UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: February 25, 1999

TO : Ronald L. Medford
Assistant Executive Director
Office of hazard Identification and Reduction

THROUGH: William H. King, Jr. WHK Jr
Director
Division of Electrical Engineering

FROM : Sheela Kadambi SK
Electrical Engineer
Division of Electrical Engineering

SUBJECT : Report on Electric and Gas Clothes Dryers

Attached is the revised report on Clothes Dryers that incorporates the comments received from your office.

Attachment

CLOTHES DRYER PROJECT

REPORT ON ELECTRIC AND GAS CLOTHES DRYERS
March 1999

Directorate for Engineering Sciences

S. Kadambi

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INTRODUCTION

For over four decades consumers have used clothes dryer appliances in their homes. Since their introduction into the market, manufacturers have enhanced dryer designs to improve efficiency and safety. However, there were an estimated 15,500 fires in 1996 associated with clothes dryers, resulting in 20 deaths, 320 injuries and about $84.4 million in property damage.

Given the estimated number of fires related to clothes dryers, the U.S. Consumer Product Safety Commission (CPSC) initiated a project in Fiscal Year '98 to assess the adequacy of the applicable voluntary standards. The project included an assessment of incident data and reports; analysis of societal costs associated with dryer related fires, and assessment of industry electric and gas voluntary safety standards. The project also included testing of a new electric dryer and a new gas dryer. Results of those tests, along with the results of the staff's assessments, are presented in this report.

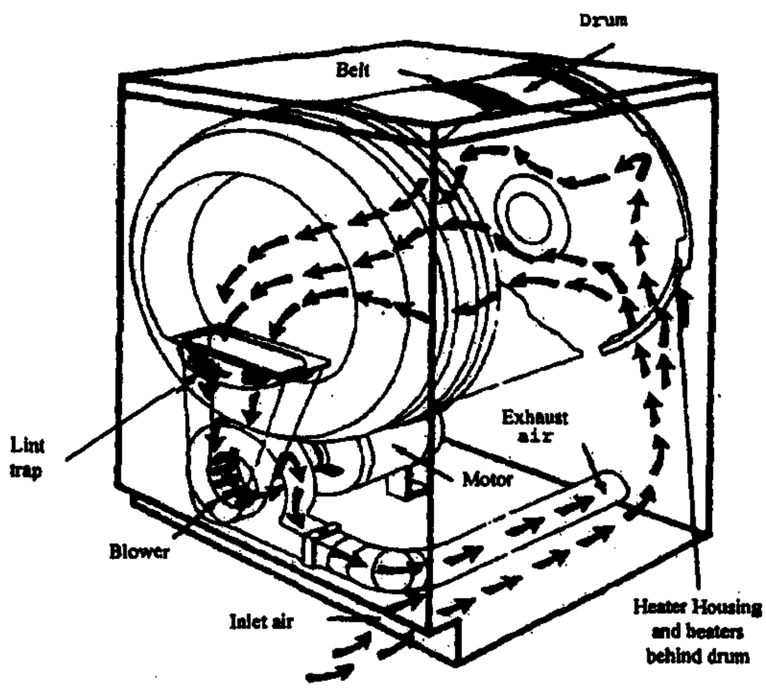
PRODUCT DESCRIPTION

The two basic types of clothes dryers defined by the primary fuel source for heating the air are electric and gas. In both types, hot air produced by the heat source is drawn through tumbling clothes inside a rotating drum and exhausted through ducting which carries the hot, damp air outside. Since their introduction in the market, dryer designs have been enhanced to improve efficiency and safety. Improvements have included humidity sensing components to automate drying times and multiple thermostats for over-temperature protection. While the humidity sensor improved efficiency, thermostats improved the safety of the dryer. These thermostats either control or limit the temperature in the dryer. Except for the heat source, the function of the major components in electric and gas dryers is similar. A 240Volt-powered heating element is the heat source in an electric dryer, whereas a gas burner is the heat source in a gas dryer. All other components in electric and gas clothes dryers are energized at 120 volts, including the motor that turns the drum and circulates the air and the control timer.

When the start button is pressed/turned (and the dryer door closed), electrical power is applied to the motor. The motor is connected to the drum by a drive belt. A bearing at the rear and plastic slides at the front typically support the drum. A switch on the shaft on the motor is operated by centrifugal force. Electrical power to the dryer circuits, including the motor, is routed through the centrifugal switch, which does not close until the motor reaches its normal operating speed. Therefore if the start button is not held until the motor reaches its operational speed, the dryer stops. Also, when the dryer door is opened, power to the motor is interrupted and the centrifugal switch opens as the motor slows down, requiring the user to re-start the dryer by pushing/turning the start button.

The blower pulls air from the room through the heat source, through the drum and pushes the exhaust air from the dryer through the duct to the outside vent. In electric dryers, the heat source is energized when the drive motor is at normal operating speed. Both the timer and thermostats are in series with the energized coiled heaters. In gas dryers, the heat source is a gas burner and, for safety reasons, the gas passes through two valves before reaching the burner opening where it is ignited. A pressure regulator controls the flow of gas. The safety valve is held open through an electrical circuit. When the voltage is cut off through control switches (automatic or manual, including when the dryer door is opened) the gas flow is turned off automatically.

Typical airflow in a clothes dryer is shown in the picture below:



INCIDENT DATA

During 1996, there were an estimated 15,500 fires associated with clothes dryers, 20 deaths, 320 injuries, and about $84.4 million in property loss in residential structures. Electric clothes dryers were associated with 8,600 fires, less than 10 deaths, 170 injuries, and about $47.5 million in property loss. Gas clothes dryers were associated with 3,200 fires, less than 10 deaths, 70 injuries, and about $14.5 million in property loss. The remaining fires, deaths, injuries and property losses were associated with undetermined types of clothes dryers. Based on the estimated dryer fires in 1996, the Directorate for Economic Analysis estimates the value of societal costs from clothes dryer fires is about $202 million.

The CPSC In-Depth-Investigation (IDI) File was searched for clothes dryer fire-related incidents occurring between 1993 and 1997 to provide information about scenarios surrounding these types of fires. Items of interest included the location of fires within the dryer, the age of the dryer, whether the lint trap was cleaned regularly, whether the dryer was in use when the fire started, frequency of consumer usage of the dryer, and whether there were prior problems with the dryer. The Hazard Analysis Division in the Directorate of Epidemiology and Health Sciences reviewed a total of 79 in-depth investigations. (See Tab A)

Of the 79 in-depth investigations reviewed, 48 reports described fire incidents related to electric clothes dryers, 22 reports described fire incidents related to gas clothes dryers, and in the remaining 9 reports, the type of clothes dryer could not be determined (See Tab A, Table 1). In the incident reports in which the fire origin was stated, the duct or the venting system was reported as the most frequent location (14 incidents), and the lint trap was noted as the second most frequently reported location (10 incidents) of the fire within the clothes dryer. Table 3 in Tab-A shows that only 29 of the 79 case reports indicated whether the consumers cleaned the lint trap regularly. Of these 29, 14 reported that the consumer cleaned the lint trap regularly and 15 reported that the consumer did not clean the lint trap on a regular basis. Fires in the lint trap and transition ducts/vents were reported for approximately 1/3 of the 79 investigated fires. In these cases the lint reportedly caught fire, and combustibles near the dryers propagated the fire. Fires reported at locations not related directly to the duct/vent or lint trap did not point to any particular failure mechanism. Fire locations such as motor, electrical system, and thermostat could be cases where these parts overheated due to the lack of proper exhaust airflow.

MARKET INFORMATION

According to estimates published by ***Appliance*** magazine, for the last 10 years (1988-1997) annual shipments of electric clothes dryers have ranged from about 3.3 million to 4.5 million units (in 1997). Shipment of gas clothes dryers have ranged from about 1.0 million to 1.3 million. Shipments of another product category, compact dryers, generally ranged from about 200,000 to 300,000. ***Appliance*** also estimates that the product saturation level (percentage of households with clothes dryers) was 55.5 percent for electric clothes dryers and 17.8 percent for gas dryers in 1997. Therefore, about 73 percent of households have a clothes dryer. Since there were about 100 million households in the U.S. in 1997, it is estimated that about 73 million clothes dryers were in use. This estimate is consistent with estimates from CPSC's product population model using historical shipment data and an assumed expected product life of about 16 years. (See Tab-B)

REVIEW OF VOLUNTARY STANDARDS

UL 2158, Electric Clothes Dryers, is the voluntary safety standard for electric clothes dryers and ANSI Z21.5.1 (CGA 7.1) is the voluntary safety standard for gas clothes dryers. Since CPSC data indicate that the largest known contributing factor to clothes dryer related fires is accumulation of lint in the air flow system, the review of the voluntary standards focussed on obstructed air flow.

Current voluntary standards do not include requirements that evaluate the long-term effects of blocked or insufficient exhaust airflow. These standards address the issue of blocked lint screen and exhaust as follows:

For electric dryers, UL 2158 paragraph 19.5 *Blockage of lint screen and exhaust*, defines abnormal tests to address the immediate occurrence of a fire hazard. The dryer is operated through one conditioning cycle for the maximum length of time as dictated by the timer. All temperature-regulating and -limiting devices are then defeated and the appliance operated under this condition, with the timer modified so as to result in continuous operation, until ultimate results are obtained or for 7 hours, whichever is less. These tests are repeated for each of the following four operating modes: dryer operated with 75% and 100% lint screen blocked, and 75% and 100% exhaust blocked.

The criteria for passing these abnormal operational tests is that the following results do not occur within seven hours:

- a) emission of flame or molten metal,
  (Note: *Drops of melted solder are not considered to be molten metal*),
- b) glowing or flaming of combustible material upon which the appliance may be placed or that may be in proximity to the appliance as installed; or,
- c) indication of flame or glowing embers in the load of clothes, either before or after the access door is opened

The ANSI Z21.5.1 (for gas dryers) in paragraph 2.14.2 addresses the same issue under, c. when the lint screen(s) and the exhaust means are blocked. The method of test is: "With the lint screen(s) blocked and with the main exhaust opening sealed shut, the unloaded dryer shall be operated until the temperature-limiting device functions to shut off the gas supply. When the limiting device functions, the temperature of the air or flue gases discharged through any openings in the cabinet shall not exceed 250°F(121°C) at the instant the device functions. Non-functioning of the temperature-limiting device shall be considered as noncompliance with this provision." The ANSI standard test method relies on a thermal-limiting device (high limit thermostat) to shut the heat source off. If for any reason the thermal limiting device malfunctions or fails under described conditions that could be a potential fire hazard.

PRODUCT EVALUATION

The project included tests on a gas and an electric clothes dryer to characterize the temperature profile of the dryers under various operating conditions. The report on the testing and results is included at Tab C.

Similar test methods were followed for both the gas and electric dryers except where the differences between the two models would not allow it. Thermocouples were installed at various locations within each dryer, particularly at locations along the flow of air (See Tab C). During the tests, the dryers' lint traps were not cleaned to allow the lint to accumulate and gradually obstruct the airflow. Temperatures were recorded for various settings with several different loads of clothes.

During one series of tests, a wad of collected lint was stuffed into the vent to simulate substantial obstruction of airflow in the transition duct/vent system. In this case, the electric dryer was run in a permanent press cycle with a small load of damp clothes. The temperatures at points internal to the dryer rose higher than the temperature when the airflow was unobstructed. At the end of the cycle, the clothes in the dryer were not completely dry. With the gas dryer, under similar conditions, a small load was run on a high heat, automatic dry setting. As with the electric dryer, the temperatures internal to the appliance were considerably higher than when the airflow was clear of the obstruction. It was observed that the clothes remained damp at the end of the drying cycle.

The tests show that for both types of dryers, when airflow is obstructed by partial blockage of the exhaust and lint screen, the temperatures inside the dryer rise significantly. While the temperatures did not rise high enough to ignite material inside the drum or the components within the appliance, the indication is that if the dryer lint screen is not cleaned and the exhaust vent is not maintained reasonably clear of accumulated lint, the temperature inside the drum and chassis will consistently be elevated above normal operating conditions. The elevated temperatures over long periods of time can degrade critical components (wire, connectors, motor, etc.) prematurely. The staff is concerned that this degradation could result in a component failure, causing a spark or flame that could ignite nearby combustibles (e.g. lint).

The importance of sufficient airflow through the clothes dryer for safe operation is well documented. Under a CPSC contract, Contract # CPSC-C-76-0078, The Illinois Institute of Technology Research Institute (IITRI) submitted a report to CPSC in September of 1977 titled "INVESTIGATION OF STANDARDS FOR SAFETY OF INSTALLED ELECTRICAL EQUIPMENT." Under paragraph # 5.6.2-Lint Indicator (page # 200) ITRII states that failure to maintain sufficient airflow elevates the internal dryer temperatures, causing thermal stress to electrical components, setting the stage for fires.

According to Norman D. Reese et al. in their article Clothes Dryer Fires in "Fire And Arson Investigator" magazine (Volume 48 No. 4, July 1998, Page # 17), "...lint fires often begin in the lint trap, especially when the trap is cleaned infrequently...When lint is left to accumulate in the filter, the airflow is impeded and the temperature will increase accordingly upstream of, and at the filter. ...A lint fire originating in the trap generally incinerates the plastic blower and housing and, until the blower is damaged from the heat or the motor stops turning, can direct a blast of flame from the rear of the dryer against a combustible wall surface."

Industry sources have also noted that dryer fires are predominantly due to lack of maintenance of the lint screen and airflow in the dryer vent system. By quantifying the air pressure in the vent/duct system, industry sources indicate elevated temperatures in the dryer when the airflow was obstructed. Dryer manufacturers stress the importance of cleaning the lint screen before each use. They add that it is also imperative to install the transition duct according to their instructions using the recommended rigid metal ducts by qualified technicians.

CONCLUSION AND RECOMMENDATIONS

Although both gas and electric dryers include a number of over-temperature protection features, an estimated 15,500 fires are annually attributed to dryers. CPSC tests, as well as other sources such as clothes dryer design engineers and fire investigators, indicate that accumulation of lint both in the lint screen and in the external vent system reduces the flow of air through the dryer and causes internal temperatures to rise. Because the dryer continues to function without any warning to the user (other than ineffective drying of the clothes), the electrical components become thermally stressed, setting the stage for a failure to occur and start a fire. Although a specific failure mechanism is not readily described, the critical importance of proper airflow is well documented.

A recent design feature called a Lint Alert is presently available on some dryer models. This is a mechanical device intended to produce a sound that warns users of excessive lint accumulation in the lint screen. At present such a device is neither part of the safety standard, nor incorporated in all presently available models and makes of clothes dryers. Incorporating a requirement for an effective lint alert may be a starting point for a solution by alerting the user of elevated temperatures inside clothes dryers. However, incorporating a restrictive airflow detection system that shuts down the appliance when the exhaust air from the appliance is insufficient is a measure that would more completely address the fire risk.

It is the view of the CPSC staff that systems should be included in clothes dryers that essentially shut down the dryer when the airflow is obstructed. These mechanisms should be evaluated for their reliability, and requirements for them incorporated into the voluntary safety standards.

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United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

Date: MAY 12 1998

TO: Sheela Kadambi, ESEE

Through: Mary Ann Danello, Ph.D., Associate Executive Director
Directorate for Epidemiology and Health Sciences

Susan Ahmed, Ph.D., Director
Hazard Analysis Division (EHHA)

FROM: Kimberly Ault, EHHA K.A.

SUBJECT: Data Summary on Gas and Electric Clothes Dryers

This memorandum provides recent data on fire-related incidents associated with both gas and electric clothes dryers. The In-depth Investigation File (INDP) was searched for clothes dryer fire-related incidents occurring between 1993 and 1997 to provide information about the scenarios surrounding these types of fires. Items of interest included the location of fire within the dryer, the age of the dryer, whether the lint trap was cleaned regularly, whether the dryer was in use when the fire started, the consumer frequency of usage of the dryer, and whether there were prior problems with the dryer. A total of 79 in-depth investigations were reviewed. The following tables summarize the items found in the investigations.

During 1995, the most recent year for which national estimates of fire losses are available, there were an estimated 15,800 fires associated with clothes dryers, 10 deaths, 290 injuries, and about $74 million in property loss in residential structures. Electric clothes dryers were associated with 9,000 fires, less than 10 deaths, 160 injuries, and about $40 million in property loss. Gas clothes dryers were associated with 3,200 fires, no deaths, 60 injuries, and about $13 million in property loss. The remaining fires, deaths, injuries and property loss were associated with undetermined types of clothes dyers.

Of the 79 in-depth investigations reviewed, 48 investigations described fire incidents related to electric clothes dryers, 22 investigations described fire incidents related to gas clothes dryers, and in the remaining 9 investigations the type of clothes dryer could not be determined. Table 1 shows the distribution of the type of clothes dryer by the initial fire location. Of the known fire locations, the duct or the venting system was reported as the most frequent location (14 investigations). The lint trap was noted as the second most frequently reported location of the fire within the clothes dryer. Other notable fire locations included the motor, drum, electrical system, and the control panel.

Table 1
Type of Clothes Dryer by Fire Location

Location of Fire	Electric Dryer	Gas Dryer	Unknown Dryer	[redacted]
Lint Trap	6	2	2	
Duct / Vent	8	4	2	
Drum	2	3	1	
Timer	3	1	0	
Control Panel	5	0	0	
Thermostat	2	1	0	
Motor	8	0	1	
Electrical System	4	1	0	
Heater Coil	1	0	0	
Plug / Cord	1	0	0	
Other	1	5	0	
Unknown	7	5	3	
[redacted]				

Source: U.S. Consumer Product Safety Commission / Indepth Investigation File, 1993 – 1997

Table 2 shows the distribution of the age of the clothes dryer involved in the 79 fire investigations. Of those clothes dryers where the age was known, most of the dryers involved in the fires were less than 5 years of age (40%). Fourteen investigations (31%) reported that the dryers were between 5 and 10 years old and 6 investigations (13%) reported that the dryers were between 11 and 15 years old. The remaining 7 investigations (16%) reported that the dryers were over 15 years old.

Table 2
Age of Clothes Dryer

Age of Dryer	Number	Percent of Known
Less Than 5 Years	18	40%
5 to 10 Years	14	31%
11 to 15 Years	6	13%
Over 15 Years	7	16%
Unknown	34	--
[redacted]		

Source: U.S. Consumer Product Safety Commission / Indepth Investigation File, 1993 – 1997

Many investigations contained sparse information concerning whether the consumer cleaned the lint trap on a regular basis (i.e., each time the dryer was used or at least once every couple loads). Table 3 shows that only 29 of the 79 reported whether the consumer cleaned the lint trap on a regular basis. Of these 29, 14 reported the consumer cleaned the lint trap regularly and 15 reported that the consumer did not clean the lint trap on a regular basis.

Table 3
Frequency of Consumer Cleaning Lint Trap

Response	Number	Percent of Known
Consumer Cleaned Lint Trap on Regular Basis	14	48%
Consumer Did Not Clean Lint Trap on Regular Basis	15	52%
Unknown	50	--
[redacted]		

Source: U.S. Consumer Product Safety Commission / Indepth Investigation File, 1993 – 1997

Table 4 shows that 55 of the investigations (86%) reported the clothes dryer power switch was in the "on" position when the fire occurred and 9 investigations (14%) reported that the clothes dryer power switch was in the "off" position when the fire occurred.

Table 4
Clothes Dryer Power Switch Position When Fire Occurred

Response	Number	Percent of Known
On	55	86%
Off	9	14%
Unknown	15	--
[redacted]		

Source: U.S. Consumer Product Safety Commission / Indepth Investigation File, 1993 – 1997

Of the 79 investigations reviewed, 13 reported that consumers had prior problems with the clothes dryers before the fire occurred and 32 reported that consumers did not have any problems prior to the fire. Thirty-four of the investigations did not contain any information from the consumer regarding prior problems with the clothes dryer. See Table 5.

Table 5
Consumer Experienced Prior Problems With Clothes Dryer

Response	Number	Percent of Known
Yes	13	29%
No	32	71%
Unknown	34	--
[redacted]		

Source: U.S. Consumer Product Safety Commission / Indepth Investigation File, 1993 - 1997

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: November 5, 1998

TO : Sheela Kadambi, ESEE

Through: Warren J. Prunella, AED, EC WJP

FROM : Charles Smith, EC CS.

SUBJECT: Clothes Dryer Fires - Market Information

The Consumer Product Safety Commission staff is evaluating injury data and product characteristics that might be associated with clothes dryer fires. The Directorate for Epidemiology and Health Sciences, Division of Hazard Analysis (EHHA), estimates that during 1995 (the most recent year for which national estimates of fire losses from clothes dryers are available) there were 15,800 fires, 10 deaths, and 290 injuries from fires associated with clothes dryers. Also, residential property losses associated with these fires were estimated to have a value of about $74 million.[1] The Directorate for Economic Analysis estimates the value of societal costs from deaths, injuries, and property losses to have totaled about $140 million.

The following market information is provided in support of staff activities.

Annual Shipments & Numbers of Units in Use

According to estimates published by *Appliance* magazine, for the last ten years (1988 - 1997) shipments of electric clothes dryers have ranged from about 3.3 million to 4.5 million units (in 1997). Shipments of gas clothes dryers have ranged from about 1.0 million to 1.3 million. Shipments of another product category, compact dryers, generally ranged from about 200,000 to 300,000.[2] (A table presenting product shipments for 1988-1997 is attached.) *Appliance* also estimates that the product saturation level (percentage of households with clothes dryers) was 55.5 percent for

[1] Kimberly Ault, EHHA, CPSC, "Data Summary on Gas and Electric Clothes Dryers," May 12, 1998.

[2] *Appliance*, "45th Annual Statistical Review," Dana Chase Publications, Inc., April 1998.

Of the 79 investigations, 18 reported the consumer frequency of usage of the clothes dryer. Ten investigations (56%) reported that the consumer used the clothes dryer 7 or fewer times per week or at most one time per day. Other clothes dryers were reportedly used between 8 and 14 times per week (4 investigations or 22%) and over 15 times per week (4 investigations or 22%).

Table 6
Consumer Frequency of Usage of Clothes Dryer

Frequency	Number	Percent of Known
7 or Less Times Per Week	10	56%
8 – 14 Times Per Week	4	22%
Over 15 Times Per Week	4	22%
Unknown	61	–

Source: U.S. Consumer Product Safety Commission / Indepth Investigation File, 1993 – 1997

In the 79 investigations, there were a total of 13 deaths and 28 injuries reported. Below are some of the scenarios involved in these deaths and injuries.

In one fire that started in the lint trap of an electric clothes dryer, a 33-year-old male and a 2-year-old male died of smoke inhalation in their apartment. Seven firefighters and five other persons were treated at hospitals for injuries. The apartment and its contents, including the electric clothes dryer, were destroyed.

In another fatal fire where 4 individuals, three adults and one child, died from smoke inhalation and thermal burns, the cause was determined to be an obstructed electric clothes dryer vent.

In August of 1997, a house fire erupted when the motor of an old clothes dryer malfunctioned, froze and overheated. Four children died in this fire and three other occupants were injured. Damage was estimated in excess of $30,000.

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electric clothes dryers and 17.8 percent for gas dryers in 1997.[3] Therefore, about 73 percent of households may have a clothes dryer. Since there were about 100 million households in the U.S. in 1997, about 73 million clothes dryers were in use. This estimate is consistent with Product Population Model estimates using historical shipment data and assumed expected product life of about 16 years.

Major Manufacturers

The market for clothes dryers has long been highly concentrated among just a few firms. ***Appliance*** estimates that Whirlpool produced 54 percent of both electric and gas clothes dryers in 1997, followed by GE (with 19 percent), Maytag (15 percent), Electrolux (Frigidaire) (7 percent), and Goodman (Speed Queen) (with 5 percent).[4] These market shares have been fairly consistent for many years.

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[3] ***Appliance***, "21st Annual Portrait of the Appliance Industry," Dana Chase Publications, Inc., September 1998.

[4] *IBID.*

Clothes Dryer Shipments, 1988-1997

Dryer Type	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	10-year Totals
Electric	3,553,900	3,522,200	3,317,900	3,294,900	3,563,000	3,853,000	4,035,800	4,019,700	4,284,000	4,510,100	37,954,500
	73.3%	72.8%	72.2%	71.9%	71.4%	72.0%	72.6%	74.7%	75.8%	76.0%	73.4%
Gas	1,046,800	1,051,700	1,002,200	1,018,300	1,153,700	1,220,800	1,303,100	1,204,900	1,244,000	1,266,000	11,511,500
	21.6%	21.7%	21.8%	22.2%	23.1%	22.8%	23.4%	22.4%	22.0%	21.3%	22.3%
Compact	250,000	267,000	275,000	267,800	275,000	275,000	220,000	160,000	120,000	155,000	2,264,800
	5.2%	5.5%	6.0%	5.8%	5.5%	5.1%	4.0%	3.0%	2.1%	2.6%	4.4%
	4,850,700	4,840,900	4,595,100	4,581,000	4,991,700	5,348,800	5,558,900	5,384,600	5,648,000	5,931,100	51,730,800

Source: *Appliance*, "Annual Statistical Review," Dana Chase Publications, Inc., April 1998.

C

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: March 12, 1999

TO : Ronald L. Medford
Assistant Executive Director
Office of hazard Identification and Reduction

THROUGH: Nicholas V. Marchica NVM
Associate Executive Director (Acting)
Directorate for Engineering Sciences

William H. King, Jr.
Director
Division of Electrical Engineering

FROM : Sheela Kadambi
Electrical Engineer
Division of Electrical Engineering

SUBJECT : Report On The Electric And Gas Clothes Dryer Tests Under Clothes Dryer Project

PURPOSE The purpose of this phase of the project was for engineering staff at the U.S. Consumer Product Safety Commission (CPSC) to become more knowledgeable about the operating characteristics of electric and gas clothes dryers and relate those to field incidents as reported in clothes dryer related fires. In accordance with this plan, tests on an electric and a gas dryer were conducted. Temperatures at various key locations in the dryers were measured under several operating conditions. The following report summarizes the tests and results.

PRODUCT DESCRIPTION The two basic types of clothes dryers, defined by the primary fuel source for heating the air, are electric and gas. For both types the hot air produced by a heat source is blown through tumbling clothes inside a rotating drum and exhausted through a vent to dispose the damp air outside via transitional ducting. Since their introduction in the market, dryers have been enhanced to improve efficiency and safety. Improvements have included humidity sensing components to automate drying time and thermostats for over-temperature protection. While the humidistat (humidity sensor) improved efficiency, additional thermostats improved the safety of the dryer. The humidistat located inside the drum is a device that senses dampness of the clothes and interacts with the timer to adjust the duration of the drying cycle. The thermostats either control or limit the temperature in the dryer.

In general, clothes dryers have at least three temperature-regulating/limiting components (two thermostats and a thermal cut off). For redundancy some models of dryers may have as many as three operational thermostats in addition to a high limit thermostat, thermal cut off and a thermal fuse. The electric clothes dryer that was used in the CPSC staff tests had a regulating (operational) thermostat, a high limit thermostat, a one-shot thermal fuse and a one-shot thermal cut-off. The gas dryer tested had a thermal cut-off but not a thermal fuse. The operating thermostat, which is in the exhaust air stream, controls the temperature of the heat within the drum. When the temperature of the air flowing across it rises to a set level, the thermostat shuts the electric heat element or gas burner off. When the temperature drops below the thermostat's lower threshold, the thermostat turns the electric heat element or gas burner back on. The high limit thermostat, located in the heater box, shuts the heat source (electric or gas) off when the temperature in the heater box rises above its preset level that is higher than the set temperature in the operating thermostat. The thermal fuse is located adjacent to the operating thermostat. The thermal fuse opens and shuts the dryer off when the temperature in the blower assembly reaches the preset temperature of the thermal fuse. When the thermal fuse opens, it has to be replaced. The thermal cut off is located on the outer surface of the heater box. This is a back up when the high limit thermostat fails. Once the temperature reaches the set temperature of the thermal cut off (set at a higher temperature than that of the high limit thermostat), it opens to shut off the heat source. Once the thermal cut off opens, it must be replaced.

Except for the heat source, the function of the components in electric and gas dryers is similar. A 240-Volt powered heating element is the heat source in an electric dryer, whereas a gas burner is the heat source in a gas dryer. All other components in electric and gas clothes dryers are energized at 120 volts, including the motor that turns the drum and circulates the air, and the control timer.

A high-end electric dryer and a low-end gas dryer were purchased. The electric dryer controls include a start button, a timer dial and a fabric temperature dial. The timer cycles on the electric dryer are automatic dry, timed dry and air dry. Under the automatic drying cycle, there are three settings: less dry, normal dry, and more dry. The fabric temperatures can be set at DELICATE LOW, KNIT MEDIUM, NORMAL PERM PRESS (at medium or high heat), and COTTON at high heat. The electric dryer includes a device to indicate excessive lint accumulation in the lint screen. This is called lint alert. The gas dryer has basic features. Under automatic drying cycles, there are two settings: less dry and more dry, and the timed dry has only medium heat setting. There are no separate fabric temperature settings except for COTTONS, which is set at high heat. The gas dryer has a start button, which energizes the motor. The gas dryer does not have a lint alert. In both dryers the maximum-TIMED DRY cycle is 90 minutes.

<u>TEST METHOD</u>: The temperatures inside the dryer during operation were measured by placing a thermocouple at the following locations: exhaust vent, inside the motor, operational thermostat, high limit thermostat, thermal cut off, chassis, inside the heater box, and inside the drum. Also thermocouples were placed inside the drum at the center of the door and at the back of the drum.

The dryers were tested at various operational conditions as follows:

Condition 1.	Cotton (High) -	Auto Dry mode/More Dry setting
Condition 2.	Cotton (High) -	Auto Dry mode/Normal Dry setting
Condition 3.	Perm. Press (Med.)	Auto Dry mode/Normal Dry setting
Condition 4.	Cotton (High) -	Timed Dry for 90 Minutes

The above conditions were chosen because they would attain the highest temperatures in their respective settings. The gas dryer purchased for the project was not equipped with a permanent press cycle. Therefore the gas dryer was not tested for condition # 3. To start the operational testing, the electric dryer was run empty under condition #1 and the gas dryer was run empty on condition #2 for ten minutes to check performance. The drying cycles were terminated by opening the dryer door.

The electric and gas dryers were tested with a manufacturer recommended full load (5.625lbs) of blended cotton terry cloth towels under conditions No. 1 & 4. A medium-size load (3lbs-manufacturer recommended) of laundry was dried under condition No.2. A small load (two lab coats) was dried under condition No.3 in the electric dryer only.

Tests were focussed on determining the effects of obstruction of airflow from lint accumulation in the lint screen. From the beginning of the tests to the end, the lint screen was not cleaned in either the electric or gas dryer. In later tests, to increase the amount of lint in the dryer duct system, collected lint was dispensed in the dryer and it was run for ten minutes. Leftover lint was removed from the drum. Next, the exhausts of the dryer vents (electric & gas) were obstructed by stuffing a wad of collected lint.

DISCUSSION: The temperature profiles in the electric dryer for each load were similar in that the temperature rose to a certain level, and maintained that level until the timer functioned to end the cycle. In the gas dryer the heat is supplied in pulses so the operating thermostat operates more often than in an electric dryer. During the pulsing process, the temperature in the drum is maintained at the set level.

Completely blocking the exhaust was the final step in the testing process. Following is a table showing the maximum temperatures under Condition 1, while drying a manufacturer recommended full (large) load of terry cloth.

Table 1 Electric Dryer-Condition # 1, 5.625 lbs. of Terry Cloth

	CLEAR EXHAUST	PROGRESSIVE LINT ACCUMULATION		BLOCKED EXHAUST
Run Number	4	8	10	12
Heater Box	108.7°C	138.7°C	156.2°C	192.4°C
Exhaust	79.7°C	67.9°C	54°C	47°C

Table 2 Gas Dryer-Condition # 1, 5.625 lbs. of Terry Cloth

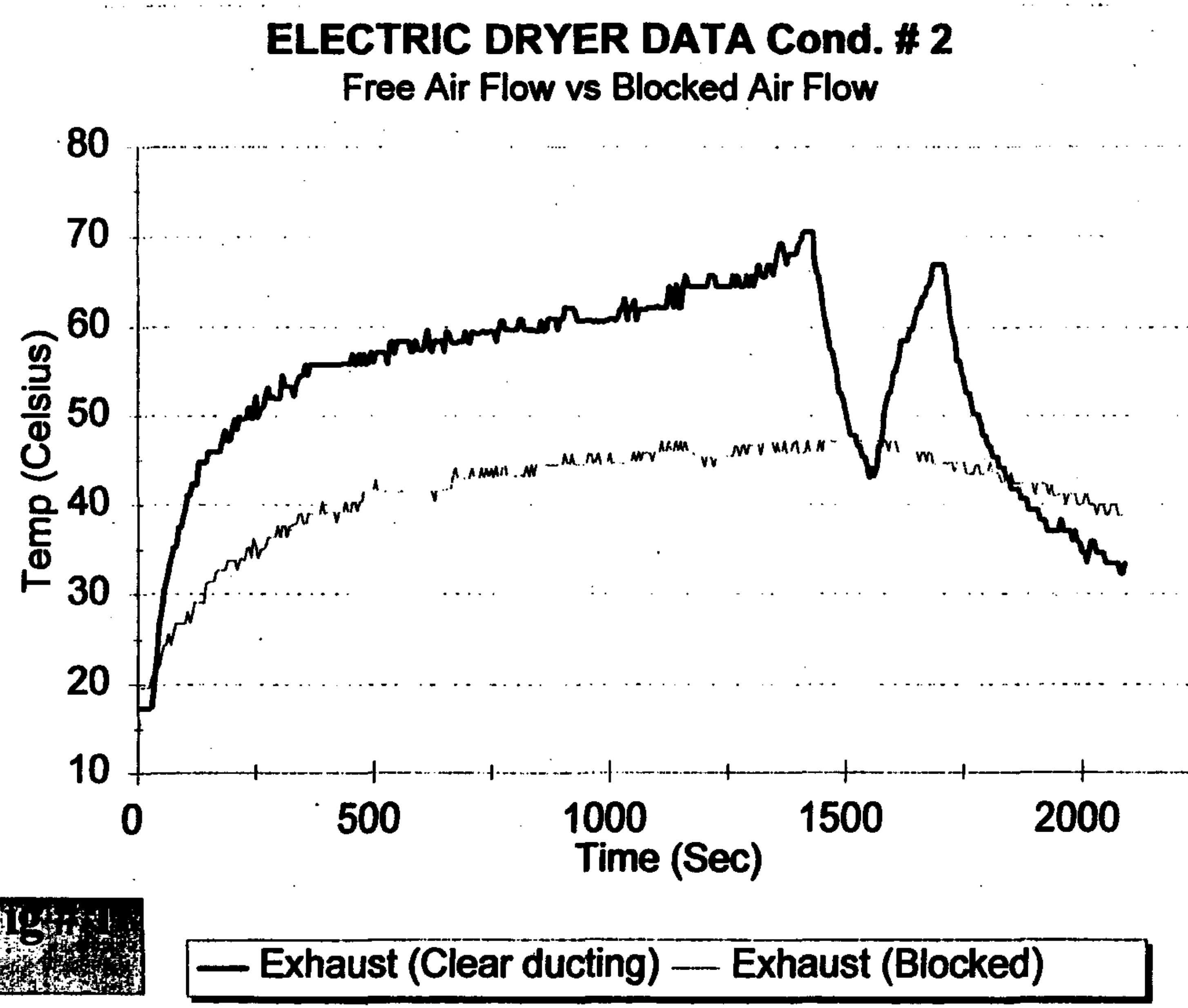
	CLEAR EXHAUST	PROGRESSIVE LINT ACCUMULATION	BLOCKED EXHAUST
Run Number	2	5	6
Heater Box	808.9°C	832.9°C	856°C
Exhaust	61.6°C	59.6°C	48.2°C

The tests show that the flow of air through the system is critical to the effective operation of the dryer. As the lint accumulated, the temperature of the heat source and in the drum gradually increased while the exhaust temperature decreased. This is illustrated in Table 1 and Table 2. This indicates that the heat does not reach the drum properly causing the system to lose its effectiveness. After the extra lint was added to the electric dryer, the lab coats were damp at the end of drying cycle. Also, when the lint was added to the gas dryer, the terry cloth towels were not dry at the end of the drying cycle.

The observation from the lab tests was that under blocked exhaust and blocked lint screen conditions, there is a significant rise in the temperatures inside the dryer. While the temperatures did not rise high enough to ignite material inside the drum or component parts of the appliances, the temperatures in the heater box and in the drum rose substantially higher as the lint collection increased.

During these tests the lint screen was intentionally not cleaned in order to check effects of lint accumulation in the air flow system. However the lint alert in the electric dryer did not sound. According to the operation and users manual, it is designed to give out a distinctive audible noise when excessive lint is collected in the lint screen.

<u>CONCLUSION</u>: The tests conducted show that, if the dryer lint screen is not cleaned and the lint is allowed to accumulate in the exhaust vent, the temperature inside the drum and chassis will consistently be elevated above normal operating conditions. As the temperature in the heater box increased due to lack of airflow, the exhaust temperatures decreased. The elevated temperatures over an extended period of time (weeks, months, or even years) may accelerate degradation of critical components inside the dryer. The electrical components become thermally stressed, setting the stage for a failure to occur and start a fire.


ELECTRIC DRYER DATA Cond. # 2
Free Air Flow vs Blocked Air Flow
80
70
60
50
40
30
20
10
Temp (Celsius)
0
500
1000
1500
2000
Time (Sec)
Exhaust (Clear ducting)
Exhaust (Blocked)

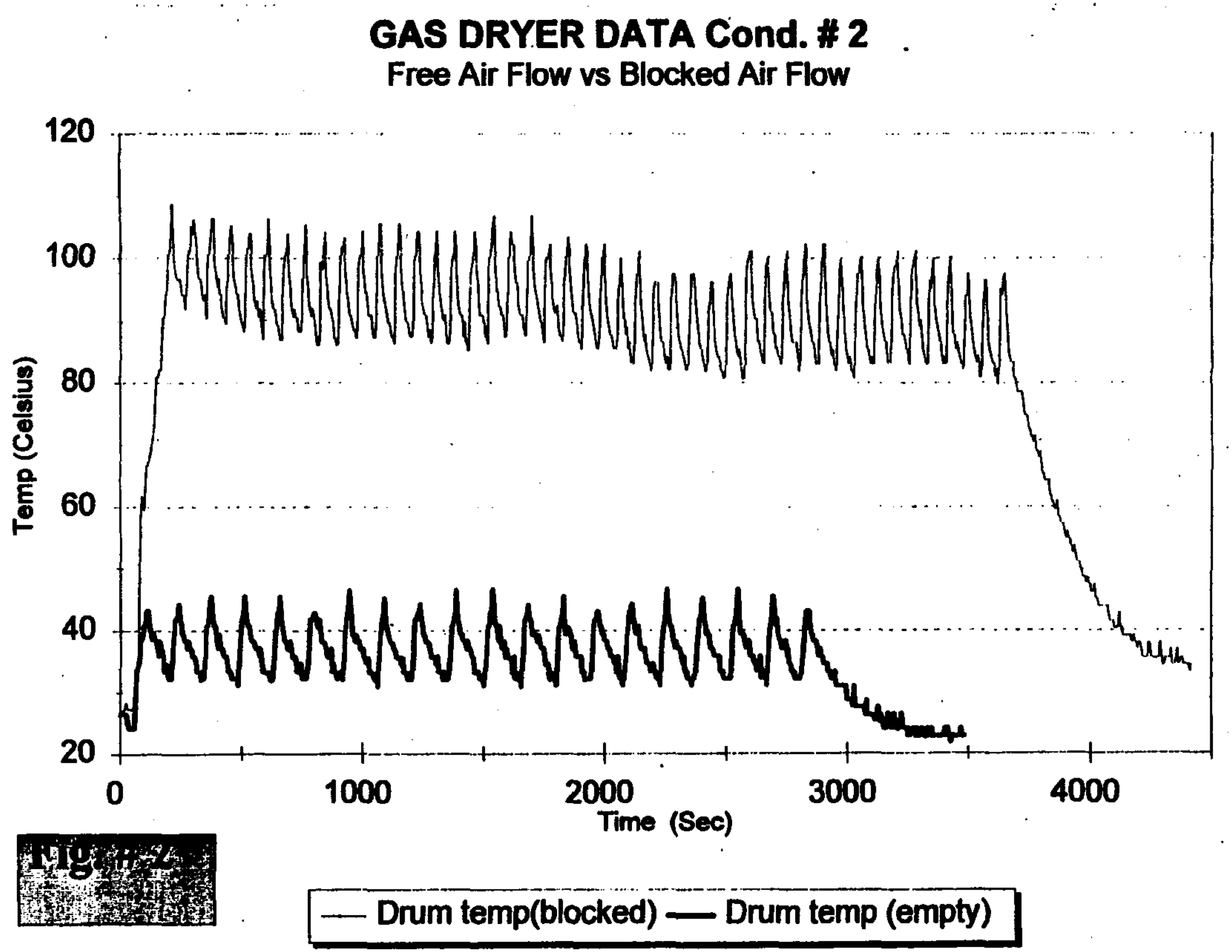

GAS DRYER DATA Cond. # 2
Free Air Flow vs Blocked Air Flow
Temp (Celsius)
120
100
80
60
40
20
0
1000
2000
3000
4000
Time (Sec)
Drum temp(blocked)
Drum temp (empty)

Fig. # 2