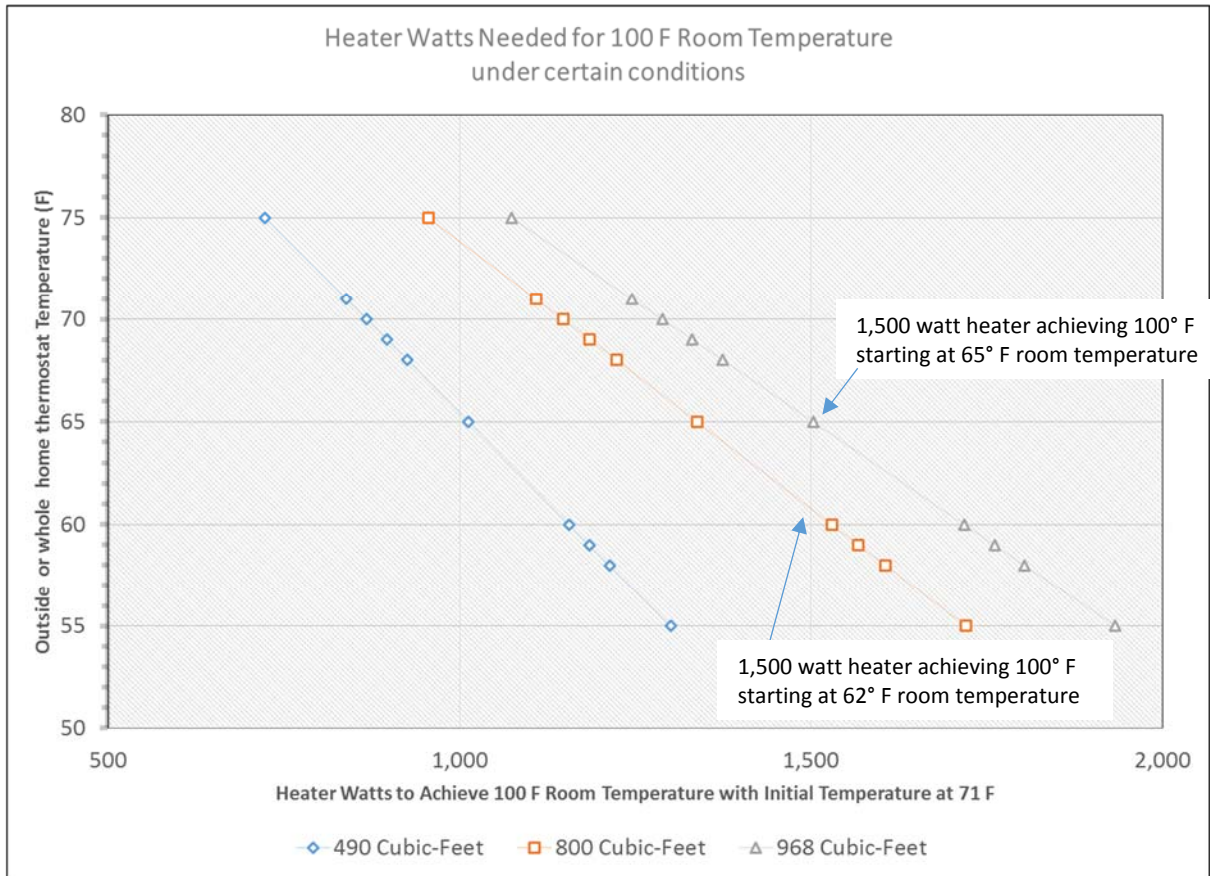


Figure 6.2. Plot of heater requirement under certain conditions, such as room size

## 7.0 CONCLUSIONS

Space and room heaters are designed to produce heat without becoming fire and shock hazards. The voluntary standards aim to achieve this objective. However the voluntary standards does not address the potential for a room or space heater to overheat in an occupied space. The heater has the potential to sustain elevated room temperatures, above safe long-term exposure levels (but below the risk of fire), which may pose a risk of hyperthermia to occupants, especially to young children, people with disabilities and senior citizens. A preliminary analysis of incidents, sample testing, and voluntary standards for room heaters indicates that these types of heaters may present an unaddressed hazard to a certain segment of vulnerable consumers, such as children and the elderly.

### Hazard

- Space or room heaters, which can be portable or fixed-in-place, can elevate the room temperature to levels that may be dangerous for some occupants.
- Small children, people with disabilities, and senior citizens may be more vulnerable in an overheated room because of their limited ability to take action.

### Voluntary Standard

- The voluntary standards for portable, fixed, and baseboard heaters do not address scenarios in which room heaters may elevate the occupied space at a temperature that may not be safe for long-term exposure.
- The voluntary standard for thermostats used in or with heaters do not address the accuracy of thermostat displayed markings.

Staff's preliminary analysis suggests steps that could reduce the risk of overheated rooms from room and space heaters.

- Educating consumers about the hidden hazard, and providing guidance on safely operating a room heater in small rooms, could allow consumers to prevent room temperatures from rising above safe levels.
- Calibrating thermostats to function at the displayed setting, and incorporating the use of only numeric displays that correspond to temperature, will reduce tolerances and improve accuracy, thus reducing the ambiguity in the intended heat output. The lack of tolerances and accuracy may lead to higher than expected temperatures.
- Evaluating revisions of the voluntary standards to include provisions addressing heater function, such as heaters incorporating sensors that accurately monitor the room temperature to prevent the room temperature from reaching an unsafe level, may prevent unexpected overheating of a room and/or incorporating warning and safety language to inform consumers of the possible hazard.

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## Appendix

### **A. Summaries of the four incidents that did not appear to be related to a faulty or malfunctioning heating system**

- A 76-year-old adult's home air conditioning had stopped working, and the July temperatures in Texas raised the indoor temperature to almost 100° F (37.8° C) for an extended period of time. This incident was not related to a heater as the cause of hyperthermia death.
- A gas heater was used indoors and produced carbon monoxide and elevated temperatures. The 76-year-old male was physically and mentally challenged, which may have contributed to the circumstances for the death. The cause of death was ruled as carbon monoxide poisoning and hyperthermia.
- An 84-year-old male was discovered unresponsive in his home. The cause of death was reported as hyperthermia from high ambient temperatures. The victim had a history of using a gas furnace and an electric portable heater at the same time. The temperature inside the home was reported as being over 100° F (37.8° C) and his body temperature was about 105° F (40.6° C) an hour after the discovery.
- A normally operating heating system resulted in two deaths. The report states the deaths of a 74-year-old female and her 60-year-old brother were most likely caused by hyperthermia due to high ambient temperatures. The home was reported as being in disrepair with large holes in the roof. The thermostat for the home's heating system was located in a poorly insulated room, which caused the furnace to operate nonstop. The two victims were discovered in another part of the home with ambient temperatures over 100° F (37.8° C).

Faulty or malfunctioning heating systems reportedly caused three adult deaths (3 incidents). Two of the incidents occurred in the winter, and one occurred in the summer. These three incidents are summarized below:

- A 90-year-old female was discovered unresponsive in her home. The temperature inside the home was reportedly 113° F (45° C). The relay switch for the heating system was faulty.
- A 51-year-old female was discovered unresponsive. The cause of death was hyperthermia from a malfunctioning heating system. The victim was physically immobile due to lower back and knee surgeries.
- An 83-year-old male was discovered unresponsive in his home in July. The temperature in the home exceeded 110° F (43° C). The heating, ventilation, and air conditioning (HVAC) system was set to cool, but was producing heat from the vents. The report states that the home's heating and cooling system was recently repaired before the incident. The male died from complications of hyperthermia.

## B. Calculations for Section 6.0 Discussion

The window and door sizes and construction for the room in one of the incidents are unknown, staff used standard door sizes and windows to determine the R-values. The standard door selected for the calculations was a wood hollow-core (1-3/4") interior door. The standard windows for the calculations were double insulating glass with a 1/2" air space between the panes. Because the IDI report noted that the space under the flooring did not have any insulation, staff selected standard flooring construction. The R-factor for the flooring was for conventional wood joist floors with 3/4" plywood subfloor covered with carpet and pad over an unheated and ventilated crawl space. Staff assumed that the interior walls are conventional wood stud walls with interior sheetrock construction. The exterior walls selected for the R-factor are conventional wood stud walls with interior sheetrock and stucco exterior. Since two of the four walls are interior walls and the other two are exterior walls, the calculated R-value is an average of the two types of walls. The selected R-factors for the different items of the room are listed below. The calculated total transmission loss is 107.7 BTU/hr/Degrees F.

### Transmission Losses Calculation

<u>Item</u>	<u>Area</u>	<u>R-Factor</u>	<u>=BTU/hr/Degrees F</u>
Windows	30 Sq.ft.	/2.04	=14.7
Doors	16.5 Sq.ft.	/2.17	=7.6
Net Walls	320 Sq.ft.	/5.31	=60.3
Ceiling	100 Sq.ft.	/51.17	=2.0
Floor	100 Sq.ft.	/4.32	=23.1
<b>Transmission Losses Total</b>			<b>=107.7</b>

To find the heat output of just the portable heater requires calculating first the heat output of the floor supply register to raise the temperature to what the whole home thermostat is set at and then calculating the heat output of the portable heater to raise the room temperature to 100°F.

The calculation for the room heater output to achieve 100°F from 71°F, which is the estimated setting by the central heating system, is shown below. The air change rate per hour for a residential is between 1 and 2 ACH.<sup>8</sup> Staff selected 1.5 as the ACH, which is the middle of the range. The environmental conditions are listed below.

### Environmental Conditions

Air Changes per hour (ACH) = 1.5  
Initial Temperature = 71° F

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<sup>8</sup> *Air Change Rates in typical Rooms and Buildings*, Retrieved November 23, 2018, from [engineeringtoolbox.com](http://engineeringtoolbox.com)

Inside Temperature =100° F  
**Temperature Difference =29° F**

The total losses were calculated to be 113 Cu Ft/Hr. The calculations are shown below,

Total Heating Requirement Calculation

<u>Room Cu. Footage</u>	<u>x Air Changes per hour</u>	<u>= Cu.ft/hr</u>
800 ft.	x 1.5	=1200
<u>Calculated Total Losses</u>		
Air Changes Loss:	1200 Cu.ft/hr. x 0.019 BTU/Cu.ft	=22.8
Transmission Loss Total:		=107.7
	<b>Total Losses</b>	<b>=130.5</b>

The total heating requirement to achieve a 100°F room with an initial temperature of 71°F was calculated using the total losses and temperature difference of 29°F. The total BTU/hr needed by just the room heater would be 3,784.5 BTU/hr and this converts to a heater output at 1,108.2 Watts. The heating requirement calculations for just a room heater is shown below:

Total Heating Requirement Calculation

<u>Total Losses</u>	<u>x Temperature Differences</u>	<u>=Total BTU/hr</u>
130.5	x29° F	=3,784.5 BTU/hr
<u>Conversion to Watts</u>		
BTU/hr. per Watt	/3.412	
<b>Total Watts (Total BTU/hr/BTU/hr per Watt)</b>		<b>= 1,108.2</b>

**C. Table of R-factors used in the calculation for Section 6.0 Discussion**

Item	°F ft² h/BTU
<b>Windows:</b>	
Double insulating glass (1/2" air space)	2.04
<b>Doors:</b>	
Wood Hollow Core Flush (1 3/4")	2.17
<b>Ceiling:</b>	
Attic air film	0.61
Sheathing	0.5
Fiberglass Batt (12 inches)	49
Sheetrock	0.45
Inside air film	0.61
Total R value	51.17
<b>Exterior Walls:</b>	
Outside air film	0.25
Sheathing	0.5

Item	°F ft² h/BTU
Inside air cavity	0.94
Sheetrock	0.45
Inside air film	0.68
Stucco <1"	0.02
Extruded Polystyrene (1")	5.0
Total R value	7.84
<b>Interior Walls:</b>	
Outside air film	0.25
Sheetrock	0.45
Inside air cavity	0.94
Sheetrock	0.45
Inside air film	0.68
Total R value	2.77
<b>Net Interior and Exterior Walls:</b>	
Average R value	5.31
<b>Floors:</b>	
Lower air film	1.23
Subfloor	0.94
Carpet and Pad	1.23
Inside air film	0.92
Total R value	4.32