EFFECTS OF CARBON FIBERS ON CONSUMER PRODUCTS

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INTRODUCTION

In order to evaluate the potential effects of carbon fibers on consumer products, the Center for Consumer Product Technology of the National Bureau of Standards (NBS) was called upon due to its familiarity with the design, construction, operation and features of major and small consumer appliances. The NBS role was to develop the basic data needed to estimate hazard and fault susceptibility. The calculation of the possibility of hazards and faults actually occurring was not included in the NBS study nor were any actual fiber exposure tests made by NBS. Home entertainment (electronic) and vehicular products were excluded.

The information we are about to present covers work done by NBS under contract[1] to NASA which will be detailed in a report to be delivered to NASA titled: A Study of the Effects of Carbon Fibers on Home Appliances[2].

R. A. Wise will discuss the test and analytical methods used and C. D. Lovett will then describe the method used to select products and the results of the NBS activity.

Once the selection of appliances to be evaluated was made, typical models were purchased, and each was disassembled and thoroughly evaluated for hazard and fault potential. Follow on activity expanded the evaluated products list with particular emphasis on gas and oil fired heating products.

METHODOLOGY

Hazard Analysis

Of the hazards considered, fire, flood, physical harm, explosion, and electrical shock, only the latter was found to be a possible occurrence particularly related to carbon fibers.

[1] *Order no. L-81246A.*

[2] *Lovett, Denver; and Wise, Robert A.: A Study of the Effects of Carbon Fibers on Home Appliances, National Bureau of Standards IR 79-1952, December 17, 1979.*

Fires due to arcing or heat from the fiber seem unlikely due to the low maximum wattage that fibers can dissipate, but this was not experimentally verified. Shock possibilities were considered for four classes of product:

1. 240 volt, direct wired
2. 120 volt, direct wired
3. 120 volt, 3 wire, plug-in
4. 120 volt, 2 wire, plug-in

Although the first three categories present no shock hazard if the appliances are manufactured and installed correctly and the electrical distribution system is correct, all categories were analyzed due to the possibility of an electrical ground connection being disconnected or of a three wire grounded plug being defeated. Since no current flows when a carbon fiber makes a connection between an electrical conductor and an ungrounded touchable conductive part of an appliance, the fiber will not burn out; and, since fibers are low enough in resistance to allow a current to flow that is large enough to cause a sensible shock, all non-insulated electrical conductors were examined. First determined was the distance of exposed electrical conductive parts (mostly terminals, frequently referred to as nodes) from any touchable conductive surface. If the distance was less than 20 mm a possible hazard was considered to exist. The 20 mm was selected on the assumption that fibers longer than 20 mm are not likely to find their way into home appliances. The exception to a simple distance measurement of uninsulated electrical connections was with open wire heaters. Such designs were evaluated by measuring the length of the heater wire or coil that was less than 20 mm from the chassis.

All potentially hazardous locations were then evaluated as to their enclosure (restriction to entrance of fibers). insulation of the nearby grounded surface (paint or enamel), air circulation, and whether the circuit was electrically energized all of the time or only when switched on. On permanently installed appliances only the ungrounded electrical parts (those not connected to the neutral incoming power line) were considered potentially hazardous. However, plug-in appliances could be connected with either input wire at above ground potential so all exposed conductors were evaluated for such appliances.

Figure 1 shows a simplified schematic diagram of an appliance. The load "L" might be considered as a single device or a very complex assembly of electrical controls and operators. In any case, it can be seen that with an ungrounded chassis, line voltage from the chassis to ground measured at "V" could result from a fiber connection anywhere along the electrical circuit such as at "A", "B", or "C". These would result in an electrical shock if a person located at "V" touched the chassis at the same time as he touched a nearby grounded conductor. All three connectors are affected by the polarity of the plug-in connections and the connection at "B" is affected by the setting of the on-off switch.

Fault Analysis

A fault was considered to be any effect on the performance of an appliance which would result in a complaint or require service action. Figure 2 is a simplified electrical schematic showing some typical electrical circuits. It can be seen that fibers across 240 or 120 volt components such as heaters "H," motors "M," etc. can have no effect since they only constitute a very small additional load on the power supply and will quickly burn out. Recognizing the very low current carrying capacity of fibers, fibers across switch connections "S" are generally no problem. The only possible faults that can arise are those shown at locations 1 and 2. Fibers located at these positions where a switch operates a very low current device such as a timer motor "T" or relay "K," (under 10 watts) could cause the timer to run or the relay to close. Very few cases were found where such conditions exist, and these were tested with a carbon fiber simulator. This is an electronic device developed at the Langley Research Center and supplied to NBS to simulate fibers of various resistances and their burnout characteristics. Electronic controls have recently begun to replace electro-mechanical controls on a few consumer products so an attempt was made to determine the effect of fibers on these electronic controls through circuit analysis. The number of potential problems that could arise was very high, and actual exposure testing in a chamber was the only evaluation possible. However, all such products had their electronic parts well enclosed; so the likelihood of a fiber falling on such circuits is extremely remote.

RESULTS OF THE STUDY

Market Statistics

An analysis of market statistics resulted in estimates of the total depreciated 1977 dollar value in U.S. homes of $50 billion for major appliances and $10 billion for small appliances. Using the total depreciated dollar value, appliance categories accounting for 80% of the estimated total values were identified and subsequently 59 models representative of these categories were selected. These selected models include specific models that are (1) representative of appliances in the field (2) representative of changing technology in appliances and (3) appliances that have rapid growth trends. In addition to these 59 models other household consumer products and equipment[2] were examined to determine if carbon fibers might have an adverse effect.

Faults

Forty-seven of the 59 appliances were nonelectronic and were considered amenable to evaluation by probe testing and analysis. The evaluation determined the potential faults and hazards that could occur if fibers should enter the electrical circuits of these selected appliances. In these 47 appliances examined, 23 potential faults were detected. Twenty of these faults were of minor consequence, such as indicator lights operating when not expected. The remaining 3 faults could result in possible false cycles.

[1]*Major appliances included: refrigerators, clothes washers, electric ranges, freezers, dishwashers, clothes dryers, microwave ovens.*

Small appliances included: vacuum cleaners, irons, toasters, fry pans, coffee makers, bed covers, blenders, can openers.

[2]*Other products and equipment included: fans, drills, gas ranges, gas clothes dryers, gas furnaces, automatic flue dampers, furnace controls, garage door openers.*

Hazards

As explained earlier, an electrical shock depends on several conditions occurring at the same time as the user physically interfaces with the appliance. Our evaluation of electrical shock did not attempt to determine whether the interaction of the user provided the right set of conditions to complete a circuit between a touchable surface and an available ground. Rather, the evaluation counted the number of exposed nodes located close enough to a conductive surface for fibers to bridge the gaps, thus creating circuits which would allow a voltage to exist on a touchable surface.

Figure 3 shows that these 47 nonelectronic appliances contained approximately 1000 exposed nodes. A group of 947 nodes represent low likelihood of hazards because of the following restrictive conditions.

1. 85% of the fibers are expected to have lengths less than 5 mm so very high exposure will be required for fibers to bridge the gaps between any one of 802 nodes and their respective adjacent surfaces.

2. Coated surfaces adjacent to 40 nodes provide insulation.

3. A group of 105 nodes are well protected by their location in nearly closed compartments.

The remaining 53 nodes can be divided into two groups. The first group of 37 nodes is found in 19 major appliances. In these major appliances the possibility of a hazard depends upon the integrity of the ground system. If the ground system is intact, the likelihood of hazard occurring is very low. The second group of 16 nodes was found in 9 small appliances which have no provision for grounding. Figure 4 shows nine small appliance models and the number of potentially hazardous nodes.

Appliance Ground System

Plug-receptacle compatibility for 3-wire plug-in appliances depends on the availability of 3-contact household receptacles which are grounded. If plug-receptacle compatibility could be assured for all major appliances. then all potentially hazardous nodes would be confined to small appliances. Since this is not always the case, we identified those appliances for which plug-receptacle compatibility is assured and those appliances for which plug-receptacle compatibility is questionable. These major appliances and the corresponding number of potentially hazardous nodes are shown in Figure 5. For example, clothes dryers, ranges and dishwashers contained 17 of the 37 hazardous nodes within this group of major appliances. Since clothes dryers and ranges are 3 wire, 240 volt appliances, their special 3 wire plugs will always be provided with compatible 3 wire receptacles, or they will be directly wired. Also, since most dishwashers are directly wired to their supply circuits, ground integrity is likely. The remaining ground system uncertainty is in 120 volt, 3 wire appliances consisting of four clothes washers which contain 13 hazardous nodes and 2 microwave ovens which contain seven hazardous nodes.

After completing the main program of consumer product analysis, several additional products were evaluated. Gas or oil furnace flame sensors of the photocell type were felt to be particularly susceptible, so several were purchased and evaluated analytically and with the carbon fiber simulator.

This extended study showed that the gas fueled appliance hazard possibilities were essentially the same as the electric counterpart designs and the electric shock hazard potential in furnaces is near zero due to the high probability that the electrical system and cabinetry are well grounded. The only possible fault-hazard condition was found to be in an intermittent ignition type furnace control which could permit fuel to flow with the flame out and igniter off. This fault is an extremely remote possibility since a fiber would have to arrive after the burner had started and then would require a flame-out to occur before the furnace had gone into its next off cycle. After the "off" cycle a fiber in this location would prevent the burner motor or gas valve from operating at the next "on" cycle.

The occurrence of any potential hazard depends on the carbon fiber transfer function into appliance compartments. If the transfer is small, the possibility of occurrence is remote. NBS did not evaluate transfer functions for appliances.

Appliances Recommended for Chamber Testing

Sixteen of the appliances were not amenable to probe testing and analysis for quantifying potential faults and hazards, the reason being:

1. Some of the models contained electronic controls. Evaluation of these electronic control models indicated that potential faults were too numerous to quantify.

2. Toaster, toaster-ovens, heaters and hand irons contain uninsulated stiff wire or sheet metal conductors. Because of the varied configuration, and the large number of possible interconnections, it is not practical to analytically evaluate the hazard potential of these products.

3. Portable room heaters, toasters, and clothes dryers contain uninsulated heater wires which are exposed to various amounts of fan and convection forced air. These products also have numerous possibilities for fiber connections.

Eleven models were recommended for chamber testing (See figure 6). Nine, because they were representative of those not amenable to probe testing and analysis. Two other products, a clothes dryer and a dishwasher, were chosen as representative appliances to quantify the fiber exposure required to cause a fault or a hazard as an indication of the vulnerability of these appliance categories and others of similar construction.

CONCLUSIONS

A. Few products were found to be susceptible to faults. For nonelectronic appliances most faults were of minor consequences. However, for electronic appliances our analysis incicated that the fault possibilities were too numerous to analyze. Therefore, these appliances were recommended for chamber testing. A review of carbon fiber chamber test data from other NASA contractors revealed <u>no faults</u> in those appliances recommended for chamber testing.

B. Our analysis showed that carbon fiber generated circuits could create many potential hazards in many appliances. However, the number of potential hazards is reduced by (1) increased spacing to fiber length ratio (2) coated surfaces and (3) the availability of correctly grounded receptacles. A review of the carbon fiber exposure data for those appliances recommended for chamber testing, in most cases, confirmed our prediction of hazards for these appliances.

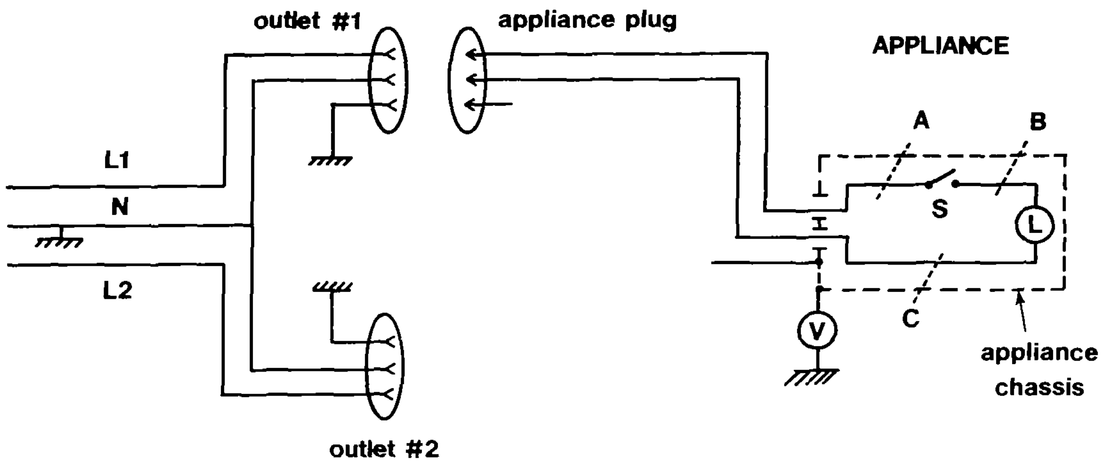

Figure 1.- Hazard analysis.

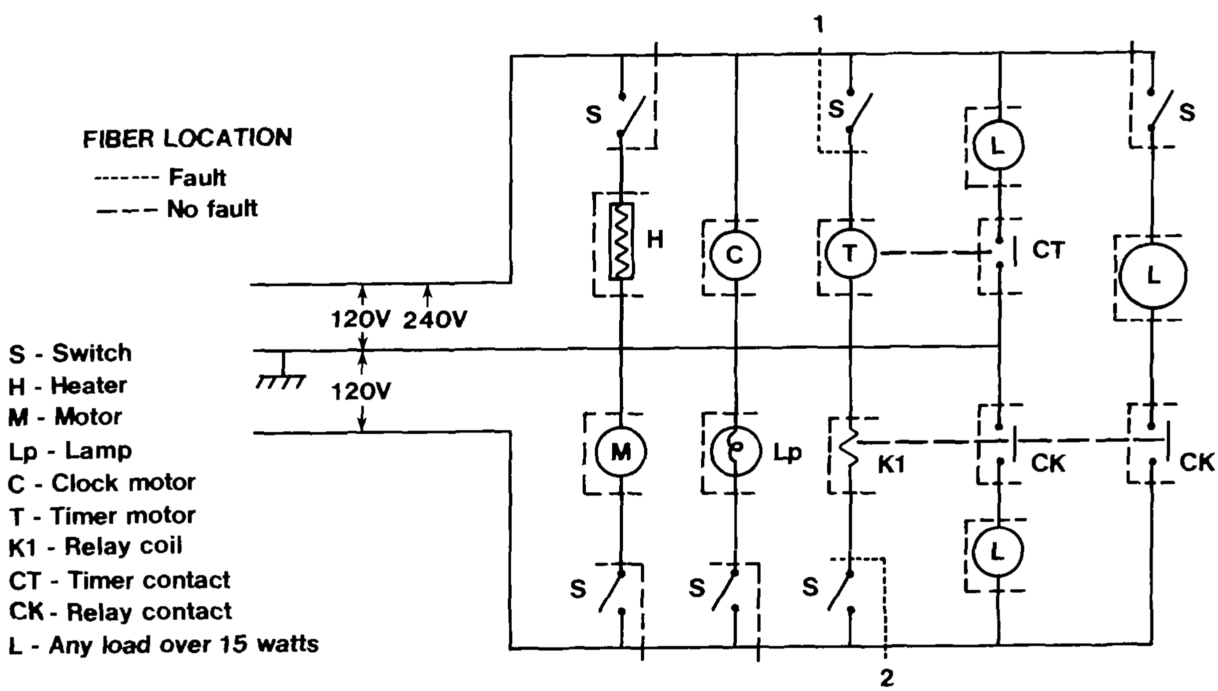

Figure 2.- Fault analysis.

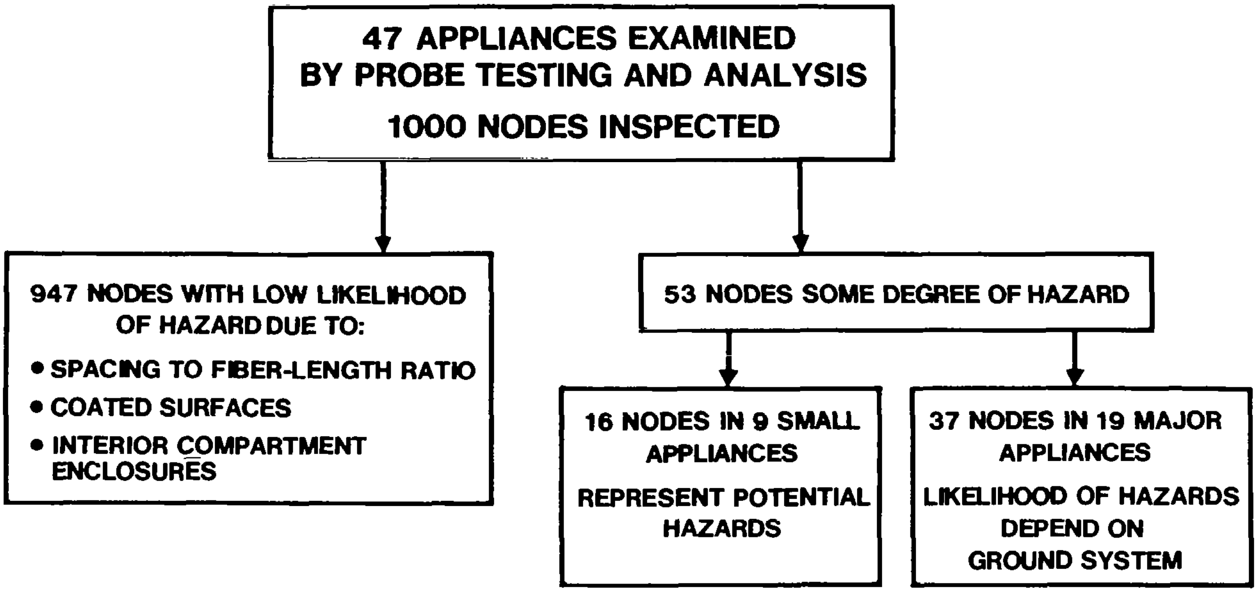

Figure 3.- Appliance probe test summary.

PRODUCT CATEGORY	NUMBER EXAMINED	NUMBER OF HAZARDOUS NODES
VACUUM CLEANER	3	4
*FOOD MIXER	3	4
*PORTABLE HEATER	3	8
TOTALS	9	16

*Hazards in these appliances were verified by carbon fiber chamber tests sponsored by NASA-Langley

Figure 4.- Small appliances with potential hazards.

PRODUCT CATEGORY	NUMBER EXAMINED	NUMBER OF HAZARDOUS NODES
CLOTHES WASHER	4	13
RANGE*	2	1
DISHWASHER*	3	5
CLOTHES DRYER*	4	11
MICROWAVE OVEN	2	7
TOTALS	15	37

* Ground system violation highly unlikely for these appliances

Figure 5.- Major appliances with potential hazards.

APPLIANCE CATEGORY	NUMBER OF UNITS
CLOTHES DRYER	2
DISHWASHER	1
TOASTER	1
TOASTER OVEN	1
HAND IRON	1
SMOKE DETECTOR	2
HEATER	1
MICROWAVE OVEN	2
TOTAL	11

Figure 6.- Appliances recommended for carbon fiber chamber test.