UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: April 18, 2003

TO	:	Jacqueline Elder Acting Assistant Executive Director Office of Hazard Identification and Reduction
THROUGH	:	Hugh M. McLaurin Associate Executive Director Directorate for Engineering Sciences Erlinda M. Edwards Director Division of Electrical Engineering
FROM	:	Anna L. Luo Electrical Engineer Division of Electrical Engineering
SUBJECT	:	Assessment of Portable Electric Fans

1. Introduction:

There were an estimated 4,500 fires associated with portable electric fans from 1990 through 1998. These fires resulted in more than 20 deaths, 270 injuries, and about $55 million in property loss. In Fiscal Year 2000 the U.S. Consumer Product Safety Commission (CPSC) staff initiated an activity to assess the adequacy of the industry voluntary standard for portable electric fans. A portable fan is a cord-connected appliance that is easily moved by hand from place to place. Portable fans consist of box fans, window box fans, dual window fans, window fans, desk/table fans, pedestal/floor fans, clip-on fans, and hassock fans.

The staff evaluation included analysis of field incident data, analysis of market information, assessment of current requirements of the applicable voluntary standards, analysis of incident samples and testing of new electric fans. The results of these tests and the results of the staff's assessments are presented in this report.

2. Incident Data: (See Tab A)

Staff reviewed 243 fan-related In-Depth Investigations (IDIs), conducted from January 1, 1990 through April 12, 2001. These IDIs included those in which the identified hazard was fire (210), potential fire (16), electrocution (12), electric shock (3), and electrical hazards (2). Failure modes identified in the IDIs included motor failure, such as motor overheated or motor seized

(110), appliance cord failure (63), and switch failure (8). In 62 cases, the cause of failure was undetermined

Further analysis of the 63 incidents involving cord failure indicated that 33 cases involved the power-supply cord (See Table 2 – IDIs Involving Power Supply Cord), 9 cases involved the cord that connects the motor and the base of an oscillating fan (See Table 3 – IDIs Involving Cords Connecting Motors and Base of Oscillating Fans), and the remaining 21 cases involved an extension cord, or repaired cord.

A contributing factor to portable fan-related fires or potential fires was the presence of plastic materials. When a fan with plastic blades, motor housing or enclosure overheated or caught fire, the plastic reportedly would melt and drip onto combustible materials such as carpet, clothing, bedding, paper, etc. Of the 226 fire or potential fire IDIs, 174 were related to a fan with the presence of plastic materials.

3. Market Sketch: (See Tab B)

The Association of Home Appliance Manufacturers (AHAM) is the trade group that represents manufacturers of household electric fans. AHAM reported that six member firms account for 75 percent or more of U.S. sales of portable electric fans. Imports represent more than 75 percent of all portable electric fans sold in the U.S. China is the major exporting country of these products and accounts for the bulk of total U.S. imports of portable fans.

Appliance, a trade publication, reports sales of portable electric fans have been in the range of 17 to 20 million per year. *Appliance* also reports that the average life expectancy of fans is 12 years. Based on this information, staff estimates there are about 200 to 240 million portable fans in use in U.S. households. In 2000, *Appliance* noted that 81.5 percent of U.S. households had at least one electric fan (excluding ceiling fans).

4. Review of Voluntary Standards:

The voluntary safety standard for portable electric fans is *Underwriters Laboratories Standard for Safety for Electric Fans,* UL 507. The voluntary standard contains several requirements designed to address failure mechanisms identified in the IDIs that could result in potential fires and shock hazards:

- **Stalled Rotor Tests**: The UL standard includes a locked rotor test to address overheating due to a stalled motor. To conform with the standard, when the rotor is locked, the temperature of the motor windings cannot exceed a temperature limit determined by the motor class or motor type (impedance protection or thermal-device protection) to prevent overheating. An impedance-protected motor relies solely upon the impedance of the motor windings to prevent overheating. A thermal-device-protected motor relies upon a built-in device such as a thermal cutoff (TCO), which is a non-resettable fuse responding to over temperature conditions, to prevent overheating. UL 507, *Electric Fans*, paragraph 20, *Motor Protection*, specifies that the over-temperature protection for motors shall comply with the applicable requirements in UL 2111, the standard for *Overheating Protection for Motors*.

- **Power-Supply Cord:** UL 507, *Electric Fans*, paragraph 14.1, *Cords and Plugs*, requires that a portable appliance be provided with a flexible cord (in accordance with Table 14.1, *Cords for Appliances*) not smaller than 18 AWG. The power supply cord of household portable electric fans must be SP-1, SP-2, SPT-1, or SPT-2 type. SP means "all thermoset parallel cord," and SPT means "all plastic parallel cord."

  SP and SPT-type cords[1] are parallel construction and have conductor insulation involving the use of a single layer of insulation. An integral web of insulation separates the two wire conductors to form the parallel construction. SP-2, SPT-2 cords have thicker insulation requirements than SP-1 and SPT-1 cords.

- **Internal Wiring:** UL 507, *Electric Fans*, Paragraph 16*, Internal Wiring – Electrical Connections*, requires that wiring between the motor and the base of an oscillating fan:

  1. have conductors with individual strands not larger than No. 34 AWG ($0.02 mm^2$),
  2. have rubber or other insulation not less than 0.4 mm (1/64 inch) thick on each conductor, and
  3. not be of such length and location that results in damage by intended operation.

5. CPSC Staff Test Methods and Results: (See Tab C)

CPSC staff purchased eight basic models of portable electric fans representing five different manufacturers from local department stores. Among eight fan models, six of them had thermal-device-protected motors, and the other two had impedance-protected motors. Prices ranged from $9.99 to $29.96. All models were listed by UL. The attributes of the fan samples are summarized in Table 1 – Portable Electric Fan Attributes.

Staff conducted several tests to evaluate the performance of the purchased samples. In addition, incident samples were evaluated. Laboratory tests included locked-rotor tests as defined by UL 2111, *Overheating Protection for Motors.*

A limited series of tests was conducted to characterize temperatures of the motor windings to determine the effectiveness of the over-temperature protective devices. The objective of the locked-rotor tests was to simulate a failure of the motor as reported in the IDIs such as motor seized, motor overheated, and fan blade blocked.

- **Locked rotor tests of thermal-device-protected motors:** UL 2111, *Overheating Protection for Motors*, Paragraph 14, *Locked-Rotor Temperature Test*, limits the temperature of the motor windings during locked rotor conditions (Table 14.1 – Maximum Locked-Rotor Temperature Limits). Class A insulation (typical enamel

[1] Paragraph 16.3 of UL 62, *Flexible Cord and Fixture Wire*

insulation found on the motor winding) cannot exceed 200^0C during the first hour, then must not exceed 150^0C after that.

The six new fans with motors using a TCO passed the locked-rotor tests. The TCOs opened in all cases in less than an hour, and the winding temperatures of the rotors reached between 72^0C and 135.5^0C (within the temperature limit specified by UL 2111).

- **Locked rotor tests of impedance-protected motors:** UL 2111, Paragraph 7, *Locked-Rotor Temperature Test*, requires that the motor windings during locked rotor conditions cannot exceed specified temperature limits (Table 7.1 – Maximum Temperatures) during 72 hours of operation. A motor with Class A insulation cannot exceed 150^0C during the 72-hour test.

  The two new fans with impedance-protected motors passed the 72-hour locked-rotor tests. The maximum temperatures of the motor windings were 54^0C and 63^0C. These two models were also tested with rotors locked for an additional 20 days. The highest winding temperatures were 55^0C and 92^0C. After the test, these fans remained operational and in good condition.

Inspection of Incident Samples: As part of the study, CPSC investigators attempted to collect incident samples from field reports. Few samples were available, since they were often discarded or destroyed by fire, obscuring evidence of how the fire started. Staff received and examined seven consumer samples. Five were involved in fire or potential fire incidents, one was an undamaged sample, and one was involved in an electrical shock incident. Inspection of the five samples involved in fire or potential fire incidents showed the following:

- In one case, the fan was reportedly a source of smoke. No evidence of overheating was observed, and the fan appeared to function normally. The fan was UL listed.
- In another case, the windings of the collected motor remained shiny under a layer of soot, again indicating that the motor had not overheated. It is unknown if the fan from which the motor came was listed by an independent testing laboratory.
- One UL listed sample was reportedly involved in an electrical shock incident. A product safety assessment of the sample did not determine a cause for the shock. There was evidence of soot and melted plastic; however, the cause could not be determined.
- In one case, the windings of the collected motor remained shiny under a layer of soot, indicating that the motor had not overheated. A second used sample, which was collected in the same household and similar to the incident one, has not malfunctioned. This unit was listed by Underwriters Laboratories, Inc.
- A UL listed box fan with a thermally-protected motor had windings that were blackened throughout, indicating overheating. The rotor still turned freely. The TCO had opened but not in time to prevent flames. (The consumer reportedly saw flames and pulled the appliance plug to disconnect power.)
- A UL listed fan with an impedance-protected motor had blackened windings, and the tape that insulates it was charred. The windings no longer had continuity and the motor no longer worked. There was no indication that the rotor had seized – the fan blades still turned freely. The insulating enamel on the windings may have broken down resulting in

overheating. (The consumer reportedly saw a small flame erupt around the motor and pulled the appliance plug to disconnect power.)

6. Human Factors Evaluation: (See Tab D)

Human Factors staff evaluated available IDIs in which the cord of a portable electric fan may have contributed to a fire or electrocution. In many cases, the investigator identified the fundamental cause as a short circuit in the cord or fan. However, the resulting damage to the cord often made it difficult to assess possible reasons for these failures. The details of several investigations permitted staff to identify four general usage patterns that could have contributed to some fire incidents. Although there may be other potential ways in which consumers will use the fan and power cord such that the cord becomes damaged or fails, staff believes the following patterns may be representative of typical consumer behaviors:

1. The consumer places the fan or some other object on top of the cord.
2. The consumer pushes furniture against a wall, pinching a cord that runs between them.
3. The consumer positions the fan such that the cord is exposed to pedestrian traffic.
4. The consumer exposes the cord to damage during storage.

Staff believes consumers will use portable electric fans in ways that could damage the cord and lead to failure. Most consumers lack detailed knowledge of how electrical products work, so consumers simply may not realize that their behavior could be hazardous. Repeated exposures to portable electric fans without incident further reinforces the perception that the products are safe and are being used in a safe manner, even if they are not. Consumers may not notice damage when not in view (e.g., if the location of the pinch point on a cord is behind furniture).

Portable electric fans may be used in children's rooms, and children are generally less knowledgeable about electrical products and their associated hazards than adults. Even consumers who are aware of the potential hazards associated with certain cord usage patterns may find it difficult to avoid situations that could damage the cord. For example, it is difficult to prevent the cord from being exposed to pedestrian traffic depending on the desired placement of the fan and the location of the electrical outlets. Consumers' efforts to prevent damage to the cord by wrapping the cord around the fan during storage could, in itself, damage the cord and lead to failure. In addition, there may be numerous opportunities for cord damage depending on how and where the fan is stored when not in use.

7. Discussion/Conclusions:

There are three primary issues related to the fire hazards described in the IDIs: overheating due to motor failure, the flammability of the thermoplastic enclosures, and overheating due to cord failure.

- **Overheating due to motor failure:** Although the incident data show that the largest number of incidents was attributed to fan motors overheating or seizing, the limited locked rotor tests conducted by CPSC staff did not provide an explanation for these incidents. Locked-rotor test results of thermally-protected and impedance-protected motor samples did not indicate any fire hazard, even in the long term testing. In some incident samples collected, the motors appeared to have failed because the enamels of the windings broke down, not because the motors were seized.

Recommendation: There are no recommendations for changes to the voluntary standard to address motor failures at this time. However, additional testing of these small motors would be appropriate. Motor failures need further research to understand features in designs that may contribute to fire incidents. These may include types of motor windings, enamels used for insulating windings, the use of motors in different applications, different environments, and the differences between aged motors and brand new motors.

- **Overheating due to cord failure:** The incident data show that the second largest number of incidents was related to the power-supply cords. Among 243 follow-up IDIs, there were 63 incidents involving cord failure: 33 cases involved the power-supply cord (See Table 2 – IDIs Involving Power Supply Cord), 9 cases involved the cord that connects the motor and the base of an oscillating fan (See Table 3 – IDIs Involving Cords Connecting Motors and Base of Oscillating Fans), and the remaining 21 cases involved an extension cord, or repaired cord.

  A Human Factors staff evaluation of IDIs indicated that although there may be other potential ways in which consumers will use the fan and power cord such that the cord becomes damaged or fails, staff believes the following patterns may be representative of typical consumer behaviors: The consumer places the fan or some other object on top of the cord; the consumer pushes furniture against a wall, pinching a cord that runs between them; the consumer positions the fan such that the cord is exposed to pedestrian traffic; the consumer exposes the cord to damage during storage.

  The current power-supply cord requirements for portable electric fans allow SP-1, SP-2, SPT-1 and SPT-2 type constructions. These single-layer-insulation types of cords are not sufficient to prevent damage as described in the IDIs.

  Recommendation: The minimum requirements for power supply cords in UL 507, *Electric Fans*, should be upgraded to provide more rugged cord constructions such as those required for vacuum cleaners.

- In addition to the power cord failures, there were nine IDIs related to the internal wiring that connects the motor and the base of an oscillating fan. Although the standard requires that the internal wiring have an insulation thickness not less than 0.4 mm on each conductor, some IDIs indicated that the insulation on the internal wiring was abraded while oscillating, and caused sparking and arcing.

  Recommendation: The requirements in UL 507, *Electric Fans*, for the internal wiring that runs between the motor and base of an oscillating fan should be improved, such as with a requirement for wire insulation to be covered with a jacket to protect against abrasion due to contact with rough edges and other mechanical damage during fan oscillation.

Table 1 - Portable Electric Fan Attributes

Type	Model	Purchase Cost	Power Rating	Switch	Motor	Enclosure/Grill/ Impeller	Comment
Window Fan	A	$29.96	120VAC-60Hz-0.5A	Plastic turn-knob switch, Push-in connection, UL&CSA recognized 6A-120VAC, 3A-240VAC	• Thermal protection, 1A-250V, 115^0C, B2 1322 • Two capacitors VIM-2.5µF	• Plastic enclosure • Plastic impeller	• A thermostat built in the unit with a quick tap connections • Intake/exhaust slide switch, UL&CSA recognized, Defond, 6A-125VAC, 3A-250VAC
Desk Fan	B	$9.99	120VAC-60Hz-0.35A	Plastic turn knob engaged to a slide switch, UL recognized, 13A-125VAC, 6.5A-250VAC	• Impedance protection • Motor: ZP. 120V, 60Hz, 0.35A	• Metal grill (front), plastic grill (back) • Plastic enclosure • Plastic impeller	•
Box Fan	C	$12.46	120V-60Hz-2.2A	Push-in connection, 3A-125VAC	• Thermal protection, 2.5A-250V, 115^0C	• Metal enclosure • Plastic grill • Plastic impeller	• Motor windings separate from dead metal only through one orange layer of paint insulation • Winding wrapped around the coil unevenly
Desk Fan	D	$12.99	120VAC-60Hz-0.82A	Push-in connection, UL&CSA recognized, 6A-120VAC, 3A-240VAC	• Thermal protection, 115^0C, 1A-250VAC	• Plastic enclosure • Plastic impeller	
Window fan	E	$17.99	120VAC-60Hz-0.85A	Push-in connection, UL&CSA recognized, 6A-120VAC, 3A-240VAC	• Impedance protection	• Plastic enclosure • Plastic impeller	
20" Box Fan	F	$19.99	120VAC-60Hz-2.5A	Push-in connection, UL&CSA recognized, 6A-120VAC, 3A-240VAC	• Thermal protection, 2.5A-250VAC, 115^0C • 2.1A, 120V, 60Hz	• Metal enclosure • Plastic grill • Plastic impeller	• Motor windings separate from dead metal only through one layer of orange colored insulation
16" Stand Oscillating Fan	G	$15.78	120V-60Hz-0.75A	Push-button switch (hi-med-low-off), no listed brand or model	• Thermal protection, 115^0C 250VAC • TP.120v-60Hz-0.75A	• Metal grill • Plastic enclosure • Plastic impeller	
12" Oscillating Fan	H	$13.96	120V-60Hz-0.55A	Push-button switch (hi-med-low-off), no listed brand or model	• Thermal protection, 115^0C 250VAC • TP.120v-60Hz-0.55A	• Metal grill • Plastic enclosure • Plastic impeller	

Table 2 – IDIs Involving Power Supply Cord

IDI	Incident Date	Type	Fan Age	Injury/ Death	Synopsis
900514CCC3423	04/26/90	16"-Oscillating	7 years	No	The plug of fan power cord was somewhat damaged. This caused the fan cord to short, and ignited a curtain.
900712CCC1548	07/03/90	Circulator (round shape)		84-year old female died	The fan power cord shorted and caused the carpet beneath it to smolder and smoke.
910508CCC1476	10/10/90	20" Box fan	2 years	2-year old female died	The insulation of the power cord was completely burned away from the fan to the receptacle.
910919CWE5013	08/21/91	Square-shape fan (box fan)	2 years	No	The consumer saw smoke coming from the side of the bed next to the wall at a point where an electric fan was plugged into an outlet. The power cord had been over stressed by being forced against the bedroom wall as the bed was shoved against the wall and caused the cord insulation to break down.
921021CCC2032	08/20/92	Oscillating	Unknown	3-year old male was electrocuted	Exposed bare wire on the power cord came in contact with an aluminum patio doorframe. The power cord had several cuts.
931027CCC1047	08/17/93	Oscillating	3-4 years	No	The fire began at point where the stress knot is positioned in the housing of the base. There was beading on the power cord conductors.
940630CCN1825	06/23/94	Oscillating	2 weeks	No	There was a break in the insulation of the power cord approximately 6 inches away from the power plug.
940726CCN2007	07/14/94	N/A	N/A	37-year old female died	The insulation of the power cord had been cut exposing both the hot and neutral conductors.
940916CCN2367	07/05/93	Box Fan	7 years	41-year old male, 33-year old male and his 12-month old twin daughters suffered burns to their feet	The carpet around and underneath the fan ignited. There was extensive arcing to the fan power supply cord.
950811CCC1917	06/19/95	N/A	10 years	No	The fan power cord overheated when it was wedged between a dresser and the wall. The rug caught fire and set fire to the dresser and other furniture.

IDI	Incident Date	Type	Fan Age	Injury/ Death	Synopsis
950906CCC2955	07/18/95	16"-Oscillating	1 year	No	The insulation of the power cord became frayed as a result of being stepped on. This caused the cord to short out and ignited the combustible materials.
950913CCC2993	07/28/95	Oscillating	20 years	No	The fan power cord overheated, shorted out, and ignited the newspaper pile underneath the fan.
950914CWE5008	08/10/95	12"-Oscillating	10-15 years	No	The power cord of the fan was frayed and shorted due to being pinched between the cabinet and the wall.
951129CCC1202	07/02/95	Box Fan	Unknown	79-year old female died	The fan was found in the center area of the burned carpet. The cord to the electric fan had overheated, ignited the carpet around the fan, and the fan was totally consumed.
960726CNE5188	08/03/95	Box Fan	1 year	No	The power supply cord was found to have beaded ends. This showed that an electrical arcing had occurred in the fan cord.
960827CCC7411	06/29/96	Window Fan	unknown	34-year, 5-year, and 3-year old females died	The fan power cord overheated, igniting combustible materials.
970616CNE5141	05/31/97	Pedestal Fan	Unknown	No	The fan cord shorted and ignited bedding materials.
980210CCC0046		20-inch Box Fan	Purchased August 1997	13-year old female died	The girl slept on the couch, which was 12 inches away from the fan in the basement. The fan cord had been burned off and showed signs of beading on the ends.
980629CCC5651	05/27/98		5-7 years		There was some evidence of the fan power cord shorting out where it was run beneath the fan housing. There was beading on the cord.
980729CNE5211	06/30/98	Floor Fan	Unknown		The fan power cord was damaged by either stepping on it or heavy boxes sitting on it. The cord overheated and ignited the cardboard boxes.
980824CMC8183	07/29/98	20-inch Box Fan	10 years	No	The metal box fan was in the attic bedroom. The homeowner saw flames on the rubber-backed area rug under the box fan. The power cord shorted out and ignited the rug under the fan.
981102HCC6040	06/13/98	Oscillating	2-3 months	Several children had minor burns	There was beading on the fan cord's conductors.

IDI	Incident Date	Type	Fan Age	Injury/ Death	Synopsis
991012CNE5309	08/30/99	Oscillating	2 months	Two females suffered smoke inhalation	There was an area where arcing had occurred between the neutral and the hot conductors of the fan cord.
990825CNE5260	08/09/99	20" Box Fan	2 1/2 years	A male had a minor burn to his finger	The fan was placed on the floor with the cord beneath it. The section of the cord that was beneath the fan was found frayed and split. This resulted in a short that ignited the carpet.
000606HCC2581	05/03/00	Box Fan	3 years	24-year old female suffered smoke inhalation, and 2nd degree burn to arm	The fan cord shorted out and ignited the clothes lying on top of the cord.
000208CNE5422	10/23/99	Oscillating Fan	Unknown	No	Fan cord overheated and ignited combustible materials.
000711HCC2662	06/16/00	16" Pedestal Oscillating	2 years	No	The fan power cord was wrapped tightly around the stand. The cord overheated, dropped onto the carpet, and ignited the carpet and clothes on the bedroom floor.
000713HCC2672	08/03/99	Pedestal Fan	Unknown	No	The fan power cord was wrapped around the fan's leg, so it was resting on the cord. The cord had shorted and caused the fire.
000713HCC0827	09/28/99	Box Fan	8-9 years	62-year female sustained burns to her face, chest, arm, and smoke inhalation	There was evidence of an electric short in the fan cord.
001011HCC2027	08/26/00	Box Fan	Unknown	No	The cord probably was crimped by something sitting on it and caused the fire.
001227CNE5992	12/23/00	Box Fan	6 month	A female and a male sustained minor burns, and smoke inhalation	The consumer's son saw the sparks and fire from the power cord.
010323HCN0448	03/22/01	Oscillating Fan	Unknown	No	The power cord was crimped by something that was placed on it and overheated to the point of catching the drop cloth on fire.

Table 3 – IDIs Involving Cords Connecting Motor and Base of Oscillating Fans

IDI	Incident Date	Type	Fan Age	Injury/ Death	Synopsis
930910CWE7045	08/24/93	7"-Oscillating	Unknown	No	Three wires entering moving part of the oscillating fan became bare and short-circuited.
930916CCC1552	06/12/93	12"-Oscillating	2 years	No	The consumer noticed that the metal oscillating bar wore away the insulation of the electrical wire that connected to the motor.
931020CWE7122	09/30/93	12"-Oscillating Fan	2 Years	No	There was a burn mark at the point where the wires enter the moving part of the oscillating fan.
950705CCN2388	06/27/95	Oscillating	Unknown	No	The cord that connects to the fan motor was partially cut and arced.
951012CCC1087	07/14/95	Oscillating	Unknown	44-year old female died	There was 3-4 inches of beading on the conductors of the power cord where connected to the motor.
960730CWE5015	06/10/96	12"-Oscillating Fan	1 year	No	The cord that connected to the motor (where the fan oscillated) was cut.
980708CCC2683	06/22/98	12"-Oscillating	2 years	No	The metal arm of the oscillating fan rubbed off the insulation of the wire. This caused sparking and arcing.
990726CCC2560	07/05/99	12" Oscillating	1 year	A female had severe electric shock	While standing on the metal furnace grill in the floor, with one hand holding the fan plug, the other hand touching the back of the fan, the consumer received a severe electric shock, burning her finger. The source of the shock was attributed to damaged wiring (near the oscillating area).
000720HCC0839	05/11/00	Pedestal oscillating Fan	2 months	No	The fan revealed evidence of pinching and abrading of the wires that connected to the fan motor. The wiring rubbed against the metal fan motor and the plastic fan motor housing when it was oscillating. Arcing occurred and ignited the plastic motor housing.

Tab A

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: May 28, 2002

TO : Anna Luo, ES
Project Manager, Portable Electric Fan Project

THROUGH: Sue Ahmed, Ph.D., AED
Directorate for Epidemiology
Russell Roegner, Ph.D., Director
Hazard Analysis Division, EP

FROM : Prowpit Adler, Statistician, EPHA

SUBJECT : Final Report on Portable Electric Fans – Fires

An estimated 20,000 residential structure fires (excluding incendiary and suspicious fires) associated with all electric fans, were attended by fire departments from 1990 through 1998. These fires resulted in an estimated 920 civilian injuries, 100 civilian deaths, and $228 million in property loss. By using methods consistent with those used to estimate losses associated with all electric fans, the Directorate for Epidemiology estimated that, between 1990 and 1998, about 4,500 (23 percent) of these fires were associated with portable electric fans. These fire incidents related to portable fans resulted in about 270 civilian injuries, more than 20 deaths, and about $55 million property loss in the United States during this time period (Table 1) [1].

The voluntary standard for fans (UL 507) generally recognizes some of the more obvious failure modes of portable fans (i.e. stalled motor, power cord insulation, switch endurance, etc.) and addresses these with performance tests. However, the standard does not account for all reasonably foreseeable failure modes, contributing factors and use patterns. In order to obtain this information, CPSC staff reviewed all 255 follow-up investigations of portable fan related incidents[2] (out of the total reported 506 incidents between January 1, 1990 and April 12, 2001). Two hundred forty three of these incidents were associated with structure fires, potential fires[3], electrocutions, electric shocks, or electrical hazards. The remaining 12 incidents involved hazards from the fan blades coming apart or loose. Since the emphasis in this memo is on fires, potential fires, electrocutions, electric shocks, and electrical hazard, only information from the 243 incidents was used. This information and the results of limited testing of portable fans by CPSC engineering staff will be used to make recommendations for upgrading the voluntary standard for fans, UL 507.

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[1] CPSC, Directorate for Epidemiology, Hazard Analysis Division, U.S. Fire Administration/NFIRS, and the National Fire Protection Association (NFPA).
[2] While they are not a statistical sample of all incidents that may have occurred between January 1990 and April 2001, they provide useful information on the incident scenarios and fan characteristics.
[3] Smoke, sparks, or burning odor.

Table 1
Estimated Residential Structure Fires, Deaths, Injuries, and Property Loss
Associated with Portable Electric Fans
1990-1998

Year	Fire Estimates[4]	Death Estimates[5]	Injury Estimates[6]	Loss Estimates
1990	500	*	30	$4.0 million
1991	600	10	40	$9.2 million
1992	500	*	30	$4.3 million
1993	500	10	40	$4.2 million
1994	500	*	30	$6.5 million
1995	400	*	20	$5.4 million
1996	400	*	20	$4.4 million
1997	500	*	30	$8.6 million
1998	600	*	30	$8.6 million
Total	**4,500**		**270**	**$55.2 million**

Source: U.S. Consumer Product Safety Commission, EPHA, U.S. Fire Administration, and NFPA.

Product Description

A portable fan is a cord-connected appliance capable of being easily moved by hand from place to place. Portable fans consist of box fans, window box fans, dual window fans, window fans, desk/table fans, pedestal/floor fans, clip-on fans, and hassock fans. Based on 243 incidents, information concerning fan type, failure mode, fan age, fan material, manufacturer and safety standard, and incident scenario is presented in Table 2 through Table 10.

Fan Type.

Based on a review of 243 portable fan-related incidents, five hazards were identified as follows: (1) fire (210 incidents), (2) potential fire (16 incidents), (3) electrocution (12 incidents), (4) electric shock (3 incidents), and (5) electrical hazard (2 incidents). Box fans, desk/table fans, and pedestal/floor fans were involved in about 65 percent of the total incidents. The distribution of portable fans classified by the hazards is presented in Table 2.

[4] Rounded to nearest 100.
[5] Rounded to nearest 10 and * denotes the estimate is less than 5.
[6] Rounded to nearest 10.

Table 2
Distribution of Portable Fans Classified by Hazards
January 1, 1990 – April 12, 2001

Fan Type	Total	Hazard
Box Fans	**67**	Fire (61), Potential Fire(3), Electrocution (1), Electrical Hazard (2)
Desk/Table Fans	**47**	Fire (39), Potential Fire (6), Electrocution (1), Electrical Shock (1)
Pedestal/Floor Fans	**45**	Fire (32), Potential Fire (4), Electrocution (8), Electrical Shock (1)
Window Fans	**22**	Fire (20), Electrocution (1), Electrical Shock (1)
Dual Window Fans	**16**	Fire (15), Potential Fire (1)
Window box Fans	**8**	Fire (8)
Clip-On Fans	**7**	Fire (6), Potential Fire (1)
Antique Small Fans	**1**	Fire (1)
Hassock Fans	**1**	Fire (1)
Portable Fans[7](Not Specified)	**18**	Fire (17), Potential Fire (1)
Electric Fans[8] (Not Specified)	**10**	Fire (9), Electrocution (1)
Electrical Product[9]	**1**	Fire (1)
Total	**243**	**Fire (210), Potential Fire (16), Electrocution (12), Electrical Shock (3), Electrical Hazard (2)**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Injury and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

Failure Modes

Based on a review of 243 portable fan-related incidents, the failure modes associated with portable fans which resulted in fires, potential fires, electrocutions, electric shocks, or electrical hazards were motors, power appliance cords, or switches (Table 3). The problems of a failed motor (110 incidents), a failed appliance cord (63 incidents), or a failed switch (8 incidents) were identified as follows:

(1) One hundred ten motor-related incidents occurred when a motor was overheated because the fan blade ceased to turn (28), a motor seized up and was overheated (55), or a motor was reported to have a wiring problem or to have a short circuit (27).
(2) Sixty-three appliance cord related-incidents occurred when a cord had a short circuit or an insulation breakdown (33), the fan oscillating motion caused a sharp edge on the fan to rub off the cord insulation (9), or a cord had been repaired/replaced by owners or attached to an extension cord (21).
(3) Eight switch-related incidents were associated with electrical fault in a switch (5) or bare/damaged switch wires (3).

[7] The type of these portable fans could not be determined because of severe fire damage.
[8] Could not determine if the fans were portable because the damage was total.
[9] Could not determine if the incident was related to the fan.

Table 3
Distribution of Failure Modes Classified by Hazard
January 1, 1990 – April 12, 2001

Failure Mode	**Total**	**Hazard**				
		Fire	Potential Fire	Electrocution	Electrical Shock	Electrical Hazard
Motor	**110**					
1. Overheated/Blade Blocked[10]		27	1	0	0	0
2. Overheated/Seized Up		49	6	0	0	0
3. Wiring/Shorted Out		25	2	0	0	0
Appliance Fan Cord	**63**					
1.Cord Failed[11]		31	0	2	0	0
2.Oscillating Motion		3	5	0	1	0
3.Repaired/Replaced/ Extension Cord		17	0	4	0	0
Switch	**8**					
1. Electrical Fault		5	0	0	0	0
2. Bare/Damaged Wire		0	0	1	1	1
Undetermined	**62**	53	2	5	1	1
Total	**243**	**210**	**16**	**12**	**3**	**2**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Injury and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

Failed motors occurred most often in a box fan (35 incidents), a desk/table fan (23 incidents), and a pedestal/floor fan (13 incidents); the remaining 39 incidents of failed motors were attributed to other portable fans (such as antique fans, clip-on fans, dual window fans, window fans, window box fans, etc.). Failed cords occurred most often in a desk/table fan (11 incidents), a box fan (10 incidents), and a pedestal/floor fan (7 incidents); the remaining 5 failed-cord incidents were to a dual window fan, a window fan, a window box fan, or a not specified electric fan. Failed switches occurred in a dual window fan (4 incidents), a pedestal/floor fan (3 incidents), and a box fan (1 incident).

[10] When the fans fell from furniture or were jammed by curtains, bedding, etc.
[11] From shorting out, braking down of insulation, being stepped on, being wedged between objects, etc.

Fan Age

According to trade experts as reported in *Appliance,* a trade publication, average life expectancy of an electric fan is 12 years. This is considered "first use", after which the product may be replaced, given away, or discarded[12].

Based on a review of 243 portable fan-related incidents, 113 incidents involved a fan that was less than 10 years old while 47 incidents involved a fan that was 10 years or older, and the remaining 83 incidents had no information on the ages of the fans (Table 4). Further review of the 243 incidents indicated that almost half of the involved fans had been purchased new or had been considered as the "first use".

Table 4
Distribution of Portable Fans
Classified by Fan Type and Fan Age
January 1, 1990-April 12, 2001

Portable Fan	**Fan Age**				
	< 1 yr.	**1yr.≤Age<5 yrs.**	**5yrs.≤Age<10 yrs.**	**≥10 yrs.[13]**	**Unk**
Box Fan	15	11	5	13	23
Desk/Table Fan	7	17	9	4	11
Pedestal/Floor Fan	5	15	4	11	10
Window Fan	1	2	1	11	7
Dual Window Fan	5	7	0	1	2
Window Box Fan	0	2	1	2	3
Clip-On Fan	1	2	0	1	3
Antique Small Fan	0	0	0	1	0
Hassock Fan	0	0	0	1	0
Portable Fan (Not Specified)	1	2	0	2	13
Electric Fan (Not Specified)	0	0	0	0	10
Electrical Product	0	0	0	0	1
Total	**35**	**58**	**20**	**47**	**83**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Injury and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

Fan Materials

In general, the contributing factor to the portable fan related fires or potential fires was the presence of plastic materials. When a fan with plastic blades, motor housing, or enclosure overheats or catches on fire, the plastic usually melts, and drips onto combustible materials such as carpet, clothing, bedding, paper, etc. Table 5 shows that of the 226 fires or potential fires, 174 of these incidents (or 3 out of every 4 incidents) were related to a fan with the presence of plastic materials.

[12] Karels, Terrance R., CPSC, Directorate for Economic Analysis, "Electric Fans", Memorandum to Anna L. Luo, November 29, 2000.
[13] Included older type fans or very old fans.

Table 5
Distribution of Hazards Associated with Portable Fans
Classified by Fan Materials
January 1, 1990 – April 12, 2001

Hazard	**Fan Material**				
	Total	**Plastic & Metal**	**Plastic**	**Metal**	**Unknown**
Fire	**210**	124	37	13	36
Potential Fire	**16**	7	6	0	3
Electrocution	**12**	2	2[14]	7[15]	1
Electrical Shock	**3**	1	0	2	0
Electrical Hazard	**2**	1	1	0	0
Total	**243**	**135**	**46**	**22**	**40**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Injury and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

Manufacturers and UL Listed[16]

The Association of Home Appliance Manufacturers (AHAM) stated that six member firms account for 75 percent or more of sales of portable fans in the U.S. market. These firms produce portable fans under a variety of brands[17]. AHAM reported that the major U.S. manufacturers also produce portable fans in overseas facilities, or purchase fans produced by overseas firms. According to AHAM, imported portable fans represent more than 75 percent of all portable fans sold in the U.S., and China is the major exporting country of these products[18].

Loss of information on the characteristics of the fans or cords most often occurred when the fans or cords were completely destroyed or discarded by the fire departments or by the owners. Based on a review of 243 portable fan-related incidents, the manufacturer or the brand of the involved fans could be identified in only 104 incidents. Information concerning safety standards on the fans, cords, or plugs was also very limited. For example, only 63 involved fans or cords were identified as UL Listed; and only 89 involved fans were identified as equipped with a cord with a 2-prong plug (37 fans), a 2-prong polarized plug (39 fans), or a 3-prong grounded plug (13 fans).

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[14] One case involved a fan with plastic blades (the other parts were unknown)
[15] Two cases involved a fan with metal stand (the other parts were unknown)
[16] UL Standard for Safety for Electric Fans, UL 507.
[17] The market distribution of these brands is not available according to the Directorate for Economic Analysis.
[18] Karels, Terrance R., CPSC, Directorate for Economic Analysis, "Electric Fans", Memorandum to Anna L. Luo, November 29, 2000.

Information concerning the incident scenarios such as (1) the dwelling types, (2) the presence or absence of safety devices (smoke alarms, fire alarms, or sprinklers), (3) the rooms where the incidents occurred, (4) the fan locations[19] at the time of the incidents, and (5) the previous problems prior to the incidents are summarized in the following tables.

Dwellings

Table 6
Distribution of Dwellings
January 1, 1990 – April 12, 2001

Dwelling Type	Number of Incidents
Single Family Home	139
Apartment, Duplex, Townhouse, Condominium	53
Mobile Home/Motor Home	23
Place of Business	19
Boat, Dormitory, or Low-Income Housing	4
Not Stated	5
Total	**243**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Injury and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

Safety Fire Devices (in the Dwellings)

Table 7
Distribution of Safety Fire Devices
January 1, 1990 – April 12, 2001

Safety Device	Number of Incidents
Operating Smoke Detectors/Fire Alarms/Sprinklers	66
No Smoke Detectors/Alarms/Sprinklers or Not Operating Detectors/Alarms/Sprinklers	66
Unknown if Detectors/Alarms/Sprinklers Worked	18
Not Stated or Not Available[20]	93
Total	**243**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Injury and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

[19] On the floor, on top of a chair, a table, a dresser, a bed, or in a window.
[20] Safety system is not available in the case of potential fire, electrocution, electrical shock, or electrical hazard.

Rooms of the Incidents

Table 8
Distribution of Rooms of the Incidents
January 1, 1990 – April 12, 2001

Room	Number of Incidents
Bedroom	126
Living Room or Family Room	40
Office	18
Kitchen	12
Basement	7
Attic (living areas)	5
Dining Room	4
Bathroom	2
Hallway	1
Other (computer room, porch, deck, garage, etc.)	12
Not Stated	16
Total	**243**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Injury and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

Fan Placement

Location of the fan played a very significant part in the fire incidents. An overheated fan on top of a carpeted floor or on a pile of papers/clothing would ignite these combustible objects. A fan mounted in a window or on a window sill with curtains or a window blind could cause a fan motor to stall (from jamming curtains or a blind in the fan blades). Placing an unstable fan on a table/desk or clipped to a desk or to a foot board of a bed could cause the fan to fall face down and stop the oscillating function of the fan. The distribution of the incidents by placement of the involved fans is presented in Table 9.

Table 9
Distribution of Fan Placements
January 1, 1990 – April 12, 2001

Placement	Number of Incidents
In the Window or Window Sill	54
On Vinyl Floor, Floor (Not Specified)	50
On Carpeted Floor	43
On Top of Piles of Papers/Clothing	39
On Top of Table/Desk/Chair	24
Clipped on Desk/Bed, Hung in Attic	10
Not Stated	23
Total	**243**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

Previous Problems

Table 10
Distribution of Previous Problems
January 1, 1990 – April 12, 2001

Previous Problem	Number of Incidents
No Previous Problems	90
Trouble Getting Fan Blade Moving	12
Cord/Plug/Switch Not Properly Function	15
Emitting Odor/Smoke/Flames/Humming Noise	12
Fan Had Been Repaired	8
Short Circuit when Oscillating	2
Problems (not specified)	5
Not Stated	99
Total	**243**

Source: U.S. Consumer Product Safety Commission (CPSC), Death Certificate and Injury and Potential Injury Incident Files, Directorate for Epidemiology, Hazard Analysis Division.

Conclusion

An estimated 4,500 of the residential structure fires attended by fire departments from 1990 through 1998 were associated with portable electric fans. These fires resulted in about 270 civilian injuries, more than 20 deaths, and about $55 million in property loss. Based on 243 follow-up investigations of portable fan-related incidents, fire was the major hazard and accounted for about 80 percent of the total incidents. About half of the fire incidents occurred in a single-family home and most often in a bedroom. An overheated fan on top of a carpeted floor or on a pile of papers or clothing would ignite this combustible object, especially for fans with plastic material where the plastic melts and drips on the object.

The failure modes associated with the portable fan-related hazards were the fan motors, powered appliance cords, or switches. The motors failed when they were overheated (because the blades jammed or the motors seized up) or when there were problems with the wiring and the fans shorted out. The appliance fan cords failed when a cord had a short circuit or an insulation breakdown; the oscillating motion caused a sharp edge on the fan to rub off the cord insulation; or when the cords were crushed, damaged, exposed, repaired, or attached to an extension cord. The switches failed when there was an electrical fault in the switches or when the switch wires were bare or damaged.

Box fans, desk/table fans, and pedestal/floor fans were involved in over half of the total incidents.

Tab B

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: November 29, 2000

TO : Anna L. Luo, ESEE

THROUGH : Warren J. Prunella, AED, EC

FROM : Terrance R. Karels, EC

SUBJECT : Electric Fans

This memo provides some market information on portable household fans. The CPSC staff is conducting an evaluation of the industry voluntary standard, UL 507 Electric Fans.

ISSUE:

From 1990 through 1998, there were an estimated 4,500 fires, resulting in 20 deaths, associated with portable electric fans. Because of these losses, staff is evaluating the effectiveness of the standard to address reasonably foreseeable failure modes, and contributing factors. The staff will then recommend improvements to the standard as warranted.

MANUFACTURERS:

The Association of Home Appliance Manufacturers (AHAM, located in Washington, DC) is the trade group that represents manufacturers of household electric fans. A spokesperson for AHAM stated that 6 member firms account for 75% or more US sales of portable electric fans. These firms produce consumer electric products under a variety of brands.

The US Bureau of the Census classifies electric fans in the Standard Industrial Classification (SIC) under product code 36341, "Electrical Fans (except industrial). " It reported that in 1995 (the latest year for which the "Electric Housewares and Fans" report -- MA36E -- is available), 19 companies produced electric fans in the US under this classification. Of these, 6 companies produced "Household window fans, permanent, portable, or roll-abouts," and 6 produced "Ceiling fans." For the "All other" category, 14 producers were listed. The "All other" category included range hood fans, oven fans, ventilating and exhaust fans, and desk and wall bracket fans. Some firms that produce a specific type of fans also produce fans in other categories.

INTERNATIONAL TRADE:

The *Harmonized System* (a numerical classification of imports and exports) classifies electric fans under code 8414.51, which includes a large number of fans other than portable fans (see products in SIC classification, above). Thus, official US import and export statistics for portable electric fans are not available.

AHAM, the trade association, reported that the major US manufacturers also produce portable electric fans in overseas facilities, or purchase fans produced by other overseas firms to specifications.

According to AHAM, imports represent more that 75% of all portable electric fans sold in the US. China is the major exporting country of these products to the US, and accounts for the bulk of total US imports of portable electric fans.

According to US government statistics under the *Harmonized System*, exports of domestically-produced portable electric fans are reported to be negligible.

SALES:

Appliance, a trade publication, conducts annual surveys of manufacturers of home comfort conditioning appliances. Prior to 1998, that firm listed shipments of fans, for the following types: Ceiling, Desk, Floor, Stand-type, Window, and Other. However, in 1998, Appliance stopped reporting sales, by type, except for ceiling fans. Following are shipment data for portable electric fans, excluding ceiling fans, for selected recent years:

Annual Portable Electric Fan Shipments, By Type

Year	1990	1992	1994	1996	1997
Type		Shipments (In Millions)			
Desk	4.0	3.6	4.2	4.5	4.3
Floor	4.3	4.9	5.2	5.2	5.0
Stand-Type	3.8	4.8	5.5	5.1	5.1
Window	1.3	1.4	2.1	2.0	1.9
Other[1]	3.7	3.3	3.1	2.7	2.6
Total	17.1	18.0	20.1	19.5	18.9

Source: **Appliance**, various issues

Based on the above table, it appears that sales of portable electric fans have been in the range of 17 million to 20 million per year during the 1990s. Significantly, **Appliance** also estimates that about 13 million of these fans would be sold yearly just for the replacement market; that is, to replace existing fans that have been taken out of use. The remaining 4-7 million units then would be expected to be sold to augment existing fans, and for use in new household formations.

USE:

Appliance noted in 2000, that 81.5 percent of all households in the US had at least one electric fan (not including ceiling fans). Thus, with about 105 million households in the US, some 86 million households are likely to have one or more portable household fans in use.

[1] May include permanent fans, as per the SIC code 36341

According to trade experts, as reported in **Appliance**, the average life expectancy of fans (excluding ceiling fans) is 12 years. This is considered "first use," after which the product may be replaced and the fans may be given away or discarded.

As noted above, industry statistics on electric fans are not complete. However, based upon a useful life of 12 years and annual sales of 17 to 20 million units, there would be on the order of 200-240 million portable electric fans in use in US households.

Tab C

United States

CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM February 27, 2003

To	**:**	Anna Luo, ESEE
Through	**:**	Andrew Stadnik, Associate Executive Director for Laboratory Sciences
Through	**:**	Edward Krawiec, Director, LSE
From	**:**	Ted Gordon, LSE

Subject **:** Test Report on Portable Electric Fans

PURPOSE

This report conveys results of the laboratory's testing of portable electric fans. The testing focused on trying to better understand how fans fail in the field and how they perform against selected safety-standard requirements.

BACKGROUND

There were an estimated 4,500 fires associated with portable electric fans from 1990 through 1998. These fires resulted in more than 20 deaths, 270 injuries, and about $55 million in property loss. CPSC began a project in FY 2000 to judge the fire hazard associated with portable fans, and in particular to assess: (1) if Underwriters Laboratories standards address foreseeable hazards and (2) if the collected fans, listed by UL, do in fact meet selected UL requirements.

INTRODUCTION

UL evaluates fans under its standard UL 507, *Standard for Electric Fans.* UL evaluates certain parts of the fan by other standards, for example, UL 2111, *Overheating Protection for Motors,* and UL 746C, *Polymeric Materials—Use in Electrical Equipment Evaluations*. First published in 1935, UL 507 has been revised eight times, most recently in December 1999 and presently includes revisions through September 2001.

OBJECTIVE

Recent investigation reports on portable fans indicate "shorts" and "failing motors" as sources of fires, but details are limited. Often the fire consumes the evidence as to how the fan ignited. Sometimes the fan is discarded and never examined at all. This study is intended to uncover more detail and in particular to learn: (1) if fans with their rotors locked overheat beyond the limits that UL 2111 allows and (2) if a pattern of failure exists among incident samples.

TEST SAMPLES

Fans for testing were selected based on the brand names the investigation reports cited most often. From among those brands, ES staff selected inexpensive models from store shelves. There was no attempt to balance the number of samples between the two motor types found in portable electric fans: thermally protected and impedance-protected. Identifying the type would be hard to do in the store. Only after the fans were disassembled could the type be determined. The type is identified by markings on the motor: ZP for impedance-protected or TP for thermally protected. (Some with no markings had a thermal device in view.)

Thermally protected motors have a thermal device—often a thermal cutoff (called a TCO)—mounted against the motor windings. The TCO senses an overheating winding, melts at a preset temperature, and leaves the fan disabled. By contrast, impedance-protected motors rely on the inductive reactance of the coiled winding. When the rotor is locked, the reactance impedes the current, which would otherwise tend to climb. The winding itself limits current and temperature.

In two models, the motors are impedance-protected; in six others, thermally protected. (They are encoded for anonymity.)

Make and Model	Type of Motor	Style
Fan A	Thermally protected	Dual window fan
Fan B	Impedance-protected	Desk fan
Fan C	Thermally protected	Box fan
Fan D	Thermally protected	Oscillating desk fan
Fan E	Impedance-protected	Dual window fan
Fan F	Thermally protected	Box fan
Fan G	Thermally protected	16-inch oscillating fan
Fan H	Thermally protected	12-inch oscillating fan

Table 1 – List of Store-Bought Fans

In addition to new fans, the staff examined fans, collected by CPSC investigators, that were implicated in fire incidents. We examined these to learn the reason that the fires began.

TEST PROCEDURES

For thermally-protected motors, UL 2111 calls for a locked-rotor test lasting until the thermal device intervenes. For impedance-protected motors, UL 2111 calls for a locked-rotor test of 72 hours, followed by a dielectric breakdown test, followed then by 15 days of a locked-rotor endurance test. Here, our study deviated somewhat from the UL requirements. The dielectric breakdown test was not conducted to avoid potential damage to a fan motor that would prevent long-term testing. Instead, the 15-day endurance test was extended to 20 days.

For thermally protected motors—a thermocouple was placed against the motor winding. Per

UL 2111 the rotor was locked, the fan energized at line voltage, and the time recorded until the device opened the circuit.

For impedance-protected motors—those in fans B and E—a thermocouple was placed against the motor winding, the rotor locked, and the temperature recorded for 72 hours. Two others of the same models were put through a locked-rotor test lasting 15 days, and beyond.

A Fluke 52II digital thermometer, used with type K thermocouples, displayed the temperatures. A thermocouple was placed against the outer turns of the winding at a convenient spot.

LOCKED ROTOR TEST RESULTS

Thermally Protected Motors: UL 2111 (section 14) requires that thermally protected motors be locked and that temperature on the winding must not exceed the values specified in Table 14.1. The table lists a temperature limit of 200º C, which corresponds to a motor that uses Class-A insulation.[1] The winding temperature must not exceed 200º C during the first hour. After that, the winding temperature must not exceed 150º C.

Besides limiting temperature rises, UL 2111 requires (1) that no part ignite or generate prolonged smoking and (2) that insulation survive the test without having charred or become brittle, and (3) that no component of the fan malfunction.

Results are in Table 2. The TCOs opened in all cases, long before the hour and before the winding temperature rose much beyond 100º C. All the fans passed.

Make and Model	Time for TCO to Trip	Final Temperature on Winding, º C
Fan A	about 22 minutes	91.6
Fan C	4 minutes, 17 seconds	135.5
Fan D	18 minutes, 50 seconds	99.8
Fan F	5 minutes, 8 seconds	72.0
Fan G	18 minutes, 58 seconds	73.5
Fan H	17 minutes, 45 seconds	100.5

Table 2 – Results of Locked Rotor Test on Thermally Protected Motors

[1] The motors in all the sample fans use Class-A insulation. The class refers to the highest allowable operating temperature of the insulation in the motor. UL recognizes four classes of insulation: A, B, F and H. For thermally protected motors, UL limits the operating temperature of Class A insulation to 200° C. Classes B is limited to 225° C, Class F to 250°C, and Class H to 275°C. For impedance-protected motors, temperatures are lower, class by class.

Figures 1 – 6, below, plot the results of the locked-rotor test, fan by fan. The plots show motor-winding temperature versus time.

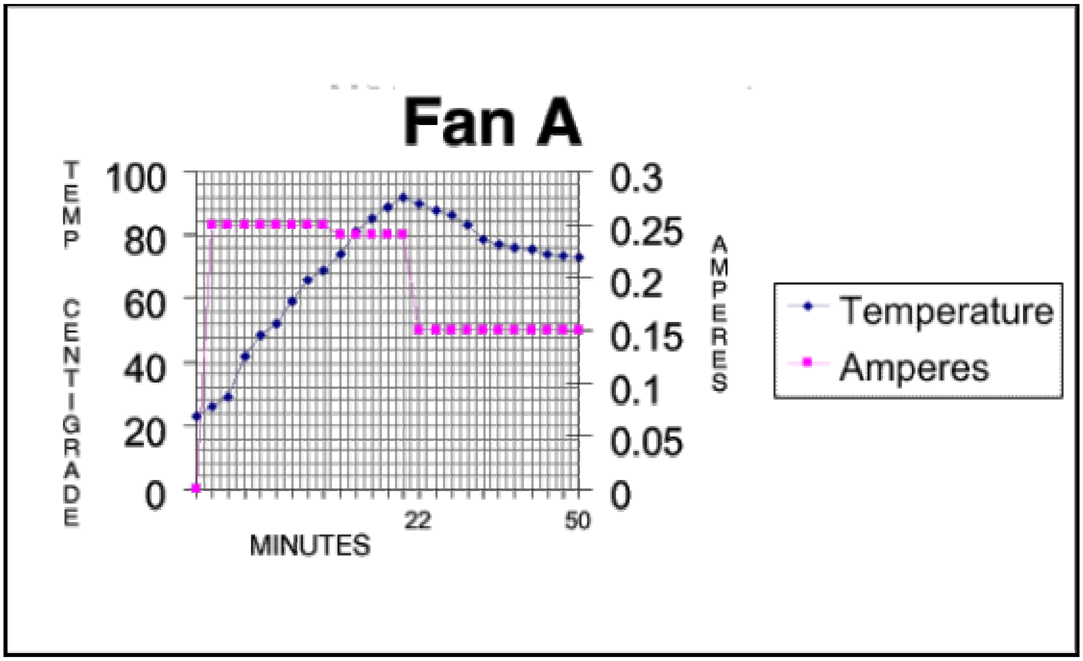

Figure 1 – Results of Locked Rotor Test.

Note: Fan A is thermally protected. It has a TCO, rated 115º C. But the fan behaved differently than the others. When the TCO opened, the motor stopped, the winding began to cool, and current dropped abruptly—but not to zero. It dropped to 0.15 amperes and continued to flow. The reason lies in the circuitry—there is a path to neutral. It goes from the winding through the starting capacitor. Two weeks later, the rotor still locked, the current remained steady at around 0.15 amperes and the temperature on the winding hovered around 50º C. It passed.

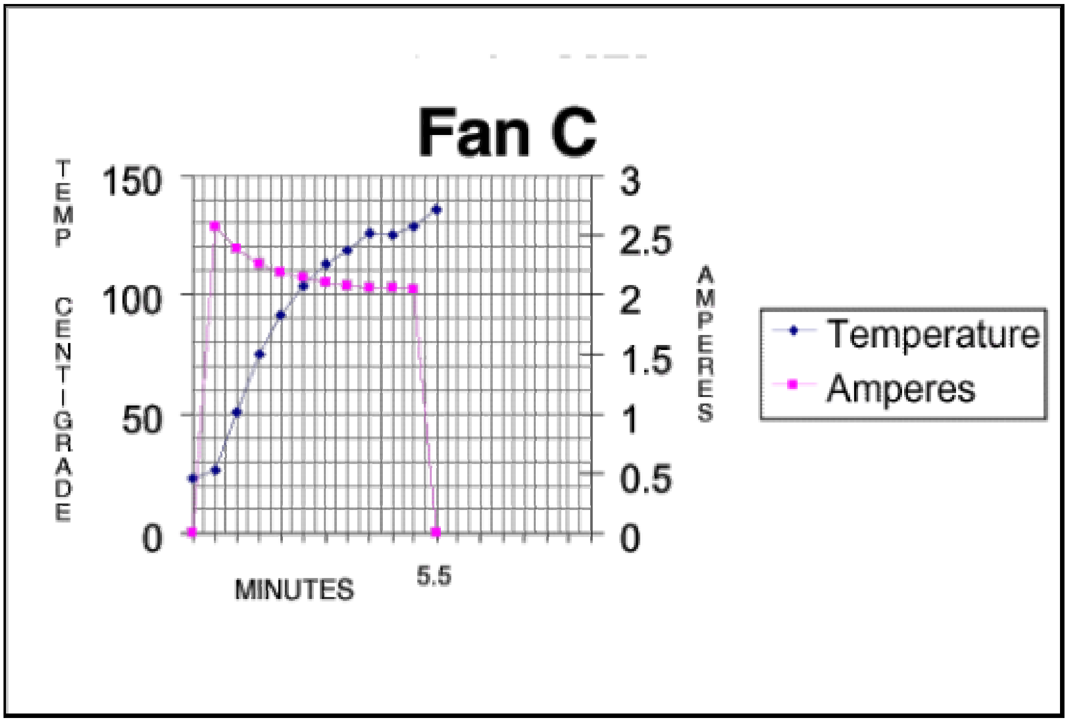

Figure 2 – Locked Rotor Test.

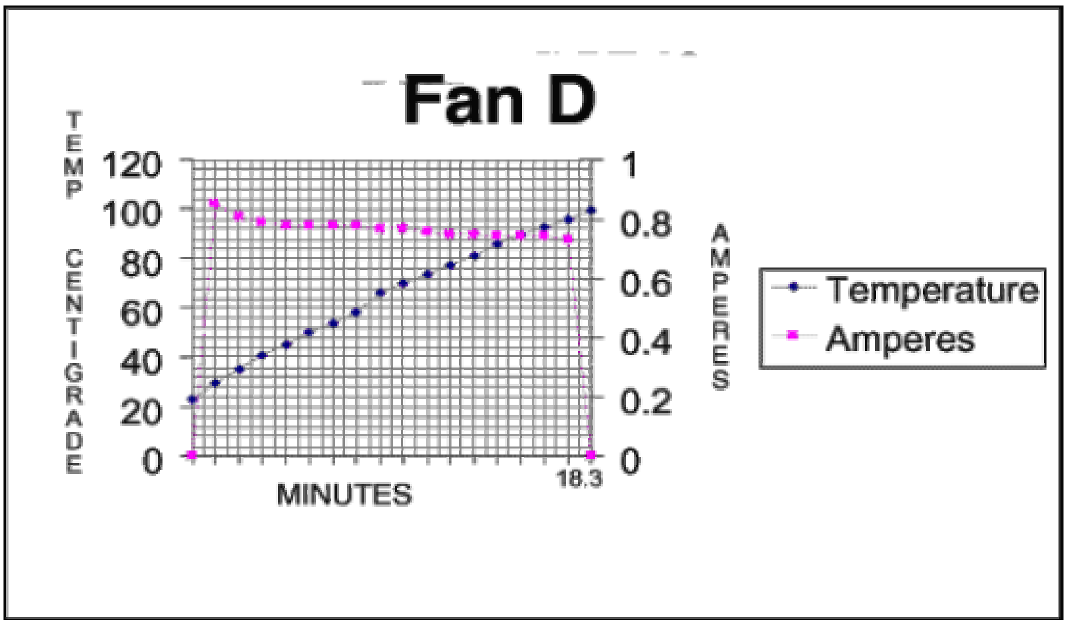

Figure 3 – Locked Rotor Test.

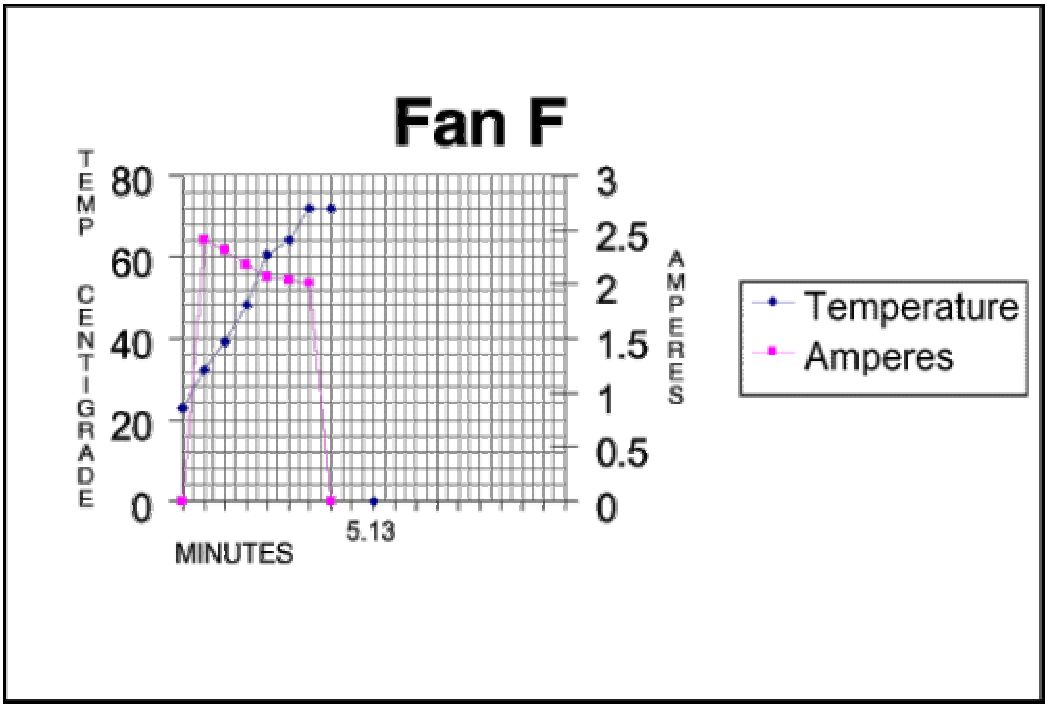

Figure 4 – Locked Rotor Test

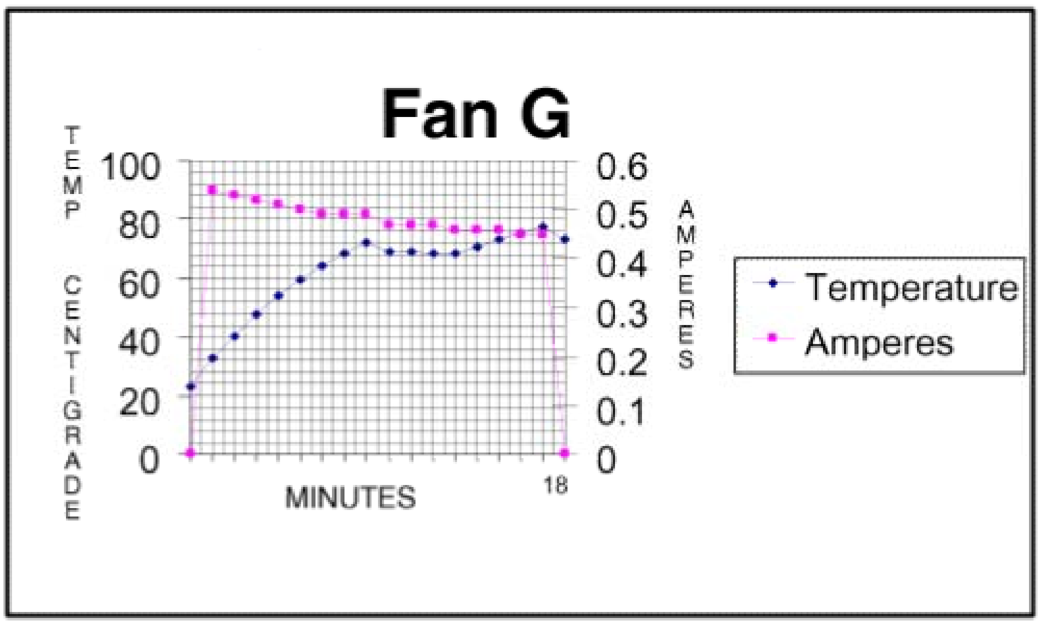

Figure 5 – Locked Rotor Test

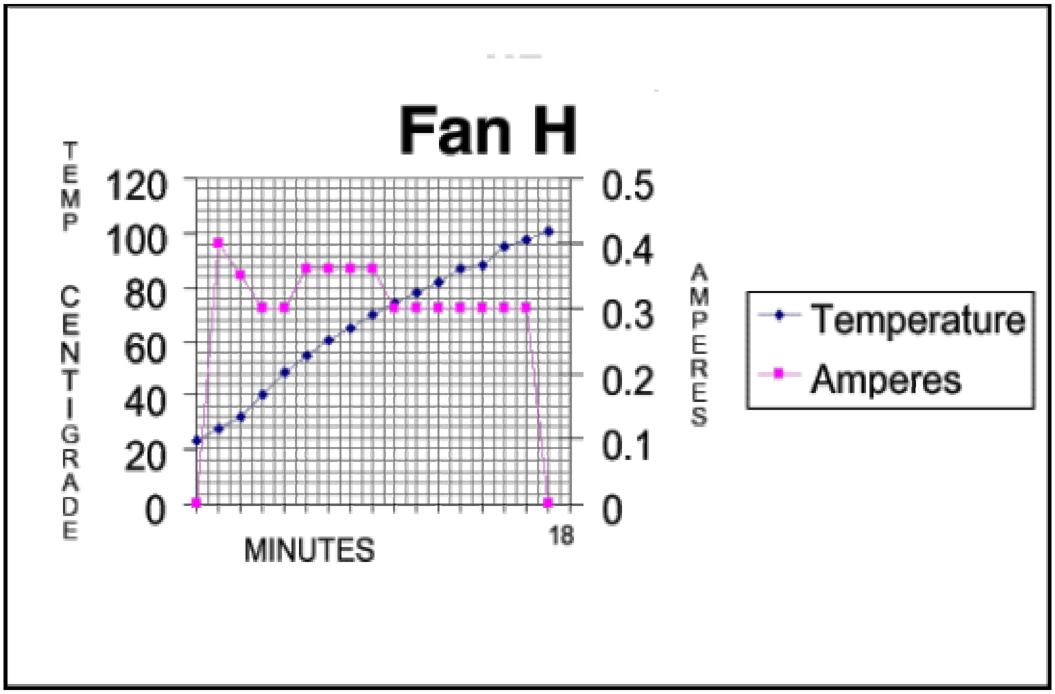

Figure 6 – Locked Rotor Test

Impedance-Protected Motors*:* In impedance-protected motors (in fans B and E), current is limited by the winding's impedance. When the rotor is locked restrained current flows indefinitely, so in principle there is no need for a thermal device to interrupt power. For impedance-protected motors, UL 2111 calls for monitoring the winding temperature for 72 hours. In that time, according to Table 7.1, the temperature on a winding having Class-A insulation must not go higher than 150º C.

Testing was done in the lab's burn room, where the 72-hour test can safely be left unattended. The room is unheated, except for a portable space heater. Plus, the tests were done in the winter, making room temperature fluctuate between 13º C and 19º C. UL specifies an ambient temperature of 25° C. The colder room likely skewed temperature readings on the windings.

Fan B, With Impedance-Protected Motor: Fan B is a small desk fan. With its switch on high and rotor locked, the current drawn by the fan leveled off at around 0.4 amperes. The winding temperature peaked at 54º C and stayed there during the 72 hours.

Fan E, with Impedance-Protected Motor: Fan E is a dual window fan. It has two fans, operated from a single switch, mounted side by side in a plastic frame. The test started out with the switch set on high and one of the rotors locked—the other was left free to spin. After 72 hours, the fans drew a total of 0.8 amperes. On the locked rotor, temperature on the winding peaked around 63º C.

A few days later, though not called for in UL 2111, the test was run for another 8 hours, during which time both rotors were locked and temperatures monitored on both windings at once. After eight hours the fan was drawing 0.83 amperes. The winding of one motor reached 103º C, and the winding of the other reached 134º C. The heat did no observable damage to either winding or other parts, and after the test both fans still operated.

Results of Longer-Term Testing: A new dual fan (Fan E) was put to a 15-day locked rotor test, along with the desk fan (Fan B) that had completed the 72-hour test. The 15-day test is required of impedance-protected motors under UL 2111, section 9. The new dual fan was tested with *both* rotors locked.

At the end of 15 days, the dual window fan was drawing 0.78 amperes. Temperature on one motor winding was at its peak of 92º C and on the other winding, at 82º C.

The desk fan was drawing 0.3 amperes at the end of 15 days, and its winding was at its peak of 55º C. The test was continued 5 days beyond what the UL standard requires. Currents and temperatures remained steady. After the test, the fans remained operational and in good condition.

INCIDENT SAMPLES

CPSC investigators supplied seven fans from the field:

1. Sample 00-860-6385 – a box fan, reportedly a source of smoke. Examined at the lab, it worked well and shows no damage.
2. Sample 00-800-2733 – an unidentified fan severely damaged. According to the IDI, it sat in an office among computer equipment. Somewhere amid the equipment a fire broke out, but an investigator collected only the remains of the fan. Its motor winding remains clean and shiny under a layer of soot—a detail that seems to rule out an overheated motor.
3. Sample 00-800-1660 – a floor fan. Reportedly it inflicted an electrical shock and later appeared as the subject of PSA 0822.00.
4. Sample 00-800-2366 – charred remains of two motors from a dual window fan. Their windings remain shiny under a coating of soot, an indication that neither motor overheated.
5. From the same household, sample 00-800-2367 – a second but undamaged dual window fan of the same model. In service for a long time, it had never malfunctioned. It was collected as an exemplary sample.

The previous five incident samples yielded no evidence that they started fires. The next two yielded ample evidence that they caught fire.

1. Sample 00-860-6500 is a box fan that carries a UL-listing mark and employs a thermally protected motor. The fan was on and began to click, the IDI report says, and flames rose from the motor. The consumer quickly unplugged the fan and the flames went out.

   The rotor still spins freely, according to our examination, but several coils of the winding are blackened throughout (photo 1). The blackening indicates a drastic rise in current and heat. The insulation broke down, not because the rotor was seized, but apparently while the fan was still turning. The TCO did open finally, but not promptly. In this case, it appears that the flames stemmed from a failure of the motor and of a TCO that responded too slowly.

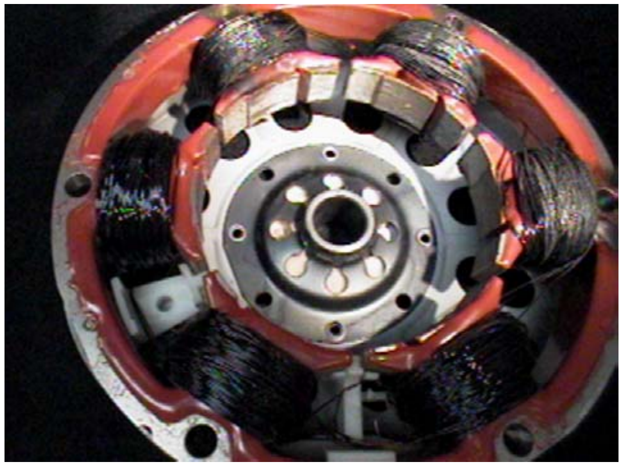

Photo 1 – Multi-winding Motor of Sample 00-860-6500, Some Windings Blackened

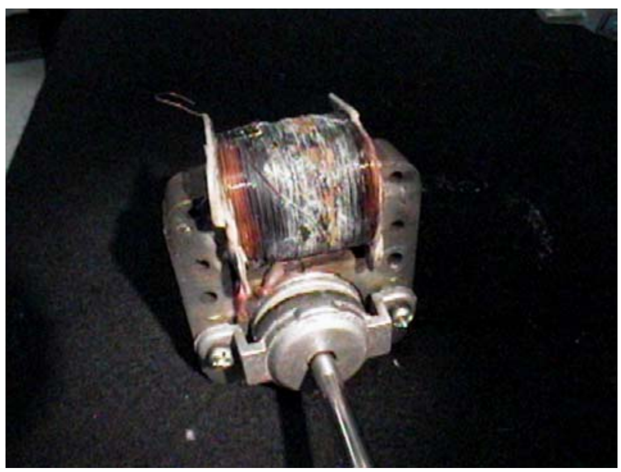

Photo 2 –Shaded-Pole Motor of Sample 00-800-1469

2. Sample 00-800-1469 (photo 2) is a dual window fan that carries a UL listing mark and employs impedance-protected motors. It ran without malfunction, the consumer reported, until a small flame erupted from around one of the motors. He was there to witness it and quickly pulled the plug. The fire apparently erupted from the winding of the right-hand motor. The winding is blackened. The tape that insulates it is charred. The winding no longer has continuity and the motor no longer works. Nothing indicates that the rotor had seized—the fan blades still spin freely. A likely conclusion is that the varnish on the winding broke down while the fan operated otherwise normally.

The dual window fan has two motors side by side, and the second still worked. It was used for testing. Run for a day, it functioned normally. The next day it was run, but with its fan blades locked. The temperature on the winding stayed below 100º C for about a half-hour then started rising. The rate of rise increased, and the winding emitted a stream of smoke. About 40 minutes into the test, the winding erupted into flames.

The dual window fan, an impedance-protected fan carrying a UL listing mark, failed the basic locked-rotor test.

CONCLUSION

The eight new fans passed the locked-rotor test of UL 2111. Among the incident samples, two failed while they were running, without any apparent drag on the rotor. One failed sample had a thermally protected motor, the other an impedance-protected motor. In either case, as the varnish broke down and temperature on the winding rose, the protection failed to keep the windings from erupting in flames.

Tab D

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

MEMORANDUM

April 18, 2003

To:	Anna L. Luo Project Manager, Portable Electric Fans Project Division of Electrical Engineering, Directorate for Engineering Sciences
Through:	Hugh M. McLaurin Associate Executive Director Directorate for Engineering Sciences
Through:	Robert B. Ochsman, Ph.D. Director, Division of Human Factors Directorate for Engineering Sciences
From:	Timothy P. Smith Engineering Psychologist, Division of Human Factors Directorate for Engineering Sciences
Subject:	Human Factors Assessment for the Portable Electric Fans Project

INTRODUCTION

From 1990 through 1998, fire departments attended approximately 20,000 residential structure fires associated with electric fans (Adler, 2002). Following a review of 243 investigated structure fire incidents reported to the U.S. Consumer Product Safety Commission (CPSC) from January 1, 1990 through April 12, 2001, staff from CPSC's Division of Hazard Analysis identified several failure modes associated with portable electric fans. One of the most common failure modes involved the power cord. This memorandum, written by staff from CPSC's Division of Human Factors (ESHF), discusses foreseeable consumer uses of the power cord that could damage the cord and lead to its failure.

DISCUSSION

Although consumers have a general understanding of electricity—for example, that it can shock you—most do not understand exactly how electrical products operate (Leonard, Griffin, & Wogalter, 1997). Additionally, most consumers' experiences with these products do not result in incident or injury. Research indicates that repeated benign exposure to products can cause consumers to underestimate their potential risks, especially if the products are very common and familiar to consumers (Sanders & McCormick, 1993, pp. 676–678; Laughery & Wogalter, 1997, p. 1176). In fact, most everyday personal risk decisions by consumers may not be a result of conscious thought processes or decisions at all; consumers are simply unaware of the dangers (Zimolong, 1997, pp. 1005–1007). In view of this, it is reasonable to assume that consumers will use electrical appliance cords in ways that are potentially hazardous and could result in failure, but that they often will not recognize what they are doing as being hazardous.

ESHF staff analyzed 33 in-depth investigations (IDIs) from 1990 through April of 2001 in which the cord of a portable electric fan may have contributed to a fire or electrocution. In many cases, the investigator identified the fundamental cause as a short circuit in the cord or fan. However, the resulting damage to the cord often made it difficult to assess possible reasons for these failures. The details of several investigations permitted HF staff to identify four general usage patterns that could have contributed to some fire incidents. Although there may be other ways in which consumers will use the fan and power cord that could lead to cord damage or failure, HF staff believes the following patterns are representative of typical consumer behavior.

1. The consumer places the fan or some other object on top of the cord.

Three known incidents involved a consumer placing the fan onto the cord.[1] This was also considered a possible cause of a separate incident,[2] and one other incident may have involved workers placing heavy boxes on the cord to a fan.[3] The latter incident took place in a restaurant and although it may not necessarily be representative of the behavior of consumers at home, it is foreseeable that portable electric fans will be used in both home and commercial environments and that power cords will be exposed to these stresses.

Ignoring the possibility of consumers intentionally damaging the cords, incidents of this type indicate that consumers either do not recognize that placing objects on the power cord is potentially risky behavior or are doing so unknowingly. In either case, this suggests that consumers may also place other items onto fan cords from time to time. The users of portable electric fans are also not necessarily restricted to adults, as one incident involving a 16-year-old demonstrates.[4] Children and adolescents will generally have even less experience and knowledge of electrical hazards than adults, which may make them more prone to placing objects onto the fan cord. In addition, the particular incident referred to immediately above occurred sometime after the child had awakened in the early morning hours and moved the fan. A consumer in this situation, regardless of his or her age, is unlikely to be fully alert and may place the fan or other object onto the cord without realizing he or she is doing so.

2. The consumer pushes furniture against a wall, pinching a cord that runs between them.

There are three known incidents in which the fan cord was pinched between the furniture and wall or between the furniture and the outlet into which the cord was plugged.[5] If consumers expect to keep the fan plugged in for long periods of time, it is foreseeable that they will run the cord behind furniture to keep it out of the way. Even if the cord is pinched, consumers may not recognize this as hazardous unless there is visible damage to the cord. Some consumers may not even realize the cord is being pinched if it occurs behind a piece of furniture that is rarely moved.

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[1] See IDI numbers 980629CCC5651, 990825CNE5260, and 000713HCC2672.
[2] See IDI number 940916CCN2367.
[3] See IDI number 980729CNE5211.
[4] See IDI number 990825CNE5260.
[5] See IDI numbers 910919CWE5013, 950811CCC1917, and 950914CWE5008.

Furthermore, in one of these incidents the fan was being used in a child's room. Like those incidents in which objects were placed on fan cords, children are less likely than adults to be aware of the risks in pinching a cord and may pinch the cord without the parent's knowledge. A separate cord-pinching incident involved a sliding door being repeatedly closed onto a fan cord.[6] However, this occurred at a bookstore rather than a home, and the unusual nature of this incident may not be representative of typical fan uses.

3. The consumer positions the fan so the cord is exposed to pedestrian traffic.

There are two known incidents in which the cord was positioned such that it could be stepped on.[7] The fire department and the insurance investigator disagree as to whether this contributed to one of these incidents,[3] but it is clear that the cord was draped across the entryway to the bedroom, which makes it likely that people would occasionally step on the cord. The other incident occurred in a restaurant, and may not represent typical usage of a fan in the home. However, as stated earlier, it is not unreasonable to expect fans to be used in restaurant environments. In addition, consumers may leave a fan cord exposed to pedestrian traffic depending on the frequency with which the fan is plugged and unplugged, the location of the electrical outlets, and the desired position of the fan. In the former incident,[3] the fan was placed at the end of the bed. Given the position of the electrical outlet into which the fan was plugged, this placement of the fan would make it difficult to keep the cord out of the flow of traffic passing in and out of the room.

4. The consumer exposes the cord to damage during storage.

There are two known incidents in which excess lengths of cord were wrapped around the stand or legs of the fan.[8] HF staff presumes that this was done to limit the amount of excess cord lying on the floor, thereby limiting its exposure to pedestrian traffic or to items being placed on it. This is also likely to be done when the fan is stored during cooler months or when it is otherwise unlikely to be used for long periods of time. For example, an in-depth investigation into a separate incident included pictures of the fan involved; these pictures clearly show the cord knotted in a way that is consistent with what one would expect if the fan was being stored away.[9] It is foreseeable that consumers would do this since there is often no obvious means of storing the cord other than wrapping it around the fan or knotting the cord. The cord could also be damaged depending on the orientation in which the fan is stored, the items in proximity to the fan during storage, etc. If the fan is stored in something opaque,[10] the consumer may not even realize that the cord is being pinched or otherwise damaged. Finally, like other incidents referred to earlier, one incident involved a teenager who probably did not realize he was wrapping the cord "too tight" around the stand of the fan.[11]

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[6] See IDI number 921021CCC2032. The fan was being used to remove paint fumes from a deck.
[7] See IDI numbers 950906CCC2955 and 980729CNE5211.
[8] See IDI numbers 000711HCC2662 and 000713HCC2672.
[9] See IDI number 930826CCC1521.
[10] See IDI number 990825CNE5260, in which a consumer stored a fan in a garbage bag.
[11] See IDI number 000711HCC2662.

CONCLUSIONS

Based on the above incidents and scenarios, ESHF staff believes consumers will use portable electric fan cords in ways that could damage the cord and lead to failure. Most consumers lack detailed knowledge of how electrical products work, so consumers simply may not realize that their behavior, such as placing objects onto the cord or pinching the cord behind furniture, could be hazardous. Repeated exposures to portable electric fans without incident further reinforces the perception that the products are safe and are being used in a safe manner, even if they are not. Furthermore, without obvious visible damage to the cord, consumers may be unaware that a cord is being damaged. Visible damage may go unnoticed if the location of damage is not in view; for example, if the pinch point on a cord is behind furniture.

Portable electric fans may be used in children's rooms, and children are generally less knowledgeable about electrical products and their associated hazards than adults. Even consumers who are aware of the potential hazards associated with certain cord usage patterns may find it difficult to avoid situations that could damage the cord. For example, it may be difficult to prevent the cord from being exposed to pedestrian traffic depending on the desired placement of the fan and the location of the electrical outlets. Consumers' efforts to prevent damage to the cord by wrapping the excess cord around the fan could, in itself, damage the cord and lead to failure. In addition, there may be numerous opportunities for cord damage depending on how and where the fan is stored when not in use.

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