A COST ANALYSIS OF THE OWNERSHIP AND USE OF TRADITIONAL AND INNOVATIVE COOKING APPLIANCES

by

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Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Housing, Interior Design, and Resource Management

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July, 1988

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(ABSTRACT)

The purpose of this study was to develop a framework for analysis and assessment of the cost of ownership and use of major cooking appliances. This involved an assessment of the monetary cost as well as the cost of human resources required to maintain and operate cooking systems. The goal was to provide information useful in making purchase decisions within a framework that can be used to organize information about cost beyond the initial purchase price. Five cooktops--conventional electric coil, induction, solid element with thermostatic control, solid element with thermal limiter, and gas--and a microwave oven were used to develop a decision-making matrix. Data were collected in the Virginia Polytechnic Institute and State University College of Human Resources household equipment laboratory. In addition, data were compiled from previous studies which included the same variables.

One-way analysis of variance, Student-Newman-Keuls, and Tukey's HDS techniques were used to analyze the data. Results were used to assign weights in the matrix used to develop a 10-point

scale which represented the total cost of owning and using a cooking system in food preparation. The scale was then used to evaluate the appliances used in this study. Based on the matrix, the microwave oven received the highest score followed by gas, conventional electric coil, solid element with thermostatic control, solid element with thermal limiter, and induction cooktops.

The cost of owning and using any of these appliances is not markedly different in terms of life expectancy, maintenance, energy, or cooking time. However, such factors as user interaction with the appliance, speed of heat-up, heat recover rate, retained heat, evenness of heating, cleaning time, and initial purchase price do vary and are likely to influence satisfaction with a cooking system.

Acknowledgements

The author recognizes everyone who has contributed to the completion of this dissertation and degree. Special appreciation and thanks are expressed to:

The Department of Housing, Interior Design, and Resource Management for use of the household equipment laboratory, instruments, and appliances.

Dr. Rebecca Lovingood, my major professor, for her endless patience, unlimited ideas, and suggestions, a continual source of guidance, inspiration, optimism, and moral support. Her relationship as a caring friend has been invaluable.

Special appreciation is expressed to other members of my committee: Dr. Nancy Barclay, who was there when I needed a shoulder to cry on and for her willingness to provide me with countless learning experiences through assistantships; Dr. Rosemary Goss for her special contributions; Dr. Janet Johnson for her expertise in foods; Dr. Walter O'Brien for his assistance and willingness to provide help from the Department of Mechanical Engineering.

The author is deeply grateful to the Electrical Women's Round Table, Inc., and Mankato State University for financial assistance; who worked long hours on developing the method used to measure heat distribution; for her proficiency in computer programming, commitment, and willingness to always give of her time. Her assistance throughout this project was vital to its completion. A special thanks is extended to Dr. Clinton Dancy who, in the absence of Dr. O'Brien, worked diligently in the completion of this dissertation.

Sincere thanks are also expressed to the many friends and my family who were always willing to listen and encourage. And to my mother, my deepest and most sincere gratitude for being there for me.

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CHAPTER I

INTRODUCTION AND BACKGROUND OF THE STUDY

Cooking appliances represent a major purchase for consumers. Because they are relatively expensive and are purchased infrequently, consumers do not really gain skill or expertise in buying these items. Consumers in the market today for a major cooking appliance are faced with new technology. The conventional gas or electric range traditionally has been the most common major appliance used for food preparation. However, the array of cooking appliances on the market has expanded to include innovative products such as cooktops with induction or solid disk elements and ovens with forced convection or microwave capabilities alone or in combination with conventional gas or electric heat sources. Cooking appliances have increased in number of designs and models, especially for cooktops and microwave ovens, and increased knowledge is necessary for selecting and operating new appliances or new features effectively and efficiently.

Methods must be developed to aid consumers in evaluating the functions of appliances so satisfactory purchases can be made (Pickett, Arnold, & Ketterer, 1986). Technical information is neither understood nor generally available to the consumer. Consumers need information, not only about the types of equipment available, but also about ways to evaluate the functions of cooking appliances in order to make choices that will give the most satisfaction.

Consumers and consumer educators frequently seek information regarding comparisons among types of cooking systems. To date, comparative information from independent sources has been limited. During the last 10 years, several studies have included the variables of operating time and energy utilization of cooking appliances. According to these studies, differences in time have been greater than differences in energy (Lovingood, Bentley, Lindstrom, & Walton, 1986). In two recent studies, attempts have been made to measure user's time (Richardson, 1982) and user interaction (Lovingood et al., 1986) as a way of expressing the human involvement with an appliance. However, an investment in an appliance also involves the initial cost, cost of operating the appliance, efficiency in energy utilization, cost of maintaining and repairing the appliance, and the expected life of the appliance. To incorporate all aspects, the selection-purchase-use decision should be based on a combination of all cost factors plus several related to quantitative or qualitative aspects of performance.

The Appliance Industry

Appliance manufacturers are expanding product offerings to make sure they have products available to meet a variety of consumer needs. Some of the present brands on the market may eventually disappear as appliance companies focus on their successes, but at this time the consumer has a wider choice than has been the case for over 25 years (Holding, 1988). The Association of Home Appliance Manufacturers (AHAM) predicts that, although the appliance market is expected to drop slightly in 1988, shipment levels in the next few years will be stable based on continued growth in: new home construction, especially in the high-end, single family homes where more appliances are installed, usually with more fully-featured models; kitchen remodeling, as American homes age and new lifestyles demand different accommodations; resale of existing homes, triggering new appliance purchases; and appliance replacement, due to an ever expanding population of appliance over 10 years old as well as to innovative features, configurations, and styling in the new product offerings (Major Appliance Industry Facts Book, 1987). Holding (1988) estimated that 65 to 70 percent of all sales comes from the replacement market.

The major appliance industry is in the midst of the most successful period in its history (Dolak, 1988). Microwave ovens represent the largest single category in shipment totals annually, increasing from 5.9 million units in 1983 to 12.4 million units in 1986 (Dolak, 1988). Estimates are that the microwave oven is approaching an 80% saturation.

During 1987, sales of gas cooking appliances exceeded 2.0 million for the first time since 1973. Estimated sales for 1989 include nearly 2.0 million gas units, 3.1 million electric units, and 11.4 million microwave ovens (Five year appliance statistical forecast, 1988). Even with an expected drop in appliance sales, the outlook for the future is favorable. However, the future success of the appliance market is dependent upon favorable economic conditions such as high employment and affordable mortgage and interest rates. A brief description of the cooktops and microwave ovens available in this vibrant market follows.

Cooking Appliance Options

Conventional Gas and Electric Coil Cooktops

Cooktops with gas burners or electric coils are similar in size, arrangement, and general cooking performance. Quality of cooking performance depends to a great extent on two factors: how fast a load (e.g., water or food) can be heated from a cold start, and the length of time a load can be held at a particular temperature. Gas and electric coil cooktops offer many of the same special features for cooking and cleaning. The major difference is in characteristics of the heat source, but design characteristics of current models of conventional coil elements make them comparable to gas burners in response time, control at low heat settings, and flexibility of control settings through the low to high temperature range (Range Basics, 1979).

Induction Cooktops

Induction cooktops for home installation were first marketed in 1972 by Westinghouse (Amthor, 1973). The cooktop is designed to generate electromagnetic waves which create heat only in magnetic cookware. Induction is as fast as gas and it can be easily controlled down to a very low temperature (Vaughan, 1986). According to Triplett (1980), induction is the most economical, the most efficient, and the safest of all forms of surface cooking. Some claim that induction cooking eliminates common problems of conventional cooking such as sticking, scorching, and uneven browning because of its more accurate temperature control and more even heat distribution.

Solid Element Cooktop

Solid element cooktops, popular in Europe for many years, have been introduced in the United States in the last 10 years. Even though the solid element is distinguished from other styles of electric surface units, it works on the same principle as a conventional coil element. A mass of metal is heated as electricity flows through a conductor enclosed within the element. Because of a greater thermal mass than the conventional coil, the solid element is characterized by gradual heat-up and long retention of heat.

Solid elements have certain advantages. These include uniform heat transfer across the entire bottom of the cooking vessel which helps to assure uniform cooking of the products (Randolph, 1984); no drip pans to clean, to re-cover, or replace; and most of the design problems common to open flames and tubular elements are avoided. Disadvantages of solid elements are that they do not glow red at the highest setting and do not get as hot as conventional coils (Electric Cooktops. . ., 1985).

Microwave Ovens

Microwave ovens offer consumers a variety of cooking possibilities. In addition to traditional conventional baking, some manufacturers offer microwave/conventional, microwave/ convection, and most recently, microwave/toast/broil/bake/ microbake all in one unit (Beck, 1986). Microwave ovens are famous for cooking fast, but not for browning foods or for cooking evenly. The addition of resistance heaters, as in the microwave/conventional or microwave/convection ovens, is an attempt to overcome the problem of limited browning.

Relative Cost of Alternatives

What is the relative cost of food preparation using these appliances? In this case, cost includes monetary costs as well as the cost of user inputs. There is a need for a compilation of previous studies and an extension of previous research to provide information necessary for a buyer's guide for comparison shopping of major cooking appliances. The traditional and innovative appliances in this study include only cooktops and microwave ovens. Traditional appliances are the conventional cooktops with electric coils or gas burners which constitute the majority of cooktops sold in the United States. Innovative appliances are the non-traditional appliances, specifically cooktops with induction units or solid elements, and microwave ovens.

Problem Statement

The purpose of this study was to develop a framework for analysis and assessment of the costs of ownership and use of major cooking appliances commonly sold in the United States. This involves an assessment of the monetary costs as well as the costs of human resources required to maintain and operate cooking systems. The goal was to provide information useful in making purchase decisions within a framework that can be used to organize information about costs beyond the initial purchase price.

In order to reach the goal of the study, it was necessary to:

1. determine the monetary cost of purchasing and maintaining major cooking appliances used for surface and microwave cooking.
2. determine the life expectancy of the appliances.
3. analyze operating costs when preparing a standard set of meals using traditional and innovative cooking appliances.

4. determine the relative cost of human resources required to operate and care for the cooking systems.

Information obtained through this research project has implications for educators (including extension personnel) and researchers in household equipment, appliance manufacturers, dealers, and consumers. Based on recommendations from this study, information may be utilized by the following groups:

1. Educators (including extension personnel) in providing information to aid consumers in the selection of cooking appliances.
2. Educators in the development of publications or programs on appliance use.
3. Researchers in the development of appropriate methodology to evaluate appliance performance.
4. Manufacturers in developing efficient cookware for different cooking systems.
5. Manufacturers in designing appliances to meet the diverse needs of today's specialized consumer market.
6. Consumers in evaluating types of appliances.
7. Educators in developing information, publications, and programs to help consumers make informed decisions about which performance characteristics could yield the greatest saving of human and material resources.

CHAPTER II

THEORETICAL FRAMEWORK AND REVIEW OF LITERATURE

Theoretical Framework

A theoretical model of the food preparation system, based on the Lovingood - McCullough (1986) household task performance system, was used to analyze the cost of owning and operating major cooking appliances. The systems framework comprises inputs, or human and material resources, which are combined to accomplish household tasks; throughputs, or processes used in task performance; and outputs, relative cost of resources, human and material, used in food production. Total cost of food preparation is a function of the combination of input and throughput factors. Assuming cost of supplies and preparation to point of cooking is constant, relative cost of food preparation in the household is a function of resource input and preparation processes. The household task of food preparation includes the total process, from assembly of resources to final clean-up.

More specifically, the person (user), tool (appliance), and food items are inputs. The throughput component is comprised of factors in the cooking process: energy, appliance operating time, other performance characteristics such as speed of heat-up, heat recovery rate, heat retention, and evenness of heating, and user interaction with the appliance in cooking and clean-up. The output is the total cost of resources (human and material) used in food production. See Figure 1 for the theoretical framework.

Review of Related Research

In order to examine the costs of utilizing the major appliances that are sold in the United States, one must examine literature regarding characteristics that may identify consumer purchase and utilization of the cooktops and microwave ovens. The review of literature describes research related to performance of traditional and innovative cooking appliances as related to energy utilization, appliance operating time, speed of heat-up, recovery rate, evenness of heating, and user interaction in cooking and cleaning. For a summary of related research see Appendix A.

Energy Utilization and Time Required for Major Cooking Appliances

Even though energy is an important consideration in the cost of appliances, energy use is not a reason to choose one model of cooking appliance over another. Ranges do not consume a lot of energy relative to other major household appliances. In recent years the energy used by major appliances has been significantly reduced (Major Home Appliance Industry. . ., Jan./Feb. 1986). At average national utility rates (8.04 cents per kilowatt-hour for

FOOD PREPARATION SYSTEM

INPUT	THROUGHPUTS	OUTPUTS
1. Human Resources a. Person	1. Cooking Process a. Appliance operating time b. Fuel energy	1. Cost of Resources Used in Food Preparation a. Human b. Material
2. Material a. Cooking System b. Food	2. Characteristics of cooking system performance a. Speed of heat-up b. Heat recovery rate c. Evenness of heating d. Heat retention	2. Food Produced
	3. User Interaction a. Cooking b. Cleaning	

Figure 1: Theoretical Framework: Food Preparation System

electricity and 56.2 cents per therm for gas), an average amount of cooking would cost $63 a year with an electric range and about $31.37 with a gas range (Federal Trade Commission rules. . ., 1988).

Top-of-the-range cooking usually uses less energy and is usually faster than conventional oven cooking, however the microwave oven may use less energy and may be faster than both top-of-the-range cooking and conventional ovens.

In comparing consumption of conventional and smooth-top ranges and microwave ovens, Lovingood and Goss (1980) found that when a microwave oven was used in conjunction with each of the ranges total energy decreased by approximately 24 to 35 percent. However, they stated that "less energy was not always consumed by the microwave oven compared with the ranges, especially those with conventional surface units" (p.239).

Several researchers have used various appliances to compare time and energy involved in preparing a week's meals (e.g.,Boschung, 1985; Clark, 1980; Hill & Anderson, 1983; Lovingood & Goss, 1980; Lovingood et al., 1986; Zalenski & Lovingood, 1985). The largest energy saving occurred when the microwave oven was used in place of the conventional oven. According to Lovingood and Goss (1980), a microwave oven used in conjunction with an electric range saved 24% in energy and 47% in time. A microwave oven used in conjunction with a convection oven saved 42% in energy and 53%

in time, whereas a microwave oven used in conjunction with surface units saved 5% in energy and 21% in time (Olson & Olson, 1985).

Speed is generally thought to be a major advantage of microwave cooking. The type of food, amount and shape of the food load, and starting temperature are factors which affect cooking time (Olson & Olson, 1985). Another factor to consider in microwave cooking is the cookware. According to Barber (1986), the material and shape of microwave cookware chosen can make a difference in the quality of food produced. Water and fats are good absorbers of microwave energy which is supported by the findings of Laughon (1980). According to Laughon, food density and moisture content are inversely correlated to energy and time in comparisons of a conventional electric range and a countertop microwave oven. Microwave cooking is generally more energy efficient than conventional oven cooking when the load size is not too large; however, in certain cases surface unit cooking may be more efficient than microwaving (Microwave Digest, 1978).

Appliance users can reduce energy consumed in cooking by using the appliance that is least energy consuming for particular cooking operations (Laughon, 1980). In a study of energy and time required to prepare selected foods with a conventional electric range and a countertop microwave oven, Laughon (1980) found that surface units on a conventional electric range used less energy than the microwave oven for many foods normally cooked on the conventional range.

In a review of literature related to energy consumption in microwave and conventional ovens, Hassoun (1982) reported that the following statements are generally supported by research.

1. Using a microwave oven takes as much or more energy than using the surface unit of a range.
2. Using a conventional oven for preparing a single item takes more energy than using a microwave oven.

Hassoun reviewed a number of studies concerning these findings and reported contradictory results. Reasons for conflicts may be due to: 1) technological changes in appliances, 2) variation in procedures -- simple vs. complex recipes, amount of water, food form (fresh, canned, frozen), techniques of the cook, size and shape of food load, and number of replications (Hassoun, 1982).

Induction, because of the design principle involved, is viewed by some to be the most energy efficient. In a comparison of efficiency of induction with conventional gas and electric cooktops, Triplett (1980) reported that in studies conducted at Roper, the electric coil cooktop used 19% more energy than the induction unit, the smooth-top used 40% more energy, and the gas-top consumed 91% more energy than the induction cooktop. Zalenski and Lovingood (1985) found energy consumption of the induction cooktop to be less than the conventional cooktop when preparing four food items (bacon, vanilla pudding, pancakes, and water - one, two, and four cups). Total operating time for the induction cooktop was also less. Although significant savings in electric energy and time can be demonstrated, Zalenski and Lovingood stated that "the actual savings may not be of practical significance to consumers given the present average national cost of electricity of 7.63 cents per kwh and the significantly higher purchase price of an induction cooktop" (p. 29).

Very little information exists on the time, energy, and cost of cooking with natural gas. Hill and Anderson (1983) found that the gas range consumed the most Btu when comparing surface preparation using a gas range, an electric range, a microwave oven, and an induction cooktop. They also reported that even though the gas range consumed the most Btu, it would cost less to operate for one year given the average national cost of electricity of 7.63 cents per kwh versus 62.7 cents per therm for gas.

Boschung (1985), using a gas range alone as well as in conjunction with a microwave oven, studied time and energy consumption in the preparation of food on the Association of Home Appliance Manufacturers (AHAM) Menu for Range Energy Testing. According to Boschung, the Btu consumption was higher using only the gas range for all operations. However, the actual cost of operating a conventional gas range for a period of a year was greater than a gas range used in conjunction with a microwave oven when performing the same operations. A microwave oven in conjunction with the gas range saved time, thus confirming the findings of those who have compared microwave ovens and electric ranges.

Other Characteristics of Performance

Speed of heat-up. Energy utilization and cooking time should be less with an induction cooktop because the heat is induced directly into the utensil, rather than heating the surface on which the utensil rests. Induction has a fast heat-up rate when compared to microwave ovens and conventional coil cooktops. Even though the rate of heat-up is fast, the rate is even greater when a large quantity (water, food) is used. Clark (1980) reported speed of heat-up of an induction unit, microwave oven, and conventional electric coil cooktop. Speed of heat-up was measured in the form of time required, in minutes, to raise one, two, and four cups of water from 70 degrees F. to boiling. On the one-cup load, the induction unit was only 15 seconds slower than a microwave oven, but when comparing a four-cup load, the induction was about 60% faster than the microwave oven and 18% faster than the conventional electric coil unit.

Gas burners provide instant heat whereas electric elements have to warm up. Theoretically, gas burners should boil water faster than electric units. The authors of Kitchen Ranges (1984) did not find this assumption to be true. From the selection of conventional electric coil and gas ranges on the market, 28 (16 electric, 12 gas) 30 inch wide, free standing models were chosen to be tested. The test was conducted to determine the amount of time needed to boil three quarts of water on both the electric and gas ranges. The water on the electric range took 9-11 minutes to boil, whereas that on the gas range took 12-16 minutes. More important in cooking fast and efficiently on an electric range is the choice of pots. The bottom of a pot should be flat and the diameter should match that of the element.

Recovery rate. In a series of thermal tests conducted to determine the recovery rate of 1-1/2 pounds of spaghetti cooked in 5 liters of water, Randolph (1983) found that the average time to return the water to the original boiling point after adding the spaghetti was 10.32 minutes.

Retained heat. In a test conducted to assess response to change in control setting, Lovingood et al. (1986) found cool-down time using the conventional electric coil, solid element with thermal limiter, solid element with thermostatic control, and induction to be related to the quantity and characteristics of the thermal mass in the individual cooking system. Response to change in control setting was assessed by heating one liter of water to boiling then turning the unit off and measuring the time that elasped before the water cooled to 190 degree F. Time from the beginning of the test to when the water temperature fell to 190 degree F. was used to compute "cool-down" time. Cool-down time was similar for the solid element and the conventional coil, but was faster for the induction unit.

The solid element retains heat for a time after the power is turned off. Theoretically, one would expect the speed of heating and cooling to be slow. Lovingood et al. (1986) found "cool-down" time to be similar for solid elements and a conventional coil when heating one liter of water to boiling then turning the unit off and measuring the time that elasped before the water cooled to 190 degrees F. However, water on the induction unit cooled to 190 degrees F. in less than one minute.

Evenness of heating. Because of basic differences in design principles of cooking appliances, one would expect a difference in heat distribution. Anderson and Goodman (1985) did a comparison of induction cooking and found no significant differences in heat distribution or the development of hot spots among the cooktops tested.

User Interaction

Cooking. Studies for years have included operating time and energy utilization of major cooking appliances. Differences in time generally have been greater than differences in energy. Richardson (1982) measured user's or cook's time as well as appliance operating time to more precisely describe the differences between cooking with a conventional range and a microwave oven. However, Lovingood and McCullough (1986) found no correlation in appliance ownership and time spent in housework. In observing the user interaction with conventional and innovative cooktops, Lovingood, Bentley, Lindstrom, and Walton (1986) noted similarities in user interaction and appliance operating time, and also noted differences in the intensity of user interaction with the cooktop. (The intensity of user interaction will be defined in Chapter III).

Cleaning. The ease of cleaning a range is affected by the design of the range. Kitchen Ranges (1984) is a report of tests with 16 electric and 12 gas ranges to determine how easy they were to clean. According to the writers, the simpler the design of the units and their surroundings, the easier the range was to clean. The best design for cleaning was one which had no decorative trim to catch dirt and had a seamless curve of porcelain enamel between the cooktops and the control panel on the backguard. Markings on control panels made cleaning difficult because of precautions that should be taken during the cleaning process. Markings can be rubbed off with steel wool or scouring powder.

Cleaning gas cooktops was easier than cleaning cooktops with electric elements (Kitchen Ranges, 1984). The burner grate on the gas cooktop can be removed and the area underneath can be wiped clean. However, to get to the drip bowls of an electric range, the elements have to first be unplugged and then cleaned. With most drip bowls, excess drippings will overflow through the hole in the middle and dirty the area under the cooktop. Many ranges have tops that can be raised or removed to make cleaning underneath easy. However, two of the ranges tested by Consumer Reports in 1984 (the Maytag and the similar Hardwick) have partially solved this problem by making three of the four drip bowls solid, without a hole in the middle (the fourth drip bowl has a hole to allow venting of the oven).

Summary

Since the arrival of major cooking appliances on the market, manufacturers have introduced an array of designs and models available in several different styles. The characteristics of each of these appliances relate to energy utilization, appliance operating time, and other characteristics of performance as well as user interaction. This study was designed to assess the cost of food preparation using these appliances.

Chapter III

DATA COLLECTION AND ANALYSIS

Empirical Model

The empirical model for this study shows the independent and dependent variables (Figure 2). The independent variables studied were purchase price, life expectancy, maintenance, energy utilization, operating time, speed of heat-up, rate of heat recovery, retained heat, evenness of heating, and user interaction in cooking and cleaning. The dependent variable was the total cost of owning a cooking system and using it in food preparation. Thus the relative cost of producing a standard set of meals (e.g., the AHAM Menu) is the function of the above independent variables. The equation is: $C = F(P+L+M+E+T+S+R+H+Eh+Uco+Ucl)$.

Where:

C = cost; P = purchase price; L = life expectancy; M = maintenance; E = cost of energy used; T = appliance operating time; S = speed of heat-up; R = recovery rate; H = retained heat; Eh = evenness of heating; Uco = user interaction in cooking; Ucl = user interaction in cleaning.

Independent Variables	Dependent Variables
Purchase price of appliance	Cost of producing selected food items
Life expectancy	
Maintenance	
Energy utilization of appliance	
Appliance operating time	
User interaction with appliance	
Speed of heat-up	
Heat recovery rate	
Retained heat	
Evenness of heat	
Ease of cleaning	

Figure 2: Empirical Model

Operational Definitions of the Variables

Dependent Variable

Cost is the total relative cost of human and material resources required to operate and maintain traditional and innovative cooking appliances.

Independent Variables

Purchase price - the initial price of appliances at time of purchase.

Life expectancy - the length of time an appliance will function effectively under normal use conditions.

Maintenance - the cost of maintaining and servicing major appliances paid by consumers during a product's useable life.

Energy utilization - the total amount of energy used in an appliance cooking operation as measured by an energy meter.

Appliance operating time - the total time measured to the nearest hundredth of a minute with a stop watch from the moment an appliance control is turned on until the control is turned off at the end of the cooking operation.

Speed of heat-up - the time required to the nearest hundredth of a minute to heat one liter of water from 70 degree F. to 209 degree F.

Recovery rate - the length of time needed to return the temperature of water to the boiling point after a food item is added.

Retained heat - the length of time heat stays in the element after the controls have been turned off.

Evenness of heating - heat distribution of the element as measured by evenness of browning.

User interaction - cooking - the intensity of involvement of the user with the appliance during food preparation as measured on a scale of:

1 = none - put food on, leave alone until done.

2 = slight - put food on, turning or stirring at appropriate times.

3 = moderate - put food on, stirring occasionally and manipulating food at appropriate times.

4 = frequent - stirring occasionally, manipulating food, and readjusting control setting.

5 = continual - constantly and intensively manipulating food or heat controls.

User interaction - cleaning - time to the nearest hundredth of a minute required to clean the cooking appliance after a food preparation activity.

Assumptions

1. Foods chosen are representative of common cooking methods and food compositions prepared on surface units by a typical family of four with a father, mother, preschool age child, and teenage son.

2. Food preparation procedures are similar to those used by a family except for use of objective measurements and control of procedures.
3. The user interaction intensity scale is reliable and valid.
4. Costs are the most important factors to use in comparison.

Data Collection

This study was designed to analyze the cost of ownership and use of traditional and innovative major cooking appliances. Data were collected in the Virginia Polytechnic Institute and State University College of Human Resources household equipment laboratory. In addition,data were compiled from previous studies which included the same variables as this study. Following is a summary of data from previous studies that were used to complete the matrix shown in Table 1.

Researcher	Appliance	Variables
Boschung (1985)	Conventional gas range used in conjunction with a microwave oven	time; energy
Lovingood, Bentley, Lindstrom and Walton (1986)	Induction; solid element; conventional electric coil	energy; time; user interaction; speed of heat-up; retained heat

TABLE 1

SUMMARY OF DATA SOURCES

Appliance	Purchase Price	Life Expectancy	Maintenance	Energy	Time	Speed of Heat-Up	Heat Recovery Rate	Retained Heat	Evenness of Heat	Ease of Cleaning	User Interaction
Traditional Electric coil	x	x	x			x	x	x	x	x	
Gas	x	x	x			x	x	x	x	x	x
Innovative Solid Element Thermal Limiter	x	x	x			x	x	x	x	x	
Solid Element Thermostatic	x	x	x			x	x	x	x	x	
Induction	x	x	x			x	x	x	x	x	
Microwave	x	x	x	x	x	x	x	x	x	x	x

x = Data collected by the researcher.

The following information was gathered from references or from tests conducted by the researcher in the laboratory.

Appliance	Variables
Conventional electric coil; solid element with thermal limiter; solid element with thermostatic control, induction	purchase price; life expectancy; maintenance; speed of heat-up; heat recovery rate; retained heat; evenness of heat, and user interaction in cooking and cleaning
Gas	Same as above plus user interaction in cooking and cleaning
Microwave oven	Same as gas plus energy and operating time

Appliances and Cookware

In the next section, appliances, cookware, and measuring instruments are listed, followed by a detailed description of the procedures used in collecting data for each cell in the matrix shown in Table 1.

A current production model of each of the following appliances was used to collect the data:

Conventional electric range - Whirlpool Model RF3165XPN (Benton Harbor, MI); 6 inch unit 1200 watts; 8 inch unit 2000 watts.

Solid element with thermostatic control - Thermador model E36 (Los Angeles, CA); 6 inch unit 1500 watts; 8 inch unit 2000 watts.

Solid element with thermal limiter - Jenn-Air Model S125; (Indianapolis, IN); 6 inch unit 1500 watts; 8 inch unit 2000 watts.

Microwave oven - Whirlpool Model MW8750XP (Benton Harbor, MI); 1.3 cubic ft. interior; 700 watts of cooking power.

Induction - Jenn-Air induction cartridge Model S125 (Indianapolis, IN); 6 inch unit 1200 watts; 8 inch unit 1600 watts.

Gas - Hardwick Model CPD99843 A 659A (Cleveland, TN); 10,000 Btu per burner.

Cookware recommended by the manufacturer of each cooking appliance was used to complete the cooking system (see Appendix B for cookware and general equipment).

Variables Measured and Instruments Used

In the laboratory work conducted for this study, three types of variables were measured: environmental, independent, and dependent. The variables were objectively measured through the use of scientific instruments as listed in Table 2.

Environmental variables, monitored and controlled to the extent possible, were room temperature and relative humidity measured with a standard laboratory thermometer and a hygrometer, respectively. Temperature and relative humidity were recorded before each test was performed.

Table 2

VARIABLES MEASURED AND INSTRUMENTS USED

Variables	Instrument	Measurement Unit
<u>Environmental</u>		
Temperature	Thermometer	Degrees Fahrenheit
Relative Humidity	Psychrometer	Percent Relative Humidity
<u>Independent</u>		
Energy	Watt-hour meter	Kilowatt-hours
Time (appliance operating time)	Stop watch	Minutes
Speed of heat-up	Stop watch	Minutes
Evenness of heat	Digitizing system	Color numbers
Recovery rate	Stop watch	Minutes
User interaction-cooking	Intensity scale	A five-point intensity scale
User interaction-cleaning	Stop watch	Minutes
<u>Dependent</u>		
Cost of food production	10 Point Scale	10 Point Scale

Independent variables were purchase price, life expectancy, maintenance, cost of energy utilized by appliance, appliance operating time, speed of heat-up, recovery rate, retained heat, evenness of heat, and user interaction in cooking and cleaning.

Purchase price was obtained from the Product Features Report (Consumer Reports, 1987). The price listed is approximate retail (rounded to the nearest dollar, as quoted by the manufacturer).

Life expectancy was obtained from a Portrait of the United States Appliance Industry (1986). Years of life expectancy is based on first-owner use of the product and does not necessarily mean the appliance has no remaining value. When a replacement is purchased, the old unit is either traded in, relegated to use elsewhere, given away, or discarded, thereby ending the life cycle of interest here.

Consumers Union, Association of Home Appliance Manufacturers, several appliance manufacturers, and local appliance stores were contacted by telephone to obtain information on appliance maintenance costs.

Data from previous studies regarding energy and time costs of appliance operation were available for all the cooktops with the exception of energy and time for the microwave oven. Twenty-seven items from the AHAM Menu for Range Energy Testing (Eisele, 1976) that are customarily cooked on range surface units were prepared

TABLE 3

REPRESENTATIVE WEEK'S MENU
(Four Member Family)

	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
BREAKFAST	Half grapefruit Oatmeal with raisins, brown sugar Perked Coffee Milk	Cranberry Juice Dry Cereal with sliced bananas and milk Toast Butter or Margarine Perked Coffee	Orange Juice *Scrambled Eggs with Bacon Strips Toast – Jam, Butter or Margarine Perked Coffee Milk	Tomato Juice Dry Cereal with Milk Toasted English Muffin Jam, Butter or Margarine Perked Coffee Milk	Orange Juice *Soft Cooked Eggs Toast – Jam, Butter or Margarine Perked Coffee Milk	Grapefruit Juice Dry Cereal with Milk Toast Butter or Margarine Perked Coffee Milk	Sliced Bananas in orange juice *Pancakes with Syrup & Sausages Butter or Margarine Perked Coffee Milk
LUNCH/ DINNER	*Beef Pot Roast with Potatoes, Carrots, Onions and gravy Tossed greens with radish slices French Dressing Hot rolls Butter or Margarine Apple Crisp Coffee or Tea Milk	*Vegetable Soup Cold Beef Sandwiches Pickles Coffee or Tea Milk	*Hot Dogs on Buns Potato Chips Pickles Fresh Fruit Coffee or Tea Milk	*Chicken Noodle Soup *Tuna and Egg Salad Sandwiches Cookies Coffee or Tea Milk	*Leftover Beef Stew Fresh Fruit – Salad Coffee or Tea Milk	*Egg Salad Sandwiches on Toast *Lemon Meringue Pie Coffee or Tea Milk	Peanut Butter & Jelly Sandwiches Carrot Strips and Celery Sticks Leftover Desserts or Fruits Milk
DINNER/ SUPPER	*Grilled Cheese Sandwiches Relish Tray (Carrot sticks, tomato, radishes, pickles) Fresh Fruit Coffee or Tea Milk	Baked Chicken with Gravy *Mashed Potatoes *Green Beans Fruit-in-gelatin Salad Refrigerated Biscuits Butter or Margarine Raspberry Sherbet Coffee or Tea Milk	*Beef Stew (with carrots, peas and potatoes) Tossed Greens with French Dressing Brown & Serve rolls Butter or Margarine Vanilla Pudding with strawberry halves in syrup Coffee or Tea Milk	*Spaghetti with meat sauce Grated Parmesan Cheese Lettuce Wedge with Italian Dressing Garlic Bread Whipped Gelatin Coffee or Tea Milk	*Braised Pork Chops *Skillet Scalloped Potatoes *Buttered Spinach *Red Hot Applesauce *Bread – Butter or Margarine *Lemon Meringue Pie Coffee or Tea Milk	Broiled Fish *Rice Pilaf *Peas with Pearl Onions Broiled Tomato Hard Rolls Butter or Margarine *Tapioca Pudding with Fruit Topping Coffee or Tea Milk	Steak Baked Potatoes *Sauteed Mushrooms *Broccoli Tossed Salad Hot French Bread Butter or Margarine Chocolate Cake Coffee or Tea Milk

*Foods prepared in this study

DEVELOPED BY THE AHAM CONSUMER EDUCATION COMMITTEE'S RANGE SUBCOMMITTEE (March 3, 1975) by the author in the microwave oven (see Table 3). This included all operations except hard or soft cooked eggs (in the shell), pancakes and sausage, and grilled cheese sandwiches. In addition, data were collected on user interaction when surface operations in the AHAM Menu were conducted on the gas cooktop. Additional information relative to these tests is included in Appendix C.

The following tests were used to determine other characteristics of performance for all appliances:

To measure speed of heat-up and recovery rate, three quarts of water were heated from 70 degree F. to 209 degree F. to measure speed of heat-up. When water reached boiling, 8 oz. of spaghetti noodles were added. Recovery was achieved when the water returned to the temperature recorded before spaghetti was added. (See Appendix C for test procedures.)

For the retained heat test, two quarts of water were heated to 209 degree F, then the heat was turned off and time recorded for the temperature of the water to drop to 190 degree F. (See Appendix C for test procedure.)

Crepes were used to measure evenness of heat distribution as determined by differences in browning patterns. The crepes were prepared according to a basic recipe and cooked on each appliance according to standardized procedures (Appendix C). Crepes were cut into quadrants (Figure 3) and a picture of each quadrant was recorded on a video tape. A procedure for finding the color den-

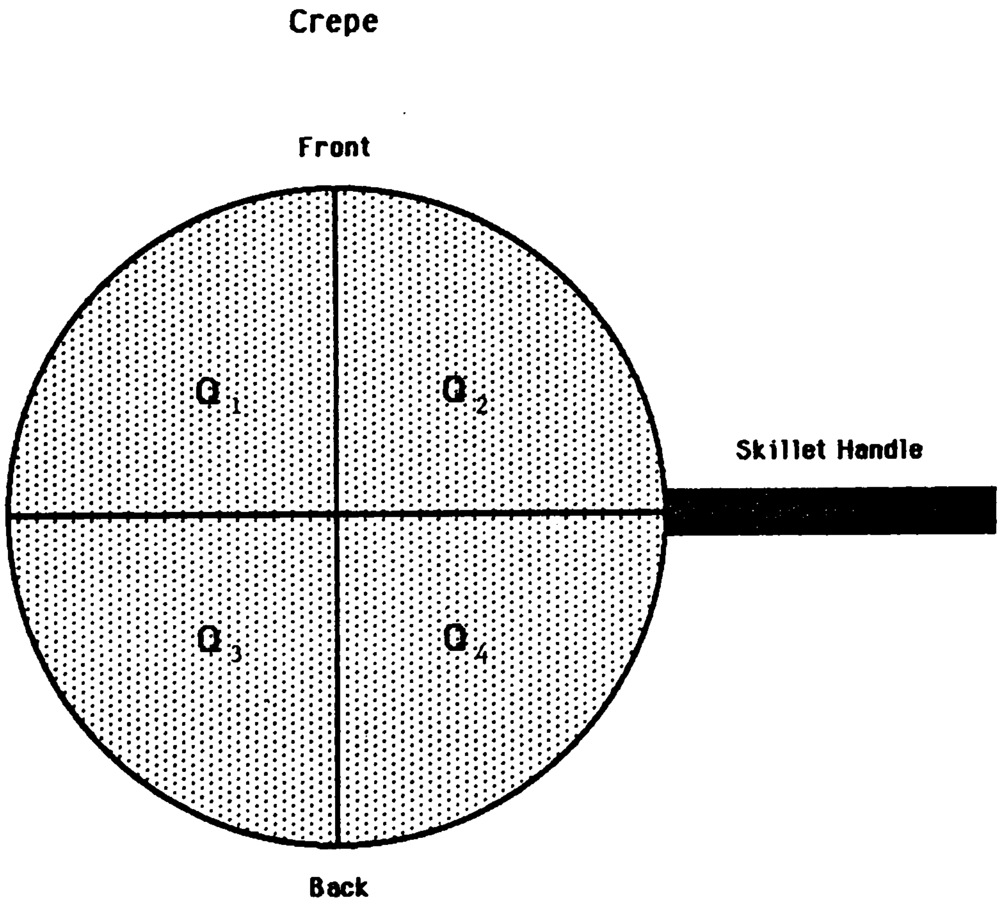

Figure 3: Division of Crepe into Quadrants.

sities in a video picture was established by the Mechanical Engineering Department at Virginia Polytechnic Institute and State University. The procedure included the setup of the hardware to perform a digitizing process on a picture and the writing of a FORTRAN program to reduce the data.

The digitizing system consists of an IBM-PCAT computer with a PIP model number 512 digitizing board (manufactured by MATROX Electronics Systems LTD). The board is then connected to a television monitor which receives its signal from a video recorder or a camera. The FORTRAN program selects the area of the picture which is to be considered and stores the digitized data on a disk. Because of the large amounts of data which are generated in digitizing, the program stores the sum of the times each color[1] is encountered in the digitizing area. The colors are represented by a number from 0 to 255, with 0 being black and 255 being white. The data appear in two parts: Part 1 includes the colors observed for each data point; Part 2 consists of the color number (0 - 255) and the number of times each color was encountered in each quadrant.

The intensity of user interaction in cooking was measured with a five-point scale developed by Lovingood et al. (1986).

[1]Here, color is used to refer to gray-scale level of the stored image. The digitizing system was able to resolve 256 different grey-scale levels from a black-and-white image. Thus, the original color video image was interpreted in gray-scale levels.

Data on user interaction were collected when surface operations from the AHAM Menu were conducted with the gas cooktop and the microwave oven. (Items from the list not appropriate for preparation in the microwave oven were hard and soft cooked eggs--in the shell), pancakes and sausages, and grilled cheese sandwiches. (See Appendix C for details.)

A boil- over test and a spatter test, described in Appendix C, were used to measure <u>user interaction in cleaning</u>. Oatmeal was used in the boil-over test and ground beef patties were used in the spatter test. At the end of the two tests, each appliance was cleaned using the procedures recommended by the manufacturer for periodic cleaning. Cleaning time was measured with a stop watch, and subjective comments were recorded.

<u>Pretesting</u>

Each step in the data collection procedure was pretested to validate procedures (i.e., to establish endpoints and general times and energy consumption to be expected during research).

A five-point scale, developed from the Hedonic Sensory Scale, was used to measure the intensity of user interaction with the appliance during cooking. Points on the scale were:

1 = none - put food on, leave alone until done.

2 = slight - put food on, turning or stirring at appropriate times.

3 = moderate - put food on, stirring occasionally, manipulating food at appropriate times.

4 = frequent - stirring occasionally, manipulating food, and readjusting control settings.

5 = continual - constantly and intensively manipulating food or heat control.

To validate the scale, vanilla pudding was cooked three times on each of the six appliances in this study by three volunteer participants. The pudding mix was prepared by the researcher and stored in bags until used. Cooking procedures were followed exactly for each test. Specific cooking procedures are described in Appendix C. Each cook used the five point scale to rate the intensity of user interaction with the appliance while cooking the pudding. A data sheet was completed for each test (Appendix D).

In order to minimize uncontrollable or unforeseen effects, tests were conducted on three different days by each cook. The Latin square form of randomization was used to determine order of appliance use. Following is the order in which tests were performed:

Cook	Day 1	Day 2	Day 3
1	AB	CD	EF
2	CD	EF	AB
3	EF	AB	CD

where: A = gas; B = induction; C = microwave oven; D = solid element with thermostatic control; E = conventional electric coil; F = solid element with thermal limiter.

Using the same scale, little difference was found in the rated scores by each cook according to type of appliance used (Table 4). The content validity of the scale is demonstrated by how representative the scale items are of the content the scale purports to measure.

Data Analysis

To analyze cost of ownership and use of traditional and innovative cooking appliances, the following statistical analyses were performed:

Variable	Statistical Test
Energy utilization	One-way ANOVA
Operating time	One-way ANOVA
Speed of heat-up	One-way ANOVA; Student-Newman-Keuls
Heat recovery	One-way ANOVA; Student-Newman-Keuls
Retained heat	One-way ANOVA; Student-Newman-Keuls
Evenness of heating	One-way ANOVA; Tukey's HDS
User interaction - cooking	One-way ANOVA; Student-Newman-Keuls
User interaction - cleaning	One-way ANOVA; Student-Newman-Keuls

TABLE 4

Mean Score of Pudding Prepared on 6 Appliances
3 Replications, Using the Intensity of User
Interaction Scale

Appliance	Cook 1	Cook 2	Cook 3
Conventional Electric Coil	3	3	3
Induction	4	4	4
Solid Element Thermal Limiter	2.6	2.6	2.6
Solid Element Thermostatic	2	2.4	2
Gas	4	3	5
Microwave Oven	2.3	2	2

Results obtained from the data analysis were used to assign weights to the independent variables. A rating scale was developed for each of the variables and was used to evaluate the total cost of owning and using a cooktop or a microwave oven.

Chapter IV

RESULTS AND DISCUSSION

Five cooktops (conventional electric coil, gas, induction, solid element--both thermal limiter and thermostatic control) and a microwave oven were used in this laboratory experiment to analyze the cost of ownership and use of traditional and innovative major cooking appliances.

This chapter is divided into two parts. In Part 1, the results in terms of each of the independent variables from this and other studies are discussed in two sections: cost of appliance ownership and cost of appliance operation and use. (See Table 1 for summary of data sources.)

In Part 2, a rating scale developed to evaluate major cooking appliances according to ownership and use is presented. Results obtained from this study were used to assign weights to the independent variables, thus these weights were used to develop the rating scale. Before these factors are discussed, it is necessary to present limitations of this study.

Limitations

1. Because of money constraints, only one brand and model of each appliance was used in this study.
2. Because of time and money constraints, only meals for one week were prepared on each appliance.

3. Laboratory tests may not be representative of procedures followed in home preparation.

4. Quantity of water used was established from other studies.

5. This study did not involve aesthetic aspects of appliances.

Part 1

Cost of Appliance Ownership

Purchase Price

Prices used in this study are approximate retail as quoted by the manufacturer and cited in Consumers Report Product Features Service (1987). For the purpose of cost comparison of the six appliances used in this study, prices were rated in the following manner: 1=low (less than $350), 2=medium ($350 -$500), and 3=high (more than $500). As Table 5 indicates, the conventional electric coil cooktop was the least expensive and was the only one rated as 3,low, or costing less than $350. The solid element with thermal limiter and gas were rated 2, medium, or costing between $350 and $500. The induction, solid element with thermostatic control, and microwave oven had the highest purchase prices and were all rated 1, high, or costing more than $500.

Life Expectancy

Years of life expectancy for the six appliances used in this study were obtained from a Portrait of the United States Appliance Industry (1986). For cost comparison, years of life expectancy were rated in the following manner: 1=low (0.00 - 6.99 years); 2=medium (7.00 - 13.99 years); 3=high (14 - 19.99 years).

Life expectancy of all appliances was rated as high, indicating that the life expectancy of the six appliances ranged from 14 to 19.99 years (Table 5).

Maintenance

Several manufacturers contacted would not release information on appliance maintenance. Similarly, information was not available from several local appliance stores due to the method of recordkeeping. According to Downing of WCI (1987), an estimated 12,000,000 appliance units are sold a year, and service is needed for an average of 2-5% of the units sold. The average service call is $30.00 or $1.40 per unit per year. It is estimated that of 100 microwave ovens sold, 10 would need service the first year, and in years two to five, 10 more would need a service call (Meyer & Sons T.V. & Appliance Inc., 1988). The main service request relates to the interlock mechanism of the oven which is part of the safety design. There are few requests for service on cooktops. Because of lack of information on appliance maintenance, weights given to the appliances used in this study are based on knowledge of educators.

Cost of Appliance Operation and Use

The following section is concerned with several important aspects of food preparation which influence decisions concerning

TABLE 5

Cost of Ownership of Six Appliances Based on Retail Prices Quoted by Manufacturers and Years of Life Expectancy Obtained From a Portrait Of The United States Industry (1986)

Appliance	Purchase Price	Life Expectancy	Maintenance
Conventional Electric	3	3	1
Induction	1	3	3
Solid Element-thermal limiter	2	3	1
Solid Element-Thermostatic	2	3	1
Gas	2	3	1
Microwave	2	3	2

Key - Purchase Price: 3 = low or $350; 2 = medium or $350-$500
1 = high or $500
Life Expectancy: 1 = low or 0.00-6.99 years; 2 = medium or 7.00-13.99; 3 = high or 14-19.99 years.
Maintenance: 1 = low, 2 = medium, 3 = high.

appliance operation and use: energy, appliance operating time, speed of heat-up, heat recovery rate, retained heat, evenness of heating, and intensity of user interaction in cooking and cleaning.

Energy and time required to prepare selected foods with traditional and innovative cooktops and a microwave oven were compared. The 27 food items prepared in this study were chosen from the AHAM Standard Menu for Range Energy Testing and were limited to those suitable for preparation on range surface units and in a microwave oven. In all studies in the data bank, each food was prepared three times on each appliance. Energy consumption was measured in watt hours for the electric cooktops and microwave oven, and in energy increments for the gas appliance. One increment is equal to 1/20 of a cubic foot of natural gas. For comparison, watt hours and increments were converted to Btu. See Table 6 for comparison of energy of the six appliances. Tests for speed of heat-up through evenness of heating were each performed three times on the 6-inch unit of the electric cooktop, on the gas burner, or in the microwave oven unless otherwise noted.

Energy

The induction cooktop used the least energy (Btu), progressing in order to the solid element with thermal limiter, the conventional electric coil, the solid element with thermostatic con-

TABLE 6

Comparison of Energy Utilization, Operating Time, and User Interaction, Traditional and Innovative Appliances, Surface Operations, AHAM Menu for Range Energy Testing

Appliance	Energy (Btu) (Total Btu)	Time (Minutes)	User Interaction[b]
Gas	40,844	480.0	2.36
Microwave	20,834[a]	293.0[a]	1.80
Solid element-Thermostat	19,793	498.4	2.02
Conventional Electric	19,455	452.2	2.42
Solid element - Thermal limiter	19,198	483.7	2.46
Induction	17,317	436.0	2.50

[a] Data collected in present study; all other energy and time data from Boschung, 1985 (gas) and Lovingood, et al., 1986.

[b] User interaction rated on scale of 1 = put food on, leave it alone until it's done to 5 = continuous stirring or manipulation of food or heat control.

trol, and the microwave oven, with the gas cooktop requiring the most energy to cook the food items from the AHAM Menu.

A one-way analysis of variance (Table 7) was performed to determine if a significant difference in units of energy existed between appliances. The gas cooktop required significantly more energy than any of the other appliances. However, the microwave oven used more energy than the other electric appliances (conventional electric coil, solid elements, and induction), but the difference was not statistically significant.

These data become more meaningful when compared to cost. In comparing cost, it is helpful to note that one kilowatt hour of electricity produces 3415 Btu (VanZante, 1964), and one therm of natural gas produces 100,000 Btu. The 1986 average cost ((Major Appliances use less energy. . ., Nov./Dec. 1986) was 8.04 cents per kilowatt hour and 56.2 cents per therm for gas. Applying the cost to the findings of this study, using the gas cooktop would cost $11.86 annually compared to $25.28 for the microwave oven, $24.25 for the solid element with thermostatic control, $23.74 for the conventional electric, $23.22 for the solid element with thermal limiter, and $21.16 for the induction (See Table 8 for energy cost comparison).

<u>Appliance Operating Time</u>

Comparisons of time are found in Tables 6 and 9. Time required in the cooking of the 27 items was recorded in minutes.

TABLE 7

Analysis of Variance
Energy Utilization, Traditional and Innovative Cooking Appliances, Surface Operations, AHAM Menu for Range Energy Testing: 3 Replications

Appliance		F Ratio	Level of Significance
		11.8114	.0001
Conventional electric coil	189.88		
Induction	169.04		
Solid element - thermal limiter	186.95		
Solid element - thermostatic	193.18		
*Gas	427.18		
Microwave	234.67		

The Student-Newman-Keuls procedure indicated that gas was different than all other groups.

*Significant difference

TABLE 8

Energy and Cost Comparison
for Preparation of Selected Items From the AHAM Menu for
Range Energy Testing on Four Cooktops
and a Microwave Oven

Appliance	Energy Btu	Week	Cost Month	Year
Gas	40,844	$ .23	$ .99	$11.87
Microwave oven	20,834	.49	2.11	25.28
Solid Element (Thermostatic Control)	19,793	.47	2.02	24.25
Conventional Electric	19,455	.46	1.98	23.74
Solid Element (Thermo limiter)	19,198	.45	1.94	23.22
Induction	17,317	.41	1.76	21.16

Note: Average cost (Appliance Letter, 1986) - 8.04 cents per kilowatt hour and 56.2 cents per therm for gas.

TABLE 9

Analysis of Variance
Time to Cook Selected Items From AHAM Menu for Range Energy Testing with Six Appliances, 3 Replications

Appliance	Mean (Minutes)	F Ratio	Level of Significance[1]
Conventional Electric Coil	150.73	.8267	.05
Induction	145.33		
Solid Element with Thermal Limiter	161.23		
Solid Element with Thermostatic Control	166.13		
Gas	160.00		
Microwave Oven	97.00		

[1]No significant differences between groups were found at the .05 level.

The microwave oven required the least time for cooking the food items (293 minutes). The solid element - thermostatic control required the most time (498 minutes). However, a one-way analysis of variance indicated that there were no significant differences in time required for preparation of foods according to type of appliance utilized.

Speed of Heat-up

Time to heat three quarts of water in a covered pan from 70 degree F. to 209 degree F. varied from 7.70 minutes for the conventional electric coil (6" unit) to 13.59 minutes for the gas. One-way analysis of variance indicated that significant differences (p=>.001) did exist between time required for boil-up according to appliance type. The Student-Newman-Keuls procedure indicated that the conventional electric coil cooktop required significantly less time for boil-up than did all other appliances tested (Table 10). The induction, solid element with thermal limiter, and solid element with thermostatic control required significantly less time for boil-up than did the gas range. Martin (1988) found support for the hypothesis that "the greater the mass and specific heat of the heating system, the greater the time required for the rate of heat transfer to become appreciable" (p. 82). Therefore, the solid elements could be expected to take longer to heat and cool than the induction, conventional electric coil, or gas.

TABLE 10

Analysis of Variance
Time to Heat Three Quarts of Water from 70°F to 209°F
on Five Appliances[1], Three Replications

Appliance	Mean Minutes	F Ratio	Level of Significance
		16.6038	.001
Conventional electric range	7.70[a]		
Induction	10.51[b]		
Solid Element - thermal limiter	11.18[b]		
Solid Element - thermostatic	11.79[b]		
Gas	13.59[c]		

[1]Test was not conducted in the microwave oven because the extremely long time required to heat 3 quarts of water makes the operation impractical.

[a,b,c]Means with same superscript are significantly different from all other means, based on the Student-Newman-Keuls Procedure.

Recovery Rate

Three quarts of water (70 degree F.) were heated to 209 degree F. After water reached the desired temperature, 8 oz. of spaghetti noodles were added. Recovery was achieved when the water returned to 209 degree F. Time to recovery ranged from 0.21 minutes for the conventional electric coil to 0.82 minutes for the gas (Table 11). One-way analysis of variance was utilized to examine differences in recovery time according to appliances. Recovery time was significantly less ($p = > .01$) for the conventional electric coil than the solid element with thermal limiter, solid element with thermostatic control, and gas (see Table 11). The recovery time for the induction was also significantly less than the gas. This test was not conducted using the microwave oven because during pretesting it was decided that the extremely long time required to heat three quarts of water makes the operation impractical.

Retained Heat

Two quarts of water (70 degree F.) were heated to 209 degree F. "Cool-down" time from the beginning of the test (209 degree F.) to when the water temperature reached 190 degree F. was used to measure retained heat. One-way analysis of variance was utilized to determine if a significant difference existed in "cool-down" time according to type of appliance.

TABLE 11

Analysis of Variance
Time Required to Return 3 Quarts Water (209°F) to the Beginning Temperature (209°F) After Adding 8 Ounces Spaghetti Noodles Using 5 Appliances[1], 3 Replications

Appliance	Mean Minutes	F Ratio	Level of Significance
		7.1306	.01
Conventional electric coil	.21[a]		
Induction	.40[b]		
Solid element - thermal limiter	.59[c]		
Solid element - thermostatic	.55[c]		
Gas	.82[c]		

[1]Test was not conducted in the microwave oven because during pretesting it was decided that the process involved in this test makes the operation impractical.

[a,b,c]Means with same superscript are significantly different from all other means, based on the Student-Newman-Keuls Procedure.

Significant differences were found between appliances ($p = .0001$). The solid element with thermal limiter required significantly more time for the temperature to drop than did all other appliances (Table 12). The induction required significantly less "cool-down" time than did the conventional electric coil, solid element with thermal limiter, solid element with thermostatic control, and gas. The microwave oven also required significantly less time for temperature to drop than did the conventional electric-coil, solid element with thermal limiter, solid element with thermostatic control, and gas.

The design of the cooktop affects speed of heat-up and retained heat. Cooktops in which the heating element is separated from the pan by intervening space or material will require a longer time to gain or lose heat (Martin, 1988). Therefore, the solid element will take longer to heat up and, once heated, will take longer to lose heat than the conventional electric coil or gas flame.

Evenness of Heating

Crepes were used in this test to measure heat distribution as determined by evenness of browning. Crepes were prepared using a basic recipe, and cooked on each appliance in appropriate cookware including a browning tray in the microwave oven, three replications each. Each crepe was cut into quadrants (Figure 3) for color analysis.

TABLE 12

Time Required for 2 Quarts of Water (209°F) Heated in 2 Quart Saucepan to Drop to 190°F - Traditional and Innovative Cooking Appliances; 3 Replications

Appliance	Mean Minutes	F Ratio	Level of Significance
		16.5005	.0001
Conventional electric range	16.65[b]		
Induction	12.66[a]		
Solid element - thermal limiter	25.20[c]		
Solid element - thermostatic	20.66[c]		
Gas	17.80[b]		
Microwave	11.13[a]		

[a,b,c]Means with same superscript are significantly different from all other means, based on the Student-Newman-Keuls Procedure.

The computer pattern analysis system and the FORTRAN program was used to analyze differences in brownness in crepe quadrants for each appliance. The objective of the method was to get a number representing the brownness of any quadrant and a color number. The overall average for whole crepes was not considered except as a composite of the four quadrants. However, this method is not foolproof; certain patterns of brown-ing will not be detected, as noted below.

The color[1] appearing in the quadrant represented color numbers ranging from 0-255 with zero being dark and 255 being white. The lower numbers (0 - 47) which represented the color of the background were deleted, therefore the color numbers for the crepes were 48-255 (Figure 4). To insure uniform results for each test, The colors were calibrated with a gray scale (see Figure 5).

A weighted value for each quadrant was calculated by multiplying each color occurring in each quadrant by the number of times it occurred. Each quadrant average was determined by 621 colors. A mean was determined over the three replications (Table 13). The color score on any individual quadrant is determined by the weighted value described. The highest mean

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[1]Color as used throughout this work should be interpreted as "gray scale"; the video images and digitization process employed involves black and white images only.

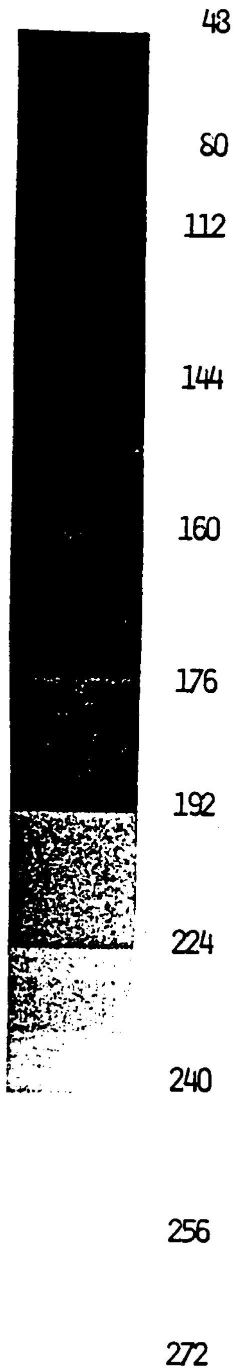

FIGURE 4: COLOR NUMBERS FOR ASSESSING CREPE BROWNNESS

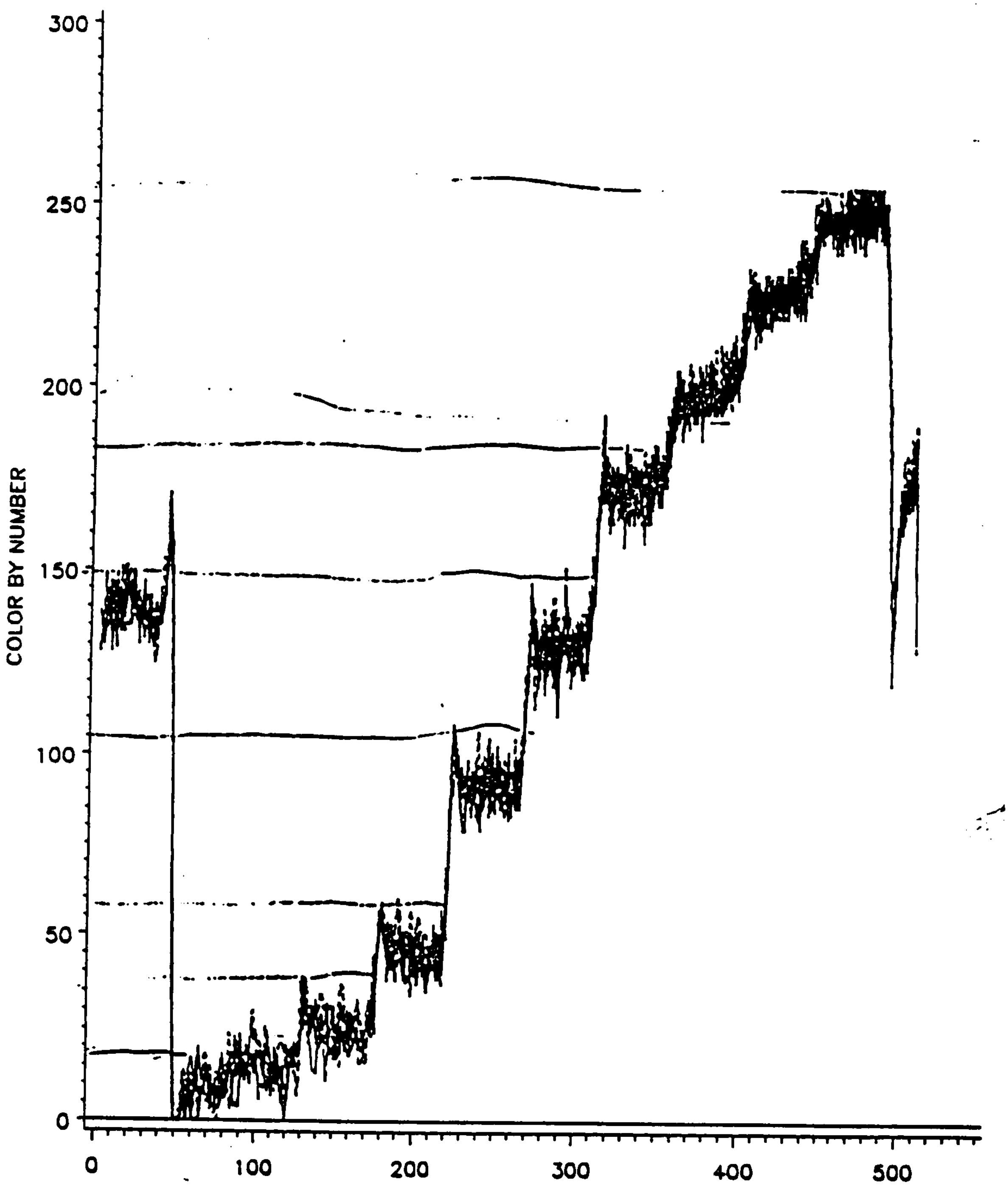

FIGURE 5: GREY SCALE CALIBRATION USED TO ADJUST COLOR NUMBERS RETURNED BY COMPUTER ANALYSIS

TABLE 13

Crepe Mean Color for
6 Appliances; 4 Quadrants, 3 Replications
(Higher Numbers Indicate Lighter Colors)

Appliance	Q_1	Q_2	Q_3	Q_4	$\overline{X}$
Conventional Electric	169.75	183.62	175.07	169.11	174.39
Induction	172.16	191.65	150.93	150.30	166.26
Solid Element (thermal limiter)	164.94	162.66	168.20	159.13	163.73
Solid Element (thermostatic control)	133.81	136.41	140.22	143.76	138.55
Gas	176.61	171.13	181.08	177.62	176.61
Microwave Oven	150.40	148.83	154.94	142.42	149.15

Note: Q_x = Quadrant 1; Q_2 = Quadrant 2, Q_3 = Quadrant 3; Q_4 = Quadrant 4 found for the six appliances was 191.65, indicating a light quadrant color, whereas the lowest mean was 133.81, indicating a darker color quadrant.

Heat distribution seemed to be similar for the conventional electric coil, solid element with thermal limiter, solid element with thermostatic control, and gas. However, differences between quadrant means indicates some unevenness in heating, or the occurrence of "hot spots". Crepes made on the solid element with thermostatic control and the gas burner had the smallest range in quadrant means, with both having a 10-point range in means. This indicates more even heat distribution than the solid element with thermal limiter, the conventional electric coil, the induction, and the microwave oven. The induction had the largest range in quadrant means (41) which indicates the most unevenness of heating of the appliances tested (for browning patterns of crepes by quadrants see Figures 6-11).

The method used in this study for determining evenness of browning was used to determine browning variations from quadrant to quadrant. Browning patterns that occur across crepes in concentric circles would appear identical for all quadrants and cannot be detected by this method.

<u>User Interaction-Cooking</u>

Along with the tests conducted to determine energy utilization and appliance operating time, the intensity of user interac-

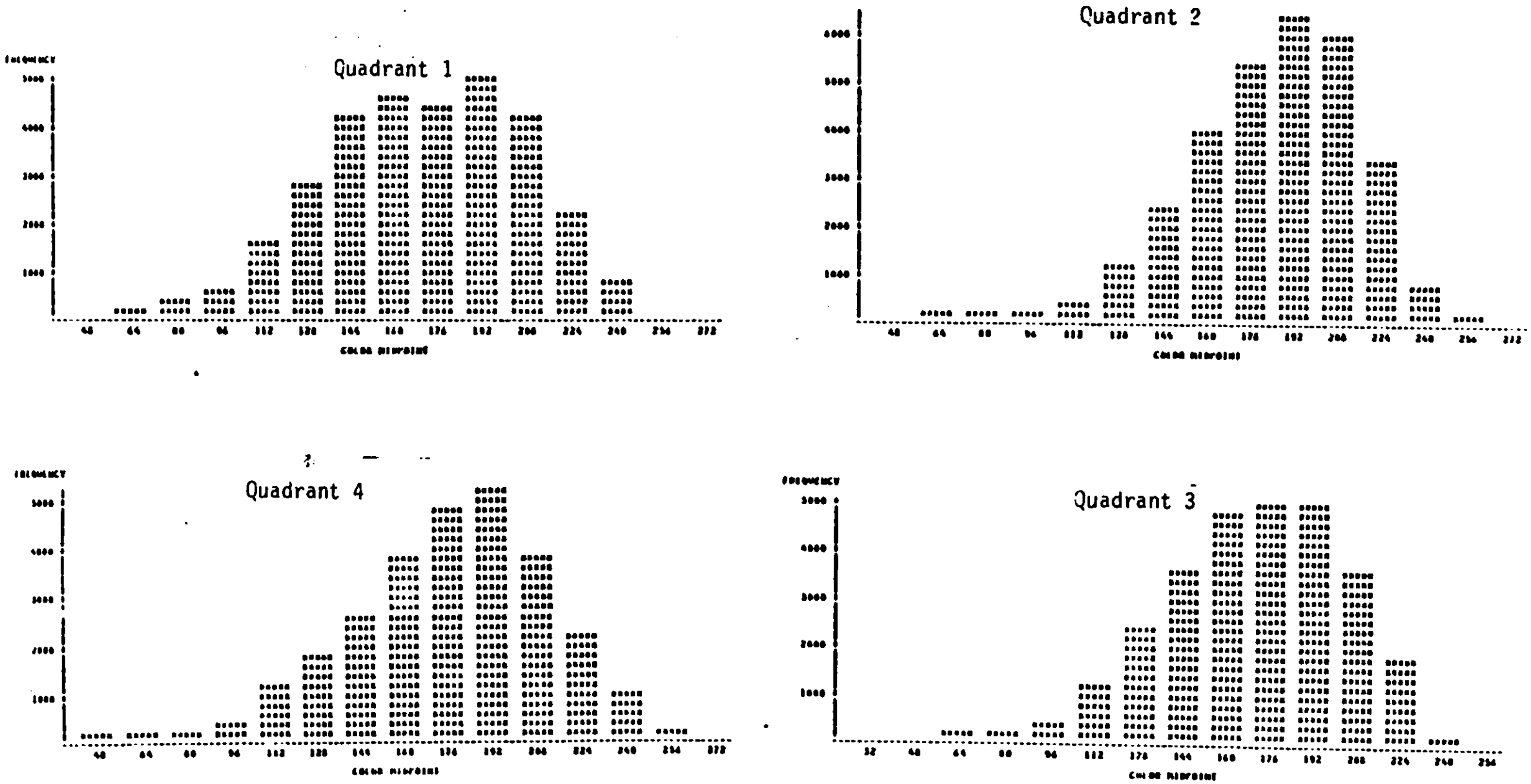

Figure 6: Frequencies of color scores of 3 replications of tests for evenness of beowning of crepes cooked on the conventional electric coil cooktop.

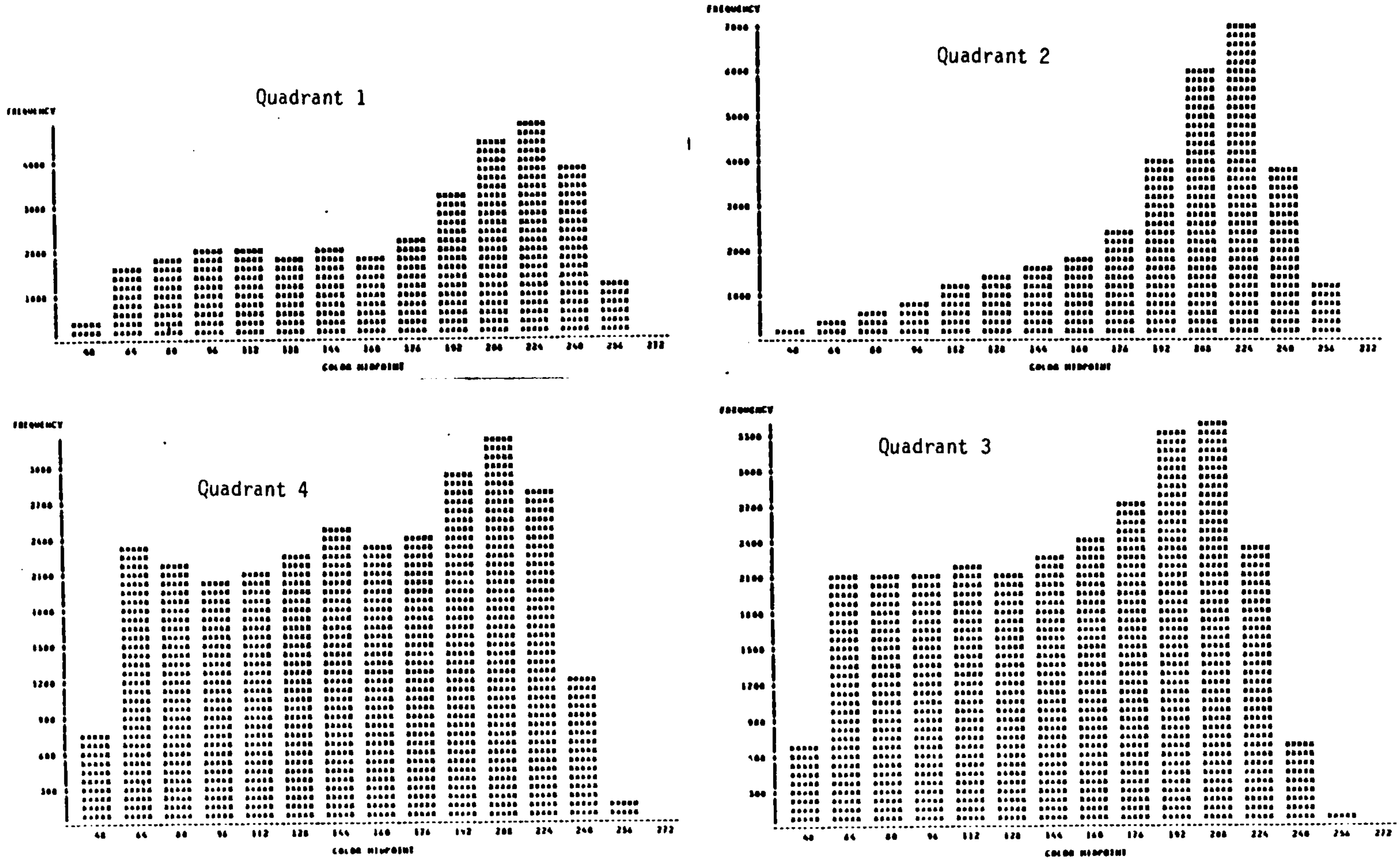

Figure 7: Frequencies of color scores of 3 replications of tests for evenness of browning of crepes cooked on the induction cooktop.

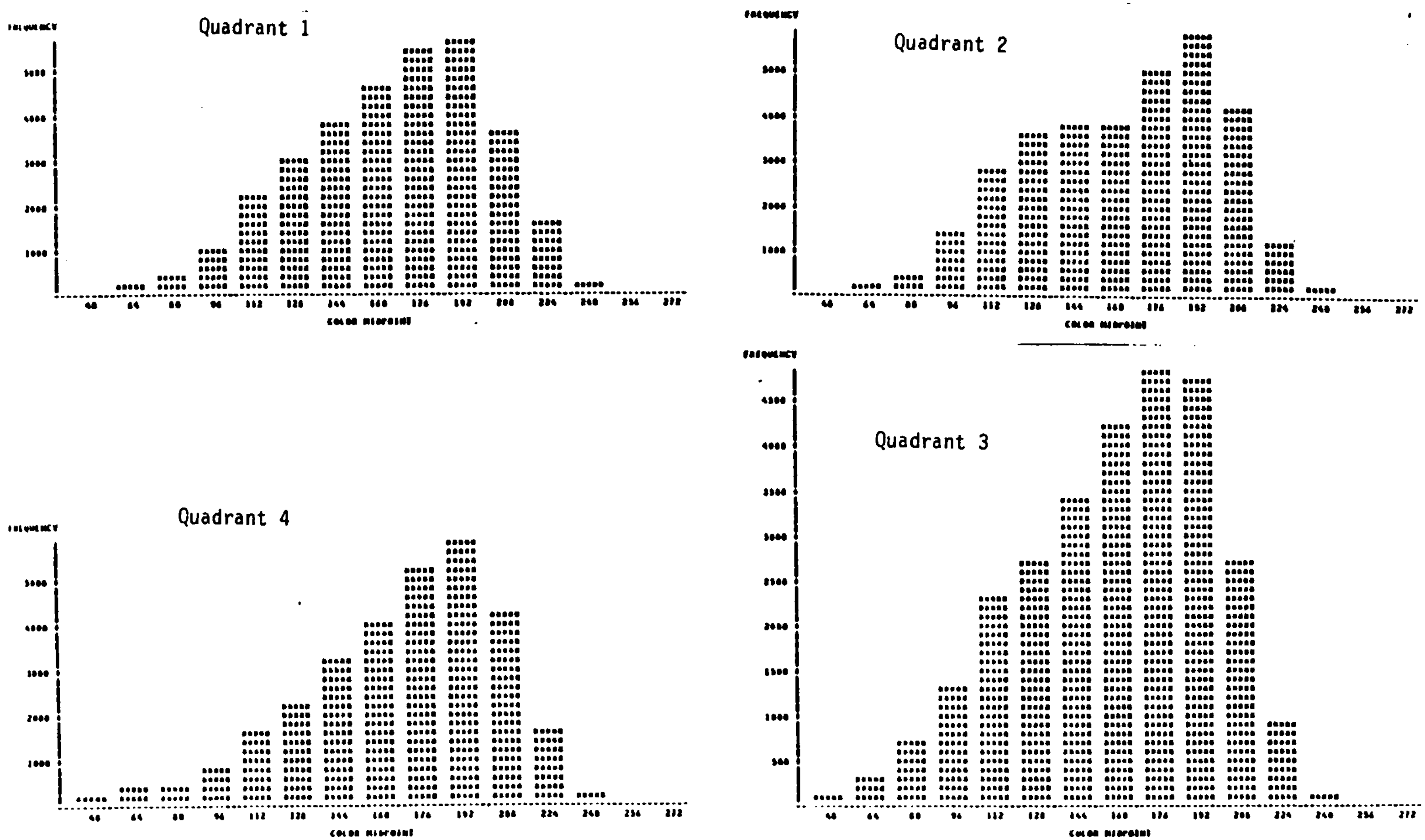

Figure 8: Frequencies of color scores of 3 replications of tests for evenness of browning of crepes cooked on the solid element with thermal limiter cooktop.

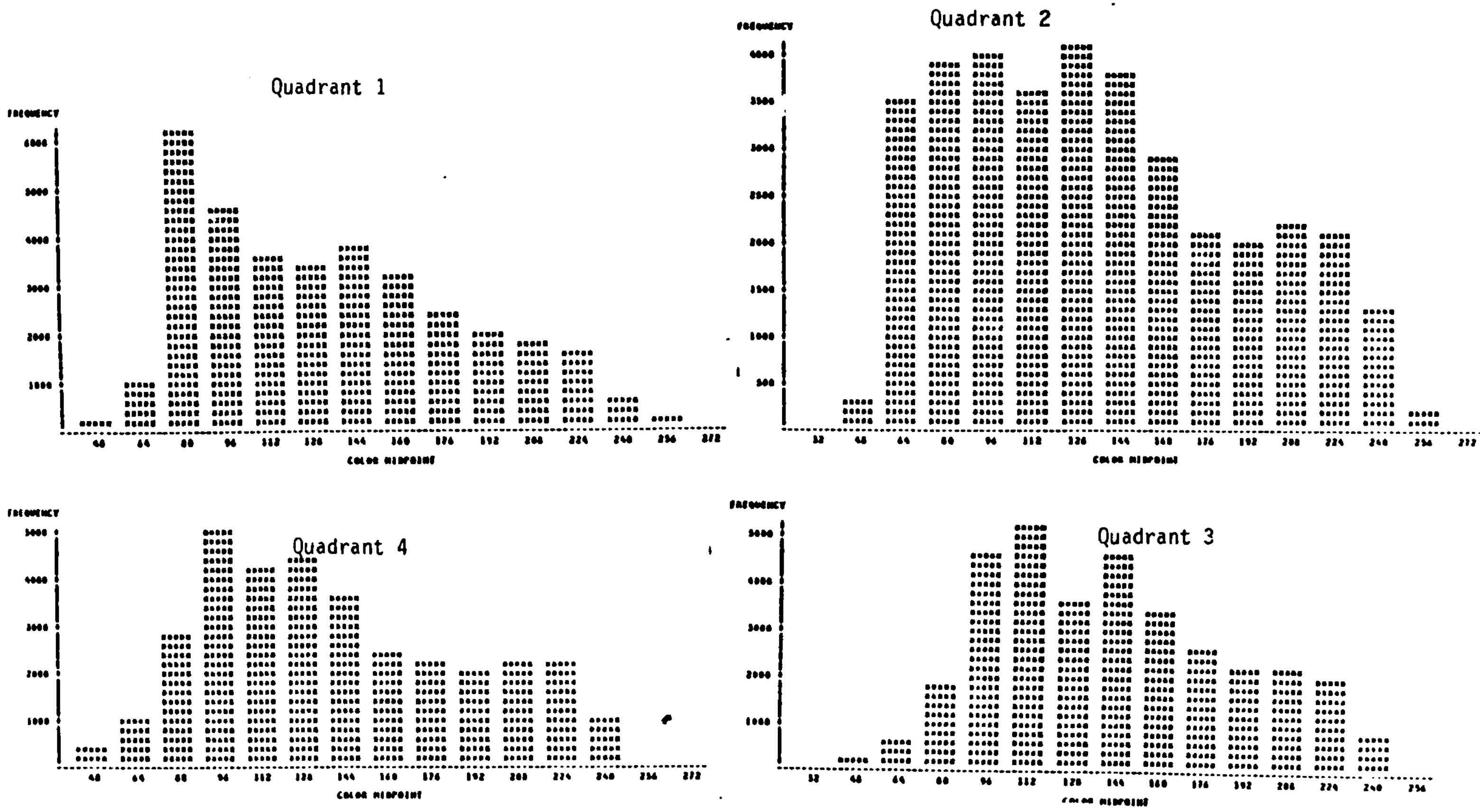

Figure 9: Frequencies of color scores of 3 replications of tests for evenness of browning of crepes cooked on the solid element with thermostatic control cooktop.

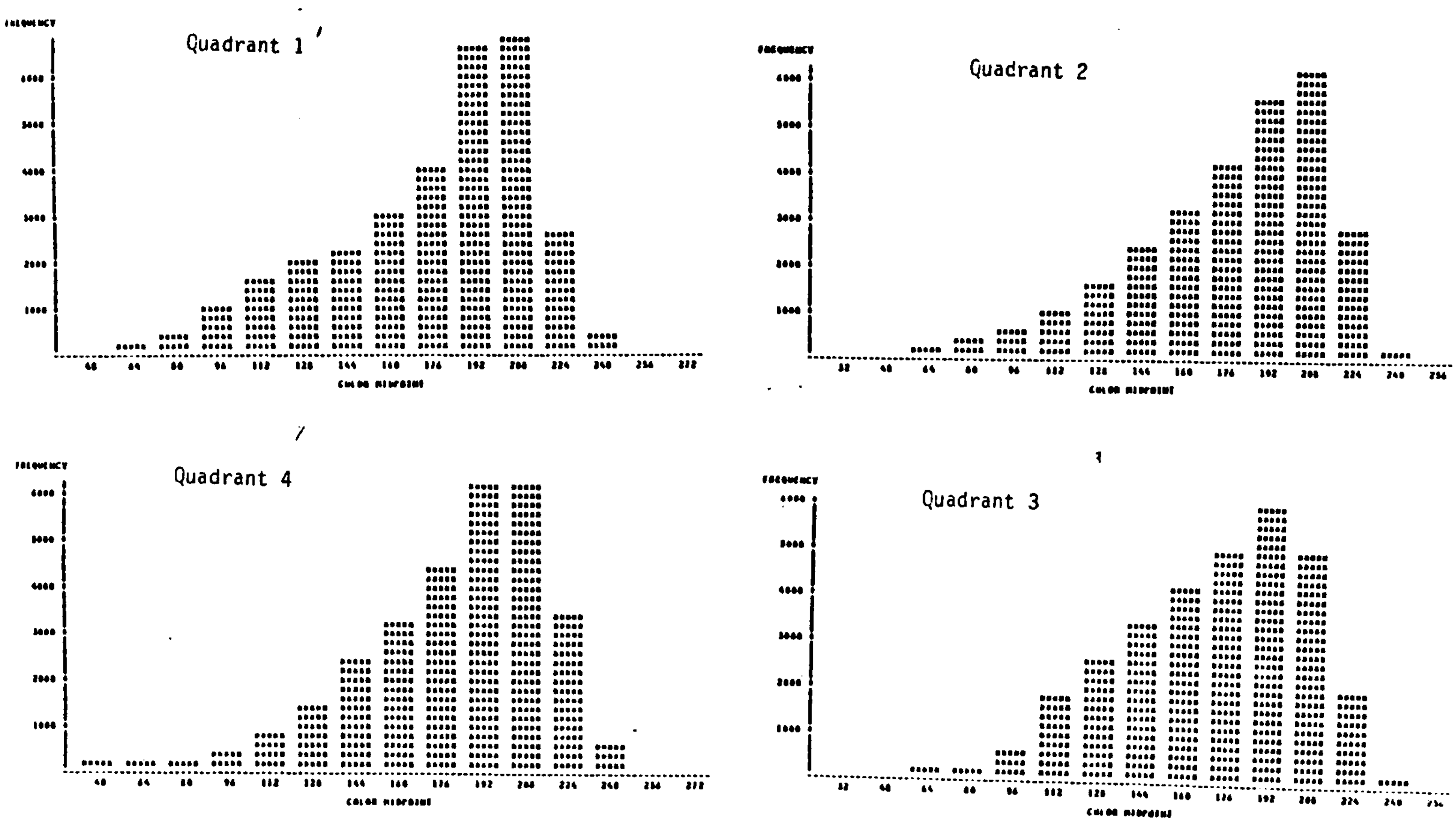

Figure 10: Frequencies of color scores of 3 replications of tests for evenness of browning of crepes cooked on the gas cooktop.

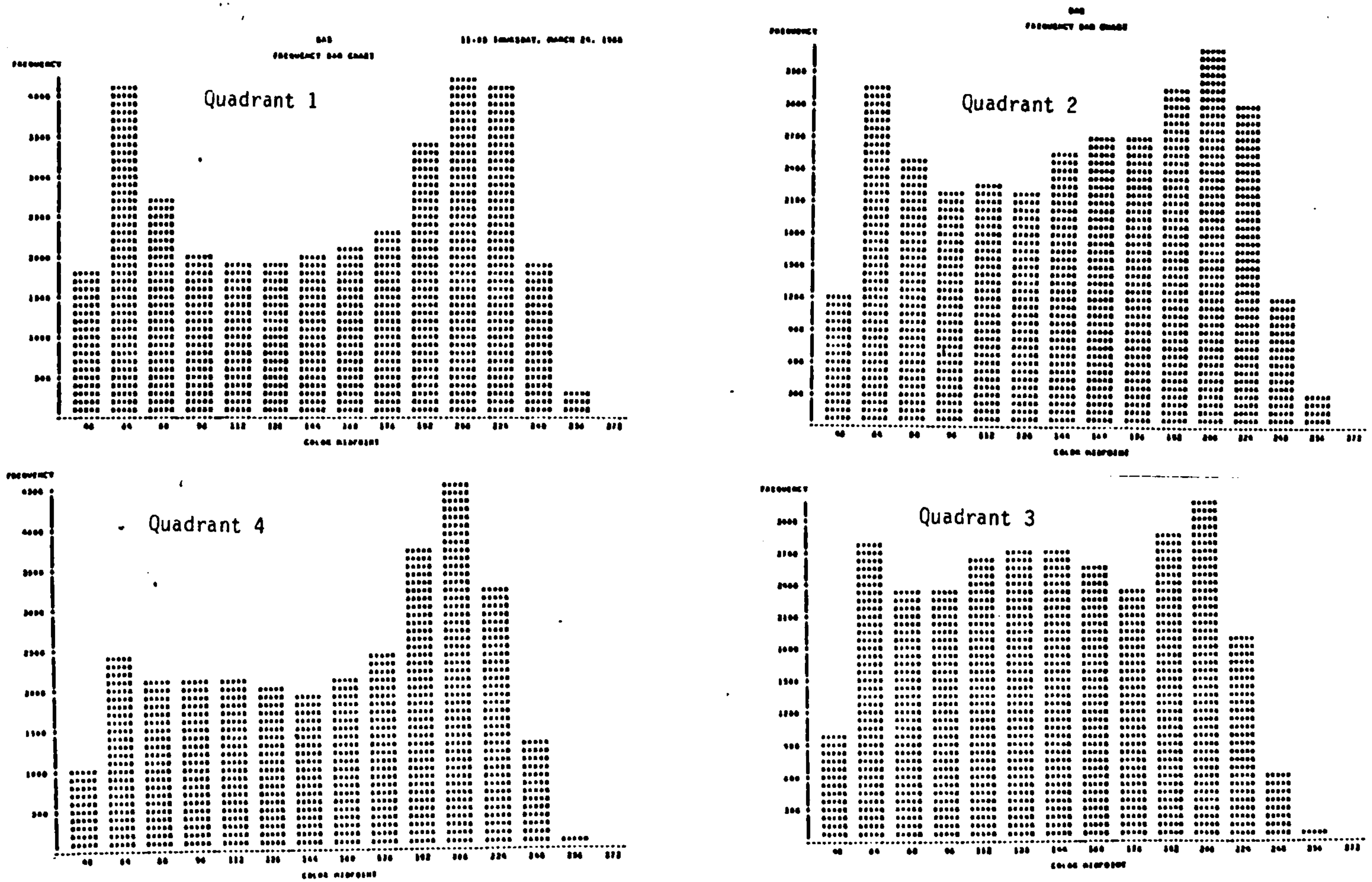

Figure 11: Frequencies of color scores of 3 replications of tests for evenness of browning of crepes cooked in the microwave oven.

tion with the cooktops and microwave oven was measured using a five-point scale. Points on the scale ranged from 1 = none - put food on, leave it alone until done to 5 = continual - constantly and intensively manipulating food or heat control. Although there was some variation for individual items, the mean for intensity of user interaction was significantly less ($p = > .01$) with the microwave oven than with the other appliances (See Tables 6 and 14).

User Interaction-Cleaning

A boilover test and a spatter test were conducted to measure user interaction in cleaning. (See Appendix C for test procedures.) At the end of the two tests, each appliance was cleaned using procedures recommended by the manufacturer. Time to clean varied from 3.44 minutes for the microwave to 8.80 minutes for the conventional electric coil cooktop.

One-way analysis of variance was utilized to analyze cleaning time according to type of appliance. Significant differences were found between cleaning time according to type of appliance ($p = .0001$) (Table 15). The conventional electric coil cooktop required significantly more cleaning time than any other appliance tested; the microwave oven, significantly less. The induction cooktop required significantly less time to clean than did the gas.

These data appear to indicate that cleaning time relates to the design and material of the appliance. The simpler the design

TABLE 14

Analysis of Variance
User Interaction With Traditional and Innovative[1]
Cooking Appliances for Surface Operations in the
AHAM Menu for Range Energy Testing: 3 Replications

Appliance	Mean	F Ratio	Level of Significance
		2.5150	.01
Conventional electeic coil	2.4222		
Induction	2.5000		
Solid element - thermal limiter	2.4667	3.5150	.01
Solid element - thermostatic	2.0222		
Gas	2.3810		
Microwave	1.8077[a]		

The SNK procedure indicated that the microwave was significantly different than four of the five other groups: conventional electric range, induction, solid element - thermal limiter, and gas.

[a]Significantly different from all other appliances

[1] 1 = none - put food on, leave along until done
2 = slight - put food on, turning or stirring at appropriate times
3 = moderate - put food on stirring occasionally and manipulating food at appropriate times.
4 = frequent - stirring occasionally, manipulating food and readjusting control settings
5 = continual - constantly stirring or manipulating food until done.

TABLE 15

A Comparison of Time Used to Clean Six Appliances (Spatter and Boil Over Test) Using Procedures Recommended by the Manufacturer; 3 Replications

Appliance	Mean	F Ratio	Level of Significance
		35.35	.0001
Conventional electric range	8.80[a]		
Induction	4.80[b]		
Solid element - thermal limiter	5.58[b]		
Solid element - thermostatic	5.71[b]		
Gas	6.10[b]		
Microwave	3.44[c]		

The SNK Procedure indicated that conventional electric range was significantly different than all other groups; that microwave was significantly different than all other groups; and that induction was significantly different than gas.

[a,b,c] Means with same superscript are significantly different from all other means, based on the Student-Newman-Keuls Procedure.

of the unit and its surroundings, the easier the appliance is to clean. Cleaning the gas took less time than the conventional electric coil because the burner grate can be removed and the area underneath can be wiped clean. However, to get to the drip bowls of the conventional electric cooktop, the elements have to be unplugged and then cleaned. Removeable parts enhance cleanability. Since the cavity walls of the microwave oven do not get hot during cooking, food particles do not burn, making cleaning easy.

The solid element design helps prevent spills from running under the heating elements. Each unit is sealed to the top with a silicone gasket which keeps spills on the top of the cooktop. However, boilovers are difficult to clean up because of the crevices. Even though the smooth, black, tempered glass surface is easily cleaned, finger prints show, making frequent cleaning necessary.

Part 2

Decision Making Matrix: Appliance Purchase

The following section includes the analysis of the cost of owning a cooking system and using it in food preparation. The relative cost of preparing a standard set of meals (e.g., the AHAM Menu) is determined through the use of the equation: Cost = F(P+L+M+E+T+S+R+H+T+Eh+Uco+Ucl). These 11 independent variables--purchase price (P), life expectancy (L), maintenance (M),energy (E), appliance operating time (T), speed of heat-up (S), recovery rate (R), retained heat (H), evenness of heating (Eh), user interaction in cooking (Uco), and user interaction in cleaning (Ucl)--and their assigned values were used to complete a decision making-matrix to be used to eveluate appliances. Appliances were ranked low, medium, or high for each of the independent variables on the basis of findings in this study (Table 16).

A 10 point scale was developed to represent the total cost of owning and using a cooking system in food preparation. The scale includes factors considered in the purchase and use of traditional and innovative cooking appliances and the weighted value assigned to each factor. Because no such matrix existed, weighting values were assigned by the researcher after careful consideration of each factor in the total equation. The following weighting values were assigned: purchase price = 3.0; life expectancy = 0.5; maintenance = 0.5; energy = 2.0; appliance operating time = 1.0; speed of heat-up = 0.4; recovery rate = 0.1; retained heat = 0.25; evenness of heating = 0.25; user interaction in cooking = 1.5, and user interaction in cleaning = 0.5.

The cost of owning and using the six appliances used in this study was evaluated using the 10 point scale (Table 17). Notice that numeric values assigned to ranking (high, medium, low) vary according to desirability of the characteristic. E.g., a low purchase price is most desirable and receives the maximum value (3),

TABLE 16

Rank Order of Appliances X Cost Factors
L = low M = medium H = high

	Purchase Price	Life Expectancy	Main-tenance	Energy	Time	User Interaction Cooking	User Interaction Cleaning	Heat-up	Recovery	Retain	Eveness of heat
Conv. Elec	L	L	L	M	M	H	H	L	L	M	L
Induction	H	L	H	M	M	M	M	M	L	L	L
Solid Elem. (Thermal Limiter)	M	L	L	M	M	M	M	L	M	H	M
Solid Elem. (Thermol)	M	L	L	M	M	M	M	M	L	M	H
Gas	M	L	L	M	M	H	H	L	H	M	H
Microwave Oven	M	L	M	M	L	M	L	H	L	L	M

TABLE 17

Matrix with Weighted Values for Each Appliance

Factor	Scale Value Score Maximum	Conv. Electric	Induction	Solid Element (thermal)	Solid Element (thermostatic)	Gas	Microwave Oven
Purchase price	3.0	3.0	1.0	2.0	2.0	2.0	2.0
Life expectancy	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Maintenance	0.5	0.5	0.17	0.5	0.5	0.5	0.33
Energy	2.0	0.67	1.33	0.67	0.67	2.0	0.67
Appliance operating time	1.0	0.67	0.67	0.67	0.67	0.67	1.0
Speed of heat-up	0.4	0.4	0.27	0.4	0.4	0.13	0.4
Heat recovery	0.1	0.1	0.07	0.07	0.07	0.03	0.1
Retained heat	0.25	0.17	0.08	0.25	0.25	0.17	0.25
Evenness of heating	0.25	0.08	0.08	0.17	0.25	0.25	0.17
User interaction-cooking	1.5	0.5	0.5	1.0	1.0	0.5	1.5
User interaction-cleaning	0.5	0.17	0.33	0.33	0.33	0.17	0.5
Total	10	6.76	5.00	6.56	6.64	6.92	7.42

Key:

Purchase Price
high = 1.0
med. = 2.0
low = 3.0

Maintenance
high = 0.17
med. = 0.33
low = 0.5

Appliance Operating Time
high = 0.33
med. = 0.67
low = 1.0

Heat Recovery
high = 0.03
med. = 0.07
low = 1.0

Evenness of Heating
low = 0.08
med. = 0.17
high = 0.25

Life Expectancy
low = 0.17
med = 0.33
high = 0.5

Energy Cost
high = 0.67
med = 1.33
low = 2.0

Speed of Heat Up
low = 0.4
med = 0.27
high = 0.13

Retained Heat
low = 0.08
med = 0.17
high = 0.25

User Interaction-Cooking
high = 0.5
med = 1.0
low = 1.5

Time to Clean
high = 0.17
med = 0.33
low = 0.5

while low retained heat is least desirable and receives the minimum value (0.08).

The microwave oven received the highest score, followed by the gas, conventional electric coil, solid element with thermostatic control, solid element with thermal limiter, and induction.

The evaluation score for the induction was lower than any of the other appliances. Although scores for life expectancy and time were similar for all cooktops, the maintenance score was lowest for the induction. While interaction of the user with the appliance in cooking and cleaning was low with the solid elements, it was lowest with the microwave oven. The solid element temperature control which automatically maintains a selected heat level, the temperature limiter of the solid element that reduces heat automatically if a pot boils dry, and the cookware allow the user to cook with minimal interaction. Speed of heat-up was slower for the gas but was similar for the conventional electric, solid elements, and microwave oven. However, heat recovery rate score was highest for the conventional electric and lowest for the gas. The score for evenness of heating was lowest for the conventional electric coil and the induction.

According to the scale, the microwave oven received the highest score. Even though the microwave oven rates high, there may be some food operations that cannot be performed to consumer satisfaction. Although some appliances rated high on certain factors, consideration must be given to personal value placed on that factor. In a society that places a premium on convenience and speed, the microwave oven may fill a particular need. On the other hand, one might choose to vary the weights in the matrix and arrive at a higher score for another appliance (place higher priority on the gradual heat-up of a solid element, for example).

Lifestyles and personal preferences also enter into appliance selection. For consumers who do not do much cooking, energy use may not be a significant factor. However, saving a few minutes of time in speed of heat-up (time to bring water to a boil) may be very important. Some consumers prize versatility, and to others, appearance is of top importance. Yet, for others, the initial purchase price may be the crucial factor in the selection and use of an appliance.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Due to advanced technology, the array of cooking appliances on the market has expanded. Increased knowledge is needed for selecting and operating these appliances.

The purpose of this study was to develop a framework for analysis and assessment of the costs of ownership and use of major cooking appliances. Five cooktops -- conventional electric coil, induction, solid element with thermal limiter, solid element with thermostatic control, and gas--and a microwave oven were used to quantify data to be used to complete a decision- making matrix. In addition, data were compiled from previous studies which included the same variables as this study.

To determine the cost of owning and using these appliances, independent variables measured for each appliance were purchase price, life expectancy, maintenance, energy, time, speed of heat-up, recovery rate, retained heat, evenness of heating, and user interaction in cooking and cleaning.

Cost of Appliance Ownership

The innovative appliances rated highest in purchase price. Design, convenience features, and materials are factors contributing to the purchase price of these appliances.

Based on information available, years of life expectancy did not differ according to type of appliance. Major cooking appliances are high priced, durable items purchased infrequently. Unless the product ceases to function, the owner may very well elect to repair it.

Cost of Appliance Use

In evaluating the appliances, it was found that operating times were similar. In general, time spent in food preparation is not affected by type of appliance utilized. Although the gas cooktop was a higher energy user than any of the electric appliances, the national average cost of gas is lower than that of electricity thus the cost of operating the gas cooktop was the lowest of the six appliances. The microwave oven was highest in energy use.

Speed of heat-up and recovery rate appear to relate to the quantity and characteristics of the thermal mass in the individual cooking system (i.e., the energy source and cookware combined). The greater the amount of thermal mass, the longer the time required to gain and lose heat.

Level of browning seemed to be similar for all appliances, however differences in browning among crepe quadrants indicated some unevenness in heating. The induction cooktop had the most unevenness of browning, as indicated by the largest range in means for the quadrants. Appliances having the most evenness of browning were the gas and the solid element with thermostatic control, both having the same range in means. Variations in browning may be a function of the cookware as well as the cooktop.

The conventional electric coil cooktop required significantly less time for boil-up than the gas. The shininess of the drip bowl makes a difference because gas burners rely partly on radiant heat, which can be enhanced by reflection, whereas electric elements cook mainly by surface contact with the pan. In addition, recovery time was also less for the conventional electric coil than for the gas and the other electric cooktops.

The intensity of user interaction in cooking and cleaning was significantly less with the microwave oven than with any of the other appliances tested. However, differences become apparent with variations in type of food items prepared and cookware used.

Time to clean varied from 3.44 minutes for the microwave oven to 8.80 minutes for the conventional electric coil. Cleaning time tends to relate to the design of the appliance. The microwave oven takes less time to clean because the cavity walls do not get hot during the cooking process and food particles do not burn, making cleaning easy.

Decision-Making Matrix

The cost of owning and using an appliance is a combination of monetary costs and the cost of user inputs. The decision-making matrix developed for this study provides a way to organize information and compare relative costs of appliances that can be used interchangeably for food preparation. The cost equation is: Cost = F(P+L+M+E+T+S+R+H+Eh+Uco+Ucl). The 11 independent variables-- purchase price (P), life expectancy (L), maintenance (M), energy (E), appliance operating time (T), speed of heat-up (S), recovery rate (R), retained heat (H), evenness of heating (Eh), user interaction in cooking (Uco), and user interaction in cleaning (Ucl) — were used to complete the matrix. Using data from a series of standardized tests, appliances were ranked low, medium, or high for each of the variables.

Using a 10-point scale to represent total cost, weighted values were assigned as follows: purchase price = 3.0; life expectancy = 0.5; maintenance = 0.5; energy = 2.0; appliance operating time = 1.0; speed of heat-up = 0.4; recovery rate = 0.1; retained heat = 0.25; evenness of heating = 0.25; used interaction in cooking = 1.5; and user interaction in cleaning = 0.5.

The microwave oven received the highest score (i.e., had the most desirable or least costly combination of characteristics), followed by the gas, conventional electric coil, solid element with thermostatic control, solid element with thermal limiter, and induction.

Conclusion

In general, food preparation with any of these appliances is not markedly different in terms of energy or cooking time but such factors as user interaction with the appliance, evenness of heating, and effect of thermal mass on temperature change do vary and are likely to influence immediate and long-term satisfaction with a cooking system.

It is assumed that consumers will make efficient choices from among available alternatives if given information relevant to a specific purchase. The decision-making matrix developed in this study can be used to analyze and assess the monetary costs and cost of user inputs in owning and using cooking systems. Information provided on purchase price, maintenance, life expectancy, energy, appliance operating time, speed of heat-up, recovery rate, retained heat, evenness of heating, and user interaction in cooking and cleaning makes it possible to distinguish among appliances. The matrix provides a way to compare appliances along a number of dimensions with data derived from a series of standardized tests.

Recommendations

For the six appliances used in this study, only one brand and one model of each were used. Further research is needed to determine if these findings hold true when using other brands and models.

This study was limited to cooktops and a microwave oven using cookware of a type recommended by the manufacturer of each appliance. Further research is needed to compare cost of other cooking systems (i.e., other appliance - cookware combinations or complementary combinations of appliances.

Research is needed to determine quality of the end product produced by each cooking system as it relates to consumer preference.

Based on the findings of this study, a survey of manufacturers, educators, and consumers should be conducted to validate weights given to factors used in the 10 Point Value Scale.

Factors considered important for owning and using major cooking appliances may be weighted differently by different users of the scale. Further research is needed to determine the influence of consumer demographics or preferences on weighted values of factors in decision making. Or, the matrix could be adapted for use with other major appliances.

The computer-based browning measurement scheme should be further investigated and developed. True color measurement systems could be utilized, and improved means could be developed to process and interpret the data.

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APPENDIX A

SUMMARY OF RELATED LITERATURE

Summary of Related Literature

Study	Author and Date	Objectives	Performance of Appliance	Variables	Statistics Used	Conclusion
Energy utilization of a smooth-top vs a conventional electric range in family meal preparation	Carucci, R. 1975	To compare energy consumption of a smooth-top range to a conventional electric range in preparation of meals for a family of four for one week	Energy consumption	Dependent: Energy consumption	Range, mean, standard deviations	There was no significant difference found in energy utilization efficiency of smooth-top and conventional electric range.
Energy consumption of a smooth-top and a conventional electric range in family meal preparation	Goss, R.C. and Lovingood, R.P. 1978				Mean differences and standard deviations	Smooth-top and conventional electric do not differ significantly in energy consumption when preparing identical meals under the same conditions.
Electric energy used by major cooking appliances	Lovingood, R. P. and Goss, C. 1980	1) To develop procedures with cooking times and heat settings to be used with the AHAM Standard Menu for Range Energy Testing and 2) to utilize energy consumption and time required to cook food in the AHAM Standard Menu in the comparing of electric ranges with conventional surface units, with thermostatically controlled units	Energy consump- and time	Dependent: Energy Independent: Major cooking appliance		Microwave oven in conjunction with the conventional range used less energy and time. The conventional and smooth-top were similar in energy consumption.

		under a glass ceramic top, with nonthemostatically controlled units under a glass-ceramic top, and with a counter top microwave oven in conjunction with each of the ranges.			
Current developments in <u>induction</u> cooktops	Triplett, R.D. 1980	To compare speeds of heat-up of an induction unit, microwave and conventional electric coil-top.	Speed of heat up	Dependent: Speed of heat up Independent: Cooking appliance	With the very small one cup load, the induction unit is only 15 seconds slower than a microwave oven, while a four-cup load is about 60% faster than microwave and 18% faster than the conventional electric coil-top.
Current developments in <u>convection</u> ovens	Clark, T.B. 1980	To compare energy consumption of 3 portable units of convection ovens and an electric oven	Energy consumption	Dependent: Energy consumption Independent: Major cooking appliance	The cost of energy for the most efficient portable convection oven was 1.7¢ and the least efficient was 2.9¢. The standard oven costs were 2.1¢.

Energy and time required to prepare selected foods with a <u>conventional electric</u> range and a countertop microwave oven	Laughan, G.W. 1980	To compare energy and time required to to prepare food items on surface units of a conventional electric range and a countertop microwave oven	Energy and time	Dependent energy and time Independent Food density, Moisture and fat content	Mean, and correlation coefficient	Food density and moisture content were inversely correlated to energy and time with both appliance.
Comparison of energy consumption, energy costs, and cooking times required to cook selected food items using four methods	Hill, S. and Anderson, J. 1983	To determine energy consumption, energy cost and cooking time of selected food items using four methods.	Time and energy		Multivariate analysis of variance Duncan's multiple-range test	A significant difference was found among the four methods when comparing the time required to cook a day's meal. Energy consumption differed significantly among the four methods of cooking.
A comparison of <u>induction gas</u> and <u>coil-top electric</u> for temperative maintenance and uniform heat distribution	Anderson, J.H. and Goodman, C. 1984	1) To compare the induction cooking with the gas and coil-top electric ranges for temprature maintenance as demonstrated by freedom from scorching and uniform heat distribution. 2) To compare magnetic surface cooking utensils for temperature maintance as demonstrated by freedom from scorching and uniform heat distribution as measured by an evenly browned product.	Temperature maintenance and uniform heat distribution		Multivariate analysis Multiple range test	No significance difference in temperature maintance and heat distribution.

Time and energy consumption in the preparation of food with a gas range and with a microwave oven used in conjunction with a gas range	Boschung, M.D. 1984	1) To develop procedures with cooking times and heat settings for the gas range to be used with the AHAM Standard Menu for Range Energy Testing. 2) To compare time and energy consumption required to cook food on the AHAM Menu using the gas range and then using a microwave oven used in conjunction with the gas range.	Time and energy	Dependent Time and energy consumption		There was little difference in the cost of using only the gas range or using the microwave oven with the gas range, however, using a microwave oven in conjunction with the gas range saved time.
Convectin vs radiant mode of a self-cleaning electric range oven: energy consumption, time, and food quality	Zumbrum, J. 1984	1) To compare energy consumption during baking and roasting specific food loads. 2) To compare amount of time used to bake and roast specific food loads. 3) To compare the quality of food loads which are baked and roaste; volume, extent of browning, and moisture content.	Time, energy, and food quality	Dependent Time used, energy used, and food quality	Mean, ranges, standard deviations, one way ANOVA and t-test	Time was saved when food items were prepared from a cold start rather than in a preheated oven regardless of the mode.

Energy and time utilization of an induction and a conventional electric cooktop in preparation of selected menu items	Zalenski, P.A. and Lovingood, R.P. 1985	To compare time and energy utilization of an induction and a conventional electric cooktop in preparation of selected menu items.	Energy and time utilization	Dependent Energy and time utilization Independent Cooktops	t-test and means	Mean total energy consumption to prepare all of the foods was 22.8% less with the induction cooktop than with the conventional cooktop.
Conventional and innovative cooktops: energy utilization, operating time, user interaction, and other characteristics of performance	Lovingood, R.P., Bentley, S.G., Lindstrom, A.B., and Walton, L.G. 1986	To compare an induction cooktop, a solid disk cooktop, and a conventional electric cooktop with respect to: appliance operating time, user interaction, energy utilization, and other characteristics of performance.	Time, energy, evenness of heat, speed of heat, and ease of cleaning	Dependent Traditional and innovative cooktops Independent User interaction, appliance operating time, energy utilization, and other characteristics of performance		Conventional and innovative cooktops did not differ in terms of energy or cooking time but such factors as food characteristics, evenness of heating, and effect of thermal mass on temperature change vary and are likely to influence immediate and long-term satisfaction with a cooking system.
Major Applaince Performance As Affected by Container Geometry and Material	Judy Barber 1986	To compare the relationship of the shape of the container to food quality. To compare the effects of container material on food quality.	Effects of container geometry and material on microwave cooking performance	Dependent Appliance performance Independent evenness of cooking; firmness; moisture content	ANOVA and Duncan's Mutiple Range Test	Performance of the microwave appliance as indicated by food quality was affected more by the shape of the container than by material. Major findings of this study suggests that the type of microwave cookware chosen can make a difference in the quality of food produced.

Study Related to Household Task Performance

Appliance ownership and household work time	Lovingood, R.P., and McCullough, J.L. 1986	To determine: 1) the relationship of selected variables to the stock of material resources, and 2) if ownership of appliances is related to differences in time spent in household work.	Dependent: Time spent in house hold tasks; Independent: Appliance	X^2 test of independence, t-test, mean, standard deviation, and analysis of covariance	Little evidence was found that appliance ownership is related to less time spent in household tasks.

APPENDIX B

COOKWARE AND GENERAL EQUIPMENT

Cookware and General Equipment

Solid element (thermal limiter and thermostatic control)

- 3 quart aluminum saucepan
- 6 inch aluminum pot (teflan)
- 10 quart aluminum pot (teflon)
- 2 quart aluminum aluminum skillet

Induction

- 3 quart stainless steel saucepan
- 6 inch stainless steel skillet
- 6 quart stainless steel pot
- 2 quart stainless steel saucepan
- 10 inch stainless steel skillet

Conventional electric

- 3 quart aluminum saucepan
- 6 inch aluminum skillet (teflon)
- 10 quart aluminum pot (teflon)
- 2 quart aluminum saucepan
- 10 inch aluminum skillet

Gas

- 3 quart aluminum saucepan
- 6 inch aluminum skillet (teflon)
- 10 quart aluminum pot (teflon)
- 2 quart aluminum saucepan
- 6 quart aluminum Dutch Oven
- 11 inch aluminum griddle

Microwave

- 3 quart casserole dish
- 10x10x2 inch browning dish
- 4 1-quart casserole dish
- micro browner
- 8 inch glass baking dish
- 33z33z5cm glass baking dish
- 5 quart casserole dish
- 2 quart casserole dish
- 1 quart casserole dish
- 3 quart casserole dish

General Equipment

- mixing spoons
- liquid measures
- dry measures
- measuring spoons
- thermometer
- stop watch
- spatula
- pancake turner
- scales
- vegetable peeler
- mixing bowl
- can opener
- tongs
- blender

APPENDIX C

GENERAL INFORMATION AND TEST PROCEDURES FOR ALL TESTS

General Procedures

Items from the AHAM Menu for Range Energy Testing were prepared using quantities and procedures developed by Lovingood and Goss (1980), manufacturer's recommendations, and procedures established during preliminary testing. All foods were cooked to a degree of doneness and were measured by objective tests using specific instruments (see Table 18).

In order to minimize uncontrollable or unforseen effects, the order of food items tested were randomly selected. The names of the 27 food items were written on separate slips of paper and placed in a bowl. Items were cooked in the order they were drawn. To facilitate purchase of supplies and use of instruments, all replications of each were completed before proceeding to the next set of tests.

All foods were purchased at the same major Supermarket in Blacksburg, Virginia, and stored in the appropriate section of an automatic defrosting refrigerator—freezer in order to minimize variations in foods at the beginning of tests. Specific preparation and cooking procedures are described in Appendix C.

A data sheet was completed on each food item as it was cooked on each appliance (see Appendix H). Information to be recorded on the data sheet included: the appliance used, the food item tested, the meal and day, the amount of energy used, the amount of time utilized, and the intensity of user interaction with the appliance.

TABLE 18

Test of Doneness

Food	Test	Instrument	Endpoint
oatmeal	viscosity	Brookfield or linespread	29.5 mm
vegetable soup	temperature	thermometer	180 F
green beans	temperature	thermometer	180 F
mashed potatoes	temperature	thermometer	170 F
bacon	tenderness	Warner Bratzler	1.83
scrambled eggs	firmness of curd	Penetrometer	.41
hot dogs	temperature	thermometer	120 F
beef stew	tenderness	Warner Bratzleer	13.5
vanilla pudding	viscosity	Brookfield	6 mm
chicken noodle soup	temperature	thermometer	180 F
spaghetti	sensory		
meat balls	tenderness	Warner Bratzler	2.6
pork chops	tenderness	Warner Bratzler	3.34
scalloped potatoes	tenderness	Warner Bratzler	1.8

Test of Doneness (Continued)

spinach	temperature	thermometer	180 F
apple sauce	temperature	thermometer	180 F
lemon pie filling	viscosity	Brookfield	11.75 mm
rice pilaf	temperature	thermometer	160 F
peas w/pearl onions	temperature	thermometer	160 F
tapioca pudding	viscosity	Brookfield	7.5 mm
broccoli	temperature	thermometer	160 F
sauteed mushrooms	temperature	thermometer	180 F
gelatin	temperature	thermometer	190 F
soft cooked eggs	temperature	thermometer	190 F
left over beef stew	temperature	thermometer	180 F

Ambient temperature, relative humidity, and autmospheric pressure were recorded daily before testing. The following variables which may affect cooking time and energy were controlled as recommended by Lovingood and Goss (1978) in their manual of procedures (pp. 4-5):

1. All water used in this study was tap water from Blacksburg system and was tempered to 70 degrees F. Blacksburg water is naturally about 3 grains hard and undergoes no treatment except purification and chlorination.
2. Whenever possible, tight fitting lids were used on pans to help bring water to a boil more rapidly.
3. Foods such as soups and pudding were heated to specific temperatures.
4. Applesauce was from No. 303 cans and frozen vegetables were from 10-ounce packages.
5. Frozen vegetables were removed from the freezer and placed on the counter beside the range as soon as water was on the unit.
6. The use care book for the induction cooktop or the recipe book for microwave oven contained the correct heat settings for many of the menu items. For the solid element, the conventional electric, and the conventional gas, the lowest settings which would maintain the desired rate of cooking were chosen.
7. At the beginning of each test, units were at room temperature.

Test: Ease of Cleaning

Conventional electric

Test 1

Shape 1 pound ground beef into 1/2 inch thick patties. Place skillet on unit. Preheat skillet on MED-HI for 2 minutes. Place patties in preheated skillet. Cook on MED-HI setting to desired doneness, turning once (8 minutes for rare and 10 minutes for well done). When patties are done, turn control to OFF. Remove skillet from unit. Let unit cool.

Test 2

Place 3 cup water (70 degree F.) and 1/2 tsp. salt in 2 qt. sauce pan; cover. Place on unit. Turn control to HI. Bring water to boil (209 deg.F.) about (4-5) minutes. When water boils,stir in 1-1/3 cup oats; cover. Let oats boil over. When oats begin to boil over, start timer and let boil over for 0.5 minutes. Turn control to OFF. Remove pan from unit. Let unit cool.

Test 3

After 2 hours; begin cleaning procedure. Start timer. Remove reflector bowls, wipe out excess spills, wash in warm soapy water. Use plastic scrubbing pads for heavy stains. Use a soft cloth and warm soapy water to clean exterior surfaces. When cooktop is cleaned, stop timer. Record time and subjective evaluation of effort to clean cooktop.

Induction

Test 1

Shape 1 pound ground beef into four 1/2 inch thick patties. Preheat skillet on MED-HI for 2 minutes. Place patties in preheated skillet. Turn control to MED-HI. Let patties brown; turn and brown on opposite side. When patties are cooked to desired doneness, turn control to OFF. Remove skillet from unit. Let unit cool.

Test 2

Place 3 cups water (70 degree F) and 1/2 tsp. salt in 2 quart sauce pan; cover. Place on unit. Turn control to HI. Bring water to boil (209 deg. F). After water boils (3-4 minutes), stir in 1- 1/3 cup oats, cover. Start timer and let boil over for 0.5 minutes. Turn control to OFF. Stop timer. Remove sauce pan. Let unit cool.

Test 3

After 2 hours begin cleaning procedure. Start timer; clean cooktop with a damp sponge or cloth using warm soapy water. If necessary, use a liquid cleanser. If a cleanser is used wipe with a damp cloth to remove any residual cleanser. When cooktop is cleaned, stop timer. Record time and subjective evaluation of effort to clean cooktop.

Solid Element with Thermal Limiter

Test 1

Shape 1 pound ground beef into four 1/2 inch thick patties. Place skillet on unit and preheat on MED-HI for 5 minutes. Place patties in preheated skillet. Cook on MED-HI setting. Brown patties; turn and brown on opposite side. When patties are cooked to desired doneness, turn control to OFF. Remove skillet. Let unit cool.

Test 2

Place 3 cups water (70 deg. F.) and 1/2 tsp. salt in 2 qt. saucepan; cover. Place on unit. Turn control to HI. Heat water to209 degrees F. After water reaches desired temperature (5 - 6 minutes), stir in 1- 1/3 cup oats; cover. Let boil until oats boil over. When oats boil over, start timer. Let boil over for 0.5 minutes. Turn control to OFF, stop timer and remove sauce pan. Let unit cool.

Test 3

After 2 hours, begin cleaning procedure; start timer. Wipe element with a damp cloth. Use mild abrasive powdered or liquid cleanser. Use soapy or scouring pads for heavy soil. Rinse throughly and heat element on a medium setting until completely dry. Use glass cleanser on glass to remove smudges and stains.

Buff with a clean dry cloth or paper towel. When cooktop is cleaned, stop timer. Record time and subjective evaluation of effort required to clean cooktop.

Solid Element with Thermostatic Control

Test 1

Shape 1 pound ground beef into four 1/2 inch thick patties. Place skillet on unit; preheat for 2 minutes on HI. Place patties iin preheated skillet. Cook on MED HI setting. Brown; turn and brown on opposite side. When patties are cooked to desired doneness, turn control to OFF. Remove skillet from unit. Let unit cool.

Test 2

Place 3 cups water (70 deg. F.) and 1/2 tsp. salt in 2 qt. saucepan. Place on unit; cover; turn control to HI. Heat water to 209 deg. F. (about 4-5 minutes). When water reaches desired temperature, stir in 1- 1/3 cup oats; cover. Let boil until oats boil over. When oats begin to boil over, start timer. Let boil over for 0.5 minutes. Turn control to OFF, stop timer and remove saucepan. Let unit cool.

Test 3

After2 hours, begin cleaning procedure. Start timer; clean cast iron unit using a powdered cleanser. Wash with a damp sponge or cloth, rinse throughly, and dry on medium heat setting.

Clean glass surface with glass cleanser. Buff with a clean dry cloth or paper towel. When cooktop is cleaned, record time and subjective evaluation of effort required to clean cooktop.

Gas

Test 1

Shape 1 pound ground beef into four 1/2 inch thick patties. Place skillet on burner. Preheat for 2 minutes on MED-HI. Place patties in preheated skillet. Cook on MED-HI setting to desired doneness, turning once (about 8 minutes for rare and 10 minutes for well done). When patties are done, turn control to OFF. Remove skillet.

Test 2

Place 3 cup water (70 deg. F.) and 1/2 tsp. salt in 2 qt. saucepan. Place on unit; cover; turn control to HI. Heat water to 209 deg. F. After water reaches desired temperature (5 - 6 minutes),stir in 1-1/3 cup oats; cover. When oats start to boil over, start timer. Let boil over for 0.5minutes. Stop timer, turn control to OFF, remove saucepan. Let unit cool.

Test 3

After 2 hours, begin cleaning procedure. Start timer. Wipe up spillovers and spatters using a dry cloth. Clean burner grates with warm soapy water. Use a soap filled scouring pad to remove dried or cooked on soil. Remove stubborn stains with baking soda paste and plastic scouring pad. After appliance is cleaned, stop timer. Record time and subjective evaluation of effort required to clean appliance.

Microwave oven

Test 1

Shape 1 pound ground beef into four 1/2 inch thick paties. Preheat browning dish in microwave oven on Cycle 1 for 3 minutes. Place patties on browning dish. Set control on Cycle 1 for 3 minutes; turn and cook an additional 2 minutes. Remove patties.

Test 2

Place 4 cups water (70 deg.F.) and 1/2 tsp. salt in 3 qt. glass casserol; cover. Place in microwave oven. Set control to Cycle 1 for 10 minutes. When water boils, stir in 1-1/3 cup oats, cover and cook until oats boil over. When boil over begins, start timer; let boil over for 0.5 minutes. Turn control to OFF. Remove dish. Let cool.

Test 3

After 2 hours, begin cleaning procedure. Start timer. Clean oven interior with a solution of mild dishwashing detergent and water;rinse and dry. To loosen soil that has dried on oven walls, place a cup of water in the oven and allow it to boil for several minutes, then wash with soapy water, rinse and dry. Clean the exterior of the oven with a mild detergent and water or liquid cleanser. When microwave oven is cleaned, stop timer. Record time and subjective evaluation of effort required to clean appliance.

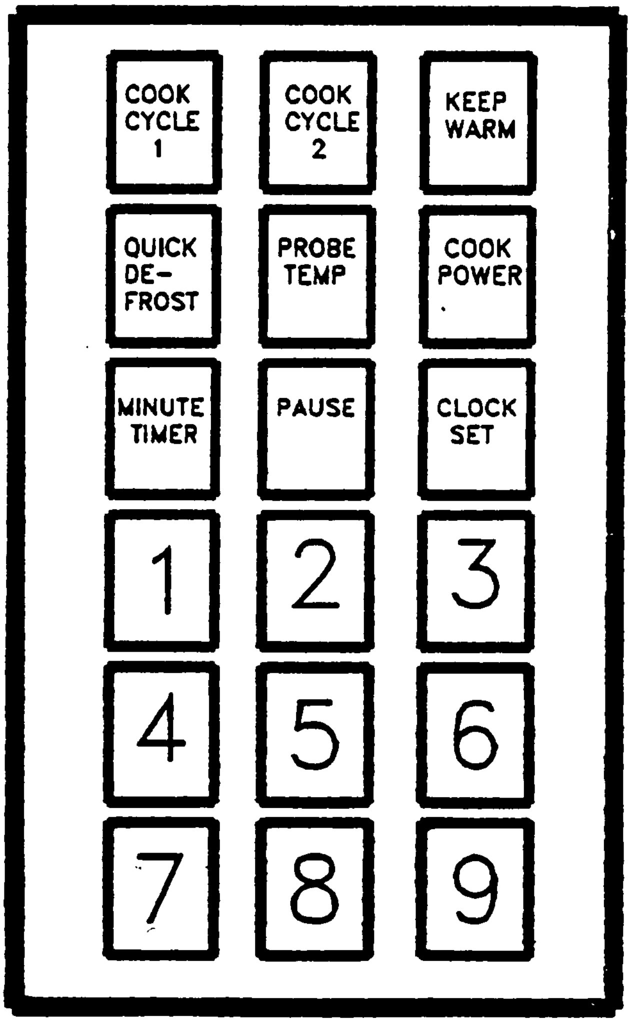
APPLIANCES AND PROCEDURES USED IN THE PREPARATION OF THE AHAM MENU FOR RANGE ENERGY TESTING

MICROWAVE OVEN

Description

Whirlpool Model MW8750XP; 1.3 cubic ft. interior; 700 watts of cooking power .

CONTROLS:



The microwave oven has 2 cooking cycles which provides up to 99 minutes and 99 seconds of cooking time in each cycle.

It also has 10 level variable power. Each number pad stands for a different percentage of cook power. Following is the percentage of cook power each number stands for, and the cook power name usually used.

Automatic 100% of full power HIGH

9 = 90% of full power
8 = 80% of full power
7 = 70% of full power MED-HI
6 = 60% of full power
5 = 50% of full power
4 = 40% of full power
3 = 30% of full power MED-LOW
2 = 20% of full power
1 = 10% of full power
0 = no power

Gas Range

DESCRIPTION:
Hardwick Model CPD99843A659A; 10,000 BTU

CONTROLS:

OFF II WARM I MED. II HIGH START

WARM

LOW

MED. LOW

MED.

MED. 2

HIGH

Procedures

AHAM Menu for Range Energy Testing

Microwave Oven

Oatmeal

Record meter reading. Measure 3/4 cup water, 1/4 tsp. saltand1/3 cup minute oats into each of 4 individual servingbowls. Mix well. Place in mwo. Set controls to Cook power 8 for 10 minutes. Start microwave oven. When mwo stops, record time and meter reading. Stir oatmeal after cooking. Let stand a few minutes before serving.

Vegetable soup

Record meter reading. Place contents of one 10 oz. can vegetable soup in 1-1/2 qt. glass casserole. Add 1 soup can water (70 deg. F.); cover. Place in mwo. Set control to Cycle 1 for 5 minutes. Start mwo; start timer. When mwo stops, record time and meter reading.

Mashed potatoes

Record meter reading.Combine1/2 cup milk,1-1/3 cup water (70 deg. F.), 2tbsp. butter, and 1/2 tsp. salt in 1-1/2 qt. casserole. Set control to Cycle 1 for 5.5 minutes. Start mwo; start timer. Remove mixture from mwo and stir in 1-1/3 cup potato flakes using a fork. Whip 1 minute. Stop timer. Record total time and meter reading.

Gelatin

Record meterreading. Place 1 cup water (70 deg.F.) in 2 qt. casserole cover.Place in mwo.Turn control to HI;start timer. When water reaches 209 deg. F., turn control to OFF. Record time and meter reading.

Green beans

Record meter reading. Drain 1- 10 oz. can green beans, reserving 2 tbsp. liquid. Place beans and liquid in 1 qt. casserole; cover. Set control to Cycle 1 for 3 minutes. Start mwo; start timer. When mwo stops, stop timer. Record time and meter reading. Let beans stand covered an additional 3 minutes before serving.

Bacon

Record meter reading. Place 8 slices of bacon between paper towels in a glass baking dish (use 2 towels beneath and 2 on top of bacon). Set mwo control to Cycle 1 for 6-7 minutes. Start mwo; start timer. When mwo stops, stop timer.

Scrambled eggs

Record meter reading. Break 6 eggs into 1 qt. casserole. Add 6 tbsp. milk, and salt and pepper to taste; beat with a fork. Add 2 tbsp. butter. Cover casserole and place in mwo. Set control to Cook Power 5 for 6 minutes. Start mwo;starttimer. Stir eggs gently with a fork. Record time and meter reading.

Hot dogs

Record meter reading. Place weiners in glass baking dish. Place in mwo. Set control to Cycle 1 for 30 seconds. Start mwo; start timer. When mwo stops, stop timer. Record time and meter reading.

Beef stew

Record meter reading;start timer. Place browning dish inmwo. Set control to HI for 5 minutes. Start mwo; start timer. When tray is preheated, brown 2 pounds stewing beef on browning tray for 5 minutes, or until brown, turning occassionally. Remove tray from mwo when meat is brown. In a 5 qt. casserole, combine beef, 2/3 cup diced onions, 1 tsp. Worestershire sauce, 1/4 tsp. garlic powder, 2 bay leaves, 1 tsp. salt, 1 tsp. sugar, 1/2 tsp. paprika, and 1-1/2 cups water, 1 pound carrots, cut in 1-inch cubes, and 1.9 pounds potatoes, quartered; cover. Cook on cycle 1 for 10 minutes. Reduce to Cook Power 7 for 50-55 minutes, or until beef is tender. Stir occasionally. Remove cover; stir; add one 10 oz. pkg. peas with remaining 1/2 cup water. Cook on HI,10 minutes, stirring occasionally. When mwo stops, stop timer. Record time and meter reading.

Vanilla pudding

Record meter reading. Prepare pudding and pie filling mix (Kroger brand, 3-1/2 oz. box) in a 4 cup liquid measure, according to direction on box. Turn control to Cycle 1 for 7 minutes. Start mwo; start timer. When mwo stops, stop timer. Record time and meter reading.

Chicken noodle soup

Record meter reading. Pour contents of one 10 oz. (approx.) can chicken noodle soup into 1-1/2 qt.casserole. Add one soup can of water. Cover and place in mwo. Set control to Cycle 1 for 5 minutes. Start mwo; start timer. When mwo stops, record time and meter reading. Let stand 3 minutes before serving.

Spaghetti

Record meter reading. Prepare meatballs using 1 pound ground beef, 2 slices bread, 1 egg, 2 tbsp. diced onion and 1 tsp.salt. Shape into 1-inch balls and place in single layer in large dish. Set controls to Cycle 1 for 7 minutes. Start mwo; start timer. When mwo stops, stop timer and drain excess drippings. Add 1-1/3 Oz. pkg. spaghetti sauce mix with mushrooms, 1 cup tomato sauce, 1-3/4 oz. can tomato soup, and 2 cups water. Place in 3 qt. casserole; cover. Set control to Cycle 1 and cook for 10 minutes, stirring occasionally. When mwo stops, stop timer. Record time and meter reading.

Spaghetti 2

Record meter reading. Place 4 cup water in 3 qt. casserole. Add 1/2 tsp. salt and 1 tbsp. oil to water; cover. Set control on Cycle 1 for 5 minutes. Add 8 oz. spaghetti noodles. Microwave on

Cook Power 8 for 10 minutes. When mwo stops, stop timer. Record time and meter reading.

Letf over beef stew

Record meter reading. Remove 3 cup leftover beef stew from refrigerator and place in 1-1/2 qt. casserole. Add 1/2 cup water; cover. Place in mwo. Set control to Cook Power 8 for 14 minutes. Start mwo; start timer. Heat stew until it reaches 200 deg. F. Reset mwo, if necessary, for additional time. When stew reaches 200 deg. F., stop mwo and timer. Record time and meter reading.

Braised pork chops

Record meter reading. Coat 1.9 pounds pork chops with a mixture of 4 tbsp. flour, 1/2 tsp. salt, and 1/4 tsp. pepper. Place in 8-3/4 x 13-1/2 inch baking dish. Cover with plastic wrap. Place in mwo. Set control to Cook Power 7 for 20 minutes. Start mwo; start timer. After 10 minutes, turn chops and continue cooking for another 10 minutes or until chops are tender and throughly done. When mwo stops, stop timer. Record time and meter reading.

Potato Au Gratin

Record meter reading. Place 2-1/4 cups diced potatoes in 1-1/2 qt. casserole dish and 1/2 tsp. salt and 1/2 cup water; cover. Place in mwo. Set control to Cycle 1 for 12 minutes.

Start mwo; start timer. At end of cooking period, stop timer and drain potatoes.

Potatoes 2

Place 2 tbsp. butter in 4 cup liquid measure and place in mwo. Set control to Cycle 1 for 30 seconds. When butter melts, stop mwo and timer. Add 1/4 tsp. salt, 1/8 tsp. pepper, and 2 tbsp. flour. Restart mwo and timer. Set control to Cycle 1 and cook 30 seconds or until bubbly. Add 1 cup milk; cook sauce 2 minutes or until thickened, stirring occasionally. Stop mwo and timer. Record time and meter reading. Add 1/2 cup diced cheese, stirring until melted. Pour cheese over drained potatoes.

Potatoes 3

Record meter reading. Place potatoes and cheese sauce in mwo. Set control to Cook Power 8 for 2 minutes. Start mwo; start timer. When mwo stops,stop timer. Record total time and meter reading.

Spinach

Record meter reading. Place one 10 oz. pkg frozen spinach in 2 qt. casserole; cover. Place casserole in mwo. Set control to Cycle 1 for 8 minutes. Start mwo; start timer; start meter. Stir spinach half way through cooking period; record time, record meter reading.

Applesauce

Record meter reading. Place 1 can (15 oz.) applesauce and 1/2 tsp. cinnamon in 1 qt. casserole; cover. Place in mwo. Set control to Cycle 1 for 3 minutes. Start mwo; start timer. When mwo stops, stop timer. Record time and meter reading.

Lemon pie filling

Record meter reading. Prepare lemon pudding and pie filling mix in a 2 qt. casserole dish according to directions on box (Kroger, 3 oz.). Place in mwo; start timer. When mwo stops, stop timer. Record time and meter reading.

Rice pliaf

Record meterreading. Placel/2 cup margarine,1/4 cup green diced, and 1 medium onion, thinly sliced, in 3 qt. casserole dish; cover. Turn control to Cook Power 8 for 5 minutes. Start mwo; start timer. When mwo stops,stop timer. Add 1 cup rice, 2 cups water, 4 oz. mushroom pieces, and 2 chicken bouillon cubes; cover; place in mwo. Turn control to Cycle 1 for 5 minutes then to Cook Power 3 for 12 minutes. Start mwo; start timer. At end of cooking period, stop timer. Record total time and meter reading.

Peas with pearl onions

Record meter reading. Drain one 10 oz. can peas, reserving 1 tbsp. liquid. Place peas and liquid in 2 qt. casserole; cover;

place in mwo. Turn control to Cycle 1 for 3 minutes. Start mwo; start timer. When mwo stops,stop timer. Record time and meter reading.

Tapioca pudding

Record meter reading. Prepare tapioca pudding and pie filling mix (Kroger, 3 oz.) in 4 cup liquid measure according to directions on box. Place in mwo. Set control to Cycle 1 for 8 minutes. Start mwo; start timer. When mwo stops, record time and meter reading.

Broccoli

Record meter reading. Place broccoli in 2 qt. casserole. Add 1/4 tsp. salt and 2 tbsp. water; cover. Turn control to HI for 8 minutes. Start mwo; start timer. Turn casserole and separate broccoli stalks halfway through cooking period. When mwo stops, stop timer. Record time and meter reading.

Procedures Written for Use in the User

Interaction - Cooking Test

Conventional Gas

At end of each test, record user interaction according to the intensity of user interaction scale of 1 = put food on, leave alone until done; 2 = put food on turning or stirring at appropriate times; 3 = put food on stirring ocassionally, manipulating food at appropriate times; 4 = stirring occassionally, manipulating food, and readjusting control settings; 5 = constantly stirring intensively or manipulating food until done.

<u>Oatmeal</u>

Place 3 cups water in 2 qt. aluminum saucepan. Add 3/4 tsp. salt; cover. Place on burner. Turn control to HI. When water boils (209 deg. F.), add 1-1/2 cup Minute oats. Turn control to OFF. Continue stirring for 1 minute. Cover and remove pan from burner.

<u>Pot roast</u>

Place 2 tbsp. cooking oil in a Dutch oven; place on burner. Turn control to HI; preheat for 1.5 minutes. Add 4 pound pot roast. After 3 minutes, turn control to MED-HI. Brown 5 minutes. Turn control to OFF, remove from heat.

Grilled cheese sandwiches

Prepare each of 6 cheese sandwiches with 2 slices of cheese. Spread 1 tsp. margarine on outside of each slice bread. Place 3 sandwiches on aluminum griddle; place on burner. Turn control to HI; start timer. After 4 minutes, turn to MED-2 (turn sandwiches as needed). Brown remaining 4 sandwiches. Turn control to OFF.

Vegetable soup

Place contents of one 10 oz. can vegetable soup in 2 qt. saucepan. Add 1 can water; stir; cover; place on burner. Turn control to HI. Heat soup to 180 deg. F. Turn control to OFF.

Mashed potatoes

Combine 1-1/3 cup water, 2 tbsp. margarine, 1/2 tsp. salt and 1/2 cup milk in 2 qt. saucepan; cover. Place on burner. Turn control to HI. Heat mixture to 209 degree F. Stir in 1-1/3 cup potato flakes with a fork until desired consistency is reached. Turn control to OFF.

Green beans

Drain beans, reserving 1/2 cup liquid. Place beans and reserved liquid in 2 qt. saucepan; cover. Place on burner. Turn control to HI. Heat beans to 209 degree F. Turn control to Off. Remove saucepan.

Scrambled eggs and bacon

Combine 6 eggs, 6 tbsp. water, and salt and pepper to taste. Beat well and set aside. Cut 8 strips of bacon in half. Place4 strips of bacon on an aluminum griddle. Place griddleon burner. Turn control to HI. When bacon fries vigorously, turn control to MED 2. Add more bacon until 8 strips are cooked. Remove bacon from skillet, drain grease. Turn control to MED. Pour eggs onto griddle; cook eggs until soft-set, stirring as needed. When eggs are done, turn control to OFF; remove griddle.

Hot dogs

Place 3 weiners in 2 qt. aluminum saucepan. Add 3/4 cup water; cover and place on burner. Turn control to HI and heat to 209 degree F. Turn control to OFF. Remove saucepan.

Beef stew 1.

Place aluminum Dutch oven on burner. Add 2 tbsp. cooking oil. Turn control to HI. Preheat 2 minutes. Add 2 pounds stewing beef cubes. Brown for 7 minutes. When brown, add 2/3 cup diced onions, 1 tsp. Worcestershire sauce, 1/4 tsp. garlic powder, 2 bay leaves, 1 tsp. sugar, 1/2 tsp. pepper, 1/2 tsp. paprika, and 2 cups water; cover. Heat to 209 deg. F. Reduce heat to simmer; cook 1-1/2 hours. Remove bay leaves.

Beef stew 2

Add 1 pound carrots, cut in 1 inch cubes, and 1.9 pounds potatoes, quarted to stew; cover. Increase heat to HI and let come to a boil. When stew boils, reduce heat to LO for 20 minutes. Remove cover; stir; add 1 pkg. 10 oz. frozen peas; replace cover. Turn control to HI and bring to a boil. Reduce to LO and cook for 10 minutes.

Vanilla pudding

Prepare vanilla pudding and pie filling mix (Kroger brand, 3-1/2 oz. box) in 2 qt.saucepan according to directions on box. Place on burner. Turn control to MED 2. Bring pudding to a boil, stirring constantly. Cook until thick. Turn control to OFF. Remove saucepan.

Chicken noodle soup

Place contents of one 10 oz. can chicken noodle soup in 2 qt. saucepan. Add one soup can water. Stir; cover. Place on burner. Set control to HI. Heat to a boil (209 deg. F.). Turn control to OFF. Remove saucepan.

Hard cooked eggs

Place 3 eggs and 2-3/4 cup water in 2 qt. saucepan; cover; place on burner. Turn control to HI. When water boils (209 deg. F.), turn control to OFF. Remove from burner. Let eggs remain in water 20 minutes.

Spaghetti 1

Prepare meatballs using 1 lb. ground beef, 2 slices bread, one egg, 2 tbsp. diced onion, and 1 tsp. salt. Shape into 1-inch balls. Place alumnium Dutch oven on burner. Add 1 tbsp. cooking oil. Turn control to HI. Preheat for 2 minutes. Add meatballs and brown. After 3 minutes, reduce heat to MED 2, drain excess fat. Add 2 cups water, 1 cup tomato sauce, 1 can tomato soup (10-3/4 oz.), and 1-3/8 oz. pkg. spaghetti sauce mix with mushrooms. Stir to combine; cover. When mixture boils, reduce heat to LO. Cook for 20 minutes. Turn control to OFF. Remove from burner.

Spaghetti 2

Place 3 qt. water in 5 qt. aluminum Dutch oven. Add 1 tsp. salt and 1 tbsp. oil; cover. Place on burner. Turn control to HI. Heat water to 209 deg. F. After water reaches desired temperature, add 8 oz. spaghetti noodles. Reduce heat to MED HI and cook 10 minutes (pan not covered). Turn control to OFF and remove saucepan.

Soft cooked eggs

Place 6 eggs and 3 cup water in 2 qt. saucepan; cover; place on burner. Turn control to HI. When water boils, turn control to OFF. Allow eggs to remain covered in pan for 3 - 4 minutes.

Leftover beef stew

Remove 3 cup leftover beef stew from refrigerator and place in 2 qt. aluminum saucepan. Add 1/2 cup water; cover. Place on burner. Turn control to MED-HI. Heat stew to 200 deg. F. Reduce heat to MED-LO and cook for 10 minutes. Turn control to OFF. Remove saucepan.

Braised pork chop

Place 1.9 lb. pork chops in skillet. Place on burner. Turner control to MED-HI. After 6 minutes, turn control to MED. After pork chops brown (9-10 minutes), add 1/2 tsp. salt, 1/4 tsp. pepper, and 1/4 cup water; cover; let come to boil. Reduce heat to LO, simmer for 30 minutes. Turn control to OFF. Remove skillet.

Skillet scalloped potatoes

PLace 2-1/4 cup diced potatoes, 1/2 tsp. salt, and 1/2 cup water in 2 qt. saucepan; cover. Place on burner. Turn control to HI. When water boils, turn control to MED-LO. Cook potatoes until tender (19 minutes). Turn control to OFF. Remove saucepan.

Cheese sauce

Place 2 tbsp. margarine in 2 qt. saucepan. Place on burner. When butter melts, add 1/4 tsp. salt, 1/8 tsp. pepper, and 2 tbsp flour. Cook until bubbly. Add 1 cup milk. Cook until thickened; stirring as needed. Add 1/2 cup diced cheese, stir until melted. Turn control to OFF. Remove saucepan.

Spinach

Place 1/2 cup water in 2 qt. saucepan. Place on burner; cover. Turn control to HI. Bring water to boil (approximately 1.5 minutes). Add 10 oz. package frozen spinach. Bring to boil. After 5.5 minutes, turn control to MED. Cook for 5 minutes. Turn control to OFF. Remove saucepan.

Applesauce

Place 1 can (15 oz.) of applesauce and 1/2 tsp. cinnamon in 2 qt. saucepan. Place on burner. Heat applesauce to 140 degree F. Turn control to OFF. Allow applesauce to stand 3 minutes before serving.

Lemon pie filling

Prepare lemon pudding and pie filling mix in 2 qt. saucepan according to directions on box (Kroger, 3 oz.). Place on burner. Turn control to MED 2. Stir constantly until pie filling comes to a full boil. Turn control to OFF. Remove saucepan.

Rice pilaf

Place 1/2 cup margarine in aluminum Dutch oven and place on burner. Turn control to MED-HI. As soon as butter melts, add 1 medium onion, chopped and cook until golden. After 5 minutes add 4 oz. mushroom pieces and 1/4 cup green peppers, diced. Cook until tender; remove (after approximately 7 minutes). Add 1/4 cup margarine, stirring until melted. Add 1 cup rice and increase heat to MED-HI 2. Brown rice, stirring as needed. After rice brown (approximately 14 minutes) add 2 cups water, 2 chicken bouillon cubes, and the vegetables. When mixture boils, cover pan and reduce heat to LO. Cook 20 minutes. Turn control to OFF and remove Dutch oven.

Peas with pearl onions

Drain 1 (17 oz.) can peas, reserving 1/2 cup liquid in 2 qt. saucepan; cover. Place on burner. Turn control to HI. Heat peas to 190 deg. F. Turn control to OFF. Remove saucepan.

Tapioca pudding

Prepare tapioca pudding and pie filling mix (Kroger brand, 3 oz.) in 2 qt. aluminum saucepan according to directions on box. Place on burner. Turn control to MED 2. Bring pudding to a boil. When pudding boils, turn control to OFF. Allow pudding to stand 15 minutes before serving.

Pancakes and sausages

Using directions on package of commercial pancake mix, prepare sufficient batter for 12-16 pancakes. Place aluminum griddle on burner and place 9 sausage links on griddle. Turn control to MED-HI. After 4 minutes, turn control to MED. Cook sausage, turning as needed, until brown (approximately 20 minutes). Remove sausage. Turn control to MED-HI and cook 4 pancakes at a time, using 1/4 cup batter for each pancake. When all batter is cooked, turn control to OFF. Remove griddle.

Broccoli

Place 1/2 cup water and 1/2 tsp. salt in 2 qt. saucepan; cover; place on burner. Turn control to HI. When water boils, add broccoli. Cover and cook for 2 minutes. Break apart with a fork. Reduce heat setting to LO and cook for 5 minutes. Turn control to OFF. Remove saucepan.

Test: Other Performance Characteristics

Speed of heat-up and recovery rate

Place 3 quarts water,1 tbsp. salt and 1 tbsp. oil in 5 qt. cooking vessel; cover. Turn control to HI; start timer. Heat water to boiling (209 deg.F.); record time. Add 8 oz. spaghetti (as per cooking instructions on package). Record water temperature immediately after spaghetti is added to water. Record the time required to recover a full boil (209 deg.F.), temperature before spaghetti was added.

Retained heat

Place 2 qt. water in a 3 qt. saucepan; cover and place on heat source. Turn control to HI. Heat water to 209 degrees F. after the desired temperature is reached, turn control to OFF. Start timer. When temperature reaches 190 deg. F., stop timer; record time.

Evenness of heat

Prepare crepes according to recipe (Basic Blended Crepes). Heat a 7-inch, lightly greased skillet over medium high heat until water drop dances when sprinkled on it. Pour1/4 cup batter into skillet. Quickly tilt skillet to cover bottom. Pour off extra batter into blender jar. Brown on first side, about 1/2 minute; turn to brown on second side. Stack with wax paper between two crepes. Place flat in plastic bag until ready for use.

General Procedures

Items from the AHAM Menu for Range Energy Testing were prepared using quantities and procedures developed by Lovingood and Goss (1980), manufacturer's recommendations, and procedures established during preliminary testing. All foods were cooked to a degree of doneness and were measured by objective tests using specific instruments (see Table 23).

In order to minimize uncontrollable or unforeseen effects, the order of food items tested were randomly selected. The names of the 27 food items were written on separate slips of paper and placed in a bowl. Items were cooked in the order they were drawn. To facilitate purchase of supplies and use of instruments, all replications of each were completed before proceeding to the next set of tests.

All foods were purchased at the same major Supermarket in Blacksburg, Virginia, and stored in the appropriate section of an automatic defrosting refrigerator-freezer in order to minimize variations in foods at the beginning of tests. Food preparation procedures were followed exactly for each test. Specific preparation and cooking procedures are described in Appendix C.

A data sheet was completed on each food item as it was cooked on each appliance (see Appendix H). Information to be recorded on the data sheet included: the appliance used, the food item tested, the meal and day, the amount of energy used, the amount of time utilized, and the intensity of user interaction with the appliance.

Ambient temperature, relative humidity, and atmospheric pressure were recorded daily before testing. The following variables which may affect cooking time and energy were controlled as recommended by Lovingood and Goss (1978) in their manual of procedures (pp. 4-5):

1. All water used in this study was tap water from Blacksburg system and was tempered to 70 degrees ± F. Blacksburg water is naturally about 3 grains hard and undergoes no treatment except purification and chlorination.
2. Whenever possible, tight fitting lids were used on pans to help bring water to a boil more rapidly.
3. Foods such as soups and pudding were heated to specific temperatures.
4. Applesauce was from no. 303 cans and frozen vegetables were from 10-ounce packages.
5. Frozen vegetables were removed from the freezer and placed on the counter beside the range as soon as water was on the unit.
6. The use care book for the induction cooktop or the recipe book for microwave oven contained the correct heat settings for many of the menu items. For the solid element, the conventional electric, and the conventional gas, the

lowest settings which would maintain the desired rate of cooking were chosen.

7. At the beginning of each test, units were at room temperature.

Crepes

1 recipe makes 10 - 11 crepes

3 eggs

1/2 cup dry milk

1/2 cup water

3 tbls. melted butter

3/4 cup flour

1/2 tsp. salt

Blend one minute in blender. Stop, scrape down the sides and blend 30 seconds more. Put 1 tsp. vegetable oil in frypan, heat on medium-heat until one drop of water sizzles. Pour 1/4 cup batter into heated frypan. Cook until top surface is dry in appearance. Remove from frypan.

APPENDIX D

DATA COLLECTION SHEETS

DATA COLLECTION SHEET

Date______________________________

Appliance__________________________

Brand______________________________

Model______________________________

Food item prepared_________________

Meal______________________________ Day____________________

Cooking Unit

Surface unit: 8"____________; 6"____________________
oven______________________________; broiler________________

	Test 1	Test 2	Test 3	Mean
Energy (watts-hours)				
After	____	____	____	____
Before	____	____	____	____
Differences	____	____	____	____
Time (minutes)	____	____	____	____
After	____	____	____	____
Before	____	____	____	____
Differences	____	____	____	____
User Interaction	____	____	____	____
Environmental Factors	____	____	____	____
Atmospheric Pressure (mm Mercury)	____	____	____	____
Temperature (diagnose F&C)	____	____	____	____
Humidity (percentage)	____	____	____	____

Test: BOIL - UP AND RECOVERY RATE

Name ______________________________

Date ______________________________

Appliance __________________________

BOIL-UP

	Test 1	Test 2	Test 3
Time to heat water to 209^0F.			
Start	_____	_____	_____
Finish	_____	_____	_____
Total time used	_____	_____	_____

RECOVERY RATE

Water temperature before adding spaghetti	_____	_____	_____
Water temperature after water is added	_____	_____	_____
Time of recovery rate			
Starting time (after spaghetti is added)	_____	_____	_____
Finishing time (after water returns to 209^0F.)	_____	_____	_____
Total time used	_____	_____	_____

Test - RETAINED HEAT

Date ______________________________

Appliance ___________________________

	Temperature	Test 1 Time	Test 2 Time	Test 3 Time
T_1	209^0F	___	___	___
T_2	190^0	___	___	___

Test: USER INTERACTION

Name ______________________________

Date ______________________________

Appliance ______________________________

Please circle

Test 1 2 3

User Interaction score

1 2 3 4 5

Date ______________________________

Test - EVENNESS OF HEAT

Appliance	Test 1	Test 2	Test 3
Conventional electric	____	____	____
Gas	____	____	____
Solid element - red dot	____	____	____
Solid element - therm	____	____	____
Induction	____	____	____
Microwave oven	____	____	____

Date ______________________________

Appliance ____________________________

Test - EASE OF CLEANING

	Test 1	Test 2	Test 3
Starting time	____	____	____
Finishing time	____	____	____
Total time used	____	____	____

VITA

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