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Lovett, C. Denver/A study of the effects
QC100.U56 NO.79-1952 1980 V1 C.1 NBS-P

(NASA)

A Study of the Effects of Carbon Fibers on Home Appliances

Reference

NBS

PUBLICATIONS

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Center for Consumer Product Technology
National Engineering Laboratory
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A STUDY OF THE EFFECTS OF CARBON FIBERS ON HOME APPLIANCES

C. Denver Lovett
R. A. Wise
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Center for Consumer Product Technology
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U.S. DEPARTMENT OF COMMERCE, Philip M. Klutznick, ***Secretary***

Luther H. Hodges, Jr., ***Deputy Secretary***
Jordan J. Baruch, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

Executive Summary

At the request of the National Aeronautics and Space Administration (NASA), the National Bureau of Standards, Center for Consumer Product Technology conducted an evaluation to determine the possible effects of carbon fibers on consumer major and small appliances. An economic risk assessment to be performed by NASA will weigh the fuel savings from using ligher weight carbon fiber materials in aircraft and motor vehicles against the possible dollar loss of equipment damaged by crash released fibers and any possible injuries. The NASA program includes avionics in both aircraft and airports, power stations, computers, hospital equipment and home equipment including appliances. This information collected on appliances is a small part of the data necessary for NASA to complete the economic risk assessment on the future use of carbon fiber composite materials.

Available market statistics were used to estimate total depreciated dollar value in U.S. homes of $50 billion for major appliances and $10 billion for small appliances. These corresponding values for 1985 are projected to be nearly $100 billion for major appliances and $20 billion for small appliances. The appliance categories (types) that make up 80% of this estimated value were determined and specific models of each category which were typical of the current design and construction were obtained for analysis and laboratory evaluation. A total of 59 appliances were examined during the study. The selection criteria was chosen to allow this limited study to assess the effects of fibers on the largest possible dollar value of appliances.

The analysis determined potential faults and hazards that might be caused by fibers infiltrating appliances. In the 47 non-electronic appliances examined, 23 potential faults were detected. Twenty of these faults would be of little significant consequence such as false signals from an indicator light or a false buzzer signal. The remaining three faults could result in possible equipment malfunction.

Forty-seven of the 59 appliances were amenable to evaluation by probe testing and analysis. A diagrammatic view of the evaluation is shown in Figure (i). These 47 appliances collectively contained 732 potential hazards. However, because of constraints such as fiber length, node spacing to the nearest conductive surfaces, surface finish and protective environmental enclosures, only 53 of these

nodes pose significant risk of shock hazard. These 53 potential hazardous nodes must be tempered by the type of power connection. Of the 53 hazardous nodes, 37 represent a hazard only if the power supply ground systems are violated. The remaining 16 hazardous nodes were found in nine small appliance models having no provision for grounding. Whether these 16 hazardous nodes would result in electrical shock to users would depend on a fiber shorting the node to the case and the user touching the case and simultaneously touching a grounded conductor with another part of the body. The probability of these conditions was not evaluated in this study.

Sixteen of the appliances selected for evaluation were not amenable to quantifying the potential faults and hazards by means of probe testing and analysis. Ten of these 16 models representing several appliance categories were recommended for carbon fiber chamber testing to determine faults and hazards. Some of the reasons for selecting these models for chamber testing are:

1. Initial evaluation of models containing electronic controls indicated that potential faults were too numerous to analyze;

2. Some appliances contain internal, bare bus-bar wiring which have numerous possibilities for fiber connections as compared with a typical node;

3. Some appliances contain uninsulated heater wires which are exposed to various amounts of fan or convection forced air and also have numerous possibilities for fiber connections; and

4. Some representative models were chosen to quantify the fiber exposure required to cause a fault or hazard as an indication of the vulnerability of this appliance category and others of similar construction.

Many of the potential hazards identified will require substantial further analysis to quantify the potential risk. Some of this analysis will be performed as part of the continuing NBS technial support to the NASA carbon fiber program.

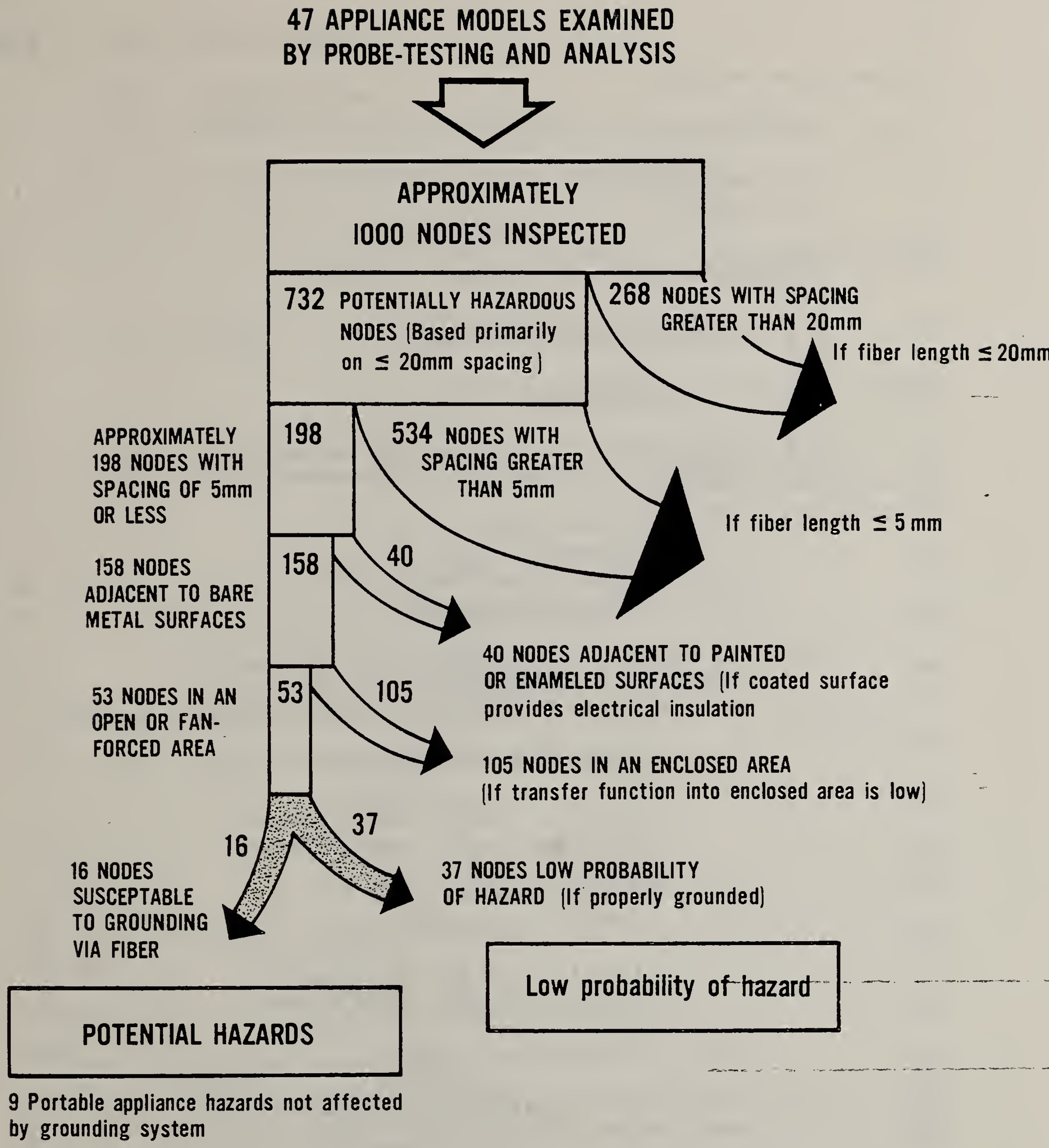

Figure i. Diagram of potential shock hazards.

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A STUDY OF THE EFFECTS OF CARBON FIBERS ON HOME APPLIANCES

1.0 Introduction

1.1 Background

Carbon fibers are being used in a new generation of composite materials. These carbon fibers are finer than human hair, fairly good electrical conductors and virtually indestructable. They are so light and millions are contained in a gram mass. The composite materials have opened a wealth of opportunities in structural engineering application for many products including consumer products (skis, fishing rods, golf clubs, tennis rackets, etc.) motor vehicles and aircraft. The potential benefits of carbon fibers are many-fold including high strength and light weight. Use of these new materials in military and commercial products are expected to result in energy savings and increased safety. In the next decade, composites may become as important to the United States economy as the steel and aluminum they replaced.

Unfortunately, these benefits are not without possible risk. With the expected rapid growth in the use of carbon fiber material in aircraft and automobiles, vehicle accidents followed by fires could become a possibly substantial source of fiber release. If released into the air, fibers can easily be transported by winds. If these fibers come in contact with electrical devices, they can create undesirable conductive circuits or initiate arcs. A variety of actual incidents have occurred supporting the hazards carbon fibers pose to electrical equipment. These fibers may cause improper operation of a device or they may cause potentially lethal voltage to be present on the device case. The National Bureau of Standards (NBS), in support of National Aeronautics and Space Administration (NASA) Langley Research Center, has performed tests and analysis to determine what adverse effects could occur if carbon fibers infiltrate the electrical circuitry of home appliances.

1.2 Scope

The Product Performance Engineering Division, Center for Consumer Product Technology (CCPT), National Bureau of Standards, followed a work plan as agreed to with personnel of NASA Langley Research Center (LaRC). This work plan was designed to accomplish the following:

1. Evaluate present appliance design which might be susceptable to harmful effects from carbon fibers and estimate the value of existing products in homes.

2. Test representative samples of current production for susceptability to carbon fibers.

3. Estimate future sales trends and design technology.

The scope of this work does not include an assessment of the risk of disseminating carbon fibers from an accident source into the circuitry of household appliances, but rather, the intent of this study is to document what may happen if carbon fibers should enter the electrical circuitry of household appliances.

The results of this evaluation will be used by NASA as a part of an economic risk assessment as to the expected future dollar loss of product/equipment due to carbon fibers and to make trade-off decisions between anticipated benefits and potential risk caused by accidental fiber dissemination inherent with the extensive use of carbon fiber composite material.

2.0 Approach

2.1 Appliance Selection

To provide NASA with useful data for an economic risk assessment, a market survey was made to select appliance categories (types) accounting for 80% of the total dollar value of appliances currently in U.S. households.

To obtain this estimated 80% of total dollar value, appliance statistics were examined to ascertain or estimate 1) saturation levels, 2) saturation growth trends, 3) annual sales, 4) forecasted annual sales, 5) average unit cost, 6) inflation trends and 7) estimate economic life. Appliances were ranked by estimated dollar value in household based on saturation and average unit cost. Two lists were compiled. One list consists of electrical major appliances which account for 80% of the total dollar value of all major appliances in U.S. households. The second list consists of small (or portable) appliances which account for 80% of the value of all small appliances currently in U.S. households. The two final lists of selected appliances to be evaluated in this program were approved by NASA.

Since the cost and time required to evaluate each model within every selected appliance ctegory is not economically justifiable, at least three models from each category that are representative of the technology used in most of the current appliances in that category found in U.S. households were selected for evaluation. To give adequate consideration to both expected future dollar loss and future vulnerability, rapid growth appliances and appliances having technologies, which are susceptible to adverse effects of carbon fibers, were selected for evaluation, respectively, regardless of the current market share. For each selected category the projected saturation and the projected dollar values of appliances expected to be in the field by 1985 were estimated. These values will assist NASA in making an economic risk assessment as to the cost of failure of appliances due to carbon fibers.

2.2 Laboratory Evaluation

Major and small appliances were evaluated for faults and electrical shock hazards due to node-to-node and node-to-case electrically conductive paths. The evaluation included both an analytical evaluation of control circuitry and actual probing of the circuits with a test instrument which simulates the electrical properties of a carbon fiber. All circuits, with the exception of some electronic controls were analytically evaluated to identify those nodes where probing for faults would yield useful information. Each circuit which was probed was also evaluated analytically to determine if there were any improper operations not detectable by probing with the carbon fiber simulator.

Data necessary to determine potential shock hazards were evaluated by measuring the spacing to ground for all uninsulated parts and by evaluating the ground integrity of all touchable metallic parts. The coating of these surfaces were noted and also the environment around the potentially hazardous nodes, including the expected air currents, and the degree of protection to infiltration of carbon fibers.

Appliance circuit diagrams were reviewed to ascertain the number of nodes and the amount of included electronic circuitry. If the number of nodes exceeded 100 or if the electronic controls were judged to be too complicated for probing with the carbon fiber simulator, that appliance was recommended for chamber testing by NASA. The results of the identified faults and shock hazards are to be used by NASA in combination with the transfer function data, developed in the chamber to assess the level of risk.

3.0 Appliance Selection

3.1 Objectives for Selecting Categories

The objectives for category selection are:

1. to identify two lists of appliances which, separately, account for 80% of the total depreciated dollar value of major appliances and small appliances currently found in U.S. households.

2. to identify appliance categoreis having significant growth trends which indicate a substantial future saturation. These identified categories were included regardless of their current saturation levels.

These objectives were established to be compatible with the overall objective of making an economic risk assessment.

3.2 Value of Appliances in Households in 1977

The value of appliances in U.S. households is determined by 1) the actual age of the appliance, 2) the estimated economic life and 3) the retail price at the time of purchase. Any appliance which remained in service, but had an age greater than the estimated economic life, was assumed to have no economic value. Also any appliances which may have been removed from service before the completion of their service life were not deducted from the existing appliance stock. The value of appliances in U.S. households is an estimate based on a systematic analysis of readily available appliance statistics. There was no attempt to refine the analysis for second order factors which have a minimal effect on estimated value.

A nonrepairable failure of an appliance will not result in a loss equivalent to the current retail price of an appliance nor will such a loss be equivalent to the initial purchase price. The economic value of an appliance at any age is assumed to be the book value as determined by the "straight line depreciation method."

Eighty percent of the total dollar value of appliances in U.S. households is based on the cumulative depreciated dollar value of all electrical major and small appliances sold during the years prior to the evaluation year for a number of years equal to the economic lifetimes of the various appliance categories.

3.2.1 Saturation

Saturation is the percent of households having a particular appliance. Appliance statistics from "Merchandising" magazine were reviewed to ascertain those appliance categories with high ¦ saturation values. An appliance category having high saturation values in conjunction with high, average unit cost are significant contributors to the total estimated value of major appliances in U.S. households. Major appliances and small appliances were ranked separately according to high saturation and high unit cost to identify those appliance categories that are the most significant contributors to the total value of appliances in U.S. households. The saturation of appliances and the number of units in the field for both major and small appliances are shown in Table 3.1.

3.2.2 Economic Life

Before the total dollar value of appliances in U.S. households could be estimated, some reasonable estimate of economic life for each appliance category was necessary. The following computational procedure was developed to estimate the economic life for each category.

Starting with 1977 annual sales data, the number of units sold annually for each particular category were summed until the cumulative number of units sold matched the estimated total units in the field in 1977. The number of sales years required for cumulative sales to equal this total defined the economic life of the particular appliance category. An example of this summation for clothes washers is shown in Table 3.2.

Using the above procedure, the economic life of each appliance category was estimated and is shown in Table 3.3. Any appliance remaining in service beyond its economic life as defined above was assumed to have no economic value for the purpose of this study.

Table 3.1

1977 Saturation, by Appliance Category and Number of Appliances in the Field

Major Electrical Appliances		Units in Field (million)	1977 Saturation (%)
1.	Refrigerators	75.8	99.9
2.	Clothes Washers	55.8	73.3
3.	Electric Ranges	41.4	55.8*
4.	Freezers	28.9	38.2
5.	Dishwashers	28.0	37.0
6.	Clothes Dryers	32.1	42.3*
7.	Room Air Conditioners	25.0	33.0**
8.	Microwave Ovens	6.2	8.2
9.	Disposals	22.3	29.5

Small Appliances			
1.	Vacuum Cleaners	75.8	99.9
2.	Irons	75.8	99.9
3.	Toasters	75.4	99.4
4.	Food Mixers	69.1	91.1
5.	Fry Pans	48.2	63.6
6.	Coffee Makers	75.4	99.4
7.	Bed Covers	44.5	58.6
8.	Blenders	36.1	47.6
9.	Can Openers	42.8	56.4

[1] Source: Merchandising, the 56 statistical issue and marketing report, March 1978.

* Source: Merchandising, March 1978, based on utilities' estimates.

** Sears, "Department of Energy/Sears, Roebuck and Company Meeting," July 20, 1978.

Table 3.2

Economic Life and Depreciated Value
of Clothes Washers in the Field in 1977

Saturation: 73.3%
Units in Field: 55.5 Million
Economic Life: 12 yrs.

Year	Units Shipped (Millions)	Average Cost per Unit ($)	Depreciation Factor	Depreciated Value ($ M)
1966	4.446	228	1/12	84.5
1967	4.323	235	2/12	169.3
1968	4.482	239	3/12	267.8
1969	4.379	238	4/12	347.4
1970	4.094	234	5/12	400.87
1971	4.609	234	6/12	538.6
1972	5.107	237	7/12	706.0
1973	5.504	245	8/12	899.0
1974	4.948	257	9/12	953.7
1975	4.228	318	10/12	1120.4
1976	4.492	348	11/12	1433.0
1977	4.933	363	12/12	1790.6
TOTALS	55.5			8711.57

Cumulative value of retail sales over the last 12 years: $11.366 billion.

Table 3.3

Estimated Appliance Economic Lives

Major Home Appliance	Economic Life (yrs)
Refrigerator	15
Clothes Washer	12
Range	18
Freezer	20
Dishwasher	10
Clothes Dryer	15
Room Air Conditioner	6
Microwave Oven	8
Disposal	9

Small Home Appliance	Economic Life (yrs)
Vacuum Cleaners	9
Irons	10
Toasters	12
Food Mixers	15
Fry Pan	7
Coffee Makers	7
Bed Covers	10
Blender	8
Can Openers	8

3.2.3 Cumulative Value

The cumulative sales values were based on a double summation. First, the annual retail dollars were summed for each sales year that was within the economic life of the particular appliance category. Secondly, these resulting totals were summed over each appliance category to obtain the cumulative sales value.

The cumulative depreciated value of the appliance was based on straight-line depreciation using the product of the annual retail sales and the ratio of remaining life to the estimated economic life and the average unit cost. The resulting depreciated values were summed for each sales year within the estimated lifetime of the particular appliance category. The cumulative depreciated value was obtained by summing these totals for each appliance category. The cumulative depreciated values or major appliances range from about 50% to 65% of the cumulative retail values.

Figures 3.1 and 3.2 show the cumulative dollar values of the most significant electrical, major and small appliances in U.S. households. The cumulative depreciated value of these appliances is estimated to be $46.5 billion and $10.5 billion for the major electrical appliances and small appliances respectively. If additional major electrical appliance and small appliance categories were considered, the cumulative depreciated values would approach but probably not exceed $50 billion for the major electrical appliances and $11 billion for the small appliances.

The dotted line in Figures 3.1 and 3.2 represents the cumulative retail values of the electrical major appliances and the small appliances purchased during the economic life of the respective appliance. Neither the cumulative retail values nor the cumulative depreciated values are adjusted to 1978 dollars, since the adjustment would not change the appliance categories selected.

3.2.4 High Growth Rate

Since the output of this study will be used to assess the future dollar loss to appliances due to adverse effects of carbon fibers, it is essential that appliance categories having significant growth trends

IN THE FIELD IN 1977

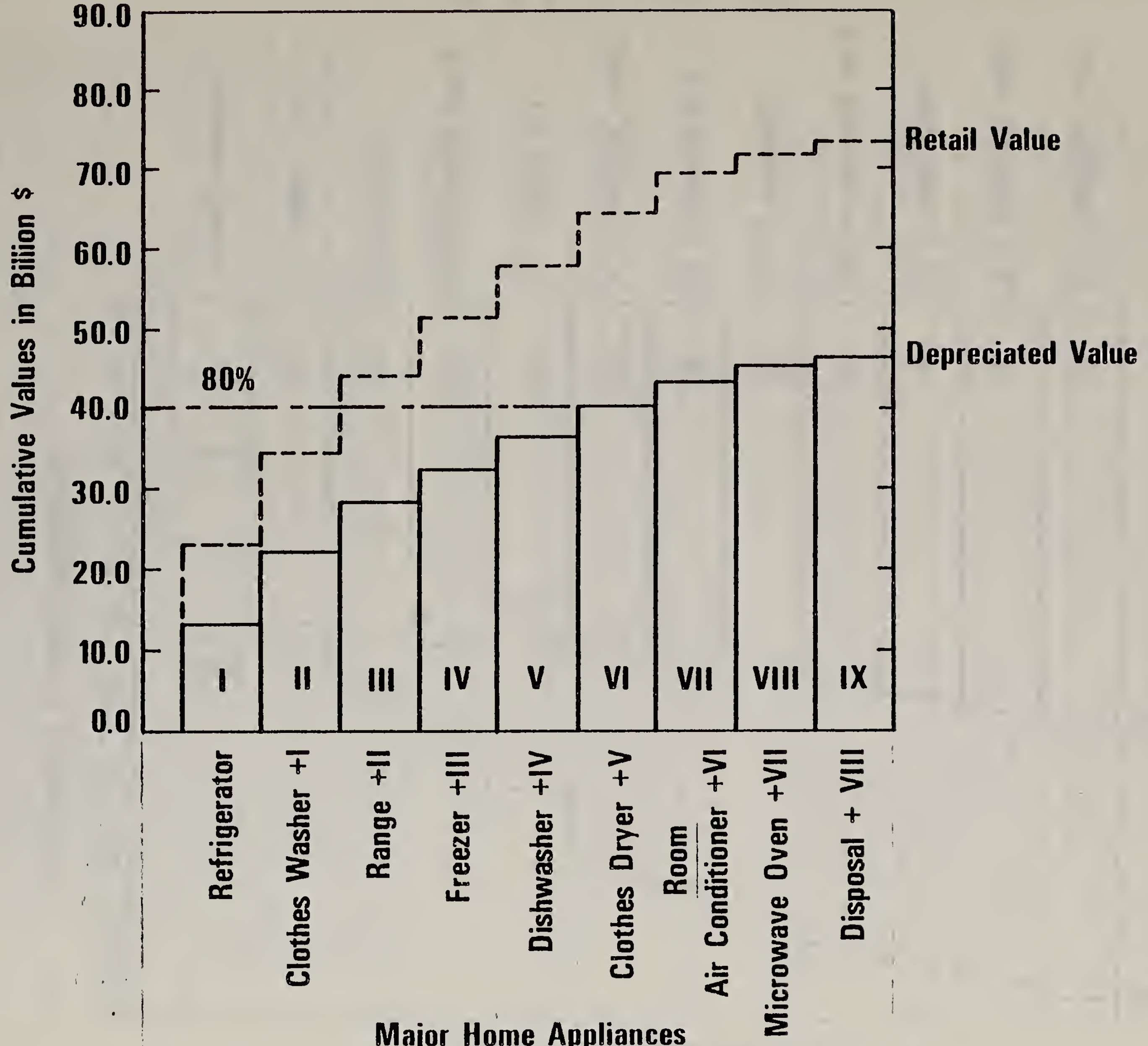


Figure 3.1

CUMULATIVE VALUE IN BILLIONS($) FOR SMALL APPLIANCES IN THE HOME IN 1977

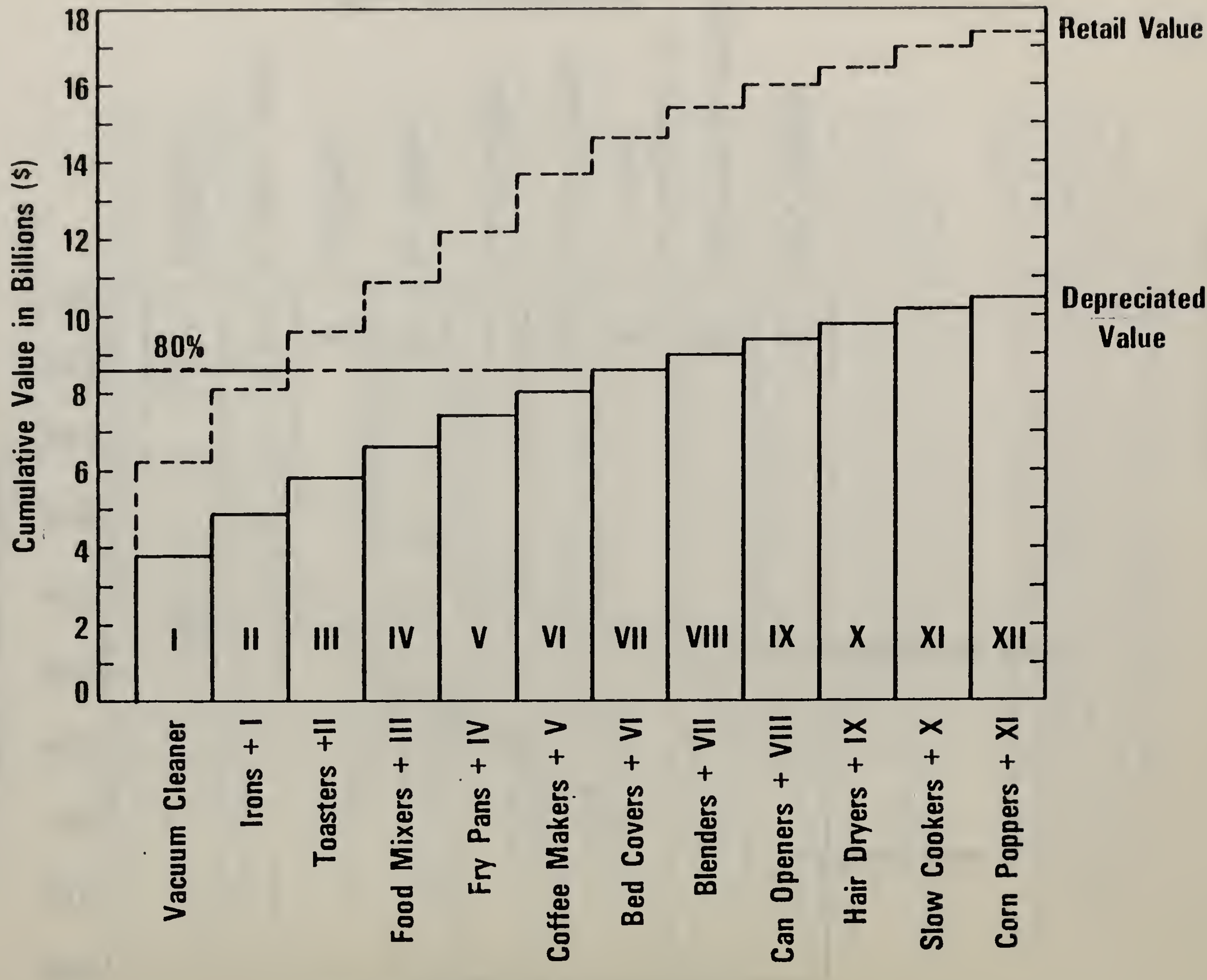


Figure 3.2

to be identified such that their contribution to the total dollar value of appliances expected to be in the field by 1985 can be quantified. Appliances which have significant growth rates and are predicted to have significant saturation by 1985 were selected for test, although the dollar value of the particular category of appliance presently in the field may be small compared with other appliance categories. Appliances which meet these criterion are microwave ovens and smoke detectors. Table 3.4 shows the saturation of microwave ovens between 1971 and 1977. The projected growth in saturation can be observed from Figure 3.5. Although the present (1977) saturation is less than 10%, it is expected to reach a saturation level of approximately 45% by 1985. This projected growth for microwave ovens is based on sales forecasts obtained from the "Appliance" magazine (January 1978). Microwave ovens are expected to contribute about $5 billion out of a total of $100 billion projected depreciated value for major appliances in 1985.

Annual sales data for smoke detectors for 1977 was 6.4 million units and the projected sales are 8 and 8.8 million units for 1978 and 1979, respectively. Many county codes are rapidly legislating smoke detectors into use and there is a rapid growth in public awareness of protection which smoke detectors provide. Its saturation is expected to be significant by 1985.

3.3 Selection of Appliance Categories for Laboratory Evaluation

The selection of appliances for laboratory evaluation consisted of identifying those appliance categories which satisfy the selection criteria discussed previously. The major electrical appliance categories collectively satisfying the criteria of significant (80%) dollar value were identified by the use of Figure 3.1. These appliance categories are: 1) refrigerators, 2) clothes washers, 3) electric ranges, 4) freezers, 5) dishwashers, and 6) clothes dryers. Although total dollar value of microwave ovens currently found in U.S. households is presently low in comparison with other major household appliances, microwave ovens has been selected for evaluation because of the projected growth in saturation. As shown in Table 3.6, the total depreciated dollar value for microwave ovens is expected to approach the $10 billion level by 1985.

Table 3.4

Saturation by Year for Microwave Ovens

Year	Saturation
1969	--
1970	--
1971	0.2
1972	0.6
1973	1.2
1974	2.2
1975	3.2
1976	5.1
1977	8.2

Same as [1].

PROJECTED PRODUCT SATURATIONS (1978-1985)

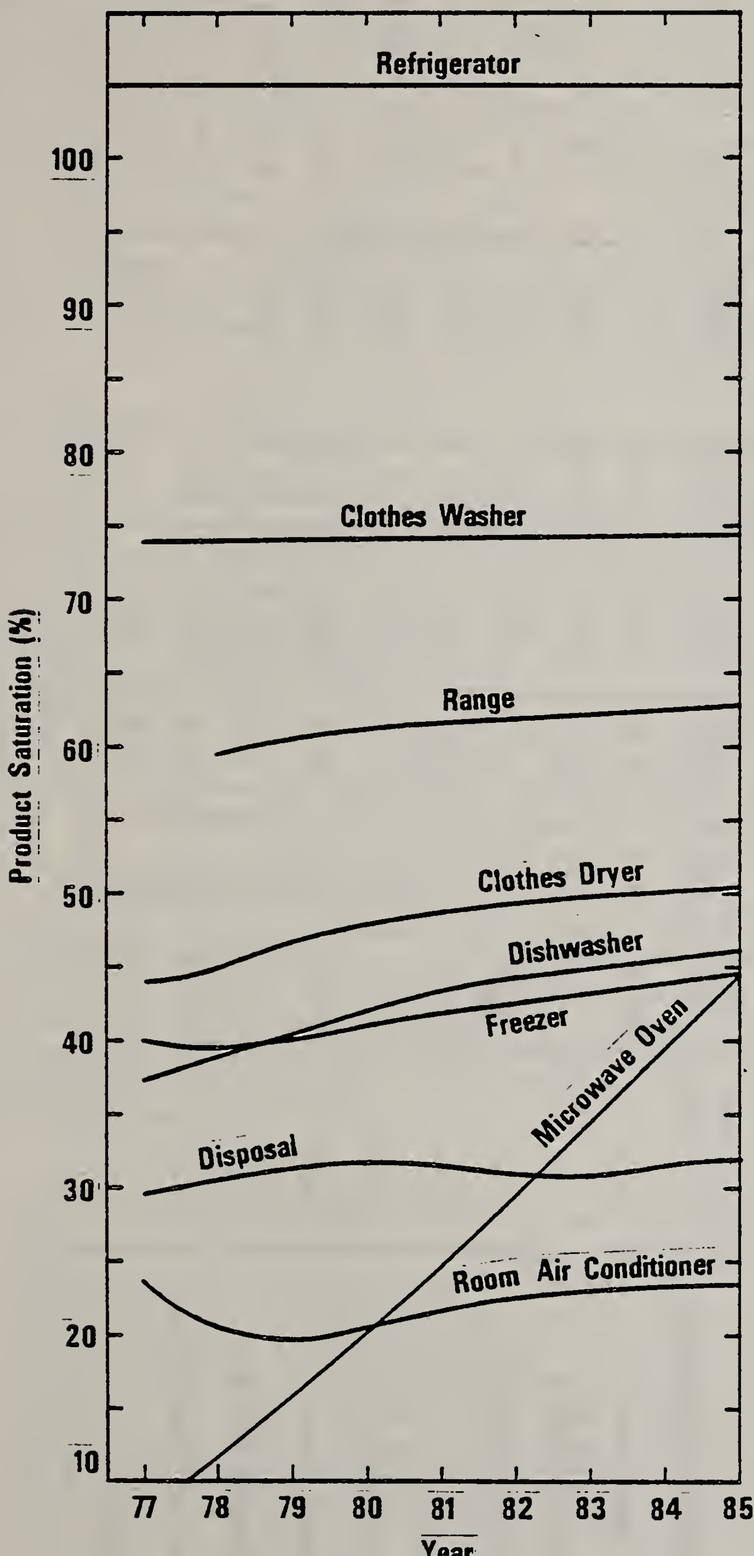


Figure 3.5

Table 3.6

Major Appliance
A Comparison of
Estimated Appliance Statistics for 1977 and 1985

Appliance Categories	Est. Economic Life	(%) Saturation		Units In-Field (million)		Retail Value In-Field ($ billion)		Depreciated Value In-Field ($billion)	
		1977	1985	1977	1985	1977	1985	1977	1985
Refrigerators	15	99.9	99.9	75.8	88.0	24.0	38.8	13.4	24.1
Clothes Washers	12	73.3	74.5	55.5	66.0	11.0	29.8	8.7	19.1
Electric Ranges	18	55.8	65.0	41.4	57.5	9.7	19.4	6.0	12.7
Freezers	20	38.2	47.0	28.9	42.0	7.1	14.0	4.2	9.6
Dishwashers	10	37.0	46.0	28.0	41.0	6.7	16.0	4.2	10.0
Clothes Dryers	15	42.3	45.0	32.1	39.0	6.3	12.0	4.0	7.0
Microwave Ovens	8	8.2	44.5	6.2	39.4	2.6	15.7	2.1	10.1
Room Air Conditioners	6	32.9	23.3	24.6	20.6	5.2	8.4	2.93	5.2
Disposals	9	29.5	34.0	22.0	30.1	1.7	4.42	1.1	2.7

Small appliance categories satisfying the criteria of significant (80%) dollar value were identified by the use of Figure 3.2. The 80% line drawn on Figure 3.2 results in the selection of sevn appliance categories which are estimated to account for 80% of the total depreciated dollar value of appliances currently found in U.S. households. These seven appliance categories are 1) vacuum cleaners, 2) irons, 3) toasters, 4) food mixers, 5) fry pans, 6) coffee makers and 7) electric bed covers. Smoke detectors exhibited significant growth in annual sales and were selected regardless of their present contribution to the total dollar value of small appliances currently found in U.S. households.

3.4 Future Market Trends and Technology Changes

Since one of the overall objectives of the carbon fiber program is to make an economic risk assesment as to the probable future dollar loss of household appliances due to adverse effects of carbon fibers, an assessment as to the future dollar worth of appliances and the future category mix is necessary. Otherwise one may spend time and effort evaluating an appliance which is obsolete and has not future market significancy. To select and evaluate appliances which have relevance to the economic and hazard vulnerability of future appliances, saturation growth trends were plotted and technology advances were noted.

3.4.1 Predicted Saturation

Various methods were used to estimate future saturation values. The availability of data and the potential contribution of the particular appliance to the expected total value were primary considerations in developing the various methods for estimating future saturation levels.

3.4.1.1 Major Appliances: Figure 3.3 shows a flow diagram of the method used to estimate saturation by year for ranges, clothes dryers, freezers, and disposals. The basic data that were used to estimate the annual saturation were the projected households and the extrapolated values of the 1975 saturation levels. The product of the number of projected 1985 households and the extrapolated, 1985 saturation is the estimated number of units that will be in the field by 1985. The difference between the

FLOWCHART FOR ESTIMATING FUTURE SATURATION LEVELS FOR RANGES, DRYERS, FREEZERS, AND DISPOSALS

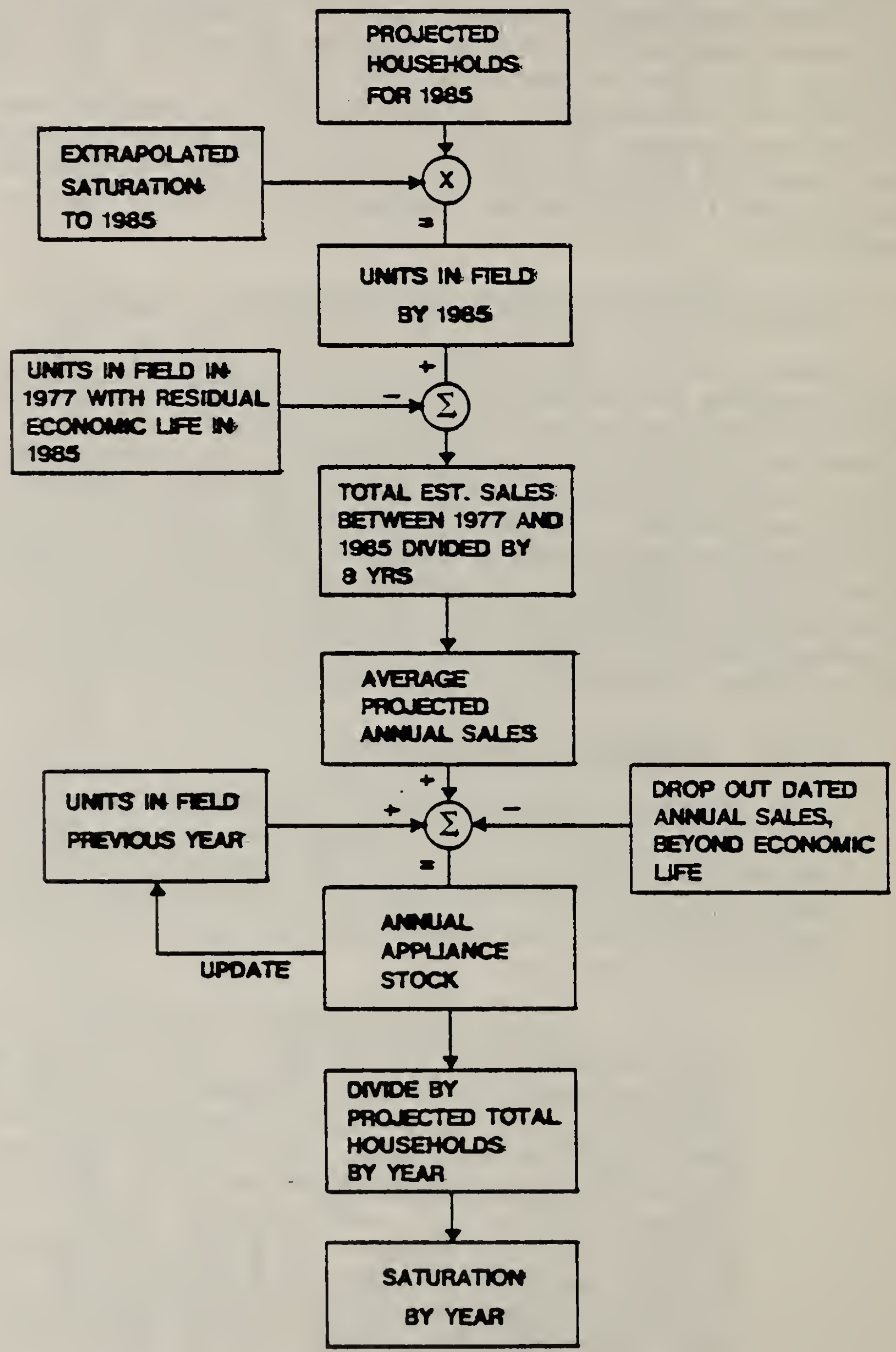


Figure 3.3

total number in the field in 1977 (with economic life extending into 1985) and the number in 1985 gives the estimated total units to be sold between 1977 and 1985. The projected average annual sales were obtained by dividing the total estimated sales between 1977 and 1985 by eight, the number of sales years between 1977 and 1985. A sample calculation of the average projected annual sales for toasters is shown in Table 3.5.

Each year's appliance stock (total units in U.S. households) is equivalent to the summation of the annual units sold during the number of previous years equal to the economic lifetime of the particular product. Therefore, the future appliance stock was calculated by adding the next year's annual sales to the current year's appliance stock and deducting the units sold for the sales year which is just beyond the lifetime of the product. The annual saturation levels were obtained by dividing the estimated future appliance stock by the corresponding projected households.

A slightly different method was used to predict the saturation levels for refrigerators, dishwashers, clothes washers, and microwave ovens. This method was formulated to effectively use the forecasted sales published in the January 1978 issue of "Appliance" magazine. The forecast covers the five-year period between 1977 and 1982.

Figure 3.4 shows a flowchart of the procedure used to estimate the future annual saturation values. The future appliance stock was calculated by adding the next year's forecasted sales to the current appliance stock and deducting the units sold for that sales year which is one year beyond the economic lifetime of the particular product. The yearly calculated appliance stock was divided by the future housing stock to obtain the projected annual saturations between 1977 and 1982. Saturations between 1982 and 1985 were obtained by extrapolation.

The projected annual saturation values calculated by the above procedure are shown in

Table 3.5

Projected Annual Sales, Depreciated Value, Retail Value of Toaster Over 12 Year Economic Life

Year	Number Shipped (Million)	Retail Value ($ Billion)	Cost per Unit ($)	Fractional Remaining Value	Depreciated Value ($ Million)
1972	6.650	.1130	18.51		
1973	6.845	.1164	17.01		
1974	7.177	.1435	19.99	1/12	12
1975	6.204	.1438	23.18	2/12	24
1976	7.397	.1767	23.89	3/12	44
1977	7.400	.1895	25.61	4/12	63
1978	7.53	.203	27.00	5/12	85
1979	7.53	.218	29.00	6/12	109
1980	7.53	.233	31.00	7/12	136
1981	7.53	.248	33.00	8/12	165
1982	7.53	.271	36.00	9/12	203
1983	7.53	.286	38.00	10/12	238
1984	7.53	.308	41.00	11/12	282
1985	7.53	.331	44.00	12/12	331
	TOTAL	2.751			1772

Product Category: Toasters
Projected Saturation: 99%
Projected Units in-Field: 88.4
Estimated Economic Life: 12
7% Inflation Rate

$$\text{Average Projected Annual Sales} = \frac{88.4 - (7.17+6.20+7.4+7.4)}{8} = 7.5$$

1983 Retail Value of Units Sold Over Lifetime of the Product: $2.751 Billion

1985 Depreciated Value of Units in the Field: $ 1.772 Billion

FLOWCHART FOR ESTIMATING FUTURE SATURATION LEVELS FOR METHOD OF PROJECTION: DISHWASHERS, CLOTHES WASHERS, MICROWAVE OVENS

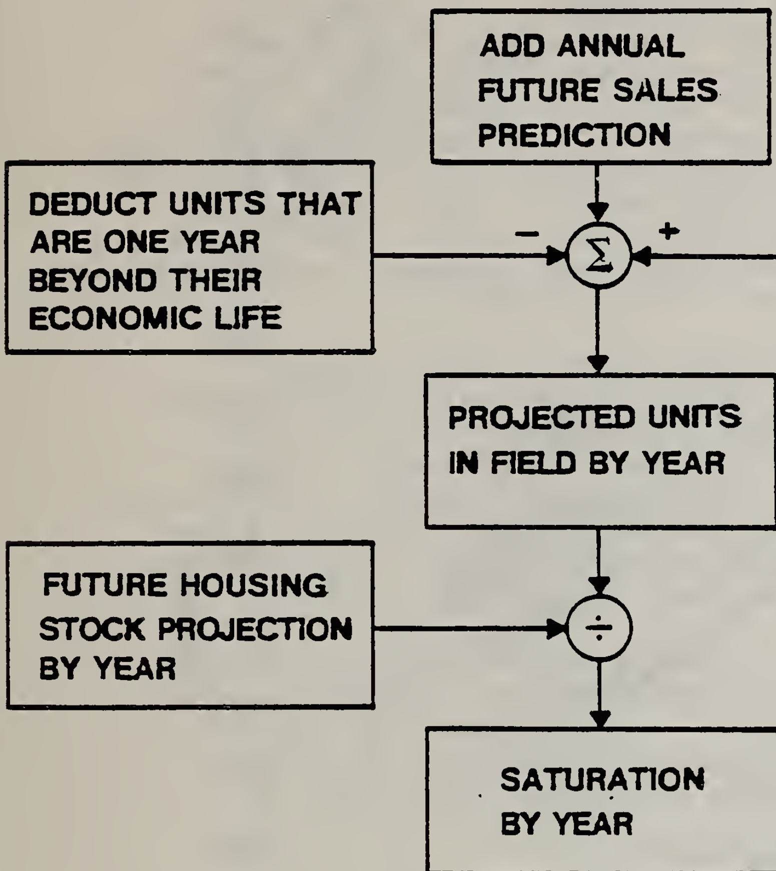


Figure 3.4

Figure 3.5. A comparison of the projected 1985 saturation values with the 1977 saturation values for each appliance category is shown in Table 3.6.

3.4.1.2 Small Appliances: The projected saturation values for blenders, can openers, electrical bed coverings, and fry pans were estimated by averaging for each product, the growth rate in saturation of the five years prior to 1977 and projecting this constant growth rate over the next eight years. These saturation values are plotted in Figure 3.6. The saturation growth rate for these four products range from 1% for fry pans to 1.7% for blenders.

For food mixers which have a higher saturation, one half of the saturation growth rate for the five years prior to 1977 was projected over the next eight years. The estimated, average projected growth rate over the next eight-year projection period is 0.7% per year. The projected saturation values for food mixers are also plotted in Figure 3.6.

A constant saturation of about 99% is projected for vacuum cleaners, toasters, irons and coffee makers. A comparison of the 1985 projected saturation values and the 1977 saturation values are shown in Table 3.6.

3.4.2 Units-in-the-Field

An estimated number of units expected to be in the field in 1985 is essential to an economic risk asessment as to the probable dollar loss of appliances due to adverse effects of carbon fibers. Such an estimate is the product of the projected 1985 saturation levels and projected 1985 households. The number of projected households was obtained from the U.S. Department of Commerce report, "Projection of the Number of Households and Families 1975 to 1990." The number of households in 1985 is estimated at 88.5 million. For each appliance category the total units estimated to be in the field by 1985 is shown in Table 3.6 for major appliances and Table 3.7 for small appliances. Also these projected cumulative values for 1985 are compared with the corresponding estimated

PROJECTED SMALL APPLIANCE SATURATION VERSUS YEAR

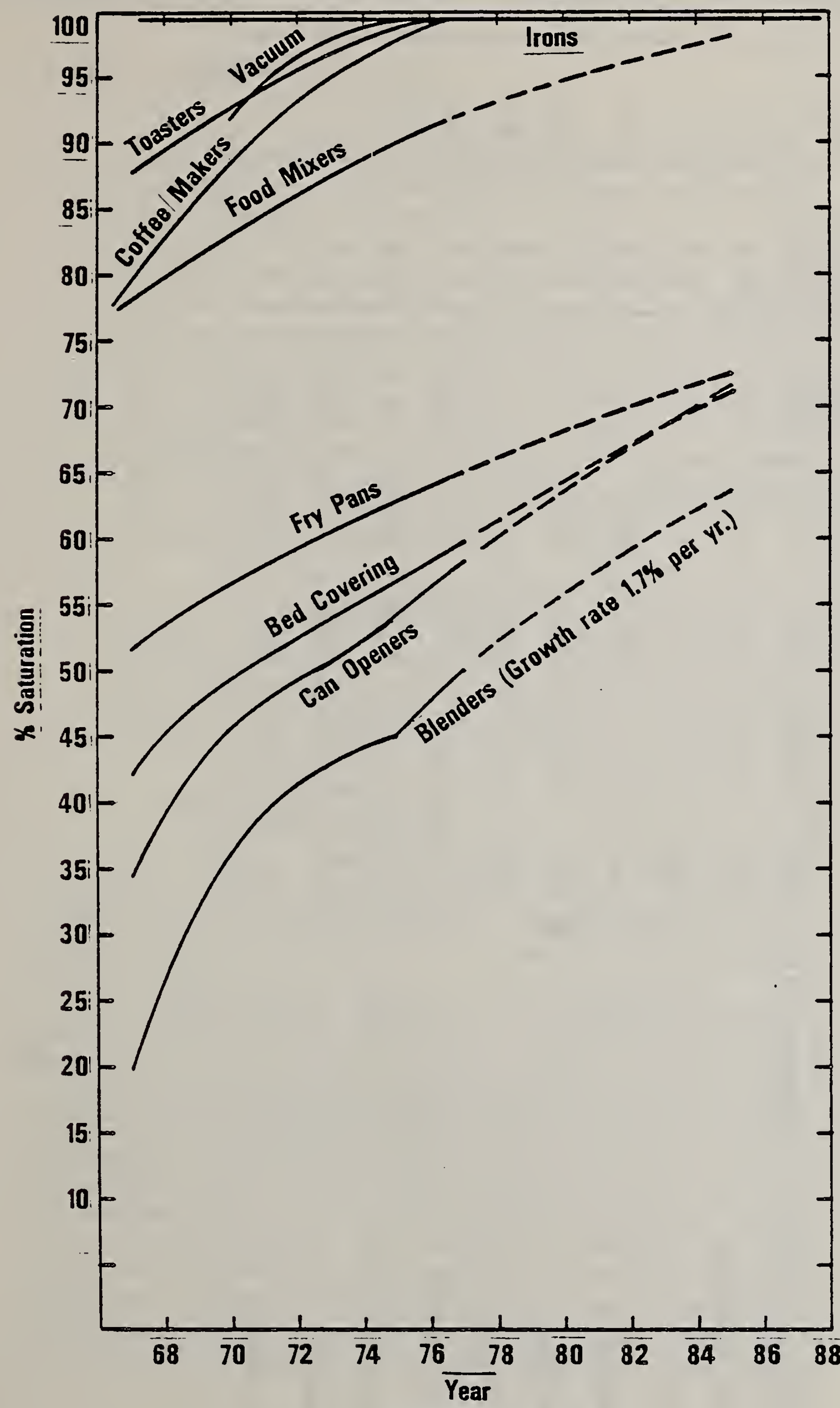


Figure 3.6

Table 3.7

Small Appliance

A Comparison of
Estimated Appliance Statistics for 1977 and 1985

Appliance Categories	Estimated Economic Life	(%) Saturation		Units In-Field (million)		Retail Value In-Field ($billion)		Depreciated Value In-Field ($billion)	
		1977	1985	1977	1985	1977	1985	1977	1985
Vacuum Cleaners	9	99.9	99.9	75.8	88.4	6.2	12.1	3.8	7.3
Irons	10	98.6	99.9	75.0	88.4	1.8	3.1	1.1	1.8
Toasters	12	99.9	99.9	78.5	88.4	1.5	2.7	0.9	1.7
Food Mixers	12	92.4	98.2	70.1	87.9	1.3	2.5	0.8	1.6
Fry Pans	7	63.6	72.5	48.3	64.0	1.3	2.6	0.8	1.6
Coffee Makers	7	99.9	99.9	75.8	88.4	1.5	3.0	0.7	1.8
Bed Covers, Elec.	10	59.9	71.2	45.4	63.8	0.9	2.0	0.5	1.3
Blenders	8	50.0	63.6	37.9	56.3	0.82	1.8	0.5	1.1
Can Openers	8	57.9	71.5	45.5	63.2	0.6	1.4	0.4	0.7

cumulative values for 1977, which are shown in Tables 3.6 and 3.7.

3.4.3 Cumulative Value

3.4.3.1 Major Appliances: The 1985 projected cumulative sales and the 1985 projected cumulative depreciated values for major appliances are shown in Figure 3.7. The cumulative retail values approach the 160 billion dollar level while the cumulative depreciated value approaches the 100 billion dollar level. These cumulative values were determined according to the procedure previously described for the 1977 cumulative values. The projected annual sales derived as part of the saturation prediction and an annual inflation rate of 7% per year for the unit cost were used as a basis of estimating the cumulative retail value and cumulative depreciated values.

3.4.3.2 Small Appliances: Projected cumulative dollar values for small appliances approaches 32 billion dollar for the cumulative retail value and approaches about 20 billion dollar for the cumulative depreciated value. These cumulative values are shown in Figure 3.8.

3.4.4 Technology Change

The most prevalent advanced technology incorporated in appliances currently being sold is the electronic control system. Electronic control in appliances range from the simple inclusion of a solid state rectifier (diode) in an otherwise electromechanical system to ultrasophisticated large scale integrated circuitry including microprocessors. Because of relative low voltage and current levels found within electronic controls, infiltrated carbon fibers may conduct enough current to randomly activate devices such as switch solenoids and diodes which may adversely effect normal operation or result in a permanent failure. Electronic controls are the only identified example of advanced technology that may have high vulnerability to carbon fiber infiltration. However, many appliances which incorporate electronic controls also have capacitance type, smooth touch-surface switches for activating various cycles. This

PROJECTED CUMULATIVE VALUES OF MAJOR HOME APPLIANCES IN THE FIELD IN 1985

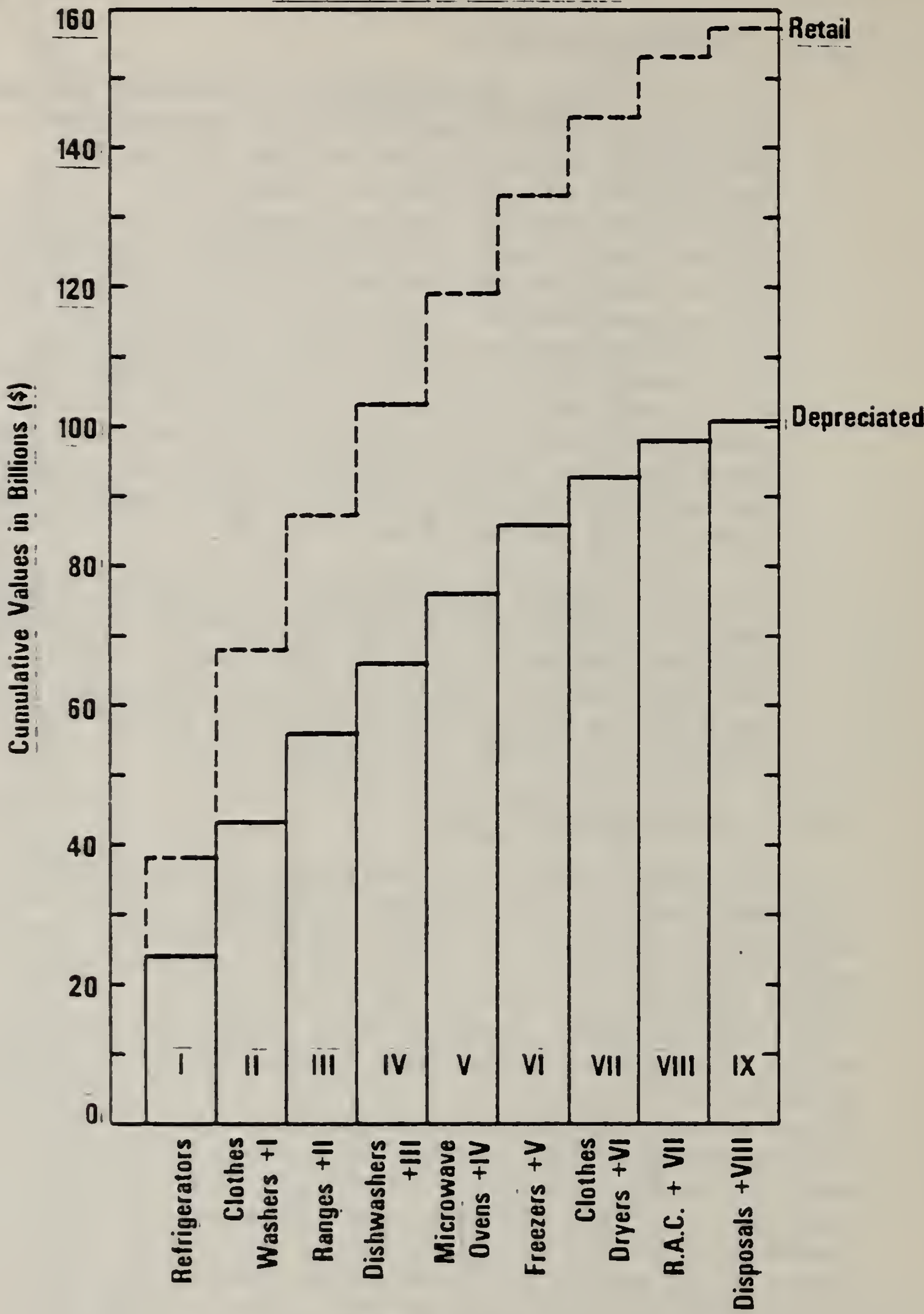


Figure 3.7

PROJECTED CUMULATIVE VALUES IN BILLION ($) FOR SMALL APPLIANCES TO BE IN U.S. HOMES IN 1985

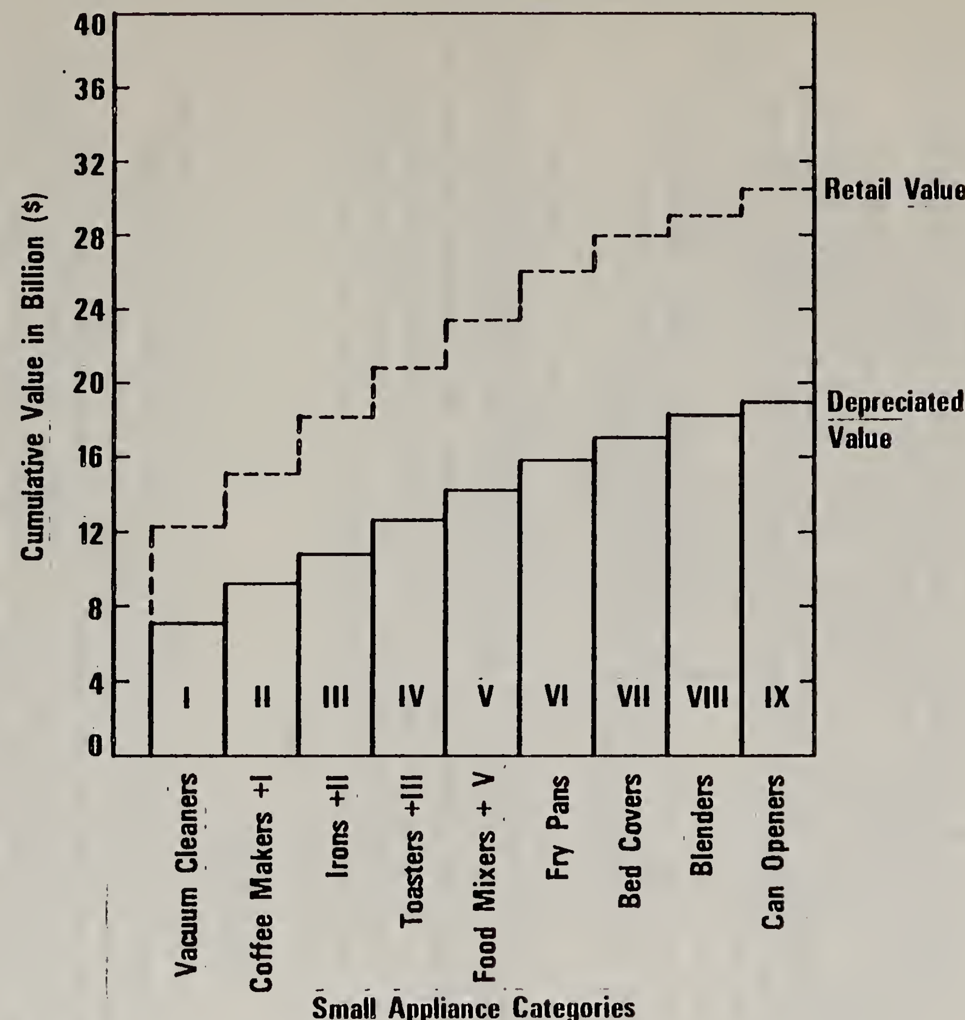


Figure 3.8

feature may offer some protection against infiltration of carbon fibers because there is an absence of pushbuttons and associated crevasses that enhance carbon fiber intrusion.

The interaction of any added protection against carbon fiber intrusion and increased susceptability due to low current and voltage characteristics of electronic control systems must be evaluated to adequately assess the risk of advanced technology appliances to carbon fibers.

Appliances selected as representative of advanced technology and examined, incorporate various degrees of electronic controls from the simplest to the ultrasophisticated. The barriers to carbon fiber transfer range from a button type control panel with many openings to a smooth, plastic film touch surface with negligible infiltration paths for carbon fibers. A dishwasher (DW-3), clothes dryer (CD-4), blender (FB-1), and range (RA-1) were selected as representative of this changing technology. The range, the dishwasher, and the clothes washer incorporated finger touch controls (no buttons) without openings.

3.5 Selection of Makes and Models for Laboratory Evaluation

Evaluation of all makes and models within each selected category was not economically justifiable under the timing and funding constraints of this study. Therefore selection criteria we established for identifying makes and models for laboratory evaluation.

3.5.1 Criteria

Three factors formulated the selection criteria for makes and models within an appliance category. First, the selected appliances were to be representative of at least 75% of each category of appliance recommended for testing. Secondly, at least three models were to be evaluated provided that this number was consistent with the time and manpower allocated. Thirdly, models were to be included that are representative of changing technology which is likely to account for a significant portion of appliances in the field by 1985 regardless of the current saturation levels.

3.5.2 Method

Industry sales profiles from "Appliance" [4,5,6] magazine were examined to identify companies that collectively accounted for about 75% of the market sales. These companies are identified in Table 3.8 and Table 3.9. The sales managers for these companies were contacted to ascertain their best selling models. Most sales managers readily divulged their model numbers which accounted for the largest percent of their sales, but the exact numerical percentage was not divulged. In most cases the sales managers indicated that several models would have to be included to account for 75% of their sales. An evaluation of several models from each company would vastly exceed the time and manpower constraints for this study. Therefore, in most cases, one model accounting for the highest percent of sales for each company that collectively make up 75% of the total sales was selected.

3.5.3 Appliances Evaluated

The availability of models, time and manpower constraints limited the laboratory evaluation to those models listed in Tables 3.10 and 3.11 by category and identifying code numbers. A brief description of the basic features of each model is given in these tables. Photographs of each model are shown in Figures 3.9 through 3.60.

Table 3.8

Major Appliance Manufacturers

Appliance	Percent of Market 1976	1977	1978
Refrigerators			
GE/Hotpoint	28	80	85
Whirlpool	22		
White-Westinghouse	18		
Frigidaire	9		
Washers			
Whirlpool	40	80	75
GE/Hotpoint	18		
Maytag	13		
Ranges			
GE	33	80	80
White-Westinghouse	12		
Magic Chef	10		
Roper	10		
Tappan	9		
Dishwashers			
Design & Mfr.	35	85	85
GE	23		
Hobart	18		

Sources [4,5,6].

Table 3.8 Cont.

Major Appliance Manufacturers

Appliance	Percent of Market 1976	1977	1978
Dryers (elec.)			
Whirlpool	40	80	85
GE/Hotpoint	20		
Maytag	11		
White-Westinghouse	11		
Freezers			
Westinghouse	27	75	80
Whirlpool	26		
Revco	13		
Admiral	10		

Table 3.9

Small Appliance Manufacturers Market Share and Ranking

Appliance	Company	1976 % of Market	1976 Rank	1977 % of Market	1977 Rank	1978 % of Market	1978 Rank
Vacuum Cleaners	Hoover	23	1				
	NUE (Eureka)	17	2				
	Electrolux	12	3			80 (include Subeam exclude Scott&Fetzer	
	Whirlpool	10	4	80 (include Sunbeam)			
	Gen. Signal	8	5				
	Scott&Fetzer	7	6				
Irons	Gen. Elec.	45	1	90 (include Scovill)		80	
	Sunbeam	19	2				
	SCM (Procter Silex)	18	3				
Toasters	Gen. Elec.		1				
	SCM		2				
	McGraw-Edison		3				
	Sunbeam		4				
Food Mixers (portable)	Gen. Elec.		1				
	Scovill		2				
	Sunbeam		3				
	Dynamic (Waring)		4				
Food Mixers (stand)	Sunbeam		1				
	Scovill		2				
	Gen. Elec.		3				
	Dynamic		4				
Fry Pans	Presto		1				
	Dart (Westbend)		2				
	Gen. Elec		3				
	McGraw-Edison		4				
	Hoover		5				
	LCA		6				
	Melita		7				
	Nat'l Presto		8				
	Regal Ware		9				
	Scovill		10				

Sources [4,5,6].

Table 3.9
(Cont.)
Small Appliance Manufacturers Market Share and Ranking

Appliance	Company	1976 % of Market	1976 Rank	1977 % of Market	1977 Rank	1978 % of Market	1978 Rank
Coffee Makers (drip)	N.A. Systems	33	1				
	N.A. Philips	17	2				
	Dart	14	3	75		75	
	SCM	7	4				
	Sunbeam	5	5				
Coffee Makers (percolator)	Regalware		1				
	Gen. Elec.		2				
	Dart		3				
	SCM		4				
	Sunbeam		5				
	Corning		6				
	Cornwall		7				
	LCA		8				
	Lake Center		9				
	McGraw-Edison		10				
Bed Covers	Sunbeam		1				
	Essex		2				

Manufacturer - Brand Name

Dart - Rockline, Westbend
Dynamics - Waring
General Signal - Regina
Hoover - Knapp-Monarch, Nesco
LCA - Faberware, Rexair, Spartus
NUE - Eureka
NA Phillips -Norelco
NA Systems - Mr. Coffee
SCM - Procter Silex
Scott & Fetzer - Douglas, Kirby
Scovill - Hamilton Beach, Dominion
Sunbeam - Northern Electric

Table 3.10

List of Major Appliances Evaluated

Appliance Type	NBS Code	Description/Comment
Refrigerators	RF-2	15.7 cu. ft. refrigerator-freezer, energy-saver switch baked enamel on outer case, epoxy enamel on steel interior lining, dual temperature controls, no frost
	RF-3	16.2 cu. ft. refrigerator-freezer, optional ice maker, dual temperature control, completely frost-free, textured embossed door fronts
	RF-1	17.2 cu. ft. refrigerator-freezer, separate temperature controls, acrylic enamel external finish, porcelain enameled interior lining, frost free.
Clothes Washers	CW-2	1.95 cu. ft. basket, temperature selector, 4 combinations, 4 cycles, optional sud-saver tub and basket, porcelain enameled cabinet is baked polymer enamel, dimension 42-1/2 in.
	CW-3	3 wash/rinse temperature combinations, 3 water level selections. Finish--tub, basket, top and lid procelain enamel; Cabinet--baked enamel
	CW-1	Capacity 19 gals., 5 temperature combinations, 3 water level selections, 5 cycles. Finish: basket and outer tub porcelain enamel, zinc-coated steel with acrylic enamel.
	CW-4	Capacity 2.6 cu. ft., solid-state controls, 3 wash cycles, automatic temperature control, continuous water level control, dispenses--bleach, softener, detergents. Finish: top, lid, and tub; porcelain; Cabinet is baked enamel. Selected as representive of changing technology.

List of Major Appliances Evaluated

Appliance Type	NBS Code	Description/Comment
Ranges	RA-1	Smooth seamless touch controls, solid-state control panel, seamless ceramic cooking surface, electric self-cleaning oven. Automatic: surface heating controls, and oven controls. Finish: porcelain enamel except acrylic
	RA-2	Automatic oven timer, flourescent lamp, oven vent duct.
	RA-3	Pyrolytic self-cleaning ovens, infinite heat control, 3-wire, 60 Hz power supply load is due rated.
Dishwashers	DW-1	Tub interior has an epoxy surface, two-cycle options, a normal full wash and dry cycle option, 700 watt heating unit.
	DW-2	7 wash cycles, hot air drying, forced air drying, energy saver switch, 1100 watt air heater. Tub--porcelain steel
	DW-3	Solid-state control activated by touch, no buttons, forced air drying, insulation porcelain enameled tub interior.
Freezers	FZ-1	15.9 cu. ft., acrylic-enamel exterior finish, porcelain enamel interior liner.
	FZ-2	16 cu. ft., no coils onback, baked enamel internal finish.

List of Major Appliances Evaluated

Appliance Type/NBS Code		Description/Comment
Clothes Dryers	CD-1	Capacity 5.4 cu. ft., electrical requirements 3-wire nominal 120/240 volts, 60 Hz a.c., standard 30 ampere fuse branch circuit (subject to local codes). Finish: top and cabinet baked polymer enamel.
	CD-2	Automatic dry cycle allows user to set the degree of dryness, also timed dry. Electrical: nichrome helix coil 240 volt, 3-wire, 5300 watt heater, 30 amp fuse.
	CD-3	Standard capacity, automatic sensor control, 4 drying selection, electrical requirements: 240 volt, 60 Hz, 30 amp required, 4 direction exhausting (bottom, rear, either side).
	CD-4	Solid-state system, pushbuttom dryness selector, 7 fabric selection, 5200 watt power master heater, drum capacity--6.9 cu. ft., finish--baked enamel.
Microwave Ovens	MOV-1	Electronic control, touchmatic selection feature, top-of-the-line model
	MOV-2	Manual dial, solid state components variable temperature

Table 3.11

List of Small Appliances Evaluated

Appliance Type/NBS Code		Discription/ Comments
Vacuum Cleaners	VC-1	upright
	VC-2	upright
	VC-3	canister
Hand Irons	HI-1	spray steam dry plastic body
	HI-2	spray steam dry with light
	HI-3	spray steam dry take apart
	HI-4	spray steam dry standard
Toasters	TO-1	Special IR Sensor & Auto. lowering
	TO-2	Sensor Control
	TO-3	Heatup/Cooldown Control
	TO-4	Std. four slice
Toaster Ovens	TOV-1	large four slice model
	TOV-2	two slice model
	TOV-3	large model, sensor
Food Mixers	FM-1	hand, low end unit
	FM-2	hand, model speed control
	FM-3	stand model-metal case
Fry Pans	FP-1	small & plastic enclosed
	FP-2	standard diecast
	FP-3	standard brazed heater
Coffee Makers	CM-1	high volume unit, drip
	CM-2	high volume-3 conductor cord
	CM-3	plastic percolator low end
	CM-4	party percolator (large)
	CM-5	high volume unit, percolator

Table 3.11

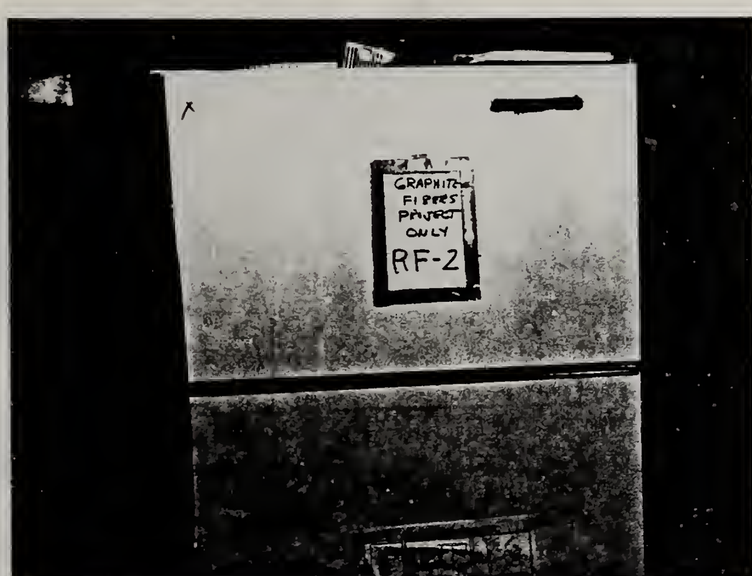
List of Small Appliances Evaluated

Appliance Type/NBS Code		Discription/ Comments
Elec. Bed Covers	EB-1	similar to all others
Food Blenders	FB-1	high technology, solid state circuit
Can Openers	CO-1	standard low end model
	CO-2	automatic turn off
Smoke Detectors	SM-1	high vol, private brands
	SM-2	std. unit--battery
	SM-3	industrial manufacturer
	SM-4	line power
	SM-5	line power & photoelectric

REFRIGERATORS

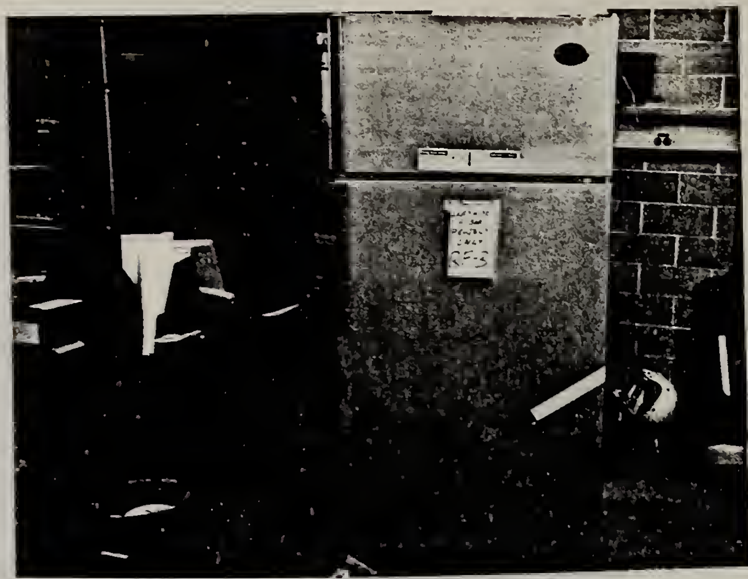
RF-1

RF-2



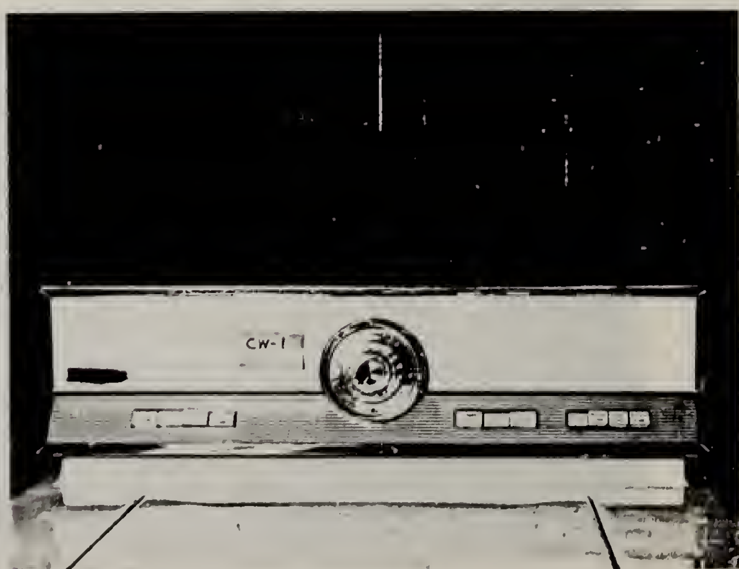
REFRIGERATORS

RF-3



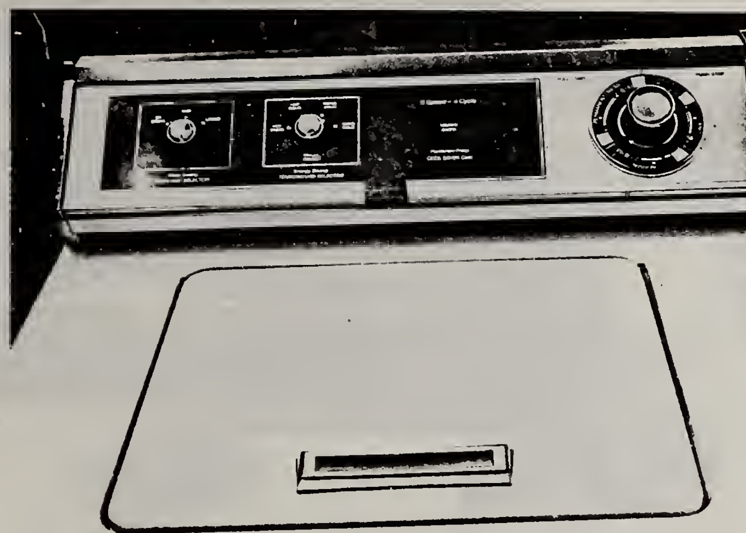
CLOTHES WASHERS

CW-1

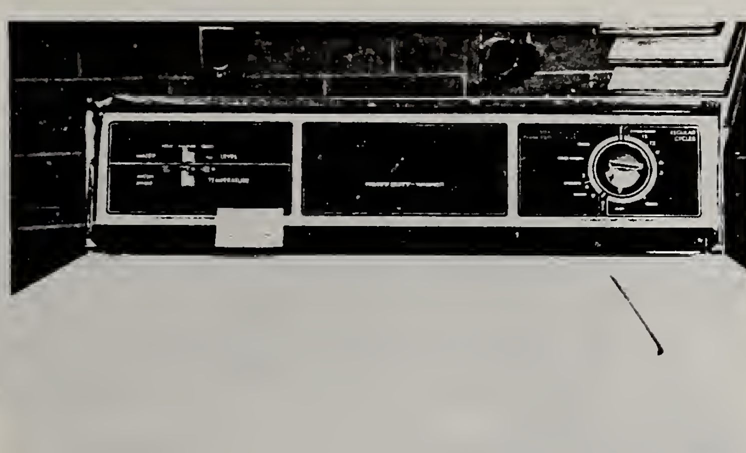


CLOTHES WASHERS

CW-2

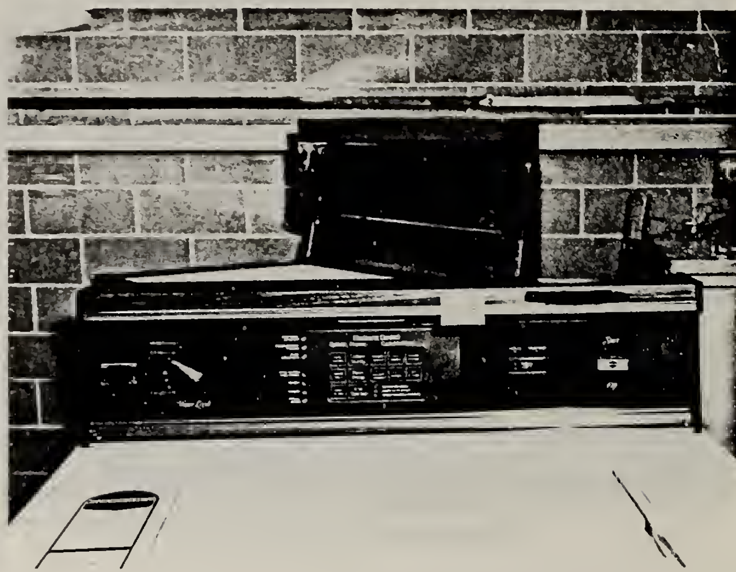


CW-3



CLOTHES WASHERS

CW-4

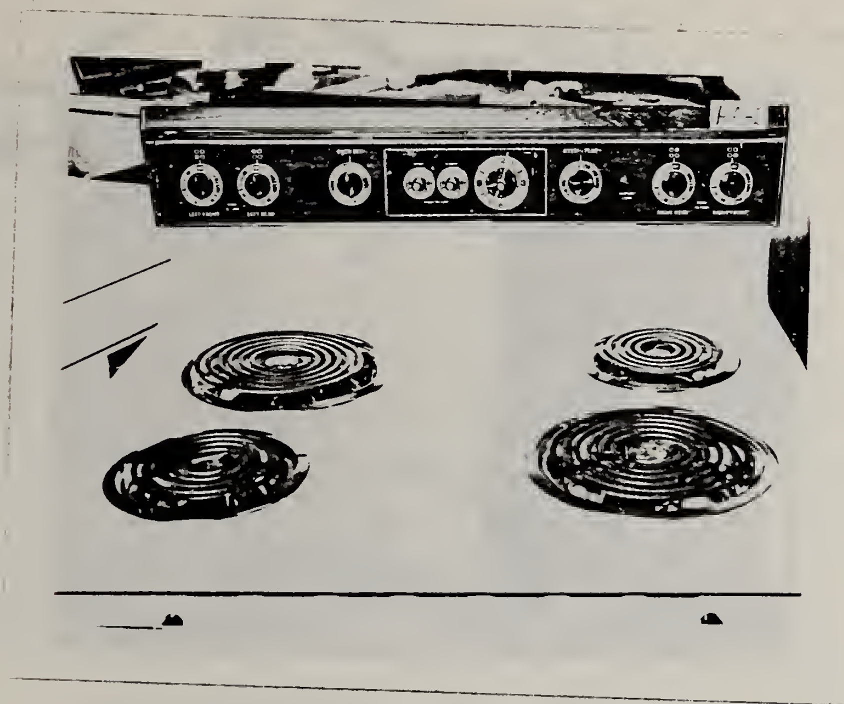


ELECTRIC RANGES

RA-1

ELECTRIC RANGES

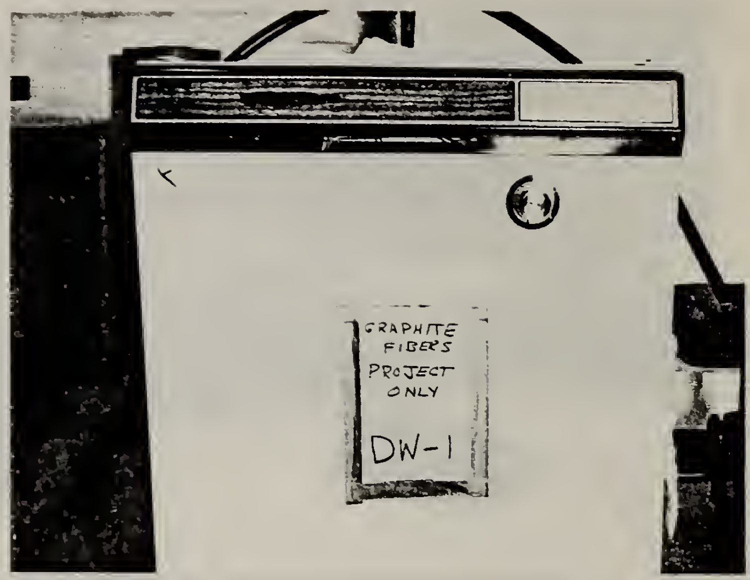
RA-2



RA-3

DISHWASHERS

DW-1



DW-2

DISHWASHERS

DW-3

FREEZERS

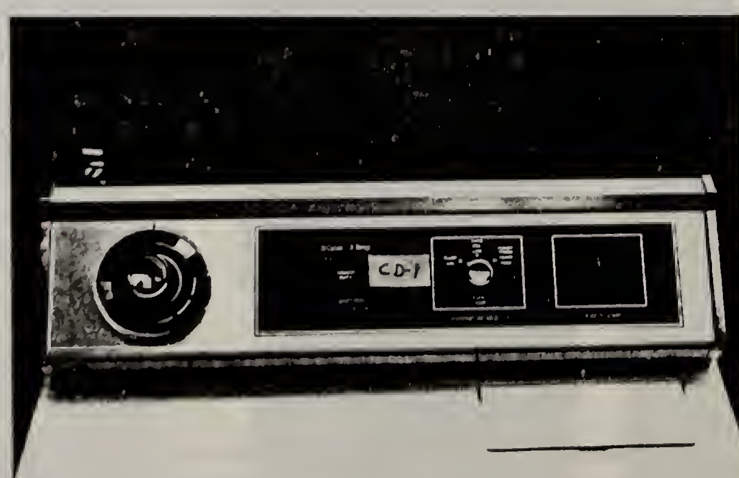
FZ-1

FREEZERS

FZ-2

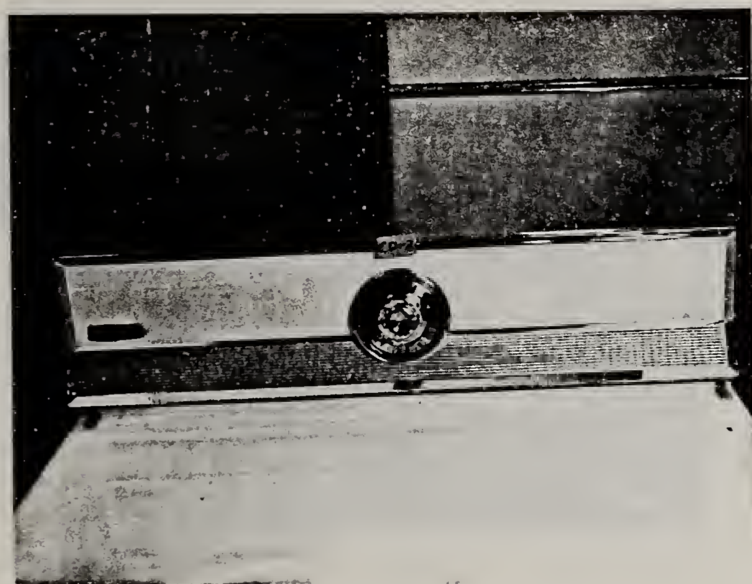
CLOTHES DRYERS

CD-1



CLOTHES DRYERS

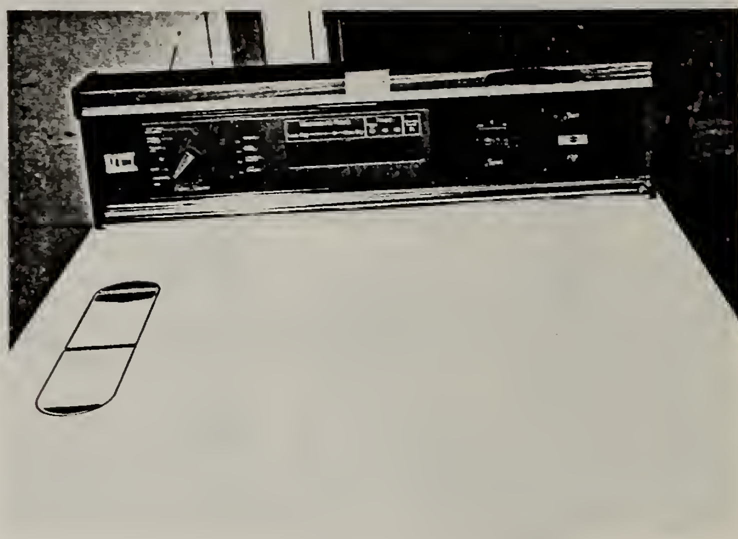
CD-2



CD-3

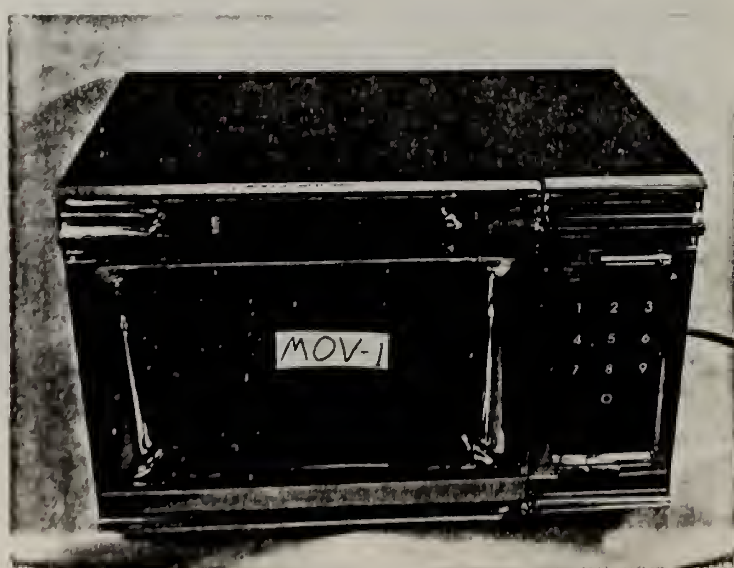
CLOTHES DRYERS

CD-4



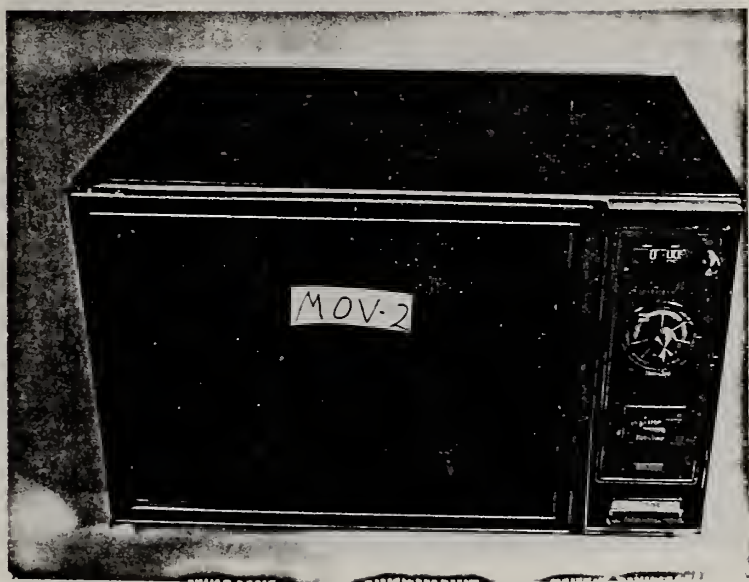
MICROWAVE OVENS

MOV-1



MICROWAVE OVENS

MOV-2



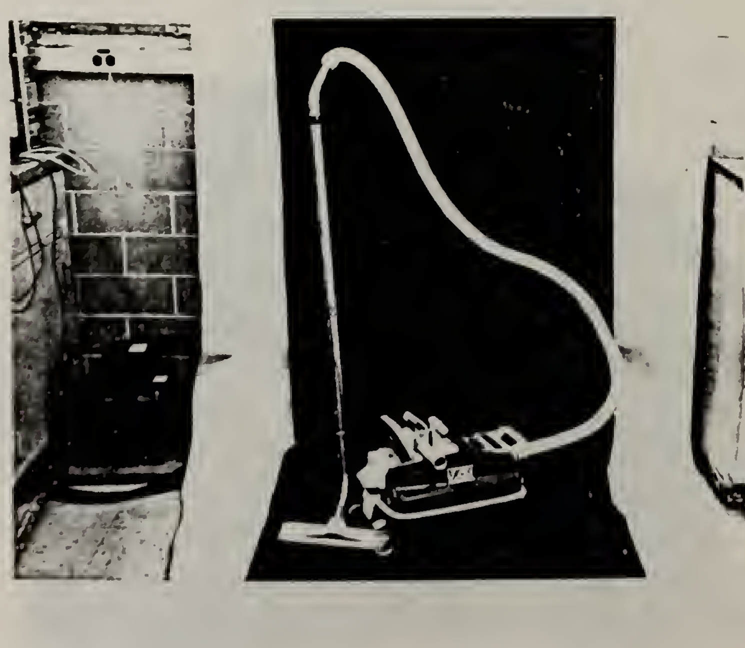
VACUUM CLEANERS

VC-1

VACUUM CLEANERS

VC-2

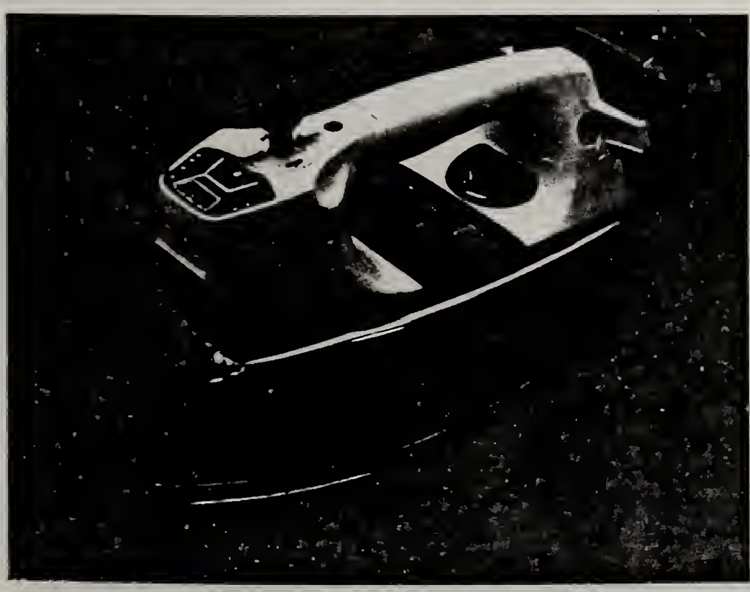
VC-3



HAND IRONS

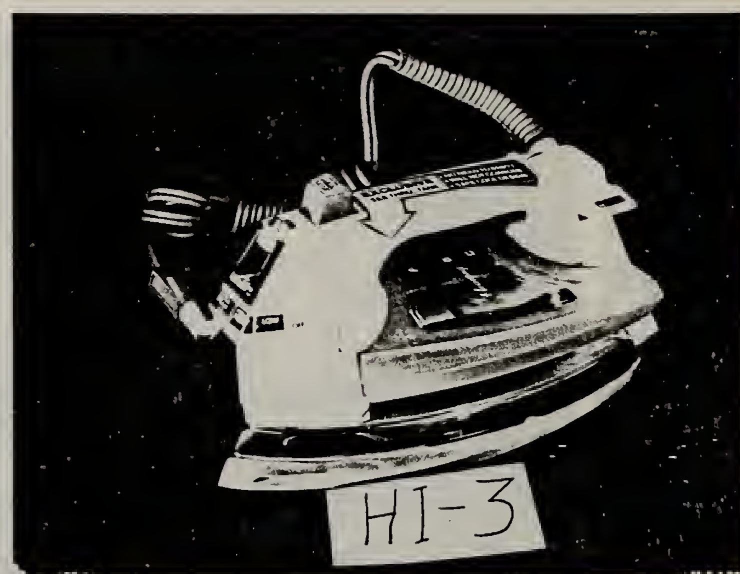
HI-1

HI-2



HAND IRONS

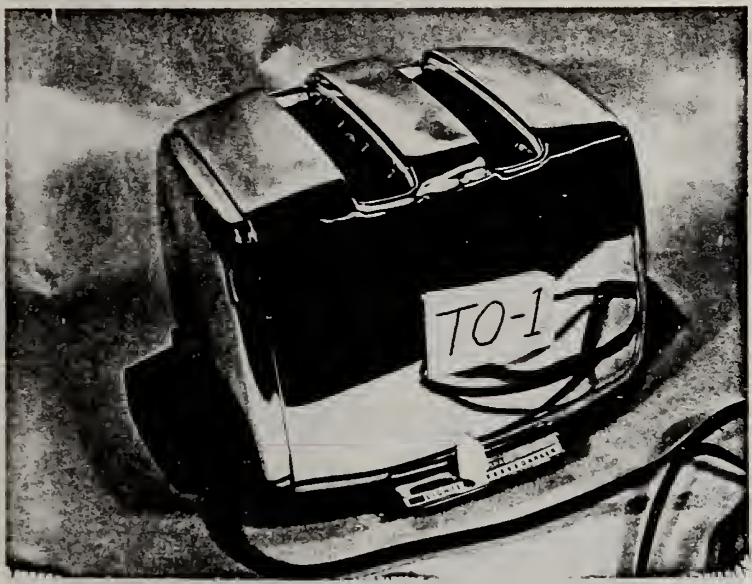
HI-3



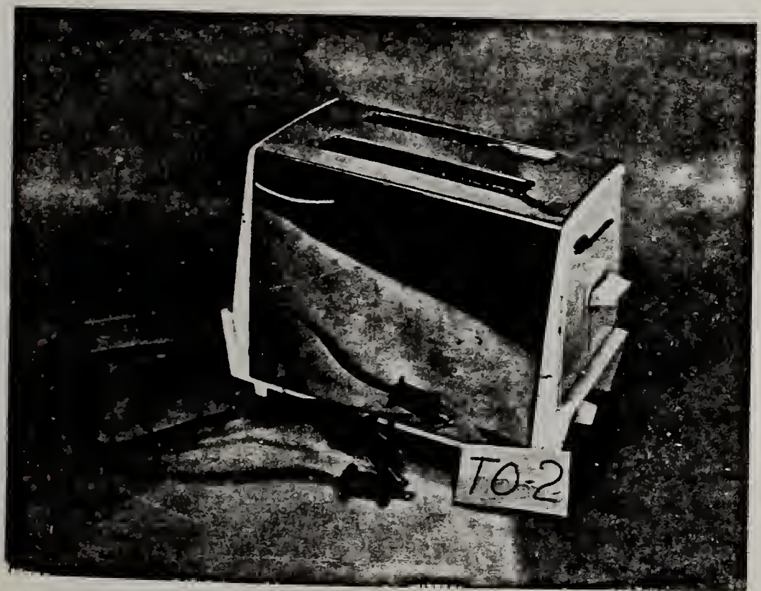
HI-4

TOASTERS

TO-1

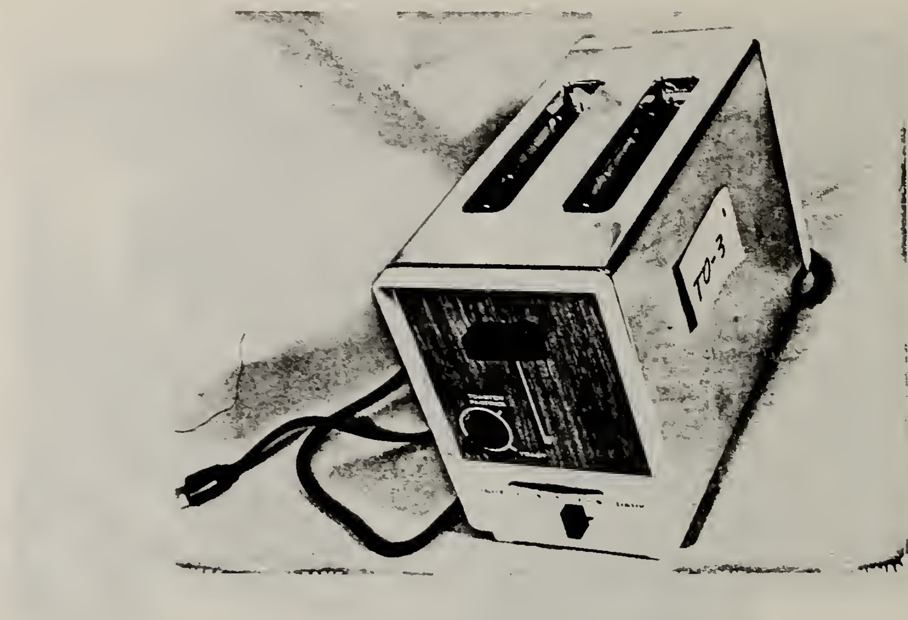


TO-2

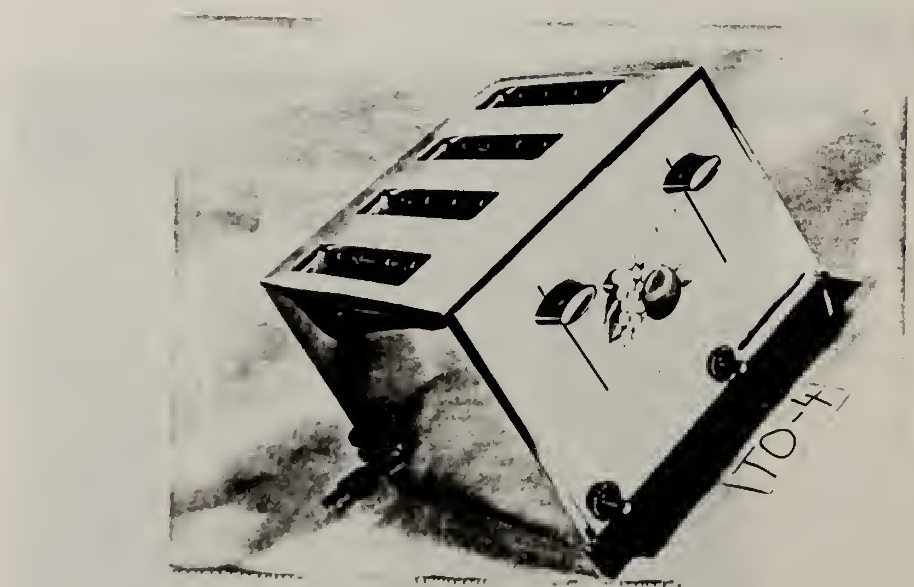


TOASTERS

TO-3

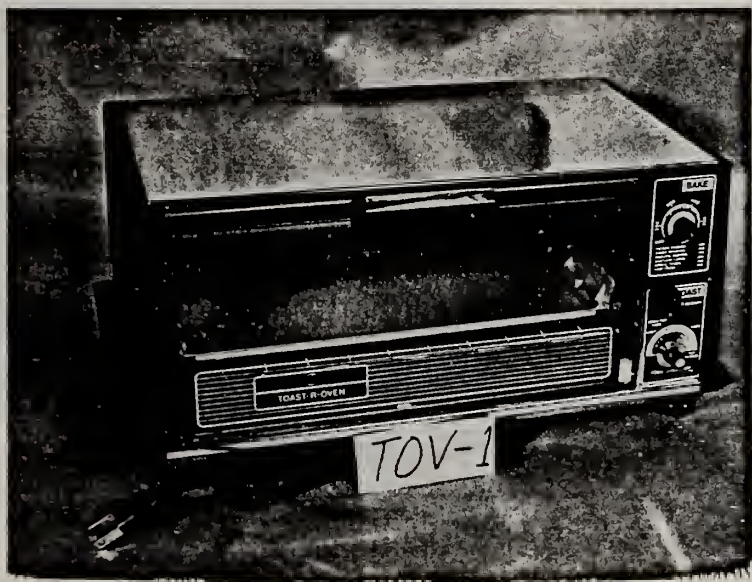


TO-4

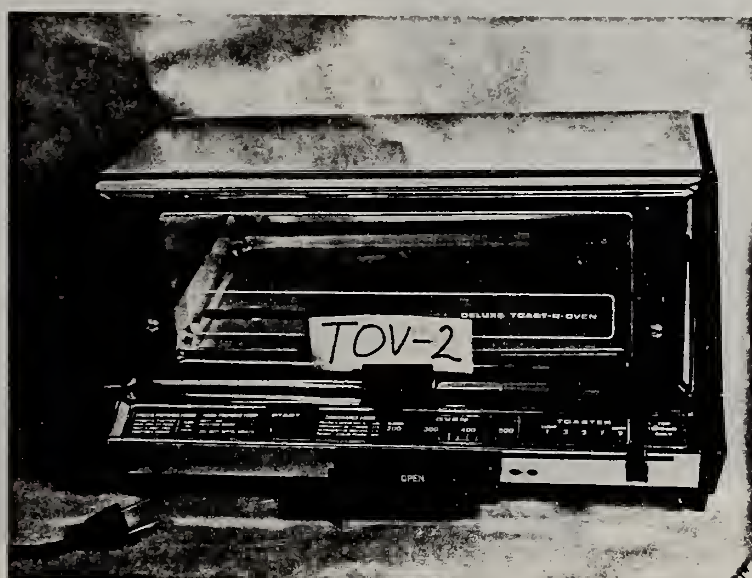


TOASTER OVENS

TOV-1

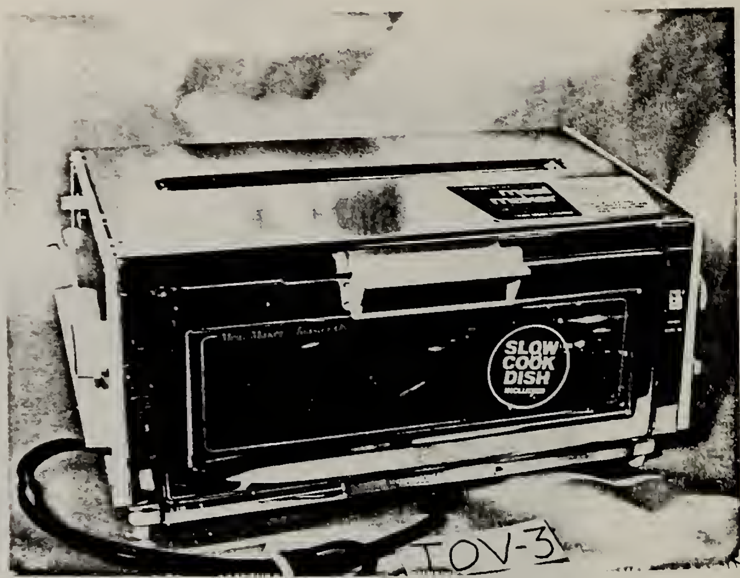


TOV-2



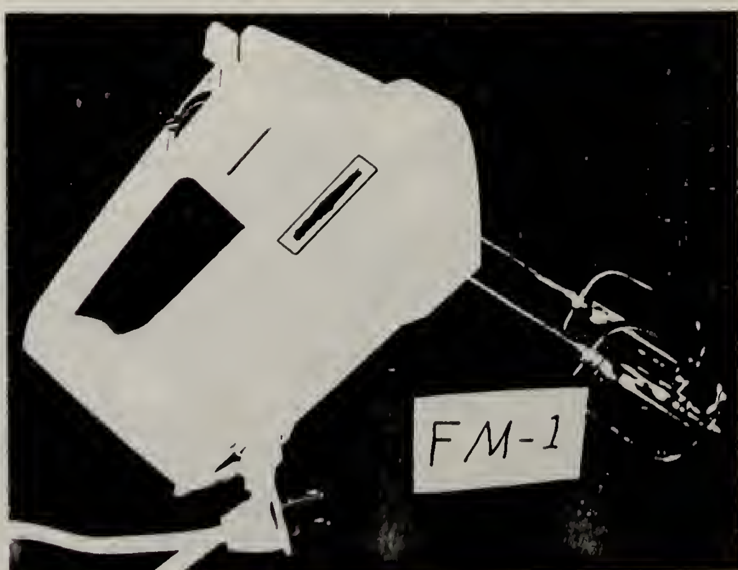
TOASTER OVENS

TOV-3



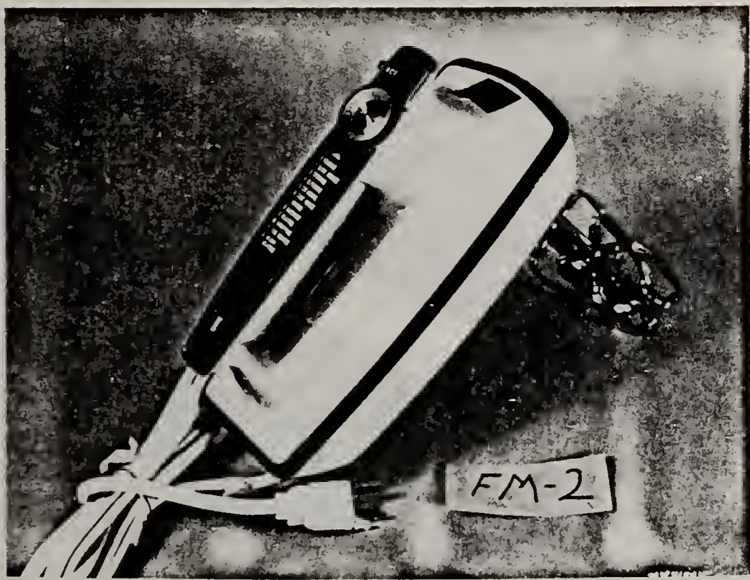
FOOD MIXERS

FM-1



FOOD MIXERS

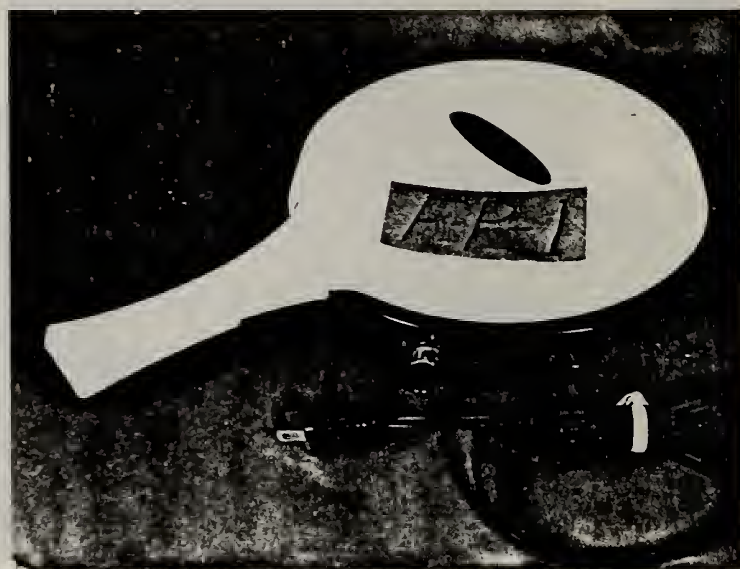
FM-2



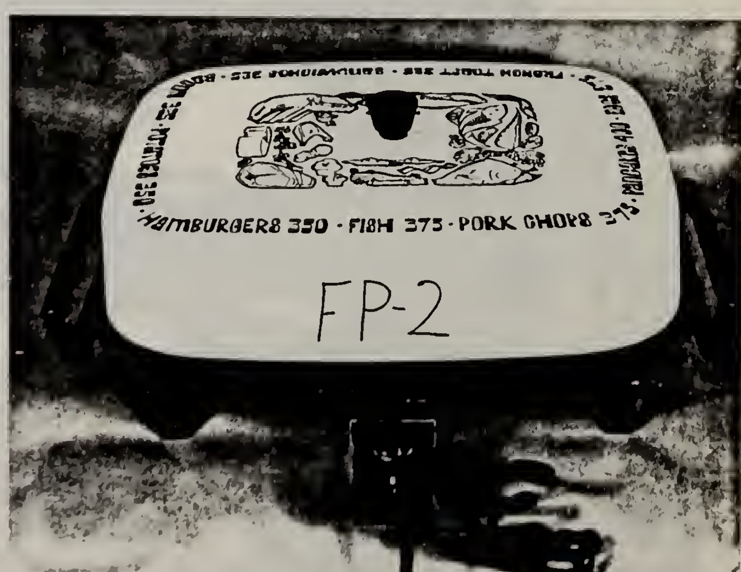
FM-3

FRY PANS

FP-1

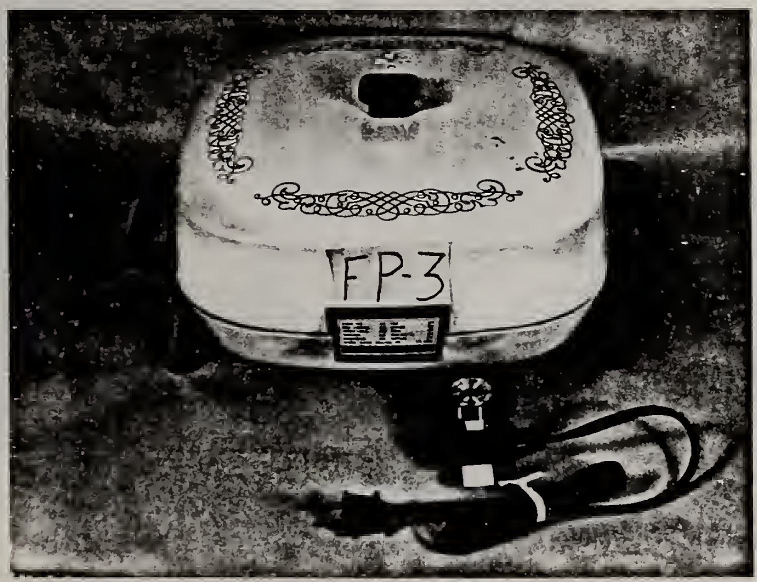


FP-2



FRY PANS

FP-3



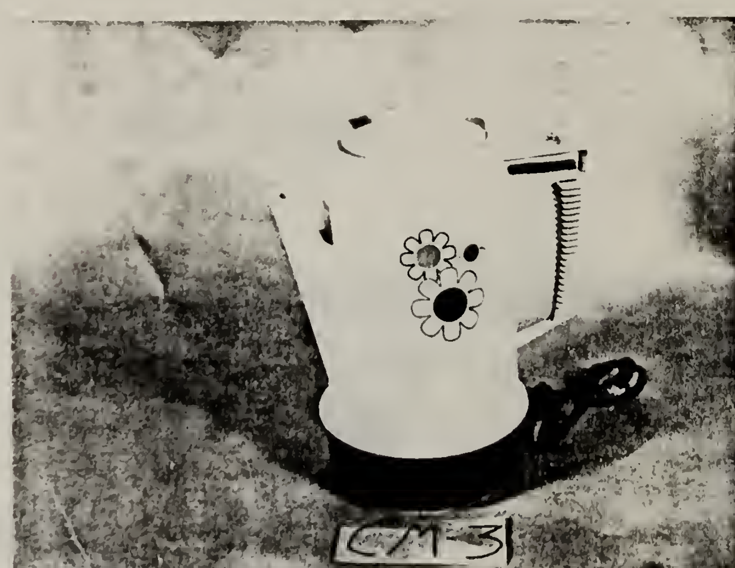
COFFEE MAKERS

CM-I

COFFEE MAKERS

CM-2

CM-3



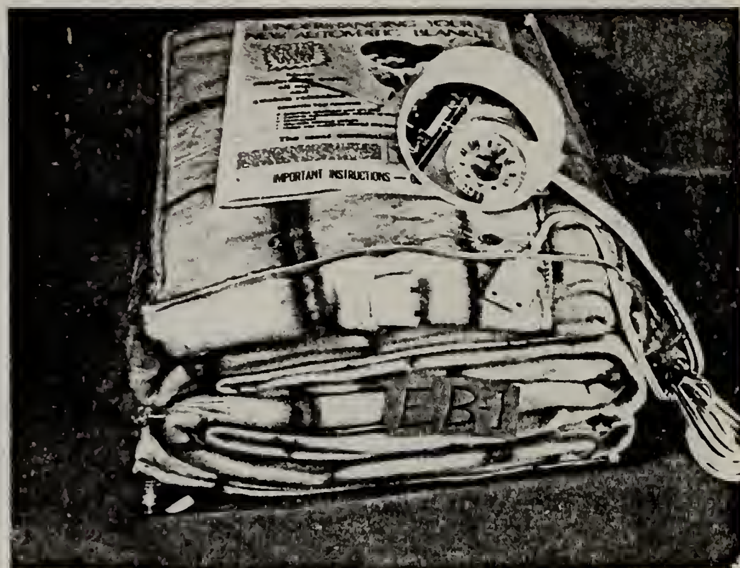
COFFEE MAKERS

CM-4

CM-5

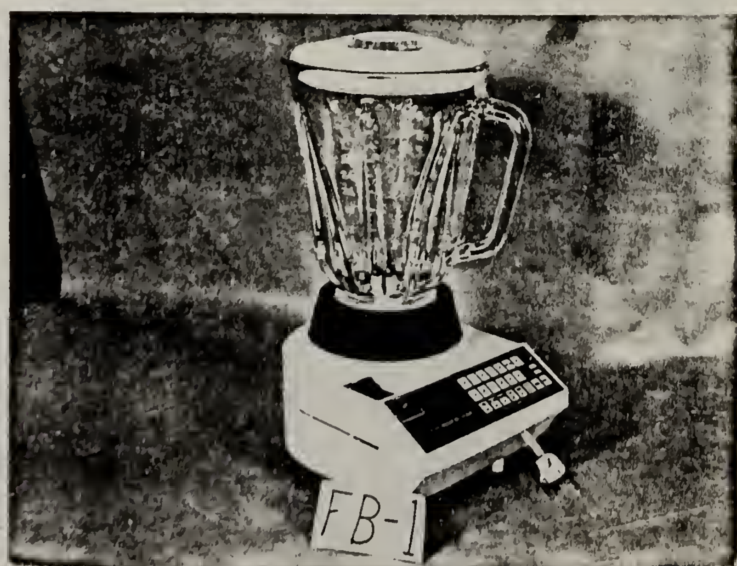
BED COVERS
(ELECTRIC BLANKET)

EB-1



BLENDERS

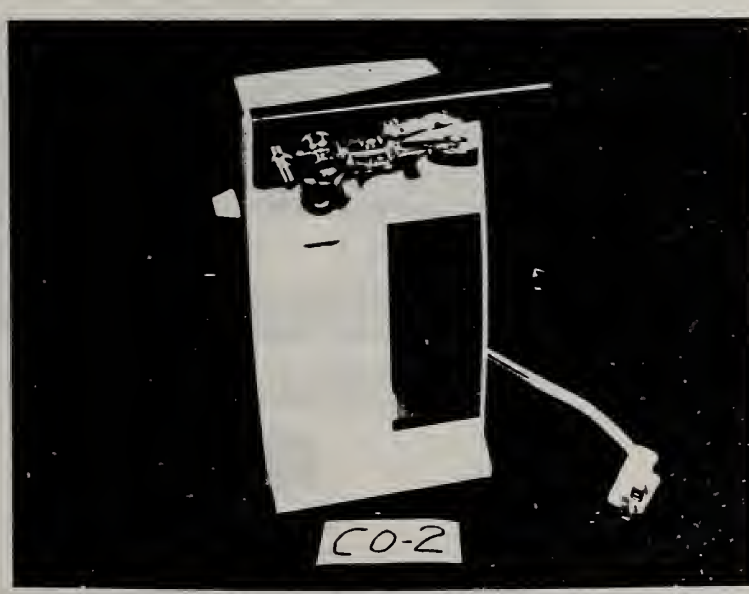
FB-1



CAN OPENERS

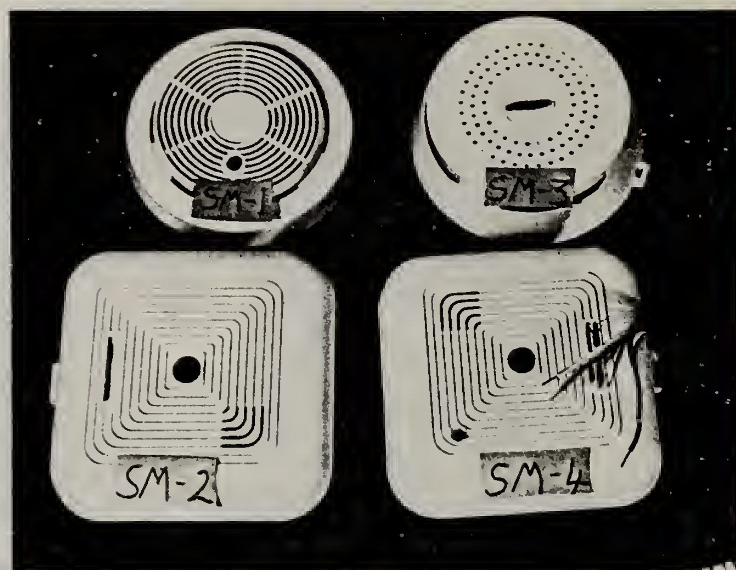
CO-1

CO-2

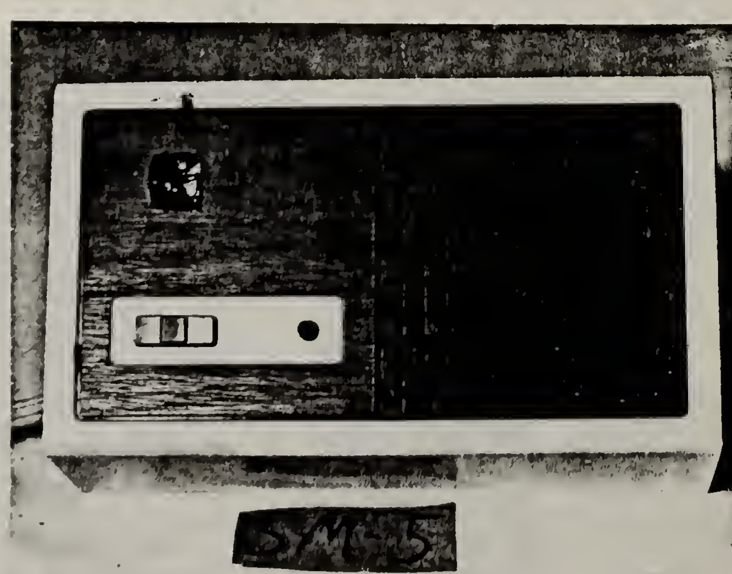


SMOKE DETECTORS

SM-1, SM-2
SM-3, SM-4



SM-5



4.0 Test and Analysis

4.1 Introduction

This phase of the NBS carbon fibers program was to evaluate hazards and faults and it consisted of a review of the conditions that could generate hazards and an analysis of the electrical circuit configurations generated by possible carbon conductive paths that would cause faults. The original NASA test procedure was tried and evaluated by NBS and a new test procedure was proposed to NASA and accepted. The analysis of hazards together with the test procedure used will be discussed first; then, the fault analysis and its test procedure will be given. Small appliances and electronic controls will be covered separately. All evaluations were based on data from NASA at the beginning of work that indicated the longest fibers of significance as 20 mm in length. Later data indicates that more than 95% of the fibers released are 10 mm or less and 85% of the fibers released are less than 5 mm in length [7]. Data on fiber characteristics [10] indicates they appear as a resistor, with a constant resistance per unit length until burnout current or temperature is approached, plus two contacts at the ends which are nonlinear with a 1 to 2 volt drop. For short high current pulses fibers burn out at about 100 millijoules [10]. The resistance per unit length for most fibers varies from about 500 Ω/cm to 3000 Ω/cm. The burnout current ranges from about 10 mA to 33 mA for most fibers and the burnout power dissipation from about 0.3 W/cm to 0.8 W/cm [11]. Therefore since most fibers are one centimeter or less in length, continuous currents conducted will be no more than about 33 mA and continuous power dissipations no more than about 1.6 W. All fibers 20 mm or less will burn out if directly connected across power line voltages of 120 V or 240 V.

NASA has the facilities for chamber testing products with various fiber lengths and exposures. Appliances not suitable for analysis have been recommended for chamber testing.

4.2 Standard Product Analysis

4.2.1 Appliance Hazard Evaluation

Aside from the potential hazards associated with appliances in normal use, three possible hazard modes could be generated by carbon fibers. These are discussed in order of importance.

1. Electrical Shock

The only way one can get an electrical shock from an appliance is to simultaneously touch an uninsulated metallic part of the appliance that has a differing electrical potential than another touched electrical conductor (not necessarily part of or connected to the appliance).

If an uninsulated, ungrounded, metallic part of an appliance can be touched, and if it is connected to an electrical voltage through a carbon fiber, sufficient voltage (120 volts) and current (up to about 33 mA) are available to cause a serious electric shock when another part of the body is touching an electrically-grounded conductor.

It should be noted that the shock hazard is less than the hazard caused by a direct line short since the fiber resistance will be in series with the body resistance resulting in a lower current level. If the fiber plus body resistance are low enough to allow current greater than the 33 mA, the fiber will burn out when it has dissipated 100 mJ which should occur in no more than 50 ms. Carbon fibers carrying currents of 33 mA or more will burnout prior to the time likely to result in electrocution. Currents below 33 mA will not likely result in electrocution (stoppage of the heart) [12]. The likelihood of death occurring from carbon fiber aided electric shock, therefore, appears to be small. It should be noted, however, that burnout will not prevent a person from feeling the shock. If multiple carbon fibers bridge the gap from ungrounded conductors to the frames of ungrounded appliances, problems are forseen.

Since virtually all major appliances are Underwriters' Laboratory (UL) Listed, they have passed tests to assure that accessible electrically conductive parts are either insulated or are constructed so they may be electrically grounded. Thus, when properly manufactured, installed, and grounded, there is little probable shock hazard generated by carbon fibers. Should a carbon fiber touch an uninsulated electrical part whose voltage is above ground and connect it to a grounded uninsulated chassis part, the fiber cannot raise the voltage because of the ground connection. The fiber may burn out but burn out is not a hazardous occurrance. In all known major appliances, the few electrically isolated parts (usually plated knobs or escutcheons) have no connecting pathway to energized nodes that could be formed by carbon fibers. It is possible that fibers completing a circuit to ground may cause a ground fault circuit interrupter (GFCI) to trip, even if the fiber would burn out. GFCI's may trip faster than a fiber will burnout. This nuisance tripping is not likely to be a significant problem for appliances since GFCI's are currently required by the National Electric Code in outdoor, bathroom and garage outlets which are not the normal locations for appliances.

Because of the above, there is no need to analyze the electrical shock effects of carbon fibers on effectively grounded appliances either operating or not (device "on" or device "off").

There is a need, however, to inspect all touchable metallic surfaces and the bonding between such surfaces to evaluate the integrity of the ground connection. The UL requirements permit considerable latitude in the means for making the connections; hence long term integrity should be evaluated. Thus a listing of all metallic surfaces that may be touched by the user was proposed by NBS and accepted by NASA as a part of the hazard evaluation. This listing requires inspection of all touchable conductive surfaces to classify the integrity of the ground connection.

If the chassis of an appliance is not grounded, two types of electrical configurations must be considered:

Type 1. 120 volt plug-in appliances with or without a ground wire such as refrigerators and

240 volt devices with no need for a neutral wire connection such as water heaters.

Type 2. 240 volt appliances with neutral third wire that may carry current (e.g. ranges, clothes dryers).

In Type 1 appliances, it must be assumed that any uninsulated electrical connection within the device can be at a potential above ground. This is so because with 120 volt appliances, the current carrying circuits that are normally connected to the electrical neutral source may be incorrectly connected to the high potential source and vice versa (plugged into unpolarized or incorrectly wired outlet either way). Even though a three prong grounding type plug is furnished for major appliances, it is possible for the user to remove the grounding prong, thus defeating its purpose. Also, 240 volt appliances without electrical neutral have all current carrying circuits connected to power sources that are 120 volts above ground electrically so a carbon fiber connecting either line to an ungrounded touchable conductive surface raises its voltage to 120 volts.

Because of the above, all uninsulated electrical connectors (nodes) must be evaluated for spacing from ground since for spacings less than 20 mm a carbon fiber could cause a hazardous condition. For this evaluation, the "Fiber Simulator" which tests for burn-out is not needed since, when the chassis is ungrounded, the fiber obviously cannot burn out because no current can flow.

Type II appliances that have 240 volt input but that require a neutral to function properly may have some nodes that need not be evaluated for hazard potential. These nodes are the ones that must be near ground potential at all times since they are connected to neutral. Such nodes of course could not generate a hazard condition even with spacing less than 20 mm. However, <u>all</u> uninsulated electrical connections (nodes) of Type II devices except those directly connected to neutral must be evaluated for spacing from the chassis or other accessible metallic part. Again, electrical test for burn out is not needed.

Open Wire Heaters

Open wire heaters are a special case of possible shock hazards that is not adequately evaluated by measuring the spacing of uninsulated nodes to ground, because the hazard condition can exist along a long length of wire. In some appliances, notably clothes dryers, high wattage high temperature heaters are constructed of high resistance (compared to copper) uninsulated wires. Typically these wires are mounted on ceramic insulators which in turn are mounted to a grounded (chassis) bare-metal surrounding support structure. They are usually, but not always, located in a forced air flow environment.

In no case can a node to node fault caused by a carbon fiber cause an electrical shock hazard with connector nodes or with open wire heaters. This is so because node to node connectors connect only electrical parts to electrical parts. Since these are all either electrically insulated from ground or already at ground potential, connecting one to another cannot expose the user to any elevated electrical voltage when the chassis is touched. In any case, node to node fiber connections are sufficiently evaluated for hazard potential since each node is separately tested by measuring its clearance from touchable metallic parts.

2. Fire

Since a carbon fiber can dissipate about 100 mJ before burnout, this low energy level is not likely to initiate a fire or cause carbonization of high temperature electrical insulating parts. The maximum continuous circuit power dissipation due to fiber connection would be 33 mA times 240 volts or 7.9 watts, but no more than 1.6 watts of this can be dissipated in the fiber without burnout. The remainder must be dissipated by other current limiting circuit components. In our judgement, this low power level in free air will not generate enough heat to ignite nearby objects. If the fiber were against an insulator, the heat generated from the one watt may cause serious carbonization over a long period of time, but again the likelihood of fire is very remote, using UL prescribed insulation. Some electronic products or electronic applications in major appliances may be designed such that long term carbonization could establish fire potential conditions. Such possibilities cannot be evaluated with a single measurement using the Electric Fiber Simulator. Only long term (hours, days, or weeks) tests could be used to determine potential fire hazard for such designs.

Besides considering heat generated by a fiber, there is also the possibility of the fiber conducting current to a resistive load within the appliance to generate heat in the load (e.g. a fiber conducting across open switch contacts (nodes)). The 33 mA in any load is judged to create a very remote possibility of a fire hazard.

A final consideration is the possibility of the fiber making a conductive path to a secondary control device (i.e. relay coil). The four watts available may be sufficient to close a relay or turn on a solid state electronic switch which in turn could start a motor, turn on a lamp or apply voltage to a heater. All of these devices are of course designed to be turned on without fire hazard and are protected by thermal devices should excessive temperatures be attained, particularly if left running continuously. This too is a UL requirement.

The only exception found to date is in an electronically controlled dishwasher which does not have a back-up safety thermostat. This possibility is discussed under "Electronic Controls."

Thus, though the probability must be considered during analysis, it may be concluded that there is little possibility of fire hazard associated with carbon fibers for appliances.

3. Physical Harm

Because of the power limitation discussed above, it is our judgment that no physical harm is likely to result to the appliance's user caused by electrical connections through carbon fibers to operating devices. Motors cannot run and/or heaters will not heat with the relatively high carbon fiber resistance in series with them and the associated four-watt limitation. Even with a burn out, the higher power would be applied for such a short period of time that no damage could be done. The only known possible hazard is if a fiber were to cause a secondary control device to turn on which in turn would turn on a motor or heater. A motor running or a false cycle of a timer controlled appliance is considered a fault condition, not a hazard. A heater turned on might represent a burn hazard, particularly in an electric range but such hazards exist even without the exposure to carbon fibers. Such conditions will be covered in the notes section of the hazard analysis.

4.2.1.1 Analysis

In analyzing the probability of hazard in appliances, it has been determined that except for a remotely possible fire or burn hazard related to secondary control devices (discussed in the Fault Evaluation section), only electric shock need be considered and then only if the appliance is ungrounded. Spacing is the prime consideration because if the distance is over 20 mm, the likelihood of a hazard is negligibly small due to the anticipated fiber length distribution. The hazard potential varies inversely with spacings less than 20 mm.

Four other factors effect the probability of hazard and each will be discussed separately.

1. Exposed Surface. The likelihood of a carbon fiber connecting a node to ground is not only related to spacing but also to the contact surface exposed to fibers. Figure 4.1 illustrates this condition. From the figure it is obvious that there is greater potential for fiber connections with the uninsulated terminal than with the insulated one and that this difference is roughly proportional to the length and width of the exposed surface. Probability analysis can perhaps be used to quantify this factor so a measurement was taken of the other dimensional parameter-exposed conductive surface less than 20 mm away from a grounded surface for later use.

2. Some grounded surfaces are electrically conductive, others are painted and so may or may not be insulated depending upon the integrity of the coating. Some surfaces may be coated with a

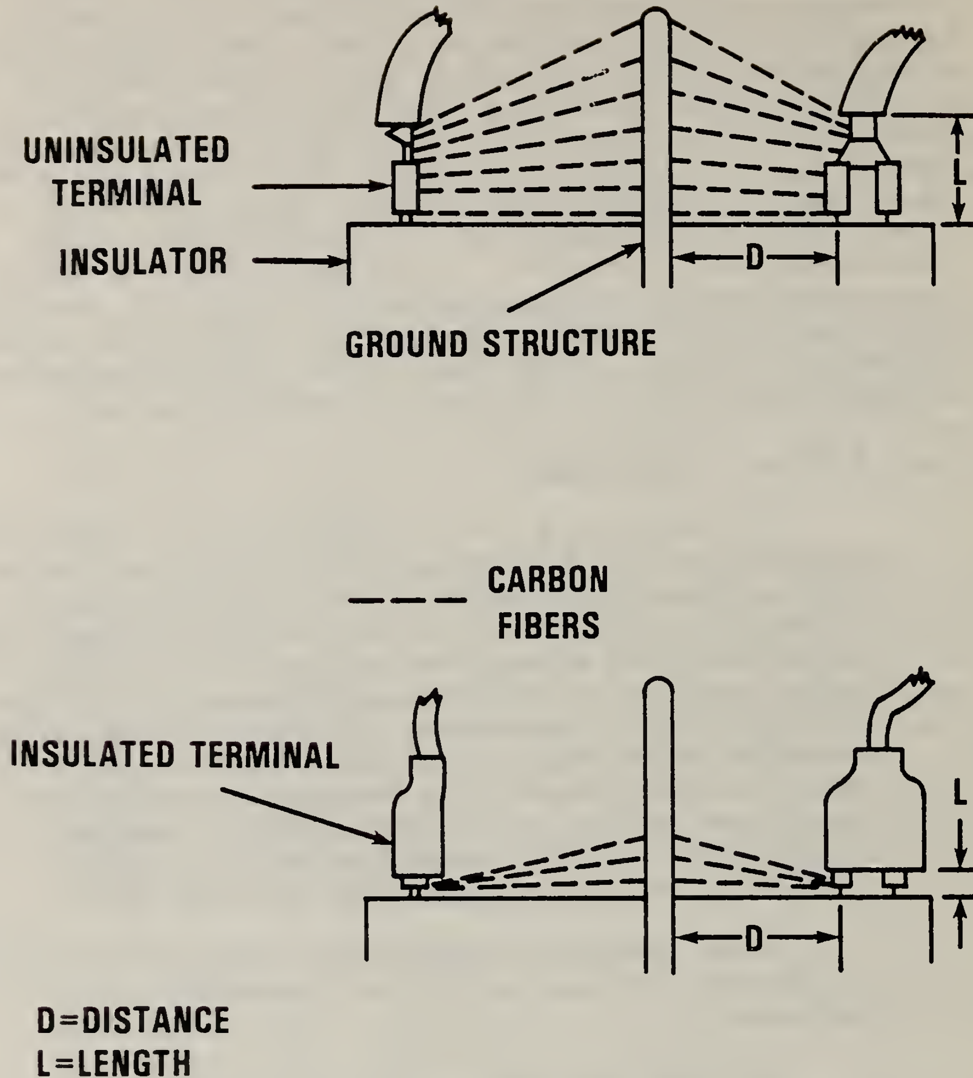


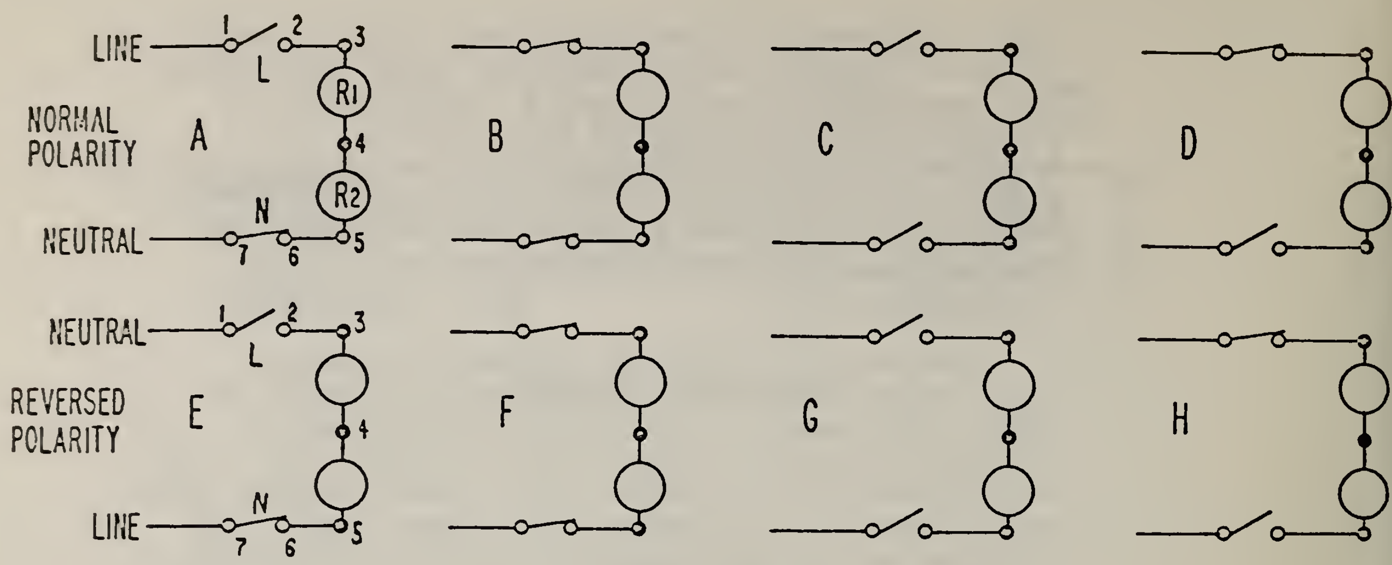
FIGURE 4.1
LENGTH FACTOR HAZARD ANALYSIS

high temperature fired porcelain enamel which is an even better insulation than paint but still not necessarily sufficiently reliable to be considered as acceptable insulation. The presence of a coating material should be noted to permit its inclusion in evaluating the overall hazard potential of a conductive surface less than 20 mm away from one exposed electrical conductor.

3. Switch position can effect the hazard evaluation only from a statistical point of view. The position of various electrical switches (on-off, timed cycle, light, etc.) will not affect the existence of a shock hazard since any electrical conductor with less than 20 mm spacing may at some time during the operation of the device be at an elevated voltage (depending upon grounding and upon the polarity of the input wires). Some nodes are directly connected to the power source so a fiber connecting these to ground would produce a hazard at all times. Other nodes are only connected to electricity when a switch is closed so a hazard would exist only while the appliance is operating and in some cases for only a short period of time during an operating cycle. In other cases, the node is not a hazard when the appliance is running but may be a hazard when the appliance is off. Figure 4.2 shows the possible circuit configurations and hazard matrix. Because of the above, the type of hazard condition switched or not switched needs to be known to complete a statistical analysis of hazard probability.

It is perhaps as probable that an ungrounded appliance will be connected with reverse polarity as for it to be connected correctly. This is so because if the ground pin is cut off the plug or if a "cheater" adapter is used, the plug or "cheater" can be inserted into the outlet either way. Thus, consideration need not be given as to which side of the incoming power lines the node is connected, or whether permanently or switched. In any case there is a chance that a carbon fiber connection to ground will cause a hazard. In Type II appliances any fiber connection to an ungrounded touchable

Circuit Configurations



Note:
1. Node numbers, loads, and switches same locations on all figure
2. Loads energized only or circuits B and F
3. R1 and R2 can be a single load
4. Either or both switches may be used
5. L = Switch is (normally) line side of incoming power
6. N = Switch is (normally) neutral side of incoming power

Hazard Matrix

Hazard

— = None

X = Continuous

R = When running

0 = When off

Figure		A	B	C	D	E	F	G	H
Polarity		Normal				Reversed			
Neutral Switch		Closed		Open		Closed		Open	
Line Switch		O	C	O	C	O	C	O	C
Node	1	X	X	X	X	–	–	–	–
	2&3	–	R	–	0	0	–	–	–
	4	–	R	–	0	0	R	–	–
	5&6	–	–	–	0	0	R	–	–
	7	–	–	–	–	X	X	X	X

Figure 4.2

metallic surface will cause a hazard but in these devices the probability of the appliance not being grounded is low.

4. The last effect on hazard probability relates to the condition of the air surrounding the node under question. If the node is completely insulated or hermetically sealed, there is no hazard involved. If the node is in a confined volume of air with only small holes or openings offering passage to fibers from the ambient air, there is a little chance for a carbon fiber hazard. Many terminals are in physically inaccessible locations but have large and numerous connecting passage ways to outside air. These terminals are considered to have a "normal" (unrestricted) chance for a fiber to cause a potential problem. Terminals located in a forced air passage with a fan blowing air across them have a somewhat better chance of carbon fiber deposit but also have a better chance for the fiber to be blown away. Thus the overall effect may be an only slightly higher than normal probability of hazard. The worst case is those node locations where a slow but steady one way flow of air is passing over the exposed connection. A hot air chimney effect or the venturi effect of nearby high air flow could create this condition. Here the air is flowing by to increase the exposure to possible fibers but the movement is not great enough to blow fibers off of the terminals. Thus, the surrounding air status needs to be evaluated for all hazardous node locations.

4.2.1.2 Test Procedure

Based on the foregoing discussion, the following test procedure was proposed to NASA, accepted, and utilized in evaluating all of the purchased appliances.

The test procedure uses three "Hazard Analysis" record taking sheets, samples of which are on the following pages. The steps to be followed in data taking after filling in the general information on Data Sheet I are as follows:

DATA SHEET I

GENERAL INFORMATION

TABLE A	
TYPE OF EQUIPMENT	
MANUFACTURER	
MODEL NUMBER	
SERIAL NUMBER	
OPERATING VOLTAGE	
CIRCUIT DIAGRAM REF NUMBER	
GRAPHICS REF NUMBER	

TABLE B		
VENTILATION TYPE		REMARKS
FORCED AIR		
CONVECTION		
WATER		
OTHER		
FILTER DATA		
FILTER TYPE		
FILTER P/N		
VENTILATION SKETCH		

TABLE C		
CONTROL UNIT TYPE		REMARKS
MECHANICAL		
ELECT/MECH		
ELECTRONIC		
OTHER		
SEALING MECHANISMS		
NONE		
COATINGS		
ENCLOSED		

DATA TAKER (INITIALS) ______________________ Date __________

1. Number all nodes on an electrical schematic or wiring diagram.

2. Fill in the product identification and node numbers on Data Sheet II.

3. Disassemble the appliance sufficiently to inspect all electrical connections (nodes).

4. Measure the distance from each exposed node to the nearest chassis (mechanical ground) or electrically conducting structure that is connected to chassis ground. If greater than 20 mm, put a check mark in the space "D" column in Data Sheet II. If the node is totally insulated put a zero in that column. If not, record the distance (to the nearest mm) in the "D" column and then proceed with the following steps recording the information in the appropriate Data Sheet II column:

a. Measure the length of the exposed metallic electrical conductor (node).

Since open wire heaters are generally coiled with the ceramic support encircling the coil, specifying the millimeter dimensions of the electrically-energized surfaces to the ground surfaces is difficult. To provide some relative measure of the potential hazard involved, the measurements illustrated in Figures 4.3 and 4.4 may be utilized.

Figure 4.3 shows a case where the coiled heater wire is more than 20 mm away from the nearest ground surface except near the ceramic support structure. In this case some of the heater wires are close to a ground point, D1, and some are near the maximum fiber length distance, D2, so an average of these two values is a reasonable estimate of the spacing, D.

While it might appear that the length of the exposed conductor would be the total stretched out length of the coiled wire, a better measure would be to consider the

Page__________

Data Sheet II
Hazard Analysis

Product______________________________ Mfgr.______________________________ Code #______________

Node	Space(mm)		Coat	Air	SW			Node	Space(mm)		Coat	Air	SW		
#	D mm>o	L mm	B,P,E	E,N FC,FF	C,S	Total	Notes	#	D mm>o	L mm	B,P,W	E,N FC,FF	C,S	Total	Notes
						Totals									Totals

Remarks

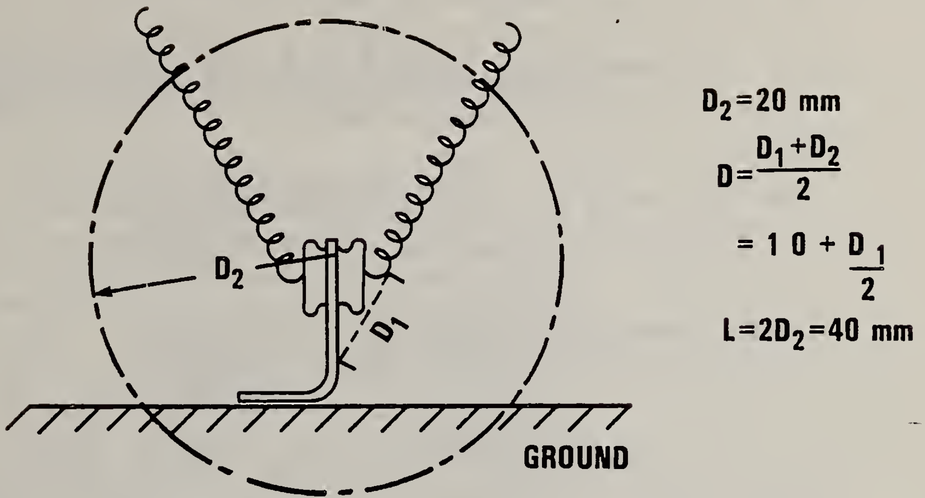


FIGURE 4.3

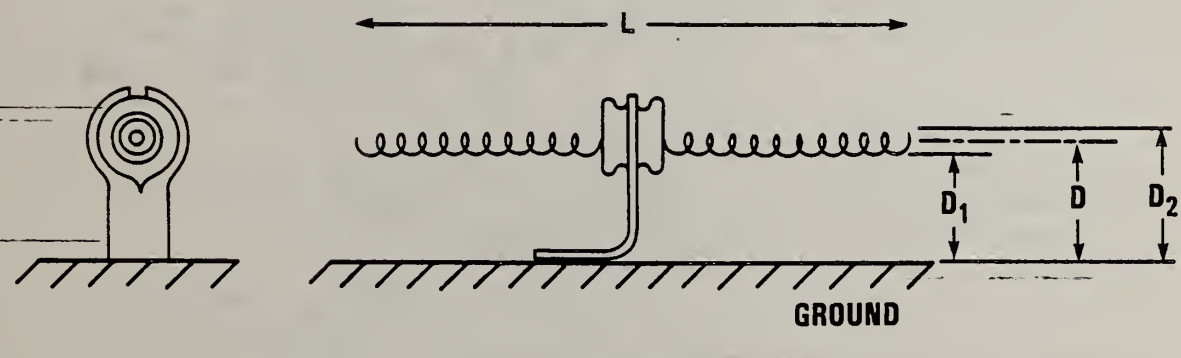


FIGURE 4.4
OPEN WIRE HEATERS HAZARD ANALYSIS

coil as a solid structure and thus the measure would be the length of the exposed coil. In the illustrated case, this would be $L=2D_2$. This measure seems consistent with the length measurement used with normal nodes or terminals.

Figure 4.4 illustrates a heater coil running parallel to a ground surface and the measurements (D&L) used are shown.

The configurations likely to be used for heaters are many and quite varied so while the figures adequately specify a measurement system for the illustrated designs, variations will have to be considered individually. For instance, a coiled heater between two flat ground plates could be considered as 2L but if the plates are not equally spaced from the coil, the heater would be considered as two nodes, with equal L's but different D's. Also, a straight line heater centered in a cylindrical support structure with less than 20 mm spacing might be a larger multiple of L.

b. Note whether the ground or chassis part is bare metal, coated with paint, or coated with a baked porcelain enamel.

c. Note the type air circulation around the node using the following definitions:

E = Node is in an enclosed compartment with no way for carbon fibers to get into the node area except for small holes or air gaps at the joints of the protective cover.

N = normal, large room area air accessibility through louvers or other such means.

FC = Forced air flow by the node either by hot air chimney effect or venturi effect.

FF = Air forced over the node by fan.

5. Analysis of the circuit diagram is done to provide the appropriate value for the switch column of Data Sheet II. This evaluation is to determine the need for a switch contact to be closed in order to create a shock hazard or whether the node may always be connected to the high voltage line. Use the following definitions:

C = Always connected to one side of the incoming power line or the other side.

S = Connected to an incoming power line conductor only when a switch is closed.

6. The columns labeled "total" are filled out as described in a later section of this report under "Data Evaluation."

7. The columns labeled notes refer to note numbers of notes listed on Data Sheet IV of the analysis (see attachement). The notes describe any peculiarities associated with the node or product under evaluation.

8. On Data Sheet III, list by an appropriate name all of the metallic parts of the appliance that could be touched by the user (coated or uncoated, plated or chrome color plastic, etc.). Parts that are welded together are considered as one part. Proceed with the following steps recording the information in the appropriate Data Sheet III column:

a. In the first column, note the approximate (visual estimate) area of the surface of the part: use "S" if under four square inches; use "M" if four square inches to one square foot; and "L" if more than a square foot.

b. Measure the resistance of the part to the ground terminal of the appliance. (Rx1 ohms range of a Simpson 260 multimeter)

Page__________

Data Sheet III
Hazard Analysis
Ground Integrity

Product______________________ Mfg.__________________________ Code #________________

Part #	Part Name	Area 1-2-3	Space mm	Coat B,P,E	Res. Ω	Type	Note #

Light scratching to break through noncoating barriers is acceptable.

c. Note whether the touchable surface of the part is conductive, paint insulated, or baked procelain enamel coated.

d. If the resistance of the part connection to ground is over one ohm or marginally connected (See e 3&4), measure its distance to the nearest node. Record the distance if less than 20 mm.

e. Note the method of connection to ground using the following definitions:

1. Wire or strap connection, metal-to-metal contact or lock/star washer.

2. Wire or strap connection, connection mostly through screw threads.

3. Connection from the part to another grounded part through stationary surface to surface contact (may be screw or bolt connected).

4. Connection from the part to another grounded part through a moving mechanical connection (hinge, bearing, etc.).

5. Isolated, no electrical connection.

In order to record the heater hazard, D and L values as shown in Figures 4.3 and 4.4 may be used and placed in the proper columns of "Data Sheet II." In this case, however, if there are multiple identical support structures, instead of just a node number, write in the number of heater nodes with an appropriate note. Also on this line should be a note number referring to a description on "Data Sheet IV, Notes" of the heater and how the hazard was evaluated.

Page____________

Data Sheet IV
Hazard Analysis
Notes

Product______________________________Mfg.________________________________ Code #______________

Note #	

4.2.1.3 Suggested Data Evaluation

The foregoing test procedure includes several factors that affect the statistical analysis of the probability of hazards being generated by carbon fibers. Since the evaluation of probabilities was not part of the NBS work plan, no action was taken on the subject. However, to indicate the reasons for suggesting the type of data to be taken in the hazard analysis, a possible formula for combining the effect of the five factors effecting hazard is given as follows:

$$HF = \frac{L \times AF}{D^2 \times CF \times SF}$$

where HF= hazard factor

L = length of the exposed node in mm

D = distance of node to ground in mm

AF = air flow factor

CF = coating factor

SF = switch factor

Possible values for the factors affecting the hazard factor could be:

AF = .5 = enclosed

1 = normal exposure

10 = chimney or venturi forced flow

3 = fan forced air flow

CF = 1 = base metal

4 = paint coated

10 = enamel coated

SF = 2 = unswitched node, Type I appliance

10 = unswitched node, Type II appliance

4 = switched node, Type I appliance

15 = switched node, Type II appliance

Of course the above proposed formula and factors are for illustration only and are only a suggested analysis. They are not the considered opinion of a knowledgeable group of experts or of experimental quantification. Further consideration should be given to improving the data base before finalizing each of the factors.

Regarding open wire heaters, it is apparent that the voltage applied from a heater wire to a nongrounded structure by a fiber will vary depending upon the position along the heater that is contacted. At some places the resultant structure voltage may be full line voltage (120V) and at others the voltage could be zero or at least less than 30 volts and therefore nonhazardous. This effect is only realized when the heater is "on." The hazard evaluation differs with 240 volt type II appliances (i.e., clothes dryers) and type I devices. On type II appliances, it would be reasonable to multiply the L/D factor by 0.75 to compensate for the nonhazardous portion of the heater wire. On type I appliances, the same factor would apply only during the time that the heater is connected to both sides of the line (switched "on"). At all other times, one side of the heater may be solidly connected to the neutral wire so with reversed polarity the entire length of heater wire could be at full line potential. This would result in a 0.5 factor for the off condition. Some appliances disconnect both sides of the heater when it is off so that no hazard exists during these periods.

The totals column was included on the Analysis Data Sheet II to provide work space for making an individual and total calculation of a hazard factor should this method be pursued.

Ground integrity was not incorporated in the hazard factor formula since this is a subjective evaluation. The secondary control of ranges was also not evaluated because there is only one electronic range known that might evidence such hazard. It will be discussed in the electronics section of this report.

4.2.2 Appliance Fault Evaluation

Fault analysis relating to carbon fibers is needed to evaluate what the effects of the fibers would be on the performance of electric appliances. Performance can be considered affected if an objectionable difference in appliance operation is noticed that would be sufficient to generate a service call for repair or to initiate owner dissatisfaction or owner repair action. Such action can occur if there is a malfunction of a component in either of the two major electrical system classifications: output and control. Each will be discussed separately.

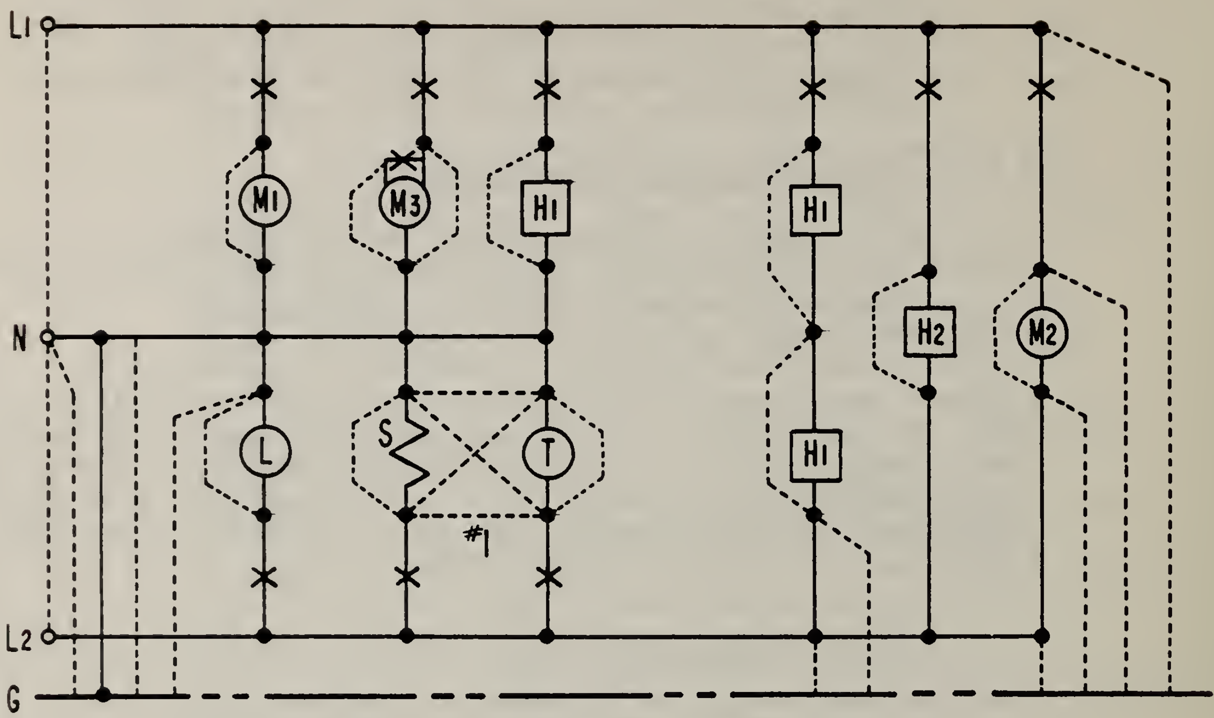
4.2.2.1 Output Devices

An output device is a component that performs some function of use to the user. Some general types are:

motors
heaters
solenoid valves
lights
clocks

With a few minor exceptions, all such devices in appliances are designed to operate with 120 or 240 volt ac power input. The exceptions are the few devices that are designed for low voltage operation. These must have another device in series with them to drop the line voltage down to their operating voltage. In appliances, transformers are generally used only in control circuits due to cost.

Figure 4.5 is a simplified circuit diagram of a power source applied to a number of operating devices. The X's on the figure



L1 = L2 = Power Input Terminals, 120/240 Volts
N = Power Input Neutral
G = Chassis Ground
M1 = Motor, 120V
M2 = Motor, 240V
M3 = Start Winding Type Motor
S = Solenoid
L = Lamp
H1 = Heater, 120V
H2 = Heater, 240V
T = Clock Motor

---- - = Carbon Fiber
——— = Conductor
X = Control Switch
0 = Terminal or Node
— -- — =

Fault Analysis
Output Devices - Single

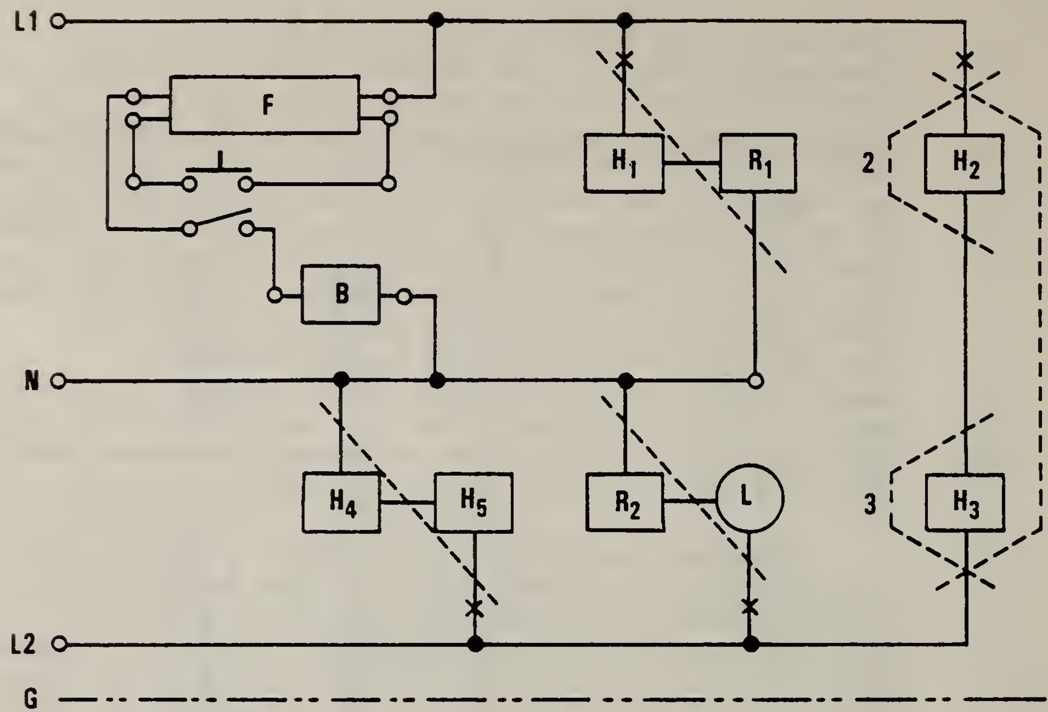
Figure 4.5

represent the control devices that will be discussed later. The dotted lines represent carbon fibers. It is obvious that all of the carbon fibers (except the three that connect the power neutral to chassis ground) will have line voltage applied to them, either 120 or 240 volts. It is also obvious that this voltage will cause the fiber to heat up and possibly burn out. In any case, the very low current flow through the fiber will not effect the operation of the device. Any burnout will occur either immediately or as soon as the voltage is applied to it. If the fiber does not burn out, it is only adding a maximum of a 33 milliampere load to the line and so will have negligible effect.

Between one pair of devices, S and T, of Figure 4.5, are shown four of the many other fiber connections that could occur between terminals of different devices. It can be seen that all such interconnections would place the fiber across 120 or 240 volts or would be across lines of equal potential. None of these connections could effect operation of the devices except the one labeled #1. This connection goes to a switched clock motor with low wattage. The clock could operate from the fiber current which would be a fault. It is unlikely, however, that a clock would have a switch (X) in its circuit. With no switch, no problem exists with any of the possible carbon fiber conductive paths. Therefore, for fault evaluation, it is not necessary to test any connectors, terminals, buss bar conductors or any nodes associated with power supply conduction circuits or output devices.

The exception to the above that should be considered is circuits where two devices are in series. The two heaters across 240 volts shown in Figure 4.5 indicate two identical units which, when in series, would have 120 volts across each. These of course behave identically to other 120 volt devices as far as carbon fibers are concerned.

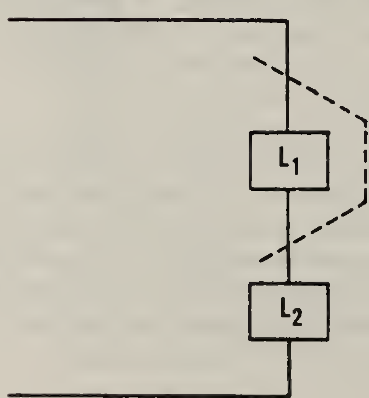
Figure 4.6A shows several configurations of output devices in series that are not pairs of



L1, N, L2, G=INPUT POWER CONNECTIONS 240/120 VOLT
F=FLOURESCENT LAMP
B=BALAST
H=HEATER H_1 to H_5
R=DROPING RESISTOR R_1 & R_2
L=LAMP

---- CARBON FIBERS

A



GENERALIZED CIRCUIT

B

FIGURE 4.6
OUTPUT DEVICES—SERIES FAULT ANALYSIS

identical devices. Only carbon fiber No. 1 is shown across the combination of two series components since this and all other such line-to-line connections will obviously not effect the operation of either of the devices.

Figure 4.6B shows a simplified circuit of two load devices in series. When considering the effect of carbon fibers across one of two devices in series, it must be noted that the maximum current a fiber can conduct for extended periods of time is less than 33 milliamperes.

This fiber current limits the maximum additional amount of power that can be supplied to a load by a fiber in parallel with a second device in series with the load to less than seven watts (7.9 W-1.6 W in fiber). Conversely, the same current limit also results in the maximum power decrease in a device shunted by a carbon fiber to about the one watt the fiber can dissipate. Thus, fibers can only effect very low wattage output devices. The only known low power output device in appliances is a clock. (Timers will be discussed in the control section.) Clocks would not be connected in series with other devices so they would not be effected by carbon fiber conduction paths.

4.2.2.2 Control Devices

Control devices are those components within an appliance that control the electrical power flow to output devices. They can be divided into three groups--primary, secondary and auxiliary.

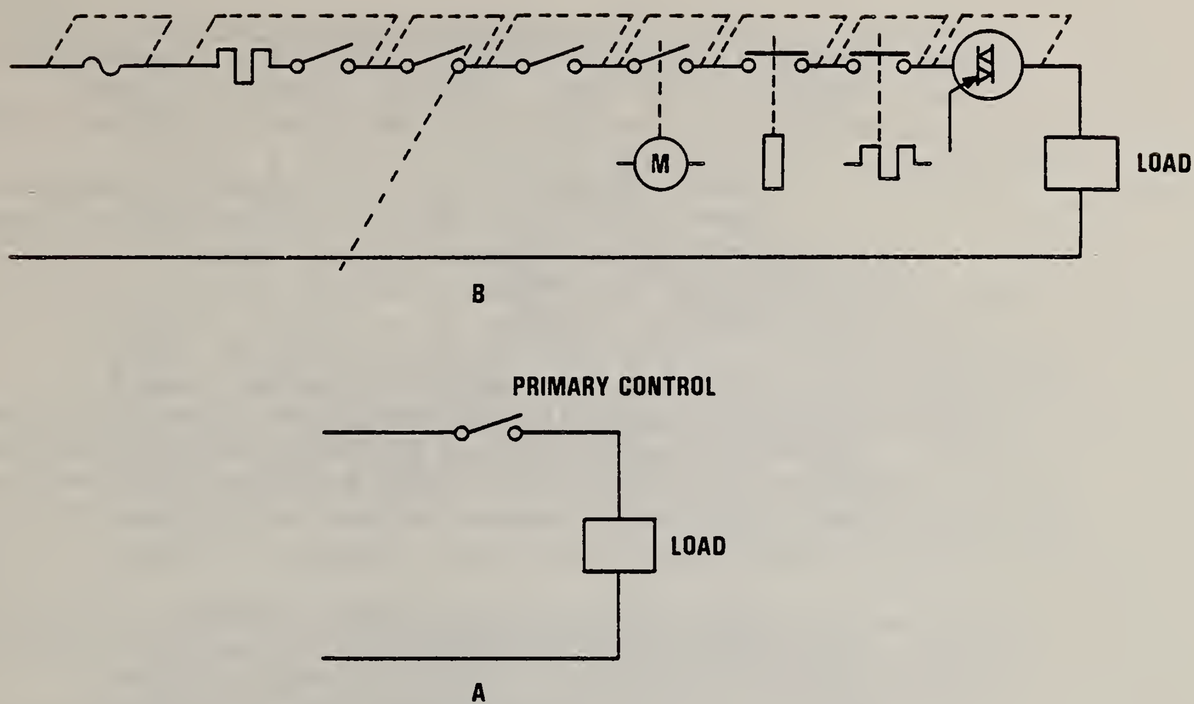
4.2.2.2.1 Primary controls are those that control output devices (loads) directly such as:

fuses (thermal, current)
circuit breakers (thermal, current, manual reset, etc.)
manual switch (rotary, slide, toggle, momentary, etc.)
sensor switch (pressure, temperature, position, etc.)
timed switch (normally open, normally closed,
    double throw)
relay contact (normally open, normally closed,

double throw)
electronic switch (ac, dc, phase controlled)

Figure 4.7A illustrates the basic circuit of all primary controls. Figure 4.7B shows a series chain that includes one of each type of primary control; any one of which, when opened, will interrupt current to the load. The dotted lines around the devices indicate possible carbon fiber paths. It can be seen that if the control device is conducting (closed) a fiber will have no effect. Except for very low-wattage loads, if the device is open, the fiber will burn out unless another control in the series chain is open. In this case, the fiber will have no effect until all other switches are closed which will then cause the fiber to burn out. One of the many possible fibers is shown drawn from a control device terminal to the line on the opposite side of the load. All such fibers will have no effect when the switch is open but will burn out when the switch (or switches) closes. Again, there would be no effect on load operation. Further consideration shows that it makes no difference whether the primary control device is in the line or neutral conductor nor will voltage effect operation. Should the fiber not burn out, its resistance would prevent enough current from flowing to cause the controlled load device to operate. The only exception to the above would be if the output (load) controlled consumes less than ten or so watts at normal voltage. Such light loads are more likely to be incorporated in electronic products than in appliances (pilot indicator lights will be discussed later). Any such low-wattage output devices must be considered separately for fault effects.

In conclusion, fault analysis of primary controls consists of an evaluation of the loads controlled. Once assured that all are over 20 watts, i.e. significantly greater than 10 watts, further evaluation or testing is unnecessary. Testing with the carbon fiber simulator would of course be needed for evaluating low power effects.



FIGURE

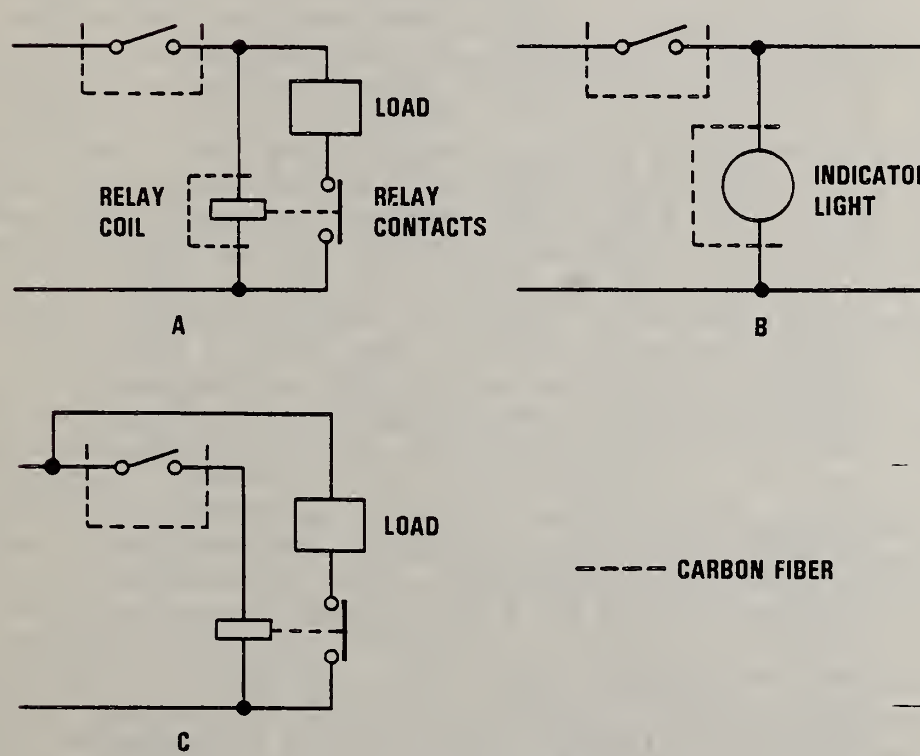


FIGURE 4.8
SECONDARY CONTROLS FAULT ANALYSIS

4.2.2.2.2 Secondary controls are ones that control output devices indirectly by means of a second electrical circuit, usually of low wattage. The types of secondary controls are:

relay (magnetic coil or bimetal heater)
timer (electric motor or electronic circuit)
electronic circuit
indicator lamp
audible signal

The last two devices may be termed secondary controls in that they prompt the user to do some action on a primary control such as turn the device off; turn a heater off, so as not to be burned; change a selected cycled from one to another; etc.

Note that all secondary controls are really electrical loads of some sort. As such they are controlled themselves by primary devices identical to those previously mentioned but at a much lower current (and sometimes voltage) level. Malfunction of a secondary device would be a fault and so all such devices must be tested with the fiber simulator. From the diagrams of Figure 4.8A and B, it can be seen that carbon fibers across the secondary control itself as fiber #1 is cannot produce a fault since the line voltage will cause the fiber to burn out and the control will not be affected even momentarily. However, the low current primary control itself must be evaluated. This is done by placing the fiber simulator in series with the secondary device (lamp, magnetic coil, timer motor, etc.) and the combination across a 120 volt power source or other voltage if so designed. If it is found that the simulated fiber will provide sufficient current to operate the device without burning out or if it operates the device momentarily before burning out, the circuit to the secondary control load must be evaluated. The circuit is first checked to see if a high power output device is always in parallel with the secondary device, such as Figure 4.8 A & B. If so, the load would cause a fiber such as #2 to burn out and no fault condition exists. If there is no parallel output device as in Figure 4.8C, the fiber can cause a fault so the circuit leading to the secondary control load must be evaluated to see if under any condition a fiber could be positioned such that it would conduct current to the device. If it can, a fault condition possibility exists and should be noted and explained.

When fault conditions are located by analysis, a double check may be advisable. The double check is to connect the appliance to a power source and then simulate the fault with the fiber simulator connected across the appropriate nodes. Any questionable possibilities of any sort should also be tested at this time. During the test, data should be taken of the test conditions and effects of the fault and such test results included with the final report.

4.2.2.2.3 Auxiliary controls are separate components within the appliance that are used to effect the operation of a primary or secondary control. The components known to be used in appliances are:

resistors (low watts, high watts)
capacitors (phase change, filtering)
transformers (low voltage supplies, lamp ballast)

Most resistors used in appliances are used to generate heat as an output device for one use or another. These would generally be over 20 watts and be tested as outputs. The few under 20 watts should be evaluated just as secondary controls were evaluated. Other resistors are used as voltage reducing and/or current limiting devices for secondary controls. These applications should also be evaluated in the same manner as secondary controls.

The few capacitors used in appliances are either used in series with motor windings or as radio noise suppression devices. They may be analyzed individually like secondary controls.

Transformers, too, should be evaluated for potential fault conditions much like secondary controls. Where transformer-like devices are used as lamp ballasts, the currents and voltages are sufficiently high that they may be considered as primary controls and need not be further evaluated.

4.2.2.3 <u>Test Procedure</u>

In order to analyze each appliance for potential fault conditions, the following procedure should be performed using the attached sample data sheets. The procedure assumes that the hazard analysis is already completed.

1. List on Data Sheet V all electrical components except primary controls, i.e., output devices and secondary control devices.

2. Record the wattage if known, or measure the resistance of all devices suspected to be high (over say 20 watts) power. Unknown power or low power devices should be noted to indicate a test is needed.

3. List on Data Sheet VI the component numbers that were noted in step 2 as requiring further evaluation.

4. Use the carbon fiber simulator to determine whether the device will operate when in series with a carbon fiber to 120 volts. Note the resistance value for burnout in the second column. If no burnout, so indicate. Note: If the device is designed to operate on a different voltage, test using the design voltage.

5. If the device will not operate in any of the test positions of the simulator, go to step 7. If the device does operate, list in column 3 the node numbers (terminals) of the device.

6. By inspection of the circuit diagram, determine what primary control or controls supply power to the low power device.

Page____________

Data Sheet V

Fault Analysis

Component List

Product______________________ Mfg.______________________ Code #__________

Comp. #	Name	or T	Comp. #	Name	or T

Page______________

Data Sheet VI

Fault Analysis
Low Wattage Components

Product Code #____________________

Comp. #	Burn-out Res.	Nodes	Sw. Nodes	Fault Y,N	Effect	Notes

7. If the answer to 5 was no, the "Fault" column 5 should be marked N. If the answer is yes, analysis of the circuit must be made to determine the effect of carbon fibers on the various nodes listed in 6 (above) of primary devices that could effect operation. If no problem (effect on performance) is possible use an "N" in column 5 otherwise use a "Y."

8. Describe the fault condition (use notes on Data Sheet VII if necessary.).

4.3 Small Appliance Evaluation

The basic difference between small appliances and major appliances as related to carbon fiber hazards and faults is that most small appliances do not have a specific power wire which will always be connected to the electrical power supply neutral. There are very few exceptions to the above and even these exceptions may not be relied upon because it is even more likely than with major appliances that the user has defeated the third conductor grounding system by cutting off the third pin on the cordset plug. Also, there are no 240 volt small appliances in the U.S., so none are of Type II.

Because of the lack of a grounding system, there is no ground integrity to evaluate on small appliances. The remaining hazard and fault analysis is essentially identical with that used for major appliances so the same analysis system (measurements and forms) was used.

4.3.1 Hazard Evaluation

Although many small appliances are completely enclosed by an insulating plastic housing, in almost all cases there are metal parts that can be touched and these are frequently interconnected through other metal parts to internal structures that are in close (less than 20 mm) proximity to exposed electrical connectors or nodes. The external metal parts then may be potential shock hazards and so must be evaluated. Since one of the two power supply connectors is neutral or at ground potential, a 50% chance exists that a fiber connecting a node to an exposed, touchable, metallic part will create a hazard. Each insertion of the plug into an outlet creates another opportunity to

Page__________

Data Sheet VII

Fault Analysis
Notes

Product__________________ Mfg.__________________ Code #__________

change a nonhazardous connection into a hazardous one. Thus, once a fiber has created a hazardous condition, the only safety factor relates to the mechanical vibrations associated with the movement of small appliances which may dislodge a fiber and cause it to move to a nonhazardous location. Except for the exposed heaters of electric room heaters, toasters, some older hot plates, etc., the electrical parts of small appliances tend to be more enclosed (less accessible to room air) than major appliances. There are ten nodes in what would be considered "normal" (unrestricted) locations as defined in the analysis of major appliance hazards, but many are either enclosed or in a moving air environment (FF or CF).

The discussion of the types of hazards relating to carbon fibers in major appliances also holds for small appliances in that electric shock is the only hazard involved. Fire, flood, or physical harm are not likely eventualities.

Special Case

In some cases, small appliances are constructed using uninsulated conductors (stiff wire or sheet metal "bus" bars). Such designs are used where very high temperatures exist in the compartment containing the wiring. Because of the heat there is usually an air vent or vents associated with such compartments to supply some convective air cooling. Toasters, toaster ovens, heaters, and to some extent hand irons are typical of such construction. Because of the many measurements and varied configurations, it is not possible to analytically evaluate the hazard potential of these devices. Two of the above products, toasters and heaters, also have exposed wire heaters. These heaters do not lend themselves to the same analysis proposed for similar heaters in major appliances since they are not surrounded by grounded bare metal support structures. The above restrictions limited the activity of this project on toasters and heaters to pictures and descriptions only. Hazard evaluation will have to be done through actual chamber testing of typical product designs.

4.3.2 Fault Evaluation

As in major appliances, carbon fibers cannot cause a fault condition in a device which consumes over about 20 watts. This is so because if a fiber is across open switch contacts, it will either burnout without supplying sufficient current to the device to cause it to operate or it might not burn out but then would supply even less power to the device (insufficient to cause the device to operate). Fibers across 120 volt terminals will only act as a negligibly small additional load or they will burn out, either case having no effect on the device. The only effect fibers could have would be to turn on a gas discharge, low wattage indicator light when it should be off. This can only happen if there is no higher wattage load in parallel with the light. Two known situations of this type are an electric blanket with the blanket disconnected from the control and a fry pan with its control unplugged from the pan; both are minor faults not likely to generate repair action.

Secondary control devices (relays, timers, etc.) are seldom used in small appliances and when they are, as in some toasters, the power used by the secondary control is so great that carbon fibers will not operate them.

Thus, with one minor problem, small appliances are not susceptable to carbon fiber caused faults. Nevertheless, in order to verify this conclusion, all of the test appliances were evaluated for fault conditions and data sheets completed.

The combination of small appliances with electronic controls will be covered in the electronics section of this report.

4.4 Electronic Controls Evaluation

Electronic circuits in appliances range from the simple inclusion of a solid-state rectifier (diode) in an otherwise electromechanical system to ultra-sophisticated large-scale integrated circuit including microprocessors. Diodes are used for power reduction in heaters or lights, for rectification in battery chargers for DC operation of electromagnetic devices and for power supplies to other electronic devices. Other than diodes, electronic circuits are included in appliances, major and small, to provide control functions, not just to replace switches. Complex control functions are accomplished with large scale integrated circuits (IC) which contain input and output circuits as well as clock circuits to provide a time base. Some connections to the IC serve a dual function as both input and output signal lines; the IC constantly switches such lines from input to output. All of today's control electronics are solid state and may use transistors, or thyristors as switches to control the a.c. power circuits. However, when the controlled functions use very high power, i.e. clothes dryer heater, clothes washer motor, etc.; the electronic control operates a secondary relay whoes contacts provide a mechanical switching function. Lower power devices or short time operation devices are directly controlled by electronic switches. Control inputs to the electronic circuit may be either mechanically operated devices, i.e. pushbuttons or water level switches, or they may be electronic sensors sensing the proximity of a finger or the resistance of a damp clothes load, etc. Power input to electronic circuits is usually supplied by a stepdown transformer with associated rectifiers, capacitors, and regulators. In some cases, a step-up or a high voltage secondary winding is also used on the transformer to supply other circuits, i.e. clothes sensor, gas discharge type display, etc. A transformer is not always used since low voltage can be obtained by using a dropping resistor. A blender circuit was found that used this system.

In most cases the control system controls the timing of operations and switches them sequentially in a selected cycle. In many appliances the control is complicated by the addition of separate sensors which modify the timing of the selected cycle.

Six electronically controlled appliances were obtained and inspected as follows:

1. clothes dryer
2. clothes washer
3. dishwasher
4. cooking range
5. blender
6. microwave oven

The electrical circuit of a several-year old electric self-cleaning oven range was obtained and as much analysis as possible was done on this limited material.

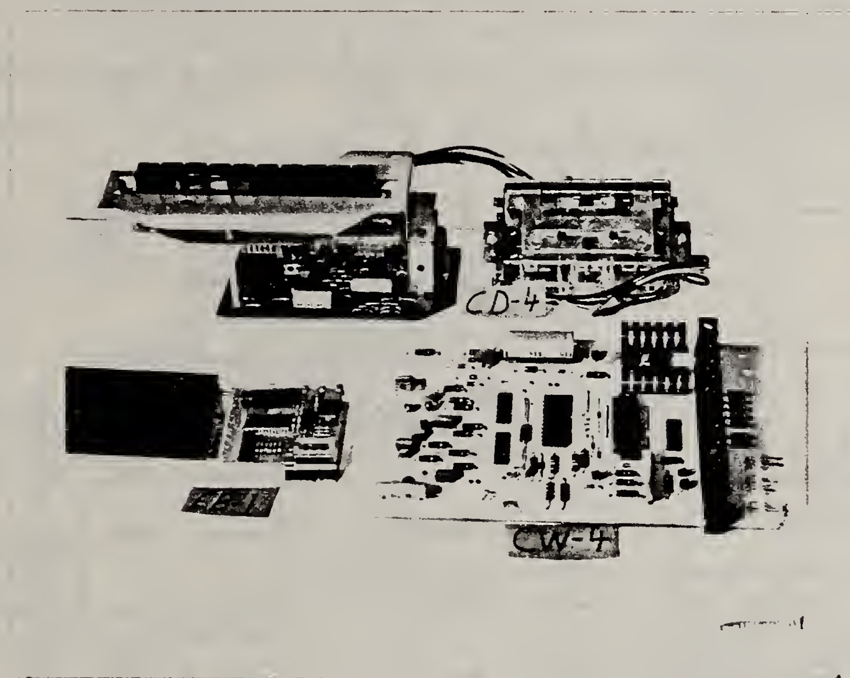
The clothes dryer circuit was analyzed extensively. The clothes washer circuit was traced but the analysis was limited to a comparison with the clothes dryer. Portions of the cooking range circuit were traced and analyzed.

The dishwasher, blender, and microwave oven circuits were physically compared to the others with only the power input circuits evaluated.

4.4.1 Clothes Dryer

The clothes dryer was disassembled and a standard analysis was made of all parts other than the electronic circuit. The electronic circuit is self-contained, see picture Figure 4.9, and consists of a single-sided printed circuit board, approximately 10 x 15 cm, with three multiconnector terminals, a power supply transformer and the electronic components mounted on it. Separately attached to the board is a 10-pushbutton switch assembly with its own printed circuit board and connector. A wiring harness interconnects the two boards and a second harness connects the main board to a relay assembly having three relays in one assembly. One of these relays can only be closed by manually depressing its armature with the "on-off" switch button. Once depressed, the closed relay contacts apply line power to the dryer and its electronic circuit which in turn supplies current to the relay coil to hold it closed. At the same time, current is supplied by the electronic circuit to the other two relays to close them (magnetically). One of the relay's contacts supplies 120 volts to the motor that turns the dryer drum. The other relay supplies 240 volts to the heater. The heater however cannot be energized unless the motor is running since a centrifugal motor switch is in series with the heater. The heater can also be turned off by a separate (nonelectronic) temperature control thermostat switch or by a safety temperature limit thermostat.

The board of the printed circuit was traced and a schematic diagram was drawn, see Figure 4.10. The type of discrete solid state devices was not known, so an assumption was made in each case. Correctness of the assumptions will not appreciably effect the analysis. Figure 4.11 is a copy of the dryer power circuits that was part of the service data included with the dryer.

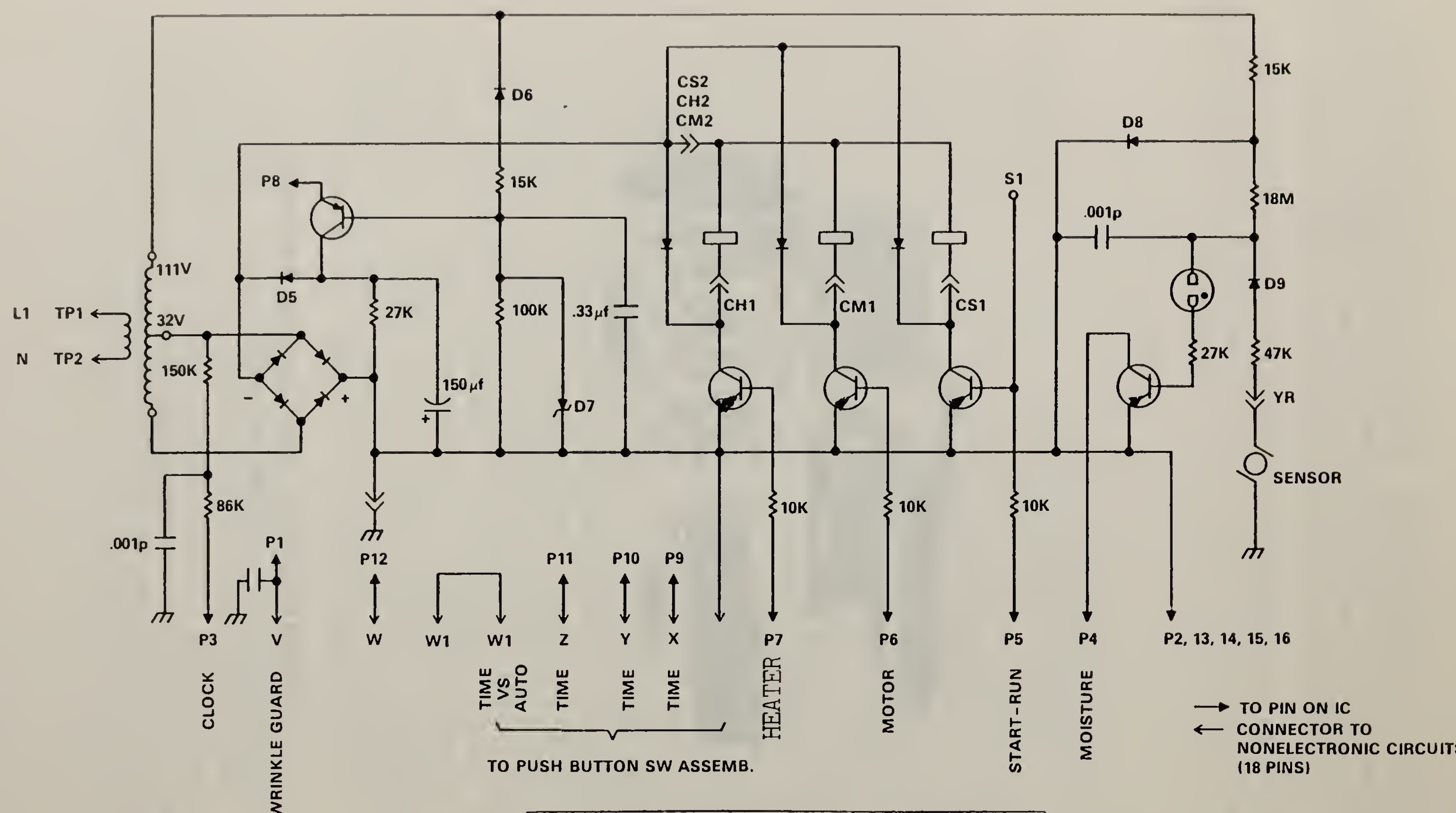


Clothes Dryer Electronic Control
CD4 (at top)

Figure 4.9

Electronic Clothes Dryer Control

Figure 4.10

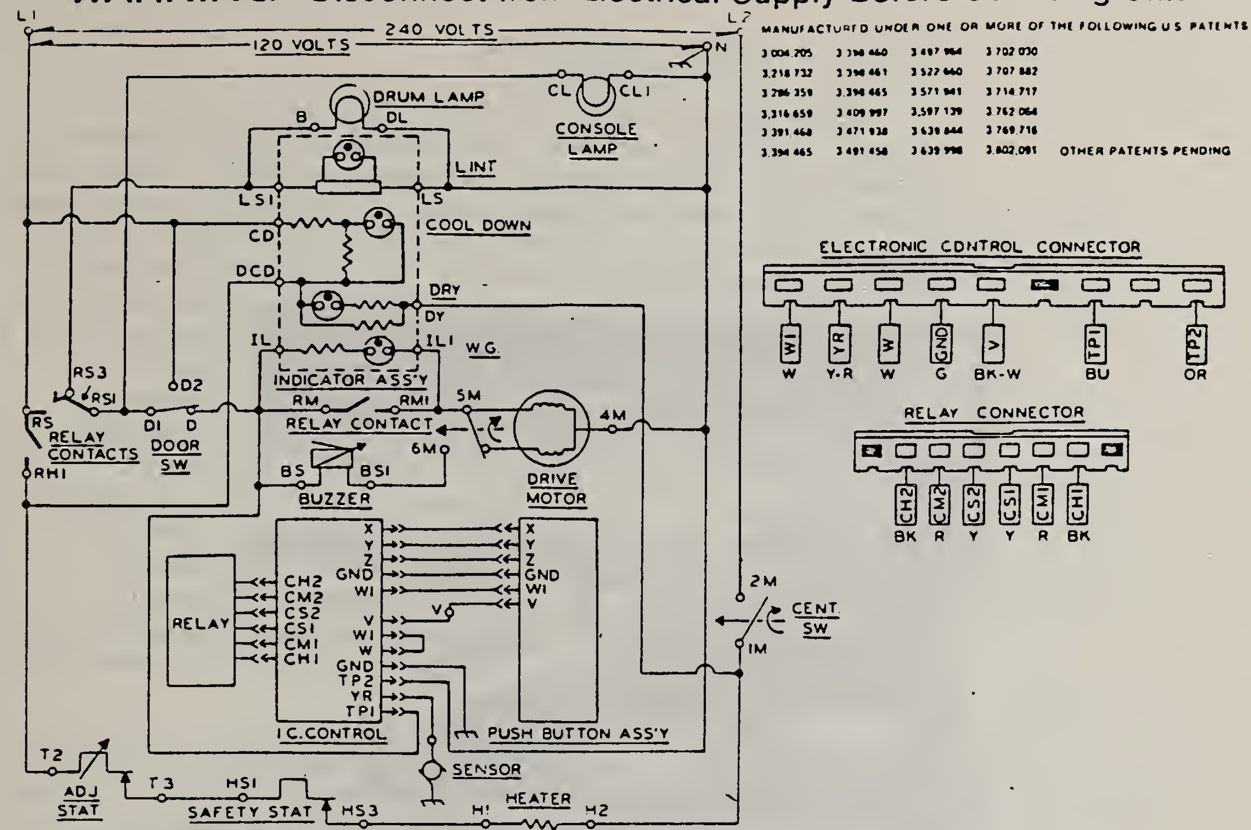


Input	Sensor 1	Sensor 2	Sensor 3	Control 4	Control 5	Control 6	Time Cont. 20	Time Cont. 40	Time Cont. 60
X	0		0				0		
Y		0		0			0	0	0
Z		0	0		0			0	
W1	0	0	0	0	0	0			

0 = Connected to ground

Note: when "V" connected to ground wrinkle guard not active

WARNING Disconnect from Electrical Supply Before Servicing Unit



ELECTRIC DRYER WIRING DIAGRAM

NEUTRAL TERMINAL LINKED TO CABINET

POWER SUPPLY

120/240 Volt 60 Hz.
3-Wire

MOTOR

350 Watts No Load
Speed – 1740 RPM CCW

HEAT ELEMENT

5200 Watts
at 240 Volts

DRUM

Size – 6.9 Cubic Feet
Speed – 45 ± 3 RPM CCW

WRINKLE GUARD III

(This is an option that allows the operator to select or omit the wrinkle guard feature for any load.)

The laundry is tumbled without heat for several seconds every 5 minutes. This tumble-wait action is repeated for about 2-1/2 hours unless the dryer door is opened sooner.

Note: Wrinkle Guard III is selected when this button is in the depressed position. It will remain depressed until it is pushed again which allows it to move back out which will omit the Wrinkle Guard cycle.

TOUCH-UP CYCLE

This cycle is used to remove wrinkles from permanent-press garments that are otherwise clean but wrinkled. Set the Fabric Selector to TOUCH-UP and push the 20 minute (TOUCH-UP) pushbutton. This setting provides 15 minutes of heated tumbling followed by 5 minutes of cool down.

Complaint	Possible Cause
LONG DRYING TIME –	Improper cycle selection. Filled lint screen. Too long or faulty exhaust system. Defective heat element. Defective thermostat. (See test procedure.) Customer using cold water rinse. Customer overloading dryer. Incorrect tumble speed. Dryer installed in cold area. Defective relay. Defective sensor. Defective IC control.
WON'T SHUT OFF –	Defective sensor. Defective IC control. Defective relay. (See Page 2 & 3 of this Tech Sheet.)
WON'T RUN –	Defective IC control. Defective relay. Door not closed. Door switch contacts D1-D open. Defective drive motor. Dryer in "Wrinkle Guard" part of cycle. Dryer selector switch in "Off" position.
STARTS, BUT WILL – ONLY RUN AS LONG AS "PUSH-TO-START" BUTTON IS HELD CLOSED.	Defective relay. Defective IC control.

Figure 4.11

689593

4.4.1.1 Hazard Analysis

One conceivable hazard condition that arises whether or not the chassis is grounded is related to the clothes wetness sensor. From the circuit it can be seen that if TP1 (line voltage) is connected by a fiber to YR, 120 volts a.c. would be applied to one of the sensor contacts. The fiber would not burn out due to the high resistance to ground through the resistors (47k Ω, 27k Ω and 18M Ω) on the electronic circuit board. YR connects to a bare metal exposed contact surface (about 3 mm x 55 mm in area) mounted on a plastic part on the rear wall of the drying drum or tub. Inspection of the circuit board shows that there is a location where a fiber of 19 mm length might make the above connection. The situation however is not hazardous since TP1 is disconnected when the door switch is opened and the door must be opened to access the sensor contact.

All other hazards related to the electronic circuits are limited to locations where a fiber could connect a node connected to a power line to the chassis (not electrical neutral). Such hazards could only exist if the green wire chassis ground located at the input power line terminal board were disconnected--a very unlikely eventuality and particularly so since in all probability the moisture sensing system would not function properly without the connection. However, should the disconnection occur, the chassis can be raised above ground potential when carbon fibers connect TP1 on the electronic circuit board to a chassis structure part. Since terminal TP2 is already connected to the electrical neutral, fibers connecting it to ground would not create a hazard.

Observation of the circuit board shows 14 possible fiber connections from TP1 to other nodes. In Figure 4.12; the pencil points to TP1. One of these 14 possibilities, a connection to TP2, would be a nonhazardous burnout or nonhazardous load. Three would be directly to ground and potentially hazardous. Five connections could connect to ground through the

Clothes Dryer - Pencil at TP1

Figure 4.12

integrated circuit. These latter may or may not constitute a hazard depending on the withstand voltage of the IC. Only potentially destructive tests could determine the hazard factor. Two connections would be to a solid state device connection which would also require potentially destructive testing to evaluate. One possible node to node connection would be through a 27k Ω resistor and then through the device input to ground.

A connection to the junction between the 47k Ω resistor and the diode D9 would not be hazardous.

4.4.1.2 Fault Analysis

There are four functional areas of the circuit that might be affected by carbon fibers:

1. power circuits
2. output (relay) circuits
3. input circuits sensor
4. input circuits selection

Each of the functional areas was reviewed for possible faults due to carbon fiber connections. To attempt to itemize all of these possibilities would require a list many pages long. Many, if not most, possible fiber connections would cause fault conditions of one description or another. None of these connections appear to cause a hazardous condition to arise.

Illustrative of the complexity of listing and analyzing possible fiber connections is the following list of connective paths from the "X" input terminal of the IC to other terminals:

	No. of Possible Fiber Connections
X to terminals connected to ground	3
X to grounded switch structures	3
X to Z	4
X to W1	1
X to Y	2
X to P8 (input dc power lead to IC)	2
X of P7 (gate to heater transistor)	1
X to collector of IC voltage regulator	1
X to base of IC voltage regulator	1
X to sensor gas discharge lamp (diode side)	2
TOTAL	20

There are about the same number of possible fault connections for each of the other timing control input circuits (Y, Z, and W).

The possible fault conditions that could arise range from very simple ones such as the dryer will not turn "on" (grounded base of S1 relay transistor) and will not turn off (base of S1 connected to CS2) to very subtle fault conditions. Subtle ones would be a change in timing which would affect only the heater "on" and motor "run" timing after the dryness sensor has initiated the termination of the drying cycle. Such faults would arise from fiber interconnections of the XYZ and W circuits.

4.4.2 Clothes Washer

The electronically controlled clothes washer was also analyzed by making a schematic circuit diagram of its electronic circuit, see Figures 4.13 and 4.14. The circuits do not necessarily correctly indicate the type of three terminal solid state devices used since this information was not available. Analysis of the circuit, however, is not dependent upon the device type. The basic functional areas can be broken into the same groups as the clothes dryer and similar analysis was made for hazards and faults. The circuit board is approximately 13 x 20 cm in size and single sided. Figure 4.15 is a copy of the circuit supplied with the washer by the manufacturer.

CW - 4 ELECTRONIC CONTROL CLOTHES WASHER ELECTRONIC POWER CIRCUITS

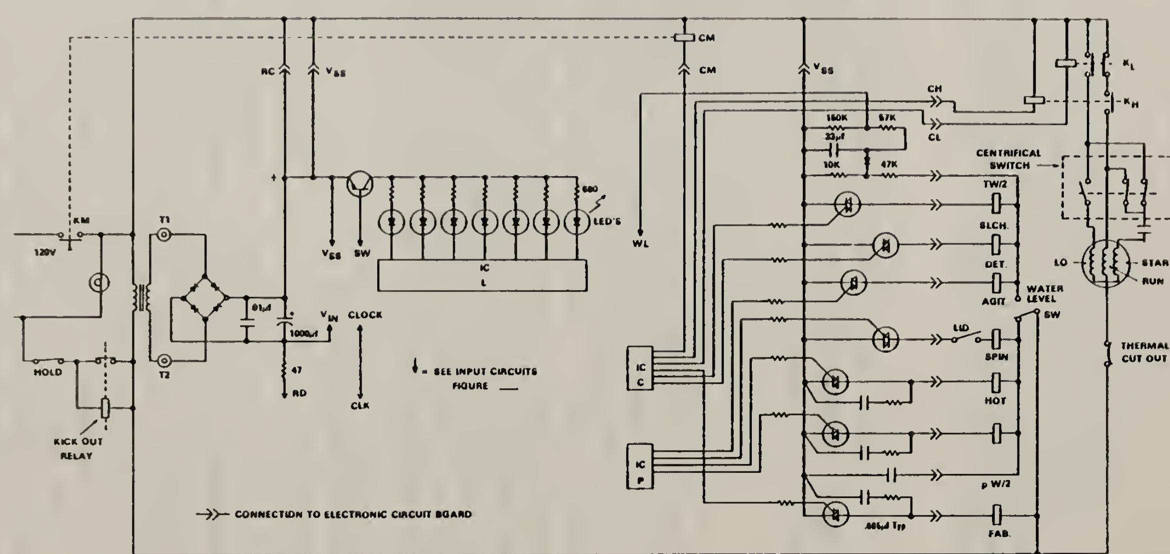
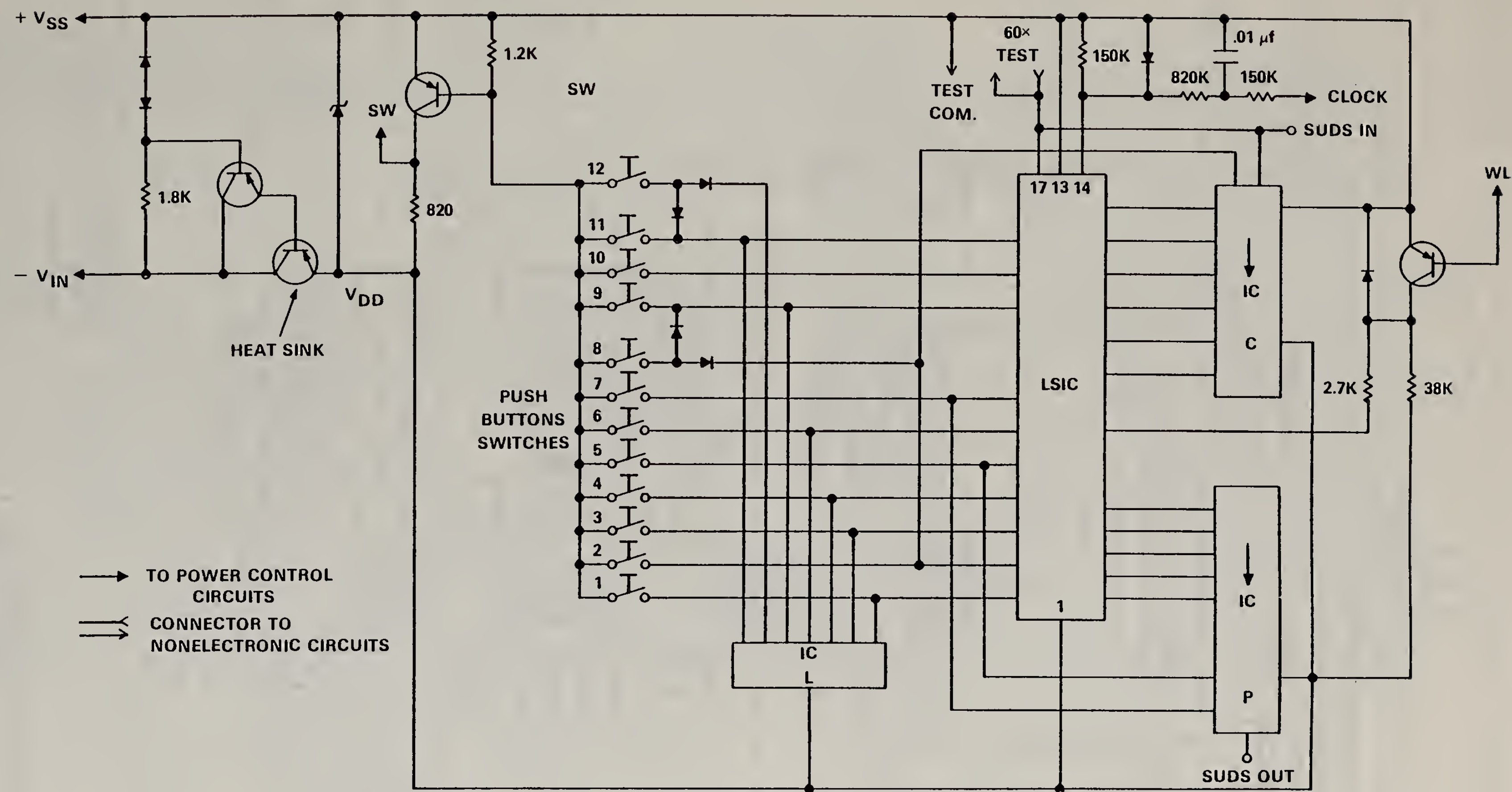


Figure 4.13



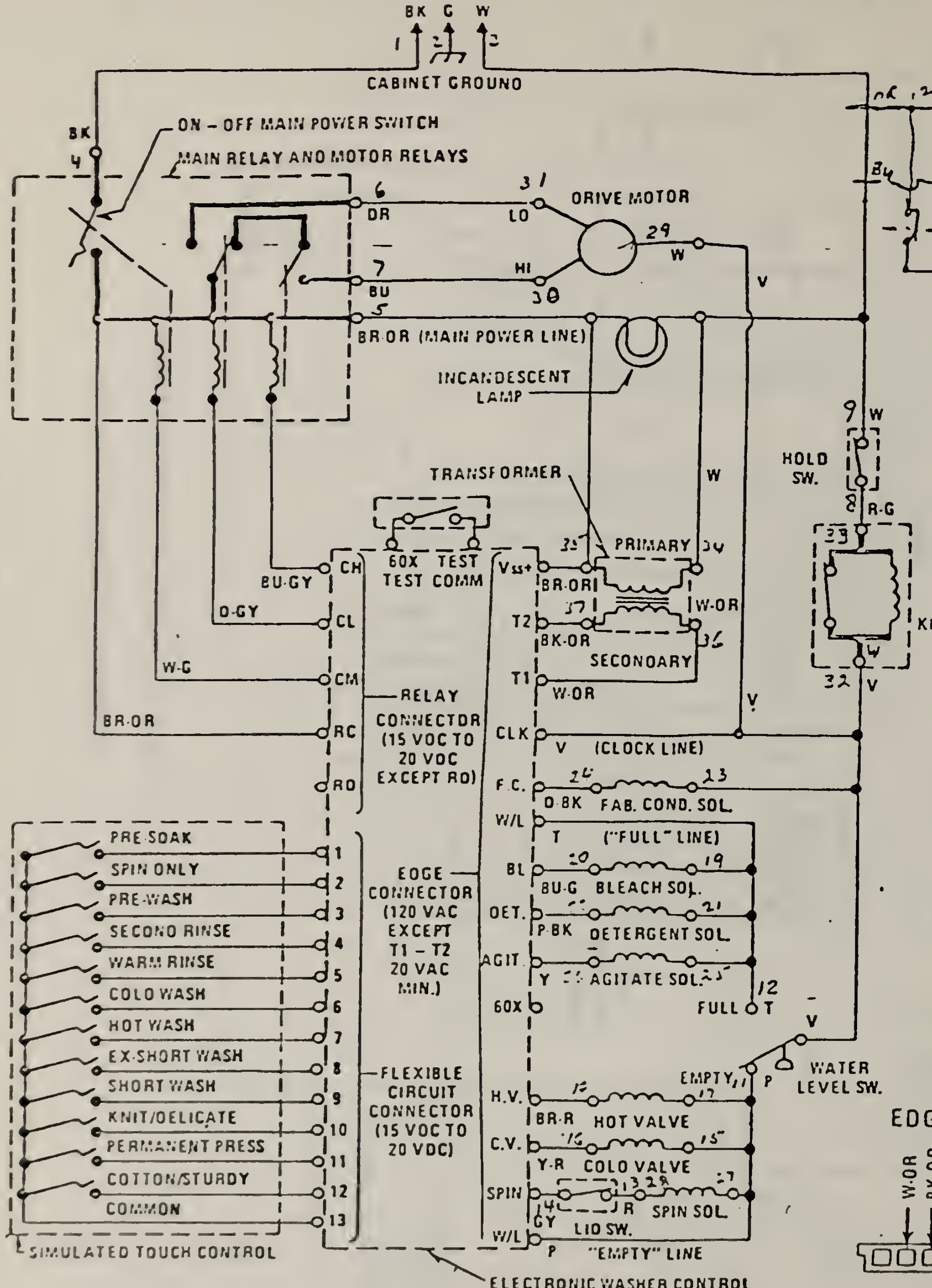
Electronic Control Clothes Washer

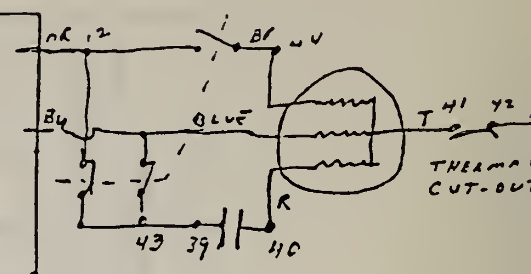
Electronic Input Circuits

Figure 4.14

TECH SHEET – RETAIN FOR SERVICE TECHNICIAN

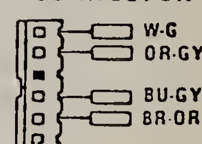
WARNING Disconnect from Electrical Supply Before Servicing Unit



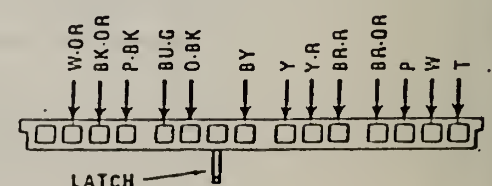


NOTE: The Cycle Sequence Chart is on page 8.

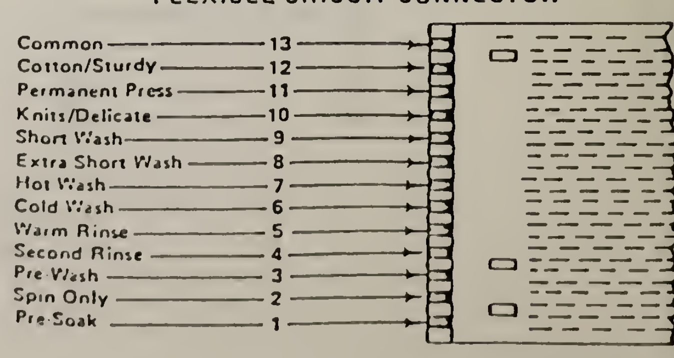
RELAY CONNECTOR

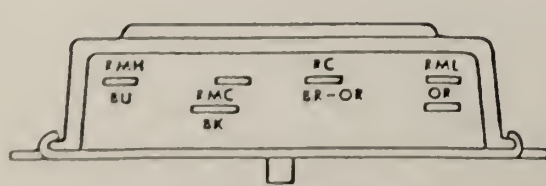


EDGE CONNECTOR (End View)



FLEXIBLE CIRCUIT CONNECTOR





RELAY CONNECTIONS
(End View)

377742 REV. A

Figure 4.15

4.4.2.1 Hazard Analysis

Since the clothes washer is a Type I appliance, circuits connected to either side of the line must be considered potential hazards with a 50/50 chance of being above ground potential. Inspection of the circuit shows that no part of the electronic circuit is directly connected to ground so any carbon fiber making contact to the chassis structure to almost any conductor on the electronic circuit board could constitute a hazard condition. Physically, there is only one location on the board that could be connected to the chassis structure with a carbon fiber. This is from the heat sink of the voltage regulator to a mounting bolt on the indicator lamp housing (13 mm). A fiber from this point (voltage regulator transistor collector to ground) would apply line voltage to ground rectified by two sets of series rectifiers in parallel (the power supply full wave rectifiers.) All other uninsulated electrical connections are more than 20 mm spacing from chassis structure.

4.4.2.2 Fault Analysis

The functional areas of the electronic circuitry for the clothes washer are the same as for the clothes dryer. The only external input circuit sensor in this case is the water level switch which is the same as that used on nonelectronic control types. As with the dryer, the number of possible carbon fiber locations that could cause fault conditions is very high--hundreds or thousands of node-to-node possibilities--so an analysis of each would be meaningless. It should be noted that whereas the dryer had only three output circuits, the washer has 10 circuits that control relays and/or solenoids. Each of these circuits has a three-terminal solid state output device (transistor or thyristor) that can be turned on, turned off or burned out by various fiber connections. Also, the dryer has 10 pushbutton switches that affect five input circuits. The washer has 12 switches affecting 10 input lines and these input lines provide signals to the lamp and control IC's as well as the main program IC.

Several possible fault conditions could keep the hot or cold water solenoid energized which would cause the water to continue flowing into the tub during the entire wash cycle. This could overflow the tub and cause water to flow onto the floor of the laundry room. Depending upon the definition used this might conceivably be termed a hazard condition.

4.4.3 Dishwasher

No schematic circuit diagram was made of the electronic circuits of the dishwasher. Pictures 4.16, 4.17, and 4.18 however show the boards and components and Figure 4.19 shows a copy of the electrical schematic diagram supplied with the unit. Both printed boards, each about 10 x 25 cm in size have a direct connection to electrical neutral and one has a direct-to-power line input. There are eight output circuits to relays, solenoid, blower motor, and thermal actuated operators that could be turned on or held off by carbon fiber connections. Also, there are two input sensing circuits--a thermostat and a float switch. Since the float switch is in series with the water valve solenoid, there is little possibility of a flooding situation caused by the electronic circuitry as there was in the clothes washer.

There is a potential hazard associated with the heater because there is no backup thermostat overheat protector. If a fiber-created circuit were to hold the heater relay closed, the heater would stay on as long as the door switch remained closed. Hazardous interior temperatures might be developed with such a fault. There are nine input circuits that control the cycles and cycle timing. Also incorporated into the dishwasher is an LED type numerical display device. The two digits of the display each have seven input circuits, any one of which might be made inoperative by carbon fiber connections.

4.4.4 Cooking Range

The electronically-controlled cooking range had a capacitance type finger presence detector (as opposed to mechanical displacement type pushbuttons) and was the only appliance found to use a planar gas-discharge type numerical display device. The printed circuit

DISHWASHER
ELECTRONIC
CONTROL

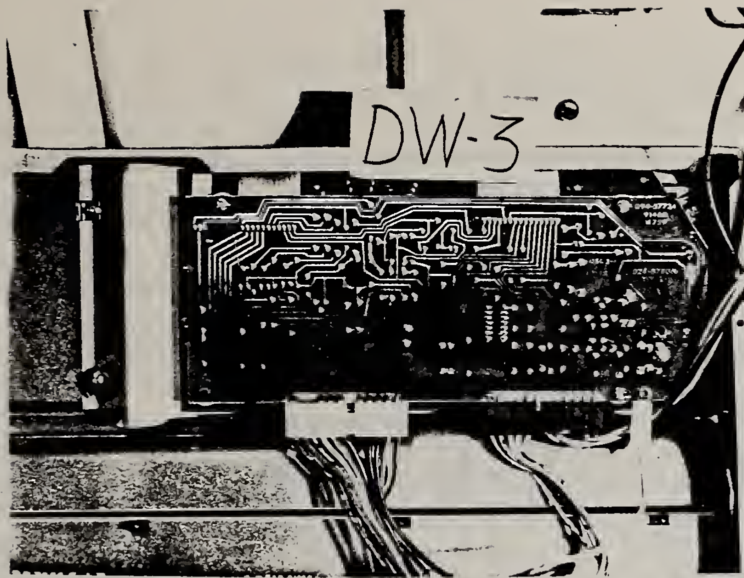


Figure 4.16

Installed in Dishwasher

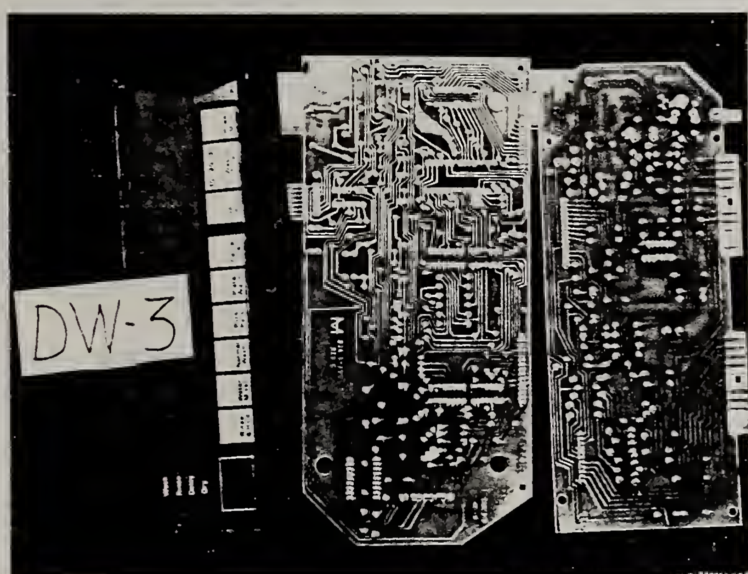


Figure 4.17

Soldered Sides

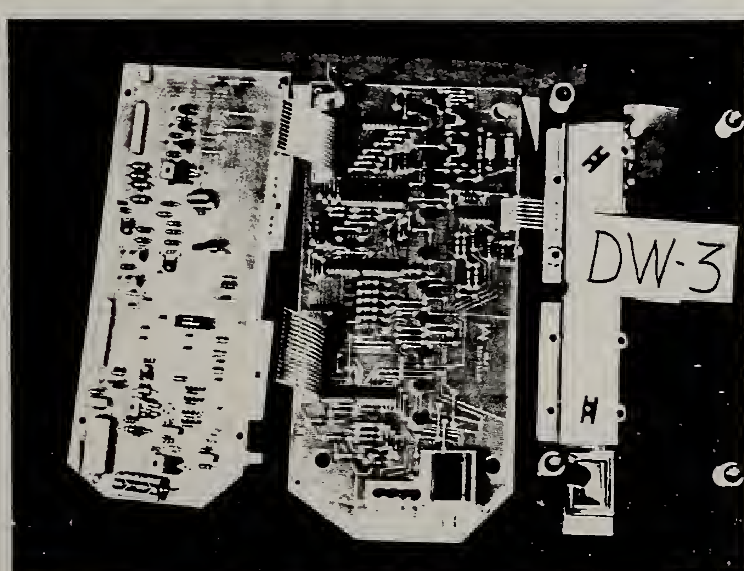


Figure 4.18

Component Sides

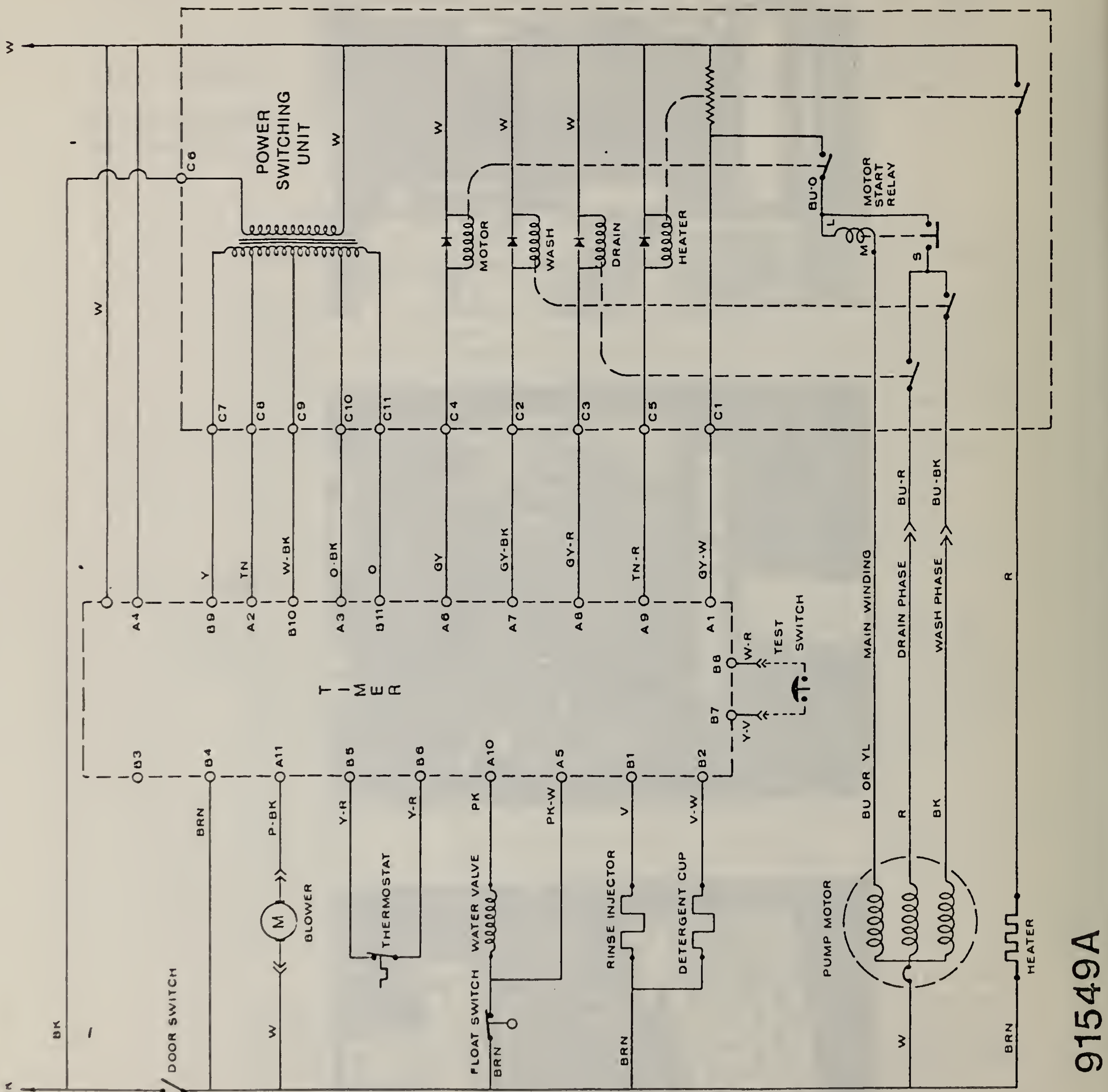

POWER SWITCHING UNIT
TIMER
MOTOR
WASH
DRAIN
HEATER
MOTOR START RELAY
TEST SWITCH
DOOR SWITCH
BLOWER
THERMOSTAT
WATER VALVE
FLOAT SWITCH
RINSE INJECTOR
DETERGENT CUP
PUMP MOTOR
MAIN WINDING
DRAIN PHASE
WASH PHASE
91549A

Figure 4.19

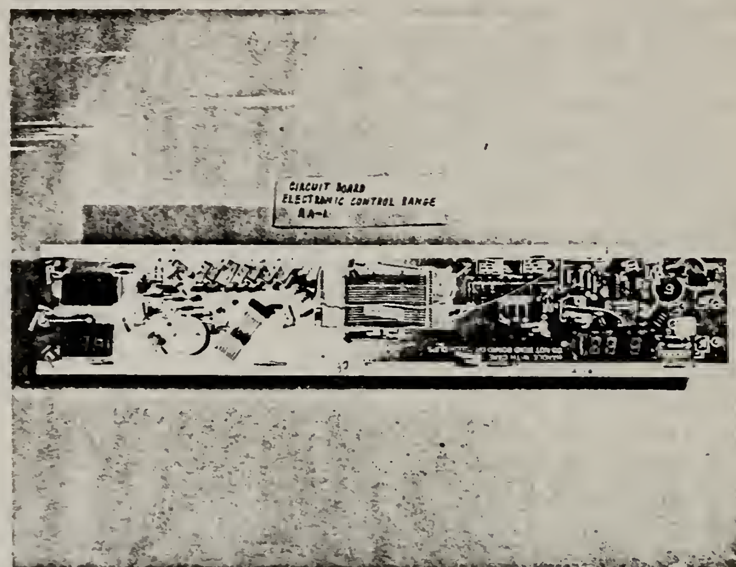
board in the range is a large one, about 12 x 58 cm. See Figure 4.20. On this board are mounted all of the electronic circuits, displays, spring contacts to the finger sensing pads, and transformer. A schematic diagram of some of the electronic circuits was drawn and is shown in Figure 4.21. Figure 4.22 is a copy of the power circuits supplied with the range. The transformer on the circuit board has a high voltage winding needed for the displays as well as a low voltage isolated winding to supply the logic circuits. This low voltage is connected to the neutral line through a voltage regulating power transistor. Because of the use of a stepup transformer, many of the circuits on the electronic printed circuit board must be considered potentially hazardous as related to carbon fiber connections less than 20 mm to structural conductive parts. The product is a Type II device and as such the likelihood of a floating chassis (ground connection removed) is minimal. Also, the circuits connected to the neutral incoming power connector (N) cannot be made hazardous. This is so because the range would be otherwise inoperative if either of the line voltage power connectors were inadvertently connected to the neutral terminal. A limited measurement of node to ground distances showed more than 20 locations on the board that were less than 20 mm from ground and thus might constitute a hazardous condition. As with the other electronic products, the fault possibilities are too numerous to itemize or analyze. Mechanical interlocks and an overlimit thermostat provide adequate protection from hazardous oven temperatures. A hot surface warning pilot light provides protection from unsuspected hot surface units should the electronic circuits cause them to turn on unexpectedly. The possibility does exist that combustable items could be left on an unattended surface unit at the time that a fiber causes the heater to go on. This is a potential hazard but such a hazard would also exist with nonelectronic type ranges since carbon fibers are not the only way the hazards could develop. This electronically controlled model range has been reported to be no longer manufactured.

4.4.5 Self-Cleaning Oven

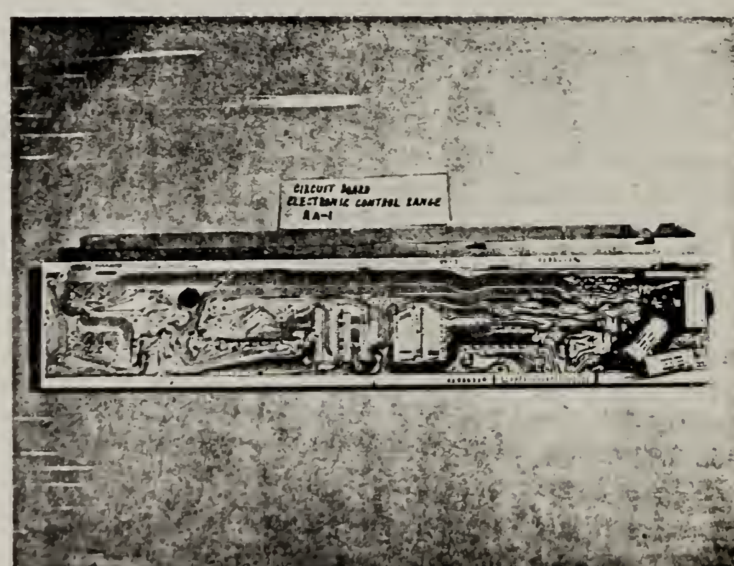
Some of the early self-cleaning oven ranges used electronic oven temperature controls which also provided the turn-off signal for the self-cleaning

Electronic Control Range

Circuit Board.

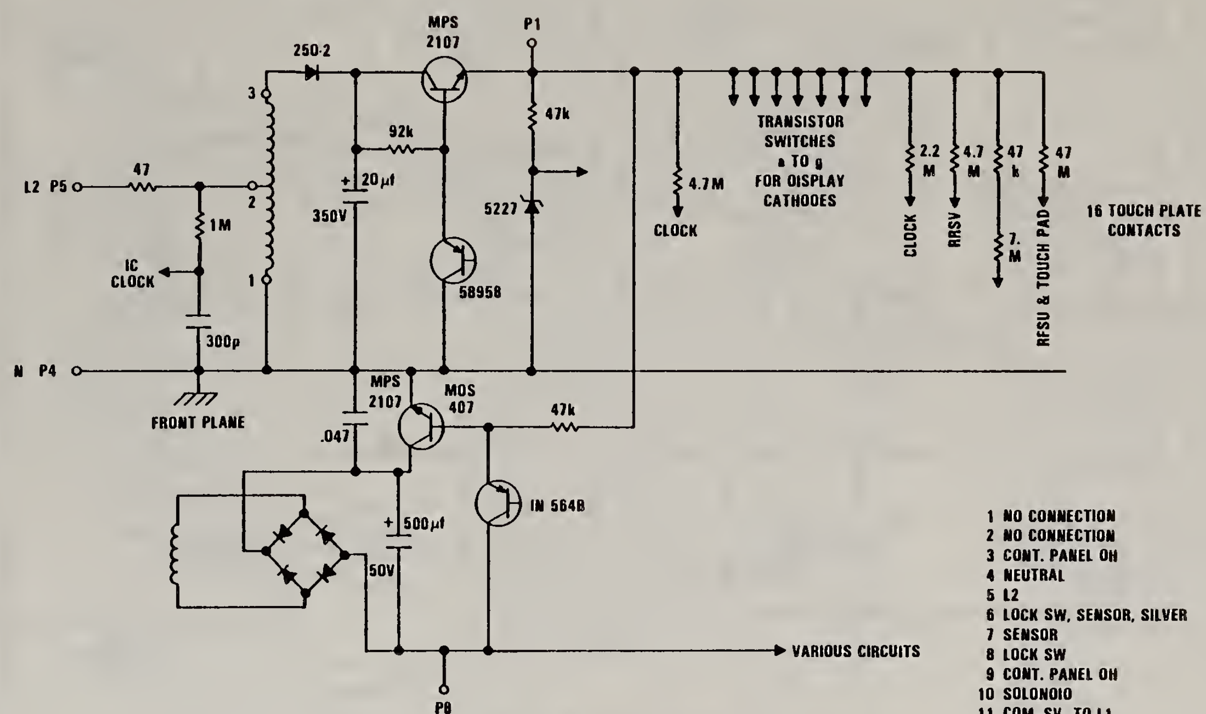


Component Side (Note Displays)



Soldered Side

Figure 4.20



029
LSIC'S 1132030
1132032
031

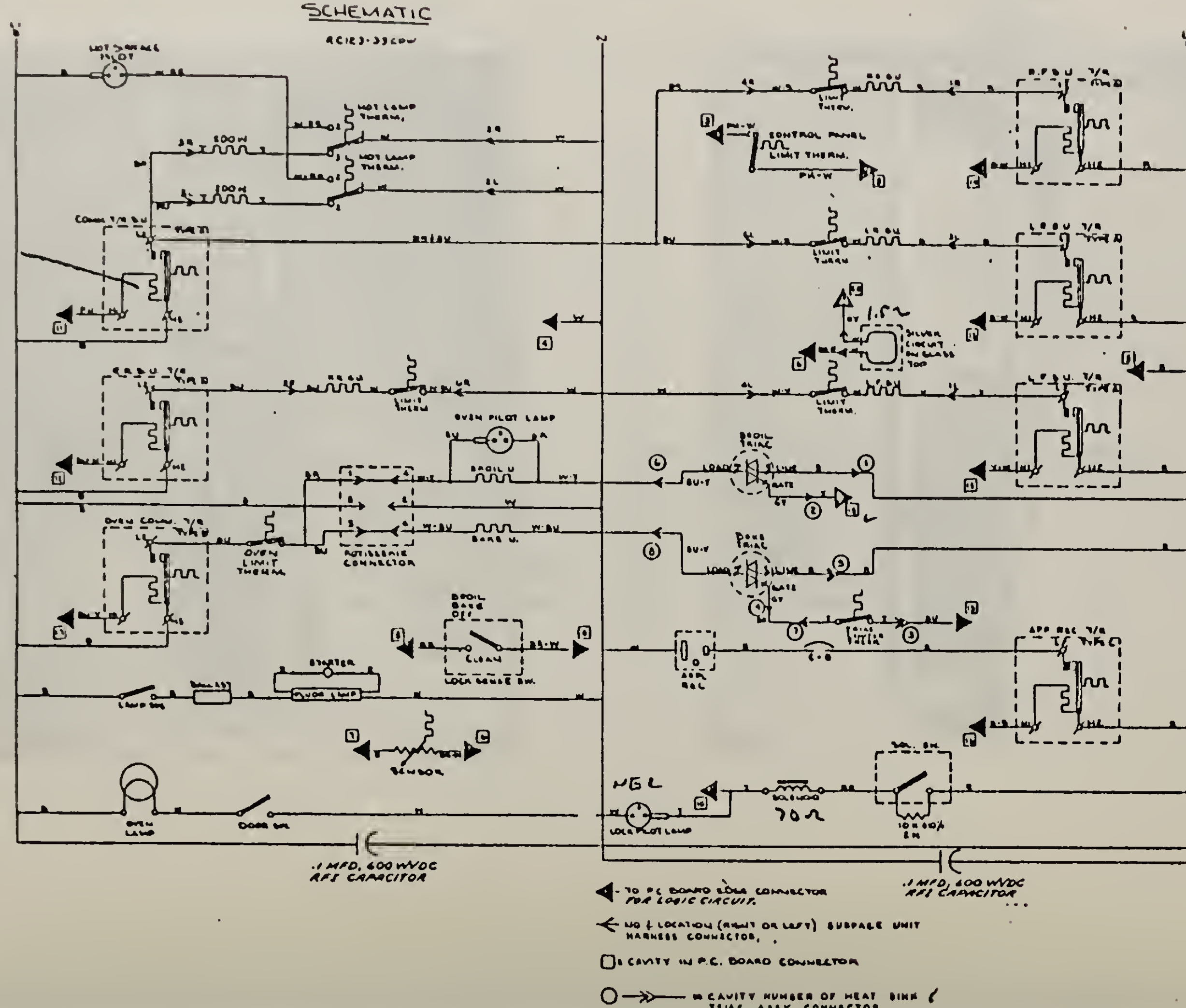
1 NO CONNECTION
2 NO CONNECTION
3 CONT. PANEL OH
4 NEUTRAL
5 L2
6 LOCK SW, SENSOR, SILVER
7 SENSOR
8 LOCK SW
9 CONT. PANEL OH
10 SOLONOID
11 COM. SV TO L1
12 RR SU
13 LR SU TO L2
14 RF SU TO L2
15 LF SU TO L2
16 OUTLET TO L2
17 COM. OVEN TO L1
18 BROIL TIME
19 BAKE TIME
20 SILVER CIRCUIT
21 NO CONNECTION

RA1 ELECTRONIC RANGE CONTROL

Partial Circuit Diagram of Control Circuits

Figure 4.21

SCHEMATIC


OVEN PILOT LAMP
OVEN LIMIT THERM.
ROTISSERIE CONNECTOR
CLEAN
LOCK SENSE SW.
STARTER
SENSOR
OVEN LAMP
DOOR SW.
.1 MFD, 600 WVDC RFI CAPACITOR
70Ω
.1 MFD, 600 WVDC RFI CAPACITOR
TO P.C. BOARD LOGIC CIRCUIT.
CAVITY IN P.C. BOARD CONNECTOR

cycle. No range was obtained for inspection but a circuit diagram Figure 4.23 was found that shows the circuits involved. These circuits were simplified in a schematic diagram Figure 4.24 to help in the analysis. Since the electronics are completely isolated from the power circuits by an isolation stepdown transformer, the electronic portion of the range should add no additional shock hazard potential. Carbon fibers making node to node connections on the electronic circuit could cause relay HW to close or prevent it from closing thus effecting oven temperatures (a fault) but would not generate a hazard due to the NAK temperature limiting thermostat.

4.4.6 Microwave Ovens

Two countertop microwave ovens were examined which both had electronics in the control systems in addition to the inherent power output components-magnetron, high voltage rectifier, capacitor, transformer, etc. One model has an electronic timer and control system with finger sensing switches. The second model has a mechanical timer but also has an additional electronic controller, which incorporates a temperature sensing circuit (meat probe) that switches the magnetron power circuit. Complete circuit diagrams were not obtained. A diagram of the power circuits but not the controls was provided with the model with the mechanical timer. No schematic was made of the electronic controls.

4.4.6.1 Hazard Analysis

Countertop microwave ovens are Type I appliances, so circuits connected to either side of the line are potential hazards. The power supply for the electronics and the high voltage for the magnetron are isolated from the power line by transformers in both models examined. These circuits should not add potential shock hazards.

Possible operation of the magnetron, described in the following fault section, due to fibers is probably not a hazard since door interlocks still function to protect operators, thermal cutouts prevent overheating and fires in the microwave power circuits and any burned food

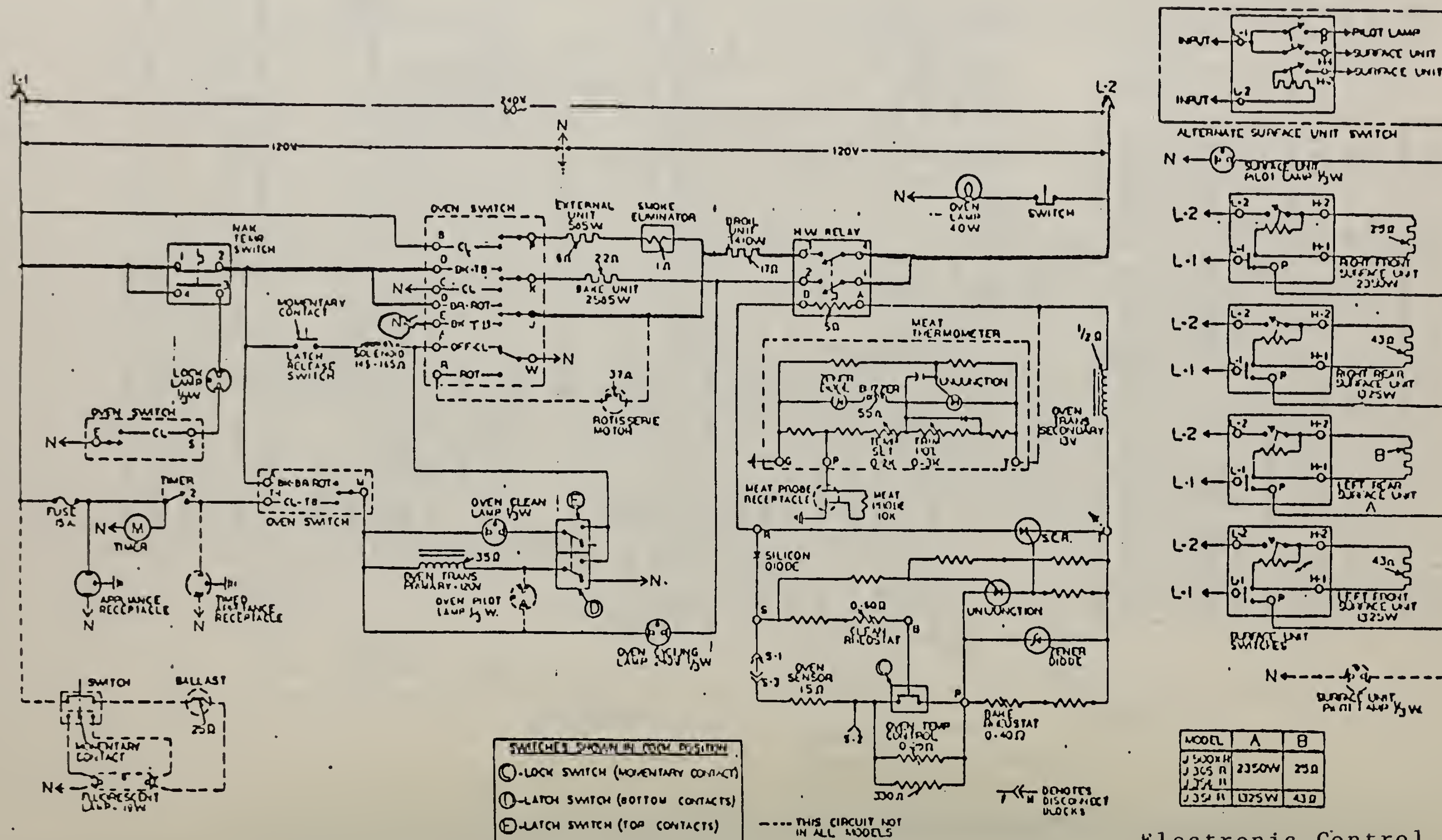
NOTE - COMPONENT & HEATING UNIT RESISTANCES SHOWN ARE NOMINAL D.C. VALUES AT ROOM TEMPERATURE. HEATING UNIT WATTAGES AND RESISTANCES SHOWN ARE FOR 240 VOLTS.

SCHEMATIC DIAGRAM

J351, 35
DWG. NO.

WARNING

POWER MUST BE DISCONNECTED
BEFORE SERVICING THIS APPLIANCE



MODEL	A	B
J 500 H, J 365 H, J 374 H	2350W	25Ω
J 351 H	1325W	43Ω

Electronic Control Left Cleaning Range
Figure 4.23

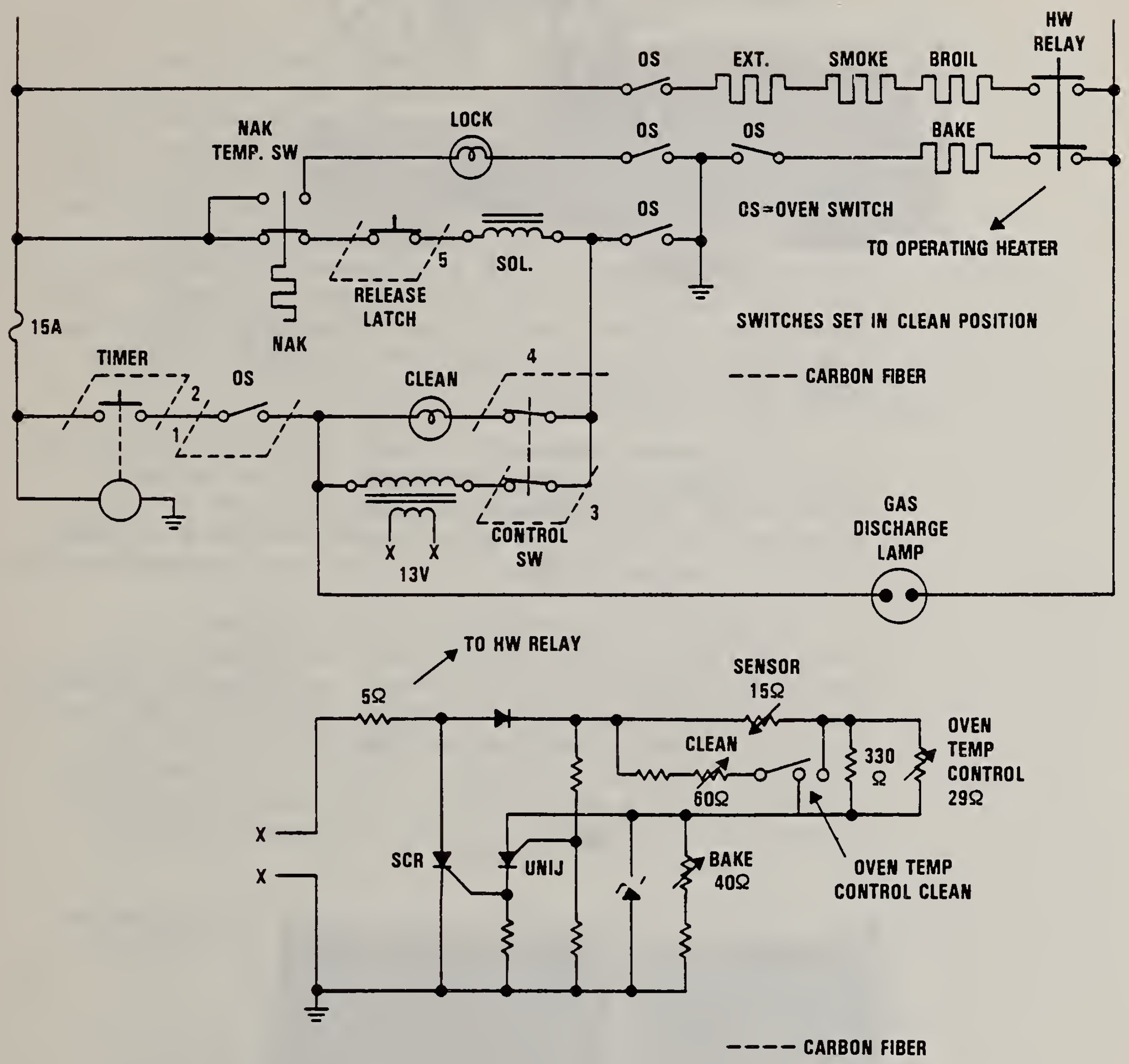


FIGURE 4.24
SELF CLEANING RANGE

would be contained in a totally enclosed metal cavity.

4.4.6.2 Fault Analysis

Both models have what appears to be a thyristor which switches power to the magnetron. It is likely that a fiber can turn on the thyristor directly or solid-state drivers could be made to turn the thyristor "on." This would turn on the magnetron. For the model with the mechanical timer, the power will still be controlled properly by the timer but will be on all the time when the meat probe is used. This operation is unlikely to be a hazard since the oven has thermal sensing and current sensing overload protection.

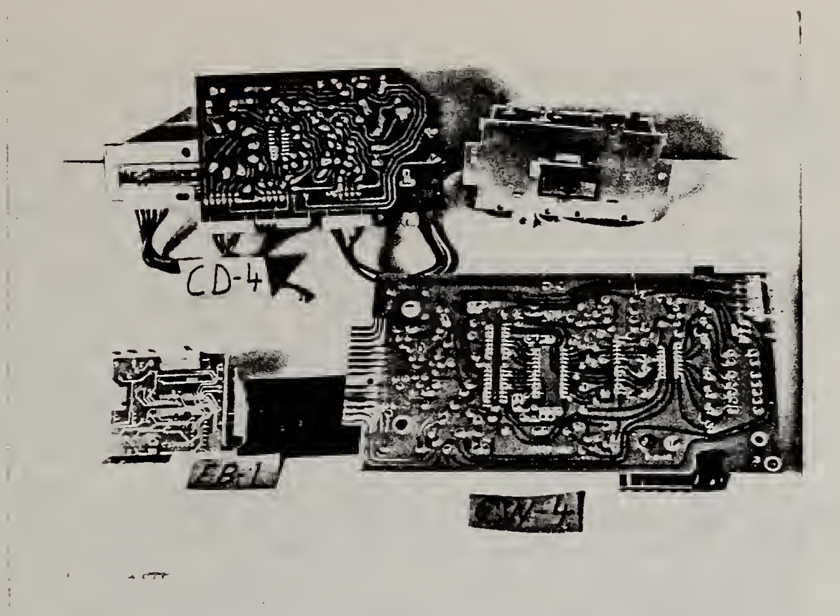
The meat probe will turn the oven off at a temperature below the setting if the sensor is shunted by a fiber's resistance. The probe examined is 50k Ω at room temperature and about 5-10k Ω in the range of cooked food temperatures.

There is a possibility of a fiber initiating an arc in the high voltage circuit. One oven was found to produce a 4kV peak square wave. One oven has a node 10 mm from the chassis and the other oven has a node 17 mm from the chassis. These distances are in the range of possible arc maintenance. The arc would short circuit the magnetron high voltage probably preventing any microwave output.

The circuits were not probed or subjected to fibers to test the possibility of arcing.

4.4.7 Blender

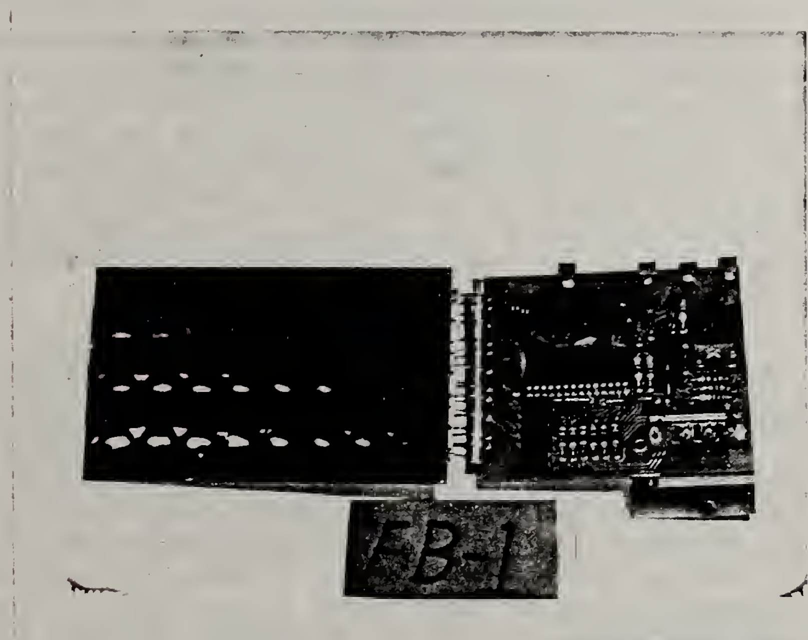
The only electronically controlled small appliance examined was a blender whose electronic circuit controlled both speed and time of operation of the motor. The electronics also provide a calculating function to perform English/Metric units conversions. No circuit diagram was drawn but pictures were taken. Figure 4.25 shows two major appliance circuit boards along with that of the blender to indicate the



Appliance Electronic Control Circuits

CD-4 Clothes Dryer
CW-4 Clothes Washer
FB-1 Blender

Figure 4.25



Blender Circuit Board
(Switch Assembly on Left)

Figure 4.26

comparative size. Picture 4.26 is a closeup to show the circuitry involved.

There are no shock hazards involved with the blender since there are no exposed (touchable) metal parts that are within 20 mm of an electrical part . Neither is a physical hazard likely since more than one operation must be made before the blender motor will run (turn mechanical on-off switch on, select speed by pushing a button, start motor by pushing the "start" button). Observation of the electronic circuit board shows that the likelihood of a fault due to fiber interconnections on input, output display or power circuits is high. In this appliance, fault conditions are aggravated by the air flow arrangement which causes the motor cooling air to flow by (partially over) the electronics. Also the very close spacing of the nodes makes many interconnections with a 20 mm fiber possible.

4.4.8 <u>Test Method Analysis</u>

The shock hazards associated with electronic circuits vary from none to many (over 20). Because of the extreme variation in circuits and construction, and because the electronic components configurations do not lend themselves to physical spacing measurements (millimeters) or fiber simulator testing the only way to evaluate electronically controlled appliances is to actually test them with exposure to a carbon fiber environment. A possible comparison could be made by testing two clothes dryers simultaneously, CD3 and CD4, since they are similar except for the control circuits. The test would need to separate any measured shock hazard conditions into those associated with the control circuits vs. power circuit hazards. Similar tests could be run on the other electronically controlled appliances.

However, it is not felt that testing all of the electronically controlled appliances examined would be meaningful since these designs are but early examples of many that will be available in the future. Undoubtedly these future products (and improved or updated designs of the present ones) will differ significantly from the now available ones (for example, in number and type of IC). These variations make an extrapolation of test data taken now no better than assuming that a test on a single clothes dryer is a rough measure of hazard sensitivity of all major appliance electronic control designs. Though availability of various designs of electronically controlled small appliances is practically nill, experience indicates that the number of possible hazardous conditions is not likely to be much different than with standard nonelectronic designs.

Faults in the electronic controls of appliances can occur in any of the following functional areas:

1. power supply
2. output controls--relays, solenoids, etc.
3. output signals--lamps, alphanumeric displays, sounders, etc.
4. input sensors--temperature, water level, etc.
5. input selectors--pushbuttons, finger sensor, etc.

Carbon fibers can cause faults by making electrical interconnections within any of the above functional areas. These faults can range from catastrophic (appliance no longer functions at all) to subtle faults not easily observed but still a likely cause of customer irritation resulting in a service call.

It has been concluded that tests for either faults or hazards in a carbon fiber environment of any of the electronic control appliances per se would not be productive. This is partly because the very first fault may be destructive so that other faults or hazards could not then be detected. Second, and most importantly, the only way many faults can be detected is by running the appliance through all of the possible cycle combinations and closely observing the operation. For instance, if the dryer were exposed and a fiber connected Y to Z, the only way this could be detected would be to run the dryer with a standard damp load of clothes with the 4th from left pushbutton depressed. The total drying cycle could then be compared to the time required by the same test (prior to fiber exposure) drying cycle time with the 4th from left button depressed and with the 2nd button depressed. This particular fault would also be detected by comparing tests run before and after on the 60 minute timed cycle vs. the 60 and 40 minute cycles prior to exposure.

It can be seen that a set of six runs with a standard clothes load plus one with the wrinkle guard "on" and three runs without clothes load plus one with wrinkle guard "on" to check the "time only" cycles would be needed prior to exposing the unit to carbon fibers. These 11 standard cycles with a record of the sequence of operations and cycle times would then be compared with the same runs after exposure. During these runs the motor, heater, and indicator lights would have to be observed to assure that they were functioning correctly. The above set of 22 tests could be run but a catastrophic fault might well abort the test during or at the very start of the first run with chamber fiber exposure. The only way to circumvent this would be to insulate the connections that lead to catastrophic failure, but this would then prevent the test evaluation of the worst case failure mode. Furthermore, testing of the dishwasher would not give results that could be directly extrapolatable to other electronic controlled appliances because the circuits and systems differ so greatly that a fault in a dryer timing cycle could well not be comparable to a fault in a clothes washer cycle. Thus, each would have to be tested individually. Because of the above the following recommendations are made.

4.4.8.1 Proposed Test

In order to evaluate the probability of a carbon fiber causing either a hazard or a fault in electronic circuits, it is proposed that an electronically controlled appliance (preferably clothes dryer CD4) be tested in an environmental chamber exposing it to carbon fibers with the following modifications having been made.

1. Disconnect the electronic circuit board multiwire connectors.

2. Connect external wires to the control relays and bring them outside the chamber. Provide external power to these wires so that the dryer motor and heater can be controlled to permit either running the unit or not during the fiber exposure.

3. Disconnect the ground strap so that the chassis voltage to neutral may be measured during the test.

4. Modify the electronic circuit board. Using multiconductor cable, connect a wire to each of the separate circuits on the circuit board. Connect the cables to a scanning multimeter (or data logger). Since the side of the circuit board opposite the electronic components is insulated with a nonconductive transparent coating, the connections can be made to this side and reinsulated so as not to change the fiber exposure conditions.

5. Using the scanner, monitor the resistance of each circuit to every other circuit and to ground during the fiber exposure period. Record any changed resistance values.

4.4.8.2 Test Analysis

The results of the above test will provide information as to the number, time, and location of fiber connections during the exposure period. This information will permit statistical evaluation providing probabilities for faults and/or hazards in the five sections of electronic circuit boards. These probabilities can be combined with a count of input/output circuits and controlled functions, circuit board area of uninsulated printed circuitry, component density, etc., to result in an overall probability of fault and hazard for any electronically controlled appliance. The probability can be applied to the various presently available circuit boards and also will assist in estimating the future carbon fiber related problems that may arise as the use of electronic controls increases.

4.4.9 Other Electronic Products (Smoke Detectors)

Although not considered in the small appliance category, several smoke detectors were obtained for carbon fiber effect analysis. The units were partially disassembled and inspected. Simplified electrical schematic diagrams were drawn for two of the units, see Figures 4.28 and 4.29, one of which was a battery-operated, ionization type, and the other a photo electric, line cord powered type. Inspection of the units shows that they can range from very simple with

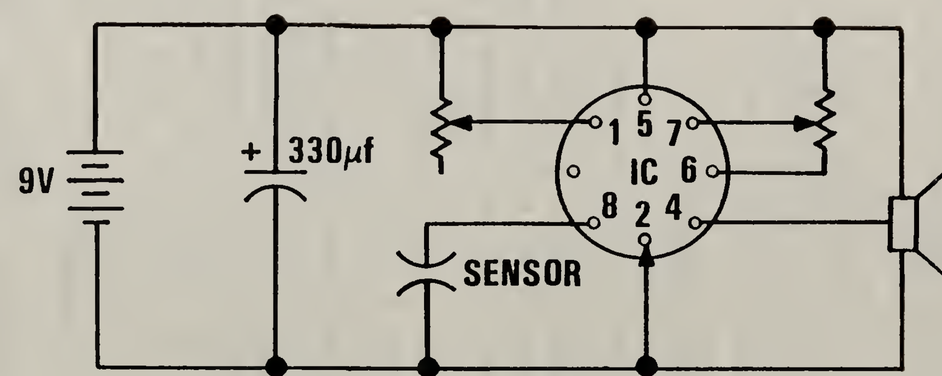


FIGURE 4.28

BATTERY OPERATED SMOKE ALARM

PHOTOELECTRIC SMOKE DETECTOR SCHEMATIC CIRCUIT

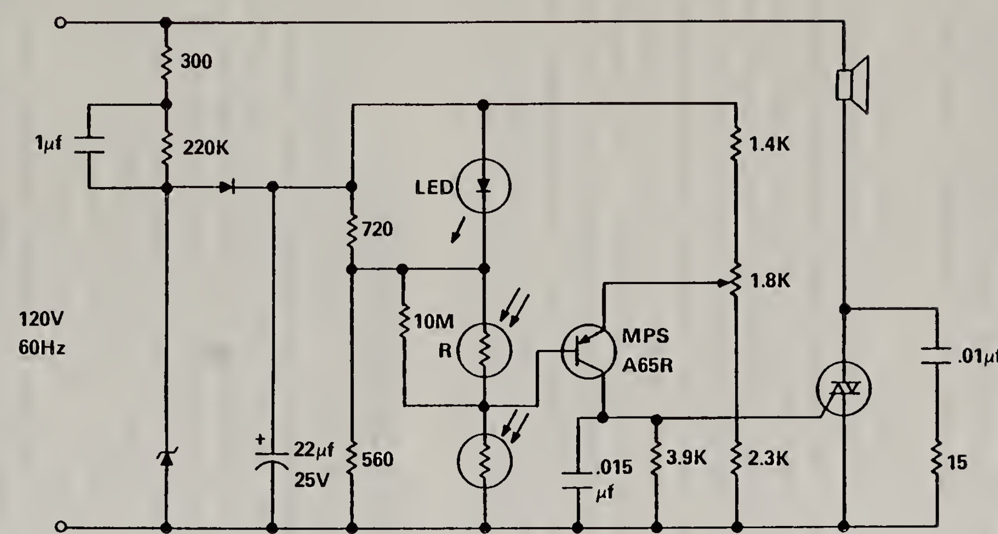


Figure 4.29

few nodes to very complex with many nodes and components. Because of the complexity and because a test would be simple to perform with little difficulty in evaluating faults (false alarm, no alarm or short battery life), it is proposed that no physical or electrical analysis be performed but rather that the units be tested in a chamber fiber exposure experiment. There are no shock hazards related to these products (no exposed touchable metallic parts), but the hazard evaluation instead is directly proportional to the fault probability.

It should be noted that the term electronic or solid state has been used by manufacturers to apply to devices incorporating only a diode as the sole claim to the term. Other products utilize electronics to control only one function with one input (lamp dimmer, drill speed control, range temperature control, etc.). Such devices make better claim to the term "electronic." The potential for fault or hazard is greater than for the nonelectronic equivalent, i.e., perhaps two to four fault modes and two additional hazard modes for each such application. No testing is proposed for such products.

4.5 Future Product Design Trends

In the past 20 years or so only two new major appliances have been introduced, the trash compactor and the microwave oven and only the latter appears likely to be a significant factor in the future. Two major appliances have shown large market saturation gains during these years; the dishwasher and the clothes dryer but their basic designs have not changed significantly. While load capacities of appliances have tended to increase and styling has evolved slowly from rounded to square corners, there have been no changes that would effect their susceptability to carbon fibers. Design changes have been toward lower costs and additional features, i.e., permanent press drying cycle, ice cube dispensers, smoothtop ranges, etc. Electrical design changes have been toward the use of more insulation and consequently lesser carbon fiber hazard potential.

In considering new technologies and their impact on either appliance designs or the function of the appliances, only the use of electronics is likely to be a major factor. Food technology, fabric technology, energy related technology, materials technology (including carbon fiber reinforced plastic parts) all may cause changes in product or product functions but none would seem to change the hazard or defect susceptability of appliances due to a possible increase in airborne carbon fibers.

When evaluating the probable future growth of electronic controls in appliances, past progress is illuminating. The availability of silicon controlled rectifiers (SCR's) started in the late 1950's and these devices made possible the control of sizeable amounts of power with solid state devices. In the intervening 25 to 30 years, little has been done in incorporating electronics into appliances for three reasons: 1) Costs were high and have only recently approached a breakeven position; 2) Electronics provided no additional function or features that were not already readily accomplished by electromechanical systems (Only the magic of the word "solid state" and possibly some reliablity improvement were potentially saleable advantages); 3) Electronic controls do not have the inherent time or cycle display available with timer-motor electromechanical controls. A display is desirable since it is frequently necessary for the appliance user to be able to visually determine the point in the operating cycle (i.e., how much longer until the wash cycle is done?).

The next ten or so years will certainly see a large growth of electronics in appliances because all three of the earlier restraints have lessened. The cost of electronic controls has fallen drastically so that now equivalent electronic systems cost only one and a half to five times as much as the electromechanical counterpart as opposed to the 10 to 20 times as much a few years ago. While electronics are not likely ever to attain a cost breakeven point, the additional benefits discussed below might outweigh a modest cost premium.

The advent of large scale integrated circuits including the microprocessor at reasonable cost permits the design of control circuits that improve the performance of products. The additional electronic computational and complex logic capabilities can be used to provide more precise control with greater flexibility than possible with electromechanical devices. This improvement usually requires the addition of sensors or transducers, however, which adds to the cost and complexity. Whether the benefits of electronic controls can be "sold through" to the consumer will largely determine the actual growth pattern of this technological advance.

Display devices have also seen drastic price reduction, due largely to the high volume of units used in applications other than appliances. Numeric or alphanumeric displays can reduce the problem of the lack of a visual point-in-cycle reference which was the third major obstacle.

All of the above indicates a certain growth in electronic controlled appliances, the question is how much. No sure answer can be given but an educated guess would be that in 10 years, electronic controls will constitute about 25% of the sales volume (units) in appliances. This would mean that perhaps 10% of appliances in use by 1988 will have advanced electronics control systems.

This growth must be considered when evaluating the potential harmful effects of a growth in the use of carbon fiber materials.

Of course the major exception to the above is the microwave oven whose power circuits are all 100% electronic. The control systems for microwave ovens are now probably about 60% electromechanical and 40% electronic, but this ratio will probably invert in the next 10-year period.

While this discussion has been directed toward major appliances, it is just as valid for small appliances. The exception is that the 10-year growth of the use of electronic controls is likely to be much less. This is because even slight cost/price increase in the small appliances marketplace is less likely to meet public acceptance. Two areas, entertainment and/or communication devices and security products, are likely to continue their extraordinary growth rate. Whether such products can be considered appliances is subject to question but since their useful output is not power, their relationship to carbon fibers is in a different category. Indicative of the growth expected is the recent announcement of two new electronic small appliances at the January 1979 Housewares Show, a Yogurt maker and an electric blanket. No reason is given in advertisements for the solid state application in the Yogurt Maker (probably a heat reducing diode) and the claim for the blanket circuit is silent operation. At the other end of the spectrum are a blender and food processor presently on the market that have very complex electronic circuitry to provide speed control, cycle time control and LED numeric readout display. A dual use for the electronics on these products is the provision for a simple computer mode to allow a few English-Metric units conversions.

4.6 Recommended Chamber Tests

It is recommended that the following products be tested in a carbon fiber chamber to measure the exposure required to cause any faults or hazards:

1. CD3 Clothes Dryer
2. CD4 Clothes Dryer, electronic control
3. TO2 Toaster
4. TOV1 Toaster Oven
5. TOV3 Toaster Oven
6. HI4 Hand Iron
7. SM3 Smoke Detectors
8. H3 Heater
9. MOV1 Microwave Oven
10. MOV2 Microwave Oven

The above product list should suffice to evaluate the general population of appliances and is based on the assumption that purging of tested appliances is possible so that each can be tested several times with essentially no carbon fibers present at the start of each test.

The reasons for selecting each of the above appliances are as follows:

1. CD-3 Clothes Dryer--"Typical" major appliance construction. The construction of all major appliances, from an electrical circuitry standpoint, are quite similar--insulated wires interconnecting components with quick disconnect flag type terminals. This similarity permits the test results from one tested appliance to be used in evaluating all other appliances using the data taken by this NBS study. What is required is to know how many carbon fiber generated electrical circuits occur under a known fiber exposure. This figure can then be applied to the "susceptability" information on each of the other appliances that were studied. The tested appliance will have a known number of nodes having a known combined "D" x "L" factor in

each of the types of environment, i.e., enclosed, normal, fan forced, convection forced. The fault and hazard occurency during standby and operating status of the tested appliance can provide the basis for evaluating most other appliances except those recommended for chamber testing.

There is no known method of evaluating the integrity of the ground system or of evaluating the probability of fibers making connection through noncontiguous paint or enamel insulation. The hazard factor of such barriers will have to be estimated.

2. CD-4 Clothes Dryer with electronic control. The test for susceptability to hazards and faults will be difficult to measure and to generalize for extension to other electronic controlled appliances. See section 4.4.8 of the main report for a proposed test method to be used for electronically controlled appliances.

3. TO-2 Toaster. Due to the "bus-bar" type construction and the open wire heaters of most toasters, the hazard susceptability of these devices cannot be analytically determined. See section 4.3.1 Special Case for a discussion relating to this product. Chamber testing must be done for this evaluation. Toasters are not susceptable to carbon fiber created fault conditions. Experience shows that the construction of most (if not at all) toasters is so similar that the test on one can be extended to all.

4&5. TOV-1&3 Toaster Ovens. Although toaster ovens do not use exposed heater elements, the electrical interconnection circuits are similar to toasters and cannot be analytically evaluated. Two units are proposed for testing since they represent well over 75% of the units in existence and they are quite dissimilar both in control circuitry and in heater construction.

6. HI-4 Hand Iron. The proposed iron is similar in construction to a majority of all irons now in use. The electrical construction is somewhat similar to toaster ovens but the similarity is not sufficient to permit extrapolation so a test is proposed.

7. SM-3 Smoke Detector. See section 4.4.9 for a discussion as to the reasons for selecting these products for testing. It is felt that the unit selected is "worst case" for potential fault conditions and the test results

can easily be used to provide a reasonable estimate of susceptability of other types.

8. H-3 Heater. This product was also discussed in section 4.3.1 of the main report. The construction of the recommended unit is quite similar to most other portable electric room heaters so the results can be generalized. The product is most interesting due to its susceptability to hazards from convective air currents.

9&10. MOV-1&2 Microwave Ovens. See section 4.4.6 of the main report for a discussion of the reasons for testing these units. The results relating to extra high voltage with the possibility of sustained arcing is of great interest with this product type.

5.0 General Summary of Faults and Hazards

General. Major electrical appliances were purchased on the open market to evaluate their susceptability to possible graphite fiber generated hazards and faults. The models were from the largest manufacturers and were their highest selling models. A review of the descriptive features and an inspection of these models indicates, with the exception of electronic controls, that they all are quite representative of appliances sold in the past 20 years, differing merely in styling and in the additions of special cycles. For example current laundry products incorporate additional cycles for handling new, synthetic fibers, and dishwashers incorporate special cycles for handling various dish loads; there may be a cycle for extra difficult loads.

Analysis and testing on all major electrical appliances indicate that the potential hazards are numerous and the potential faults are minimal for all major appliances which do not incorporate electronic controls. While the inclusion of electronic controls does not substantially change the number of hazards, the number of potential failures are too numerous to determine either by analysis or by direct probing of the circuitry with the carbon fiber simulator.

A potentially hazardous node is one with a spacing or 20 mm or less from the chassis or any touchable conductive surface. The number of hazardous nodes typically represents 50 to 75 percent of the total number of nodes. The number of potential hazards are about 40 per major appliance.

These potential hazards must be tempered by hazard type, environmental enclosure, ground integrity and relative spacing. Each of these are discussed below.

Environment Enclosure. The environmental description gives a rough gauge of difficulty for carbon fiber intrusion. The three classes of environmental enclosures are:

1. Enclosed (E)--This is an enclosure which has a few small openings which make it difficult but not impossible for carbon fiber intrusion.

2. Normal (N)--This is a semi-enclosed area having many accessible openings.

3. F/C--This is an area which is exposed to fan-forced air or convection forced air.

Hazard Type. There are four hazard types which are described by the finish of the nearest surface in the vicinity of a particular node and whether a particular node is continuously electrically active or whether a particular node is switched to be active during certain parts of the duty cycle. The four hazard types are described below.

1. Continuous Bare (CB): This is a node which is continuously electrically active and has a spacing 20 mm or less to a bare metal surface.

2. Switched Bare (SB): Ths is a node which during certain phases of the duty cycle is switched to be electrically active and is 20 mm or less to a bare metal surface.

3. Continuous Painted/Enamel (C P/E): This is a node which is continuously electrically active and has a spacing of 20 mm or less to a painted or enameled surface.

4. Switched Painted/Enamel (S P/E): This is a node which during certain phases of the duty cycle is switched to be electrically active and has a spacing of 20 mm or less to a painted or enameled surface.

Spacing. The spacing between an active node and the nearest conductive surface is one of the parameters that will determine the probability of a particular length fiber making a connection and the resistance to current flow from an active node through fiber to a conductive touchable surface or to the chassis. The smaller the spacing, greater the possible current flow due to lower fiber resistance. Spacings were measured between nodes and conductive surfaces. Four spacing groups were determined as follows:

- <5 All spacing which measured less than 5.9 millimeters.
- 6-9 All spacing which measured 6 to 9.9 millimeters.
- >10 All spacings which measure at least 10 mm but less than 20.1 mm.

Ground Integrity. Ground integrity for each appliance was not quantitatively evaluated but a review of the data taken and inspection of the appliances evaluated does not indicate a significant likelihood of hazards due to disconnected or poor grounds between accessible touchable parts, either due to manufacturing defect or due to probable degradation of connections during the life of the product.

Faults and Hazard Statistics. A total of 59 appliance models were evaluated. However 16 of these appliances were not amenable to a complete evaluation by analysis and probe tests. Ten of these 16 models are being recommended for chamber testing because 1) some contain electronic controls and 2) some contain internal bare-bus bar wiring or uninsulated heater wires which presented an unwieldy number of possibilities for carbon fiber shorting and 3) some are representative models chosen to quantify the fiber exposure required to cause a fault or hazard as an indication of the vulnerability of a particular appliance category and others of similar construction.

Forty-seven of the 59 appliances were amenable to a complete or partial evaluation by probe testing and analysis. Table 5.0 shows a summary of hazard statistics. The 47 appliances examined collectively contained almost 1000 nodes of which 732 were determined to be potentially hazardous nodes. However, these potentially hazardous nodes must be tempered by the expected fiber length, node spacing to the nearest conductive surface, and the type of environmental enclosure.

According to the China Lake Barrel Burn Test results published in NASA conference publication 2074 [7], most of the fibers are less than 5 mm in length. Therefore, nodes having spacing greater than 5 mm to the nearest conductive surface would require multi-fibers to bridge the gap between a node and the surface. Additionally, tests conducted for NASA to determine "the vulnerability of quick disconnect-connectors to carbon fibers" indicate that when the fiber length is less than the space between the node and the conductive surface, the exposure required to bridge the spacing with multi-fiber bridges is orders of magnitude greater than when the fiber length to spacing ratio is greater than unity [8]. If this is a valid conclusion, then all nodes with spacing greater than 5 mm are significantly less susceptable to capturing fibers as compared with nodes which have a spacing small than 5 mm.

Of the 732 potentially hazardous nodes, 158 have spacings less than 5 mm to the nearest conductive surface. About 66% of these 158 nodes are located in an enclosed area, which greatly impedes carbon fiber intrusion. A Bionetics fiber chamber test on a clothes dryer [9] *applicable to 5 mm or less spacing

TABLE 5.0 SUMMARY TABLE OF FINDINGS -- APPLIANCE CATEGORIES EXAMINED

		Refrigerators/ Freezers	Clothes Washers	Ranges	Freezers	Dishwashers	Clothes Dryers	Microwave Ovens	Vacuum Cleaners	Hand Irons	Toasters	Toaster Ovens	Food Mixers	Fry Pans	Coffee Makers	Bedcovers	Blenders	Can Openers	Smoke Detectors	Portable Heaters	TOTALS
	Total Models Examined	3	4	3	2	3	4	2	3	4	3	4	3	3	5	1	2	2	5	3	59
	Total Potential Faults in All Models	0	1	0	0	8	6	3	0	1			0	2	1	1	0	0		0	23
	Faults Affecting Functional Operation	0	0	0	0	0	1	2	0	0			0	0	0	0	0	0		0	3
SPACINGS	Total Nodes	48	155	193	17	161	191	78	9	18			23	16	31	6	6	6		36	994
SPACINGS	Total Potential Shock Hazards ● with 20 mm or less spacing	29	113	152	11	81	158	54	7	16			15	16	31	6	4	4		35	732
SPACINGS	● less than 10 mm spacing	10	24	53	7	40	53	26	7	15			9	12	27	3	4	4		24	318
SPACINGS	● 5 mm or less spacing	0	25	23	1	26	29	19	4	15			8	7	26	1	3	3		8	198
SPACINGS	● 5 mm or less spacing adjacent to bare metal surface	0	22	22	0	6	24	17	4	15			4	6	26	1		3		8	158
SPACINGS – ENVIRONMENT*	● In enclosed area (E)		9	21		1	13	10	0	15			0	6	26	1		3		0	105
SPACINGS – ENVIRONMENT*	○ In normal area (N)		13	1		4	11	0	1	0			0	0	0	0		0		0	30
SPACINGS – ENVIRONMENT*	● In convection forced area (F/C)		0	0		0	0	0	0	0			0	0	0	0		0		0	0
SPACINGS – ENVIRONMENT*	● In fan forced area (F/F)		0	0		1	0	7	3	0			4	0	0	0		0		8	23
POWER CONNECTION	Models Recommended for Chamber						X	X		X	X	X							X	X	
POWER CONNECTION	Number Models containing Electronic Controls		1	1		1	1	2									1		5		12
POWER CONNECTION	Some Models contain Bare Bus Bar or Uninsulated Heater Wires						X			X	X	X									
POWER CONNECTION	240 V, 3-wire			X^Δ			X^Δ														
POWER CONNECTION	120 V, 2-wire								X	X	X	X	X	X	X	X	X	X		X	
POWER CONNECTION	120 V, 3-wire	X	X		X	X^Δ		X											X^Δ		
POWER CONNECTION	Battery																		X		
POWER CONNECTION	Δ-May be plug-in or direct wired																				

indicates that the transfer function into an enclosed area is more than two orders of magnitude smaller than the transfer function into a normal area. These nodes should have a lower likelihood of causing a hazardous electrical shock condition.

The remaining 34% of the hazardous nodes are loacted in a normal or a fan forced area which is susceptable to carbon fiber intrusion. Therefore, after considering vulnerability restraints such as fiber length, spacings to nearest conductive surface, protective surface coating and environmental impedence, about 53 nodes out of 732 nodes may pose significant potential shock hazards if the appilance is not properly grounded. However, 37 of the 53 nodes were found in 120 volt or 240 volt, 3-wire appliances and if these appliances are properly grounded these nodes would present low probability of electrical shock hazard. The remaining 16 nodes were found in nine portable appliances (120 volt, 2-wire) in which the electrical shock hazard is not affected by the grounding system. These 16 nodes are potentially hazardous.

5.1 Refrigerators Summary

Three refrigerators were evaluated, see Table 5.1, to assess their susceptability to possible carbon fiber generated hazards. Inspections of three refrigerators revealed that most electrical components are either located in a fan-froced air path or fairly well enclosed by interior panels. Those electrical components which are located in a fan-forced air path are routinely exposed to lint accumulation and other airborne particles, and therefore must be appropriately designed for this type of harsh environmental conditions

Hazardous Nodes: The three refrigerators evaluated collectively contained 48 nodes. Twenty-nine or 60.4 percent of these nodes were determined to be potentially hazardous nodes. The nodes were not equally distributed between the three refrigerators, that is; RF-1 had a total of 23 nodes which includes 14 hazardous nodes, RF-2 has a total of 21 nodes which includes 13 hazardous nodes, and RF-3 has a total of four nodes which included a hazarous node. Although the circuit diagram for RF-3 shows more than four nodes, these other nodes are either completely enclosed

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Refrigerator-Freezers

ID	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS	REMARKS
No.	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E	NO.	
RF 1	23	14	4	3	2	6	4	0	19	0	4	10	16	10	5	7	0	
RF 2	21	13	1	2	8	0	5	0	8	0	4	9	12	>	6	6	0	
RF 3	4	2	0	1	0	1	2	0	0	0	2	0	29	>	13	8	0	
	48	29	5	6	10	7	11	0	27	0	10	19	57	10	24	21	0	Totals

Product = clothes washer, clothes dryer, etc.,
ID no. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes:
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard:
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.1

or substantial disassembly of components would be required to attain accessibility.

Hazard Types: The 48 hazardous nodes are classified by hazard type which (1) describes the coating or finish of the conductive surfaces within a 20 mm spacing from nodes and (2) whether the nodes are continuously electrically active or switched to be electrically active during certain phases of the duty cycle. Of the 48 hazardous nodes, six nodes were of the "continuous-bare" type; seven nodes were of the "switched-bare" type, fives nodes were of the "continuous-painted/enamel" type and ten were of the "switched-painted/enamel" type.

Environment: The 29 potentially hazardous nodes are to be tempered by the environmental conditions which may impede carbon fiber intrusion or promote carbon fiber intrusion. Nine of the 29 hazardous nodes were located in an enclosed area while the remaining 20 hazardous nodes were located in a fan-forced air path. The 20 nodes located in a forced air path would be more readily exposed to an airborne particles such as lint or carbon fibers.

Spacing: None of the 48 hazardous nodes had a spacing of less than 6 mm. About two-thirds of the hazardous nodes had a 6 to 9 mm spacing to the nearest conductive surface. The remaining one-third of the hazardous nodes had a 10 to 20 mm spacing.

The three refrigerators evaluated contained 57 touchable surfaces. However 41 of these surfaces had greater than a 20 mm spacing to the nearest node. One of the main cabinet surfaces and the freezer compartment interior wall had a 12 mm spacing to the nearest node. One wall of the refrigerator compartments had a 10 mm spacing to the nearest node; none of the surfaces that were less than 20 mm from the nearest node were bare-metal surfaces.

Faults. Of the three refrigerators evaluated no faults were detected either through analysis of the electticao circuits or by probing with the carbon fiber simulator.

5.2 Clothes Washers Summary

Hazardous Nodes. The four clothes washers evaluated, see Table 5.2, collectively contained 155 nodes. Seventy-three percent (113) of these nodes were

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Clothes Washers

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
CW 1	44	33	0	7	3	19	11	17	0	7	3	23	11	4	5	5	0	
CW 2	42	38	1	4	6	25	29	9	0	4	17	17	11	4	4	3	1	
CW 3	41	15	0	0	5	9	9	8	0	4	1	10	10	6	4	6	0	
CW 4	28	27	0	10	0	16	7	21	0	10	3	14	9	4	5	4	0	
	155	113	1	21	14	69	56	55	0	25	24	64	41	18	18	18	1	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes:
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard:
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.2

determined to be potentially hazardous nodes. The hazard nodes as a percent of the total nodes per unit, range from a low of 37% for CW-3 to a high 90% for CW-1. The relative degree of hazard for a particular node is affected by its environmental condition which can either impede or enhance carbon fiber intrusion. Out of a total of 113 hazard nodes about 50% (or 56) of these nodes were located in an enclosed (E) having very small openings which make it difficult but not impossible for fiber to infiltrate. The other 50% of these nodes were located in normal (N) area having many accessible openings. None of the potentially hazardous nodes were located in a forced air path.

Hazard Type. About 19 percent of the potentially hazardous nodes were continuously electrically active and were less than 20 mm from bare metal parts. The second most hazardous type node is one that is electrically active only during certain portions of the duty cycle and are within 20 mm of a bare metal part. Fifty-six percent of the potentially hazardous nodes fall in this category, the "switched to bare" metal (SB). The third most hazardous nodes is a continuously active node which is located within 20 mm of a painted enamel insulated surface. Only one of 113 total potential hazardous nodes of this type was continuous painted/enamel (C P/E). The fourth hazard level are those nodes that are switched to be electrically active during certain portions of the duty cycle and are within 20 mm of a painted or enamel surface. About 12 percent of the total 113 potential hazardous nodes were switched and could conduct current through a carbon fiber to a painted or enamel coated surface.

Spacing. About 12.4 percent of nodes are less than 6 mm away from a conductive surface, 21 percent of the nodes are between 6 mm to 9.9 mm away from a conductive surface and the remaining 56.6 percent of the nodes were within 10 to 20 mm from a conductive surface.

Faults. Only the clothes washer (CW-4) which has electronic controls was judged to possess potential faults too numerous to determine by analysis or to detect using the carbon fiber simulator. Of the three other clothes washers, only one fault was detected which would cause a temporary malfunction. With the exception for electronic controls, permanent or temporary malfunctions due to carbon fiber intrusion is likely to be minimal. However, the potential for shock hazard could be numerous depending on many factors including environmental enclosures, the conductivity of surfaces adjacent to active nodes, relative spacing between active and conductive parts and the ground integrity.

5.3 Electric Ranges Summary

Three electric ranges were evaluated, see Table 5.3. Two of the units RA-2 and RA-3 were representative of current large volume sellers. The RA-1 unit was an electronic controlled unit using large scale integrated circuit control chips and other solid state circuitry on printed circuit boards. This control technique may be a future design trend. The other two units are more representative of present units and older units. The more varied the control operations on the range the greater the number of nodes and the greater the potential for hazards and/or faults from carbon fiber bridging.

The electric ranges operate from a 3-wire, 240-volt, 60 Hz power source with 120 volts 60 Hz available for some low heat conditions. Also an electric clock timer may be supplied. The units incorporate temperature control of surface, oven and broil elements with the use of thermal sensory switches, thermal relays, triacs, and range timers. Operation of the top surface cooking elements and oven bake and broil elements is frequently indicatd by pilot lights of 1/3 watt. Oven inspection lamps are usually 40 watts, 120 volts.

The printed circuit control board for the electronic control unit is located at the top and back of the RA-1 unit which is the location of the controls for the conventional units. The approach for determining faults or hazards for this control unit would be to test this portion in a fiber chamber. The category summmary is based upon this approach.

Hazards. The three units contained a total of 193 nodes of which 152 (79%) are classed as potential hazards of 20 millimeters (mm) or less. Individually this is 79% for RA-1, 74% for RA-2, and 81% for RA-3. The hazard types are principally continuous to bare metal (CB) and switched to bare metal (SB). The

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Ranges

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
RA 2	50	37	3	11	2	21	37	0	0	6	4	27	41	1	26	13	0	
RA 3	64	52	3	16	5	28	40	12	0	6	12	34	24	2	15	7	0	
RA 1	79	63	1	14	3	46	63	0	0	11	14	38	30	5	19	8	0	electronics
	193	152	7	41	10	95	140	12	0	23	30	99	95	8	60	28	0	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes :
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.3

percentages are RA-1, CB = 22% and SB = 73%; RA-2, CB = 30% and SB = 57%, and RA-3, CB = 31% and SB = 54%. The remaining hazards types are continuous to either paint or enamel (C P/E) and switched to paint or enamel (S P/E) surfaces which act as insulators until degradation.

Hazard Spacing. Of the total number of hazards 16% are less than 6 mm, 20% are 6 to 9 mm and 65% are 10 to 20 mm spacing from the nodes to a conducting surface.

A total of 60 bare parts and 28 painted enameled parts that are touchable during normal operation by a user are identified. Many nodes have spacing of less than 5 mm but most of thess are in an enclosed environment.

Environment. All of the nodes on units RA-1 and RA-2 and 40 out of 52 of RA-3 are considered located in an enclosed environment. The remaining 12 nodes of RA-3 are in a normal environment.

Faults. Analysis of possible fault data indicates no permanent faults would occur due to fiber bridging because of high currents required by the elements connected to the nodes. If a timer is started by a fiber bridge it activates a high current parallel load to cause a burnout.

The possibilities for fault from fibers in the electronic control unit of the RA-1 range were too numerous for analysis or evaluation with the fiber test simulator. More reliable information could best be obtained in a fiber test chamber.

5.4 Freezers Summary

Freezers are very similar to refrigerators in that both have compartments that are fairly well enclosed having only interior compartment air circulation and both also have compartments that intermittently exchange large amounts of air with the room environment during a large portion of the day. While some of the electrical components which are enclosed by freezer doors, interior panels and insulation are reasonably well protected from carbon fiber intrusion, other electrical components located in a fan-forced air path are routinely exposed to airborne particles. However, some of the electrical components have covers which enclose all nodes. These covers have only small openings for the entrance of insulted wires.

Hazardous Nodes: The two freezers evaluated, see Table 5.4, collectively contained a total of 17 nodes 11 or 64.7 percent of these nodes were potentially hazardous nodes because they are within 20 mm of a conductive surface. Freezer FZ-1 has 10 nodes of which seven are hazardous nodes. Freezer FZ-2 has seven nodes of which four are hazardous nodes.

Environment. Six of the potentially hazardous nodes were located in an enclosed environment and the remaining 5 nodes were located in normal areas. All electrical components that are located in a fan-forced air path have nodes that are enclosed and are almost completely protected from possible carbon fiber attachment.

Hazard Type: The 11 hazard nodes are classified by hazard type which (1) describes the coating or finish of the conductive surfaces within a 20 mm spacing from nodes and (2) whether the nodes are continuously electrically active or switched to be electrically active during certain phases of the duty cycle. Of a total of 11 hazardous nodes, only one node is a "continuous bare" type, one node is a "switched bare" type, six are "continuous painted/enamel" type and three are "switch-painted/enamel" type.

Spacing: Since spacing between a node and a conductive surface affects the probability of carbon fiber connection the distribution of the spacing was noted. Only one of the nodes had a spacing less than 6 mm. Six of the nodes had a spacing between 6 to 9 mm and four of the nodes had a spacing between 10 and 20 mm.

5.5 Dishwasher Summary

Three dishwashers were evaluated, see Table 5.5. These were the largest volume selling models. It is expected that these units would be representative of the current and past units. The models cover the low end builder's model to the top-of-the-line model. This selection covered differences in spray arms or towers, dish rack design, detergent dispenses, and special cycles of light soil, pots and pans, sani-cycle, and plate warming. More operations will increase the

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Freezers

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
FZ1	10	7	5	0	2	0	4	3	0	1	4	2	13	13	6	5	0	
FZ2	7	4	1	1	1	1	2	2	0	0	2	2	9	>	5	4	0	
	17	11	6	1	3	1	6	5	0	1	6	4	22	13	11	9.	0	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Modes : Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less
Types of Hazard : C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal
Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters
Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts
Faults No. = number of possible fault conditions

Table 5.4

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Dishwashers

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
DW3	46	34	10	1	19	4	0	34	0	19	9	6	28	5	11	7	0	
DW2	87	47	2	9	25	11	23	23	1	7	5	35	21	6	15	5	8	
DW1	28	0	0	0	0	0	15	13	0	--	--	--	24	--	--	--	0	all nodes insulated
	161	81	12	10	44	15	38	70	1	26	14	41	73	11	26	12	8	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes:
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.5

possible number of nodes and create a greater potential for hazards and faults.

The household dishwashers are of three types; (1) undercounter, (2) convertible and (3) portable. The undercounter is permanently installed and is less likely to be a hazard or fault problem than the other two. It is the largest seller on the market. The portable has the smallest percentage of the market. All units operate on 120 volt 60 Hz power source. Our evaluation was on three undercounter models.

All dishwashers now have a three-wire electrical connection or cordset. Those with plugs (portables or convertibles) may not be grounded if they are used with a three-to-two adapter into an ungrounded electrical receptacle. If any machine loses its case electrical ground, this increases the hazard potential from the nodes that are 20 millimeters (mm) or less from conducting surfaces that can be touched by the user.

Hazards. The total number of nodes for the three machines is 161 but only 81 are considered potential hazards. The builders model dishwasher (DW-1) had all nodes insulated so no fiber could cause a fault or hazard. The hazard nodes are divided about equally percentage wise between the other two machines. The hazard types of classes and percentages are (1) continuous bare (CB) of 12%, (2) switched bare (SB) of 20%, (3) continuous insulated by paint or enamel (C P/E) of 15%, and (4) switched insulated by paint or enamel (S P/E) of 50% (percentages are rounded).

Hazard Spacing. The spacing of nodes considered hazards is 30% for 5 mm or less, 18% for 6 to 9 mm, and 50% for 10 to 20 mm for the DW-2 and DW-3 machines. All nodes of DW-1 are insulated.

The DW-1 dishwasher's touchable surfaces are all greater than 20 mm away from current carrying nodes. On DW-2 and DW-3 the minimum distance between a node that could be a potential hazard is 6 mm and 5 mm respectively. There are a total of 73 touchable surfaces for the three units. Only 26 bare metal and 12 painted or enameled metal are considered as potential, but remote, hazards from fibers.

Environment. All of the nodes in the DW-3 dishwasher are in a normal environment while those in the DW-1 and DW-2 units are equally divided between enclosed and normal. Only one node in any machine is considered in a forced fan or convection air current location.

Faults. The DW-2 dishwasher is the only machine where a fiber could cause a fault. This is in eight locations. The type of fault is bridging of nodes causing false indication of portions of the cycle sequence or false running of the program timer or rapid advance timer.

Due to the fact that a large percentage of dishwashers are installed under a counter with only the front door and bottom panel as exposed surfaces, hazard and fault probability due to fibers is less than for fully exposed appliances like clothes washers and dryers.

5.6 Clothes Dryers Summary

Four clothes dryers were evaluated, see Table 5.6. One of the four dryers, CD-4, incorporated electronic controls. Since most dryers are 240 volt appliances, they are either directly wired to the electrical power source or plugged in with a special three-wire cordset. Because of this and because there is always a factory-installed grounding strap, the likelihood of a dryer not being grounded is extremely remote. In the case where the ground is disconnected, the hazard nodes show in Table 5.6 were identified.

Hazardous Nodes. The four clothes dryers collectively contained 191 nodes. About 83% or 158 of these nodes were determined to be possibly hazardous nodes. The hazardous nodes as a percent of total nodes per unit range from a low of about 72% for CD-4 to a high of 100% for CD-1. However, the relative hazard of these nodes must be tempered by their environmental enclosures. The percentage of total potential hazardous nodes (158) found in each type of environmental enclosure are 26.5% for "Enclosed (E)"; 41.7% for "Normal (N)"; and 31.6% for "F/C."

Hazard Type. The 158 total potential hazards are classified by hazard types which 1) describe the coating or finish of the conductive surfaces within a

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Clothes Dryers

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
CD1	47	47	2	7	6	32	12	19	16	8	12	27	17	3	8	7	0	
CD2	46	33	3	4	2	24	0	17	16	6	3	24	14	12	6	8	4	
CD3	45	40	1	4	5	30	24	14	2	11	7	22	15	2	9	6	2	
CD4	53	38	4	7	9	29	6	16	16	4	2	32	16	2	7	7	0	
	191	158	10	22	22	115	42	66	50	29	24	105	62	29	30	28	6	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes : Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less
Type of Hazard : C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal
Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters
Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts
Faults No. = number of possible fault conditions

Table 5.6

20 mm spacing from the node and 2) whether nodes are continuous electrically active or switched to be electrically active during certain phases of the duty cycle. Of the 158 hazardous nodes 11.4% were "continuous-bare (CB)" type; 6.3% were "continuous-painted/enamel (C P/E)" type; and 9.5% were "switched-painted/enamel (S P/E)" type.

Spacing. About 66.4% of the hazardous nodes had a 10 to 20.1 mm spacing to the nearest conductive surface. Approximately 15.2% of the hazardous nodes had a 6 to 9.9 mm spacing. The remaining 18.4% of the nodes had spacings to the nearest conductive surface of less than 5 mm.

Faults. The likelihood of faults in clothes dryers due to carbon fibers is low. The possible faults consist of a false cycle due to a fiber causing the cycle control timer motor to run when it is not supposed to or an audible alarm to operate at the wrong time. As can be seen from the summary table for clothes dryers, there is a total of six possibilities of this fault occurring in the units tested.

5.7 Microwave Oven Summary

Two microwave ovens were evaluated, see Table 5.7. Both had electronic control systems which were not evaluated. One has a mechanical timer. The microwave generating circuit and power wiring were evaluated. The ovens are 120 VAC powered and have a three-wire grounding cord but have potential hazards if the ground circuit is not connected.

Hazards. The two ovens have 78 nodes of which 54 or 69% are potential hazards.

Hazard Type. Of the potential hazards 4% are continuously energized and connection to painted or enameled surfaces C-P/E; 31% are continuous to bare surfaces CB; 4% are switched and to painted or enameled surfaces S-P/E; and 61% are switched and connections to bare surfaces.

Environment. Of the nodes which are potential hazards 43% are in enclosed areas and 57% are in fan forced or convection forced areas.

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Microwave Ovens

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
Mov1	55	35	0	11	0	24	4	0	31	10	4	21	13	7	6	1	2	Electronic controls not ~~evaluated~~
Mov2	23	19	2	6	2	9	19	0	0	9	3	7	12	9	7	2	1	" "
Mov3	78	54	2	17	2	33	23	0	31	19	7	28	25	16	13	3	3	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes : Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.7

Spacing. Of the potential hazards, 35% are less than 5 mm from a surface; 13% are between 6 - 9 mm and 52% are greater than 10 mm.

Faults. Each oven has a potential for fiber initiated arcing in the magnetron high-voltage power supply. One model has 2 nodes less than 20 mm from the case and the other model one node. An additional potential fault in each oven was identified in the electronic control system and is described in section 4 in Electronic Controls.

5.8 Small Appliances

General. A total of 39 different models of small appliances were evaluated to assess any adverse affects of carbon fibers with respect to generating hazards and faults. In general, these models are the best selling models of the four largest companies with respect to sales volume. In contrast with major appliances, these small appliances generally have fewer nodes by a factor of ten. The number of nodes range from a low of two nodes to a maximum of 13 nodes. But, almost all of these nodes were determined to be potentially hazardous. However, extensive use of plastics as exterior housings of small appliances provides some protection against potential shock hazards. Still there are some hazards associated with small exterior metal parts, even though the exterior housing is predominately plastic. Many of the total nodes per appliance were found to be within 20 mm of a conductive metallic surface which were connected to exterior metal parts. Therefore, casings that are predominately constructed, see Table 5.9, of plastics do not completely eliminate all shock hazard potential. Only one model (FB-1) of 39 models of small appliances incorporate electronic controls. The faults identified in the summary tables are exclusively of possible faults associated with the electronic controls. Out of 39 appliances, five faults were identified. No more than one fault in each of the five appliances were found.

5.9 Vacuum Cleaners Summary

Three vacuum cleaners were evaluated, see Table 5.9. The two upright cleaners and one tank type model are representative of the variety of available units.

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Vacuum Cleaners

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
VC1	2	0	0	0	0	0	0	0	0	0	0	0	5	>	2	2	0	
VC2	3	3	0	0	0	3	0	3	0	1	2	0	10	>	7	2	0	
VC3	4	4	0	2	0	2	0	0	4	3	1	0	13	>	2	5	0	
VC4	9	7	0	2	0	5	0	3	4	4	3	0	28		11	9	0	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes:
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.9

They are also similar to units that have been in service for several years.

All vacuum cleaners operate from a 120 volt, 60 Hz power source. Some have an exit port so the cleaner can be used as a blower by inserting the normal vacuum hose attachment at another location. The cleaners use mechanical adjustments on the upright types and different attachments on the tank types to clean different surfaces and pile thicknesses of carpets. These features, therefore, do not increase the number of electrical nodes. The mechanical adjustments are such that there is only a remote possibility of increasing the fault and hazard characteristics of the cleaners from fibers.

Hazards. The vacuum cleaners have only a small number of nodes. A total of nine (9) are noted for these three units. The cleaner VC-1 has two nodes, none are potential hazards. Cleaners VC-2 with three nodes and VC-3 with four nodes are all potential hazards for each machine.

Hazard Types. The type hazard for VC-2 and VC-3 cleaners is in only two of the four hazard categories. The VC-3 cleaner had two continuous to bare metal (CB) and two switched to bare metal (SB) hazards. The only other hazards of 20 mm or less are three (3) switched to bare metal (SB) for the VC-2 cleaner.

Environment. The nodes located in cleaner VC-1 are not of interest due to the spacing. Three (3) nodes in VC-2 are in a normal (N) environment and all four nodes of VC-3 are in a fan or convection forced air (F/C) environment.

Hazard Spacing. The node spacings on VC-1 are all greater than 20.1 mm. On the other two cleaners four nodes are spaced 5.9 mm or less to a conductive part and three nodes are spaced 6 to 9 mm to a conductive surface.

A total of 28 separate surfaces are identified as touchable by the user of these cleaners. These are bare metal (11 places) and paint or enamel (9 places) with the balance plastics. Due to construction techniques all are greater than 20 mm away from any node.

Faults. Due to the manufacturing techniques used for this category of appliance, the absence of low wattage components and node spacing, no faults or temporary false operation should occur from carbon fiber bridging.

5.10 Hand Irons Summary

A total of four hand irons were evaluated, see Table 5.10. These irons were basically the largest volume sellers. In addition to the basic function they had spray, steam, and/or dry features. These features could increase the number of electrical nodes for possible exposure to fiber contamination. The irons operate from a 120 volt 60 Hz power source. Their power ranged from 700 watts to 1200 watts. The iron controls and indicators are mainly a thermostat with adjustment for fabric temperature selection, steam button, and ready and/or on indicators light.

Hazards. Three of the irons had four nodes and the other (HI-3) had six nodes. All nodes are classed as potential hazards (20 mm or less) in all irons except HI-3 which had four of the six nodes classed as potential hazards.

Types of Hazards. Only two types of hazards were present in the four irons. They were continuous bare (CB) and switched bare (SB). Each iron contained two of each of these.

Hazard Spacing. The spacing between electrical nodes and metal surfaces was concentrated in the less than 6 mm range for a total of 15 locations and with one spacing of 10 to 20 mm and none between the 6 and 9 mm range. There were 32 touchable separate parts with a spacing range of 1 to 3 mm that could be potential hazards. Only 10 of these are bare metal (B) and three are paint or enamel (P/E) surfaces.

Faults. The hand irons are fault free due to the high wattage required except in the case of HI-2 where a fiber could bridge nodes to cause false operation of the ready light.

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Hand Irons

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
HI1	4	4	0	2	0	2	4	0	0	4	0	0	5	2	2	0	0	
HI2	4	4	0	2	0	2	4	0	0	4	0	0	8	1	3	1	1	
HI3	6	4	0	2	0	2	4	0	0	4	0	0	5	2	2	0	0	
HI4	4	4	0	2	0	2	4	0	0	3	0	1	8	3	3	2	0	
	18	16	0	8	0	8	16	0	0	15	0	1	26	8	10	3	1	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes : Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less
Type of Hazard : C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal
Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters
Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts
Faults No. = number of possible fault conditions

Table 5.10

5.11 Toasters and Toaster/Ovens Summary

A total of four household electric toasters were examined to determine if they could be analyzed for potential faults and hazards caused by carbon fibers. The basic toaster contains a resistance heater supplied by a 120 volt 60 Hz power source. The toasters covered the range of 700 to over 1400 watts of power consumption. Basically the units contain a resistance heater, thermal sensing element to adjust for toast darkness, thermostat to cut off unit, and the mechanical lowering and raising mechanism controlled by the thermostat and toaster selection control. All have a two-wire cordset without a ground wire.

After disassembly of the units and visual examination of the design layout used for these appliances, it was concluded this appliance category should be tested in a fiber chamber for the following reasons. Many areas along the heater element/elements could be classified as nodes being less than 20.1 mm away from metal surfaces. The operation of the darkness toast lever and the position of the toast, when lowered, changes the possibilities for fiber bridging. Therefore, the procedure used for node determination, hazards and faults for the other appliances seemed cumbersome and non-productive. In a fiber chamber test, these toasters would be exposed to the various expected lengths and concentrations of carbon fibers and the results could be more conclusive.

The toaster/ovens are in the same category as the toasters but perform more cooking functions. In addition to making toast these can be used to bake, broil, brown, thaw, and warm in the preparation of home prepared and convenience foods. They are larger than toasters and have more temperature selections and variety of preparation features. These increase the number of electrical control nodes as compared to a toaster. The heaters on the toaster/ovens are resistance elements enclosed in cylindrical hollow rods. The resistance elements are insulated from the encasing rods. The greatest danger from the heaters is burns and there is only remote possibility of an electrical hazard should a heater become connected to the rod case.

The three toaster/ovens used for this evaluation are 120 volt 60 Hz powered and range from 1350 to 1500 watts power consumption. The visual inspection of each unit after disassembly indicated a large number of movable metal arms, levers, springs, cams, etc.

Like the toasters it was concluded that analysis of faults or hazards from fibers would be cumbersome and inaccurate for the toaster/ovens. Therefore, it is recommended that a representative group of these be evaluated in the fiber test chamber.

5.12 Food Mixers

Hazardous Nodes. The three food mixers evaluated, see Table 5.12, collectively contained 23 nodes. Fifteen of these nodes were classified as potentially hazardous nodes. All of the hazardous nodes were contained in Food Mixers FM-2 and FM-3. All of the nodes contained in FM-1 were totally enclosed in the motor housing. Therefore, there are no possibility of hazards due to carbon fiber infiltration into food mixer FM-1.

Types of Hazards. Out of a total of 15 potentially hazardous nodes, eight nodes were "continuous bare" type, two nodes were "switched bare" type, two nodes were "switched to painted/enamel type" and three were "continuous to painted/enamel" type.

Environment. All of the hazardous nodes are located in a fan or convection forced environment.

Hazard Spacing. Eight of the 15 hazardous nodes had a spacing of less than 6 mm. Only one node had a spacing between 6 and 9 mm, and six hazardous nodes has a spacing within the 10 to 20 mm range.

The three food mixers evaluated had 21 touchable surfaces. One of these surfaces has minimum spacing to the nearest node of 2 mm. ALl other touchable surfaces are greater than 20 mm away from the nearest node. The one touchable surface that is located 2 mm from the nearest node is a painted surface with high resistance.

Faults. No faults were identified either by probing with the carbon fiber simulator or from analysis of circuit diagram.

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Food Mixers

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
FM1	8	0	--	--	--	--	--	--	--	--	--	--	4	>	1	0	0	
FM2	8	8	0	6	0	2	0	0	8	2	1	5	6	>	2	0	0	
FM3	7	7	3	2	2	0	0	0	7	6	0	1	11	2	3	2	0	
FM4	23	15	3	8	2	2	0	0	15	8	1	6	21	2	6	2	0	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes :
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.12

5.13 Fry Pans Summary

Three electric fry pans were evaluated, see Table 5.13. All units are very similar in construction. They contain a heating element, a thermal switch for temperature selection, and a neon lamp to indicate when the unit is heating. One unit contained a thermal fuse. All units operate from a 120 volt 60 Hz power source. They all use a two-wire cordset, without the third ground wire. The power required for these fry pans ranged from 450 watts to 1300 watts.

Hazards. A total of 16 nodes are present in the three fry pans. All nodes are potential hazards since they are 20 mm or less from another node or to another conductive part. Fry pans FP-2 and FP-3 each have six hazards and FP-1 has four hazards.

Hazard Types. All three fry pans each have three continuous bare (CB) type hazards. Units FP-2 and FP-3 each have three switch bare (SB) type hazards and FP-1 has one of this type.

Environment. A total of 14 of the hazards are in an enclosed environment. The remaining two on FP-2 are in a normal environment.

Hazard Spacing. Out of a total of 16 hazardous nodes seven are less than 6 mm, five are spaced between 6 to 9 mm and four are spaced from 10 to 20.1 mm.

Fry pan FP-1 has a minimum spacing of 2 mm between a node and a touchable part that could be a personal hazard. All the other nodes are spaced greater than 20 mm. A total of 13 significant touchable parts were identified with seven being bare (B), two paint or enamel (P/E) and the others insulators.

Faults. The FP-1 and FP-2 pans could have a false indication of heating from a fiber activating the neon lamp. A fiber in the cordset of FP-3 when it is unplugged from the pan could cause the heating neon indicator to turn on.

5.14 Coffee Makers Summary

Coffee makers are not only common in the homes but are very popular and numerous in other locations such as small business offices, individual offices,

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Fry Pans

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
FP 1	4	4	0	3	0	1	4	0	0	3	1	0	4	2	2	0	1	false signal
FP 2	6	6	0	3	0	3	4	2	0	2	3	1	5	>	2	1	1	false signal
FP 3	6	6	0	3	0	3	6	0	0	2	1	3	4	>	3	1	1	see note 2,3
	16	16	0	9	0	7	14	2	0	7	5	4	13	2	7	2	2	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes :
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closest spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.13

trade shops, etc. A total of five units were evaluated, see Table 5.14. They are considered representative of currently available types and tose in use.

The coffee makers operate from a 120 volt 60 Hz powersource. The construction techniques make use of a variety of plastics to mold the parts which provide electrical insulation but also could melt and/or catch fire if subjected to overheating from electric malfunction of the unit.

The basic coffee maker uses a heater and a thermostat that functions when the coffee is ready. The costlier models have additional features such as brew switch, brew light, warm switch, warm indicator light, and warm heating element. These increase the number of nodes and potential hazards.

Hazards. The number of nodes per coffee maker for four of the five units ranged from 3 to 6 with CM-2 having 13 because of more brewing features. The total node count is 31 and the potential hazards count (31) is the same.

Hazard Types. A total of 16 continuous to bare metal (CB) and 13 switched to bare metal (SB) were defined. Only two switched to paint or enamel existed.

Environment. All of the nodes of 20 mm or less spacing for the five coffee makers are considered to be in an enclosed environment.

Hazards Spacing. Twenty-six (84%) of the nodes are spaced such that a fiber of less than 6 mm could bridge from an active node to another node or a conductive part. The other five nodes (16%) are spaced 6 to 9 mm away from contact points.

The five coffee makers have a total of 25 touchable parts which could be a potential hazard to a user. Only nine of these parts are bare metal and the spacing to a potentially active node ranges from 1 to 8 mm.

Faults. Of the five coffee makers evaluated only one had a potential fault that could occur with a fiber. The unit CM-2 could give false indication of being on

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Coffee Makers

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
CM 1	4	4	0	2	2		4	0	0	4	0	0	4	8	1	0	0	See Notes 1,2,3
CM 2	13	13	0	4	0	9	13	0	0	10	1	2	5	3	2	0	1	See Note 1
CM 3	3	3	0	2	0	1	3	0	0	3	0	0	5	1	2	0	0	
CM 4	6	6	0	4	0	2	6	0	0	6	0	0	6	2	2	0	0	
CM 5	5	5	0	4	0	1	5	0	0	3	0	2	5	4	2	0	0	
	31	31	0	16	2	13	31	0	0	26	1	4	25	18	9	0	1	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes :
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.14

or it could indicate false operation of the warm heating element.

5.15 Electric Blanket (Bed Covers) Summary

A single electric blanket was evaluated, see Table 5.15. This unit was considered typical of the majority of electric blankets presently available. It operates from a 120 volt 60 Hz power source and consumes 135 watts maximum. This unit had an on-off switch, neon lamp on indicator and a thermostat heat selector control. Other thermostats were associated along with the heating elements.

Hazards. A total of six nodes are present which are potential hazards. All six of these are less than 20.1 mm to other conductive surfaces.

Hazard Types. The categories of hazard types are two continuous bare (CB) and four switched bare (SB).

Environment. All nodes are in an enclosed environment since they are contained in the control for the blanket.

Hazard Spacing. The potential hazard nodes are spaced from conductive surfaces as follows: 1 node at 5.9 mm or less, two nodes at 6 to 9 mm and three nodes at 10 to 20.1 mm. A total of six touchable surfaces of potential hazard exists on the blanket control. The minimum spacing to a hazard for any of these surfaces is 2 mm. The only hazard surface is one of bare metal. All others are non-conductive.

Faults. If the blanket is unplugged from the control but the control is still plugged to the power source a fault could occur. This is a false indication of the blanket being on if a fiber shorted a node causing the "on" neon indicator to function.

5.16 Food Blender Summary

A single food blender was included in the group of small household appliances. Design layout is typical of a large percentage of these units except this unit had electronic control of the blending functions. All operate with a two-wire cordset (no ground wire) from a

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Electric Blanket

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
EB 1	6	6	0	2	0	4	6	0	0	1	2	3	6	2	1	0	1	

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes:
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
N = Normal
F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.15

120 volt 60 Hz power source. The power consumption for this unit is 330 watts.

After disassembly and visual inspection of the unit, it was concluded that representative units of this appliance category be tested in a fiber chamber for more realistic and accurate evaluation of fiber effects.

5.17 Can Openers Summary

Two household electric can openers were evaluated, see Table 5.17. These units operate from a 120 volt 60 Hz power source with a two-wire cordset containing no ground wire. The power required is approximately 175 watts. The basic circuitry consists of a small motor and the on-off switch; therefore, these units have only a small number of nodes.

Hazards. Can opener CO-1 contains four nodes and CO-2 only two nodes. Only the nodes of the CO-1 unit are hazards due to being 20 mm or less to adjacent surfaces.

Hazard Types. The hazards of CO-1 are two of continuous bare (CB) and two of switched bare (SB) types.

Environment. All nodes (4) of CO-1 and (2) of CO-2 are in an enclosed environment. A large portion of the units make extensive use of molded plastic housing components.

Hazard Spacing. The hazard spacing on CO-1 measured less than 6 mm for three nodes and 6-9 mm for one node. All nodes for the CO-2 units are greater than 20 mm.

There are 13 touchable surfaces on both can openers as potential hazards. The minimum spacing of a touchable surface on CO-1 is 2 mm to a hazard node or other potential conductive surface. The touchable surfaces on CO-1 are three continuous bare (CB) and three paint/enamel (P/E) areas.

Faults. No potential faults were noted due to fiber contamination.

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Can Openers

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
CO 1	4	4	0	2	0	2	4	0	0	3	1	0	7	2	3	3	0	
CO 2	2	0	0	0	0	0	2	0	0	0	0	0	6	>	3	0	0	
	6	4	0	2	0	2	6	0	0	3	1	0	13	2	6	3	0	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes :
  Total = highest count of nodes
  Haz. = Uninsulated nodes of 20 mm or less
Type of Hazard :
  C = continuous
  S = switched
  P/E = paint or enamel insulated
  B = base metal
Environment, Air Circulation :
  E = Enclosed
  N = Normal
  F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
  6-9 = 6 to 9.9 millimeters
  >10 = 10 or less than 20.1 millimeters
Ground Integrity :
  Total = number of touchable parts
  Min. Spac. = closet spacing in mm
  B = number of bare metal parts
  P/E = number of paint or enamel insulated parts
Faults No. = number of possible fault conditions

Table 5.17

5.18 Heaters

Hazardous Nodes. Collectively, the three portable heaters evaluated contained a total of 36 nodes. All except one of these nodes were classified as potentially hazardous nodes in that they were within 20 mm of a conductive surface. Thirty-three of the hazardous nodes were located in a fan-forced or convection forced area. The remaining two nodes were located in a normal area. Refer to the section on Heaters to determine the relation between the number of nodes per heater coil.

Type of Hazard. Fourteen of the 35 hazardous nodes were classified as "continuous bare" type, 17 nodes were classified as "switched-bare" type one was of the "continuous bare" type and remaining three nodes were of the "switched painted/enamel" type.

Hazard Spacing. Eight of the 35 hazardous nodes had a spacing of less than 6 mm to the nearest conductive surface. Sixteen of the hazardous nodes had a spacing between 6 to 9 mm and 11 hazardous nodes had spacings between 10 and 20 mm. These three heaters had 15 touchable surfaces. Six of these 15 touchable surfaces were bare-metal and five were painted/enamel. The remaining four surfaces were either greater than 20 mm from the neraest node or were constructed of a non-conduction surface.

Faults. No faults were identified either through probing with the carbon fiber simulator or through analysis of the circuit diagram.

5.19 Smoke Detectors

Five smoke detectors were inspected. Three of these smoke detectors operate on a 9-volt battery supply. The other two units operate on 120 volts 60 Hz supply. These smoke detectors were from the largest manufacturers and were popular models. Each of these five units were completely enclosed in a plastic housing which was intended for either ceiling or wall mountings. Therefore, shock hazards were judged to be minimal.

Since all five smoke detectors were electronic devices, the number of potential faults was not evaluated. All five units are recommended for chamber testing.

GRAPHITE FIBER HAZARD AND FAULT SUMMARY

PRODUCT Portable Heaters

ID No.	NODES		TYPE HAZARD				ENVIRONMENT			SPACING			GROUND INTEGRITY				FAULTS NO.	REMARKS
	TOTAL	HAZARD	C P/E	CB	S P/E	SB	E	N	F/C	<5	6-9	>10	TOTAL	MIN. SPAC.	B	P/E		
H 1	10	10	1	5	1	3	0	2	8	2	3	5	5	3	1	3	0	
H 2	15	14	0	3	1	10	0	0	14	4	8	2	6	>20	2	2	0	
H 3	11	11	0	6	1	4	0	0	11	2	5	4	4	4	3	0	0	
	36	35	1	14	3	17	0	2	33	8	16	11	15	7	6	5	0	Totals

Product = clothes washer, clothes dryer, etc.,
ID No. = CW 2 (clothes washer), CD 3 (clothes dryer), etc.,
Nodes :
Total = highest count of nodes
Haz. = Uninsulated nodes of 20 mm or less

Type of Hazard :
C = continuous
S = switched
P/E = paint or enamel insulated
B = base metal

Environment, Air Circulation :
E = Enclosed
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F/C = Fan or convection forced

Spacing: <5 = 5.9 or less millimeters
6-9 = 6 to 9.9 millimeters
>10 = 10 or less than 20.1 millimeters

Ground Integrity :
Total = number of touchable parts
Min. Spac. = closet spacing in mm
B = number of bare metal parts
P/E = number of paint or enamel insulated parts

Faults No. = number of possible fault conditions

Table 5.18

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NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS IR -79-1952	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE	5. Publication Date
A Study of the Effects of Carbon Fibers on Home Appliances	6. Performing Organization Code
7. AUTHOR(S) C. Lovett, R. Wise, C. Gordon, K. Yee	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, DC 20234	10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*	13. Type of Report & Period Covered 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

At the request of the National Aeronautics and Space Administration (NASA), the National Bureau of Standards, Center for Consumer Product Technology conducted an evaluation to determine the possible effects of electrically conductive carbon fibers on consumer major and small appliances. The information collected is a part of the data necessary for NASA to complete an economic risk assessment on the future use of carbon fiber composite materials.

Available market statistics were used to estimate total depreciated dollar values in U.S. homes for major and small appliances. Models which were typical of the current design and construction were obtained for analysis and laboratory evaluation. A total of 59 appliances were examined during the study.

The analysis determined potential faults and hazards that might be caused by fibers infiltrating appliances. Few potential faults of significant consequence were found. Some potential electrical shock hazards were identified. Whether these would result in electrical shock to users would depend on a fiber shorting a live contact to the case and simultaneously touching a grounded conductor with another part of the body. The probability of these conditions was not evaluated in this study. Many of the potential hazards identified will require substantial further analysis to quantify the potential risk.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Appliance failure, appliance hazard, carbon fibers, electrical shock graphite fibers, shock hazard

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PRINTED PAGES
☐ Unlimited ☒ For Official Distribution. Do Not Release to NTIS	UNCLASSIFIED	
☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003- ☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price

USCOMM-DC