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COMPARATIVE UTILIZATION OF ENERGY BY HOUSEHOLD ELECTRIC AND LIQUEFIED
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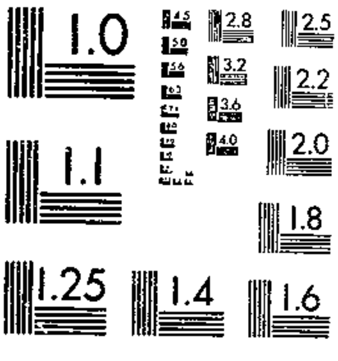

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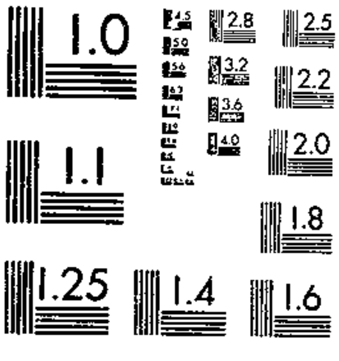

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Comparative Utilization of Energy by Household Electric and Liquefied Petroleum Gas Ranges, Refrigerators, and Water Heaters[1]

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SUMMARY

The comparative utilization of energy of electricity and of liquefied petroleum gas for home cooking, refrigeration, and water heating was studied in a series of tests extending over the greater part of a year. Some of the tests were based on simulated home use of appliances, others were of engineering types.

Ranges, refrigerators, and water heaters used were of types generally available. All were either moderate-cost models or had units or burners of types obtainable on moderate-cost models; deluxe features that would affect energy utilization were not used or were metered separately. Since the information to be obtained would be used mainly in connection with the selection of new appliances, some top-of-range units and burners of advance design were included. However, all were generally available on the market at the time of the study and the indications were that they would come into wider use in the near future. For example, one electric range had a small unit with a 1,600-watt input; another electric range had one small unit of the flash-heat type. All of the gas ranges had surface burners of the double-throat type and three had burners of rated inputs that met or approached inputs required for ranges using natural or manufactured gas.

Refrigerators were of 8- or 9-cubic foot storage capacity. Electric water heaters were of nominal 66-gallon capacity, gas heaters of 30-gallon capacity.

The energy figures reported in this bulletin are on the basis of kilowatt-hours of electricity and cubic feet of gas, and their equivalent energy values in British thermal units (B. t. u.). No attempt is made here to interpret the findings in terms of cost of operation.

Amounts of energy used for top-of-range cooking were similar

[1] Submitted for publication April 1953.

for the electric ranges studied; energy used by the ovens varied more widely from one range to another. On the other hand, the gas ranges studied showed considerable variation in energy for top cooking, while the ovens differed only slightly in use of energy. Some of the variation in energy use by gas ranges for top cooking was apparently due to differences in the B. t. u. inputs of the burners; those with the higher inputs used less total energy than did burners with lower inputs.

In comparing electric ranges with gas, it was found that for top-of-range cooking the gas ranges (constant-burning gas pilots included) used from 1.60 to 2.34 times as much energy (B. t. u.) as did the electric ranges. Gas range ovens used from 1.89 to 2.48 times as much energy as electric range ovens. For cooking a series of meals, which included both top-of-range and oven cooking in a predetermined ratio, the combined top and oven figures showed that the gas ranges used from 1.82 to 2.33 times as much energy as the electric ranges.

Though comparison of speeds of cooking was not an objective of the study, complete time records were kept for purposes of energy computations. An analysis of the time data shows that general statements concerning relative speeds of cooking with electricity and LP-gas cannot be made because there was no clear-cut superiority of one type of fuel over the other. When the 8 ranges (4 electric and 4 gas) were ranked according to the time for cooking 8 days' meals the 2 types were intermingled; ranges using the same fuel ranked both first and last.

Gas refrigerators studied used considerably more energy under all conditions of test than did electric ones. A comparison of refrigerators of approximately 8-cubic-foot capacity in an ambient of 70° F., showed that the figure for gas energy was from 10 to 18 times as great as that for electric energy. The 9-foot refrigerators in a 110° F. ambient (the highest ambient temperature used) were found to have comparative energy figures 7 to 9 times as great for gas as for electricity.

All refrigerators showed a marked increase in energy use with rising ambient temperature even at higher average cabinet temperatures. The rate of increase was less for the gas than for the electric refrigerators. However, it was impossible in one gas refrigerator to maintain the required cabinet temperature in a 110° F. ambient.

Electric water heaters studied were similar in the amounts of energy used; gas heaters showed a wider variation. The greatest differences between heaters were found at the minimum, or 38-gallon, drawoff. At the higher drawoffs (78 and 112 gallons) differences were less. In comparing electric with gas water heaters it was found that the gas heaters used from 1.85 to 2.22 times as much energy at the 38-gallon drawoff as electric heaters. As amounts of water withdrawal were increased, the rate of energy increase was less for gas heaters than for electrics. At the 78-gallon drawoff, gas heaters used from 1.58 to 1.81 times as much energy as electric ones, and at the 112-gallon drawoff, from 1.49 to 1.74 times as much.

INTRODUCTION

Rural areas throughout the country in recent years have seen a great increase in the network of electric lines carrying power to farms. At the same time the use of liquefied petroleum has spread into ever-increasing numbers of communities.

Where both types of energy are available, a choice must often be made between the two when a range, refrigerator, or water heater is to be purchased for the house. One important factor in the choice is the cost of operation, which in turn is based on the relative utilization of energy by the different appliances as well as on the rates per unit quantity of each type of energy. Available information on such utilization is meager, outdated, or from sources that might be biased. Estimates published in 1938 by the National Bureau of Standards [2] are outdated because since that time there have been many improvements in appliances which affect their efficiency in the utilization of energy.

Some research has been carried on in the laboratories of individual companies or trade associations. In some cases, however, only one appliance of each energy type was used for comparison, and usually manufactured or natural gas rather than liquefied petroleum gas.

Utility companies in a few localities have kept energy records of ranges in regular use in homes. Because the conditions of use cannot be controlled in such situations, figures so derived do not have a high degree of accuracy.

To obtain accurate information on the consumption of the two types of energy for refrigeration, cooking, and water heating by current models of appliances, research was conducted by the Bureau of Human Nutrition and Home Economics, U. S. Department of Agriculture, under a "Cooperative Agreement" with the National Electrical Manufacturers Association. The Bureau supplied laboratory facilities, instruments, and supervisory personnel, and also techniques for engineering tests. The Association deposited with the United States Treasury funds to be used for the purchase of food, miscellaneous supplies, those LP-gas appliances which were not consigned by their manufacturers, and for the employment of additional professional personnel and any necessary custodial help. All such employees were hired by the Bureau and worked under the sole direction of its supervisory staff.

Members of the Association also consigned the number of electric ranges, water heaters, and refrigerators required for the investigation. These appliances were chosen by lot from among those produced by NEMA member companies. The LP-gas appliances were selected by the Bureau of Human Nutrition and Home Economics after consultation with gas appliance manufacturers and their affiliated associations.

Broad plans and procedures for the study were decided on by a committee representing the Association and the Bureau and

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[2] Weaver, E. R. Propane, butane, and related fuels. [U. S.] Natl. Bur. Standards Cir. C420, 21 pp. 1939.

throughout the study technical advice was obtained from the National Electrical Manufacturers Association, the American Gas Association, and the Liquefied Petroleum Gas Association. The conduct of the research and preparation of the report of findings were responsibilities of the Bureau. The manuscript for this publication was reviewed by all three associations.

Ranges and refrigerators were studied under conditions simulating normal home use—that is, in the cooking of meals and storage of food in a kitchen-type laboratory. In addition, standard engineering tests were used for refrigerators. Water heaters were given only the engineering type of test.

From the figures obtained in this research, ratios were derived which indicate relative utilization of energy (B. t. u.) by the electric and gas appliances. However, to calculate relative costs on a dollars and cents basis, local rates and the B. t. u. content per unit for each of the two types of energy would have to be applied.

Although this study was concerned primarily with energy consumption by the appliances studied, data were also obtained on time for cooking food and for making ice cubes.

ENERGY SUPPLY

ELECTRICITY.—Electric equipment was operated on a 3-wire, single-phase system with power supplied by the power plant on the Research Center. By means of two automatic induction regulators, voltage was maintained at 118 ± 1 and 236 ± 2 (118 v. for refrigerators, 236 v. for water heaters, and 118-236 v. for ranges). One regulator was located in the line to the kitchen where range and refrigerator use-tests were conducted; the other, in the line to the constant-temperature room where engineering tests on refrigerators and water heaters were made.

LIQUEFIED PETROLEUM GAS.—A pair of tanks of commercial propane with a combined capacity of approximately 600 decitherms was installed outside the building and gas was brought into the laboratory through half-inch copper tubing. Tanks were refilled approximately every 60 days.

Gas pressure was regulated at the tanks to give a "constant" pressure of 11 inches measured by a water manometer at the point of entrance of the gas to the laboratories. The wet-test gas meters used in the kitchen and engineering test room were equipped with manometers that were not long enough to measure the gas pressure when water was used as an indicating substance, so mercury was used instead. Since the density of mercury is so high that small variations in pressure could not be measured at the meters, regular gas-pressure readings were made at the longer water manometer for greater accuracy.

COMPARATIVE ENERGY VALUES OF ELECTRICITY AND GAS

To compare the utilization of energy by electric and gas equipment the metered kilowatt-hours of electricity and cubic feet of gas were converted to their energy value in terms of British thermal units.

In the conversion of metered energy, correction factors were applied where necessary. Volumes of metered gas were reduced daily to volumes under standard conditions of 60°F. and a pressure of 30 inches of mercury at 32°.

Samples of gas were sent at intervals to the National Bureau of Standards for spectrometric analysis. Since the heating value of the gas varied from one sampling to another, the value of each sample, as shown in the accompanying tabulation, was applied to the gas until the next sample was taken.

Gas sample	*B. t. u. per cu. ft.*	*Gas sample*	*B. t. u. per cu. ft.*
1	2,522	4	2,493
2	2,486	5	2,486
3	2,495	6	2,485

KITCHEN-USE TESTS OF RANGES AND REFRIGERATORS

Pattern of Work

The pattern of work for the kitchen-use tests was based on the cooking of meals on each of 4 electric and 4 LP-gas ranges. Gas and electric ranges were used alternately—each for a period of 4 consecutive weeks. A gas refrigerator was used with each gas range and an electric refrigerator with each electric range. The dates of use of the ranges and refrigerators are shown in table 1.

The test meals consisted of 3 meals a day for a family of 4 for each of 8 days. Since 2 replicates of each day's meals were done on consecutive days there was a total of 16 days of regular

TABLE 1.—*Dates of kitchen use of ranges and refrigerators*

Dates (1951–52)	Gas range	Electric range	Gas refrigerator	Electric refrigerator
Dec. 10–Jan. 11	E		N	
Jan. 14–Feb. 8		A		L
Feb. 11–Mar. 7	F		O	
Mar. 10–April 4		C		M
April 7–May 2	H		N	
May 5–May 29		B		K
June 2–June 26	G		O	
June 27–July 25		D		J

cooking on each range. This was done within the 4-week period. In each week 4 days were used for cooking of meals and the fifth for other work connected with the tests—extra baking, preliminary work on ranges or refrigerators to be used later, and compilation of data.

Laboratory work was carried on by two home economists. While one prepared and cooked food the other read meters, timed operations, and kept records. The 3 meals for each menu day were cooked on 2 consecutive days, and workers alternated duties to permit each one to cook all meals in the entire series on each range. On the first day one worker cooked the morning and the evening meals, the other the noon meal; the next day the first worker cooked the noon meal, and the second the morning and evening meals. The worker who cooked the noon meal was responsible for such daily routines as reading the barometer and checking water level in wet-test gas meters.

MENUS USED

Menus for the 8 days' meals cooked in the kitchen tests are given on page 8. The menus were worked out with the following considerations in mind:

1. Light, medium, and heavy meals were included in the proportion found in a survey of meal patterns of farm families in California, Nebraska, and Rhode Island.[3]

2. Dishes included were chosen from those commonly used in different parts of the country. A group of menus collected in 1939 from gas utility home service directors in Grand Rapids, Mich.; San Francisco, Calif.; Providence, R. I.; Minneapolis, Minn.; and Atlanta, Ga., as typical of low cost menus in their respective geographical areas was used as a guide. The judgment of staff members who have lived in different parts of the country was also considered.

3. Menus were checked against the pattern known as the "basic seven"—a guide commonly used for planning diets, which puts needed foods into seven groups and indicates the number of servings per person per day to be included from each group.[4]

4. The menus selected are believed to represent a reasonably normal distribution between top-of-range and oven cooking. It is widely accepted that the usual ratio of range use is 80 percent top-of-range and 20 percent oven. Since there is no general agreement as to how these percentages are to be applied, it was decided in this study to apply them to the number of cooking operations; each heating of one burner, unit, or oven was considered one operation regardless of the time involved or the number of dishes put into the oven at one time. It was recognized that such operations vary widely in their demand for energy. However, experi-

[3] Woolrich, A., Baragar, A., Kuschke, B., and others. Cooking utensils based on meal patterns. Jour. Home Econ. 40: 305-308. 1948.

[4] United States Bureau of Human Nutrition and Home Economics. National food guide. U. S. Dept. Agr. Leaflet 288 (8 pp.), illus. 1946.

ence shows that the ratio of oven to top cooking varies so widely from one family to another, and even from time to time in the same family, that any ratio selected is arbitrary.

5. Short-, medium-, and long-time cooking operations were included for both top-of-range and oven cooking.

6. Commonly used methods of cooking—boiling, frying, and baking—were included.

7. The kind and amount of baking of breads, cakes, cookies, and pies to be included was determined by the results of surveys of farm families in four regions.[5]

8. No attempt was made to control or evaluate the cost of food, but most dishes included were moderate in cost and required simple preparation.

9. Menus were adjusted as needed to make it possible to keep meter readings separate for oven and surface cooking and to solve some minor problems in the scheduling of work. This occasionally resulted in a repetition of some food within a day—something that would not usually occur in menus set up as guides for the planning of meals.

Recipes were chosen and tested to determine their suitability as to ease of preparation and standardization, and the palatability and attractiveness of the food.

Insofar as possible, the foods used for the entire series of meals were selected, procured, and stored in a manner to maintain constant quality throughout the study.

Meats and chickens were obtained from the Bureau of Animal Industry, U. S. Department of Agriculture. Paired beef roasts, pot roasts, and packages of pork chops were marked so that one of each pair could be cooked with an electric range, one with a gas range. Bacon, spareribs, and all ground meats were weighed into lots of sizes needed for a single meal. All meats and chickens were packaged, frozen, and stored in the 0° F. section of a two-temperature walk-in farm freezer in which the temperature was maintained at 0° to –10° F.

Frozen vegetables for cooking and frozen cherries for pies were purchased at one time and stored in chest-type freezers.

Potatoes were stored in a room maintained at a temperature of 42° F. Apples, in loosely tied plastic bags, were stored at a temperature of 35°. Onions in mesh bags and carrots buried in sand were stored in a 32° room.

Canned foods to be used in cooking were purchased as needed; the same brands were used throughout the study as far as possible.

Packaged mixes were used for griddle cakes, biscuit, pastry, cookies, cake, and gingerbread to simplify preparation and to maintain uniformity of products. Brands selected were those that were available at the local market and likely to be so as long as the study continued. These were purchased as needed.

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[5] United States Bureau of Human Nutrition and Home Economics in cooperation with State Agricultural Experiment Stations. Housing needs and preferences of farm families . . . a comparison of data from studies in four regions. U. S. Dept. Agr. AIB 96, 63 pp. 1952.

MENUS FOR 8 DAYS

Breakfast	Noon Meal	Evening Meal
Fruit French toast Sausage Coffee Milk	Fried Chicken Gravy Sweetpotatoes Green lima beans Tomato and cucumber salad Bread Butter or margarine Ice cream Cookies Coffee Milk	Bacon and tomato sandwiches Fruit Cake Iced tea Milk
Fruit Griddle cakes Sausage Coffee Milk	Baked squash Turnip greens Cornbread Butter or margarine Canned fruit Cookies Coffee Milk	Pot roast with Potatoes, carrots, onions Cabbage slaw Bread Butter or margarine Cake Milk
Fruit juice Oatmeal Toast Butter or margarine Coffee Milk	Pork chops Mashed potatoes Green beans Fried apples Bread Butter or margarine Frozen strawberries Coffee Milk	Cheese souffle Peas Jellied fruit salad Bread Butter or margarine Gingerbread Hot chocolate
Fruit Fried cornmeal mush Coffee Milk	Meat pie Waldorf salad Bread Butter or margarine Cake Coffee Milk	Creamed codfish Potato patties Stewed tomatoes Bread Butter or margarine Tapioca pudding Milk

BREAKFAST	NOON MEAL	EVENING MEAL
Fruit juice Bacon Fried eggs Coffeecake Coffee Milk	Ham-and-egg-salad sandwiches Cherry pie Milk	Roast beef Browned potatoes Broccoli Carrot and pineapple salad Bread Butter or margarine Baked apples Tea Milk
Fruit Cooked cereal Scrambled eggs Toast Butter or margarine Coffee Milk	Spareribs Sauerkraut Mashed potatoes Beets Bread Butter or margarine Apple pie Coffee Milk	Baked beans Escalloped tomatoes Brown bread Butter or margarine Canned fruit Cookies Tea Milk
Fruit Grits Bacon Fried eggs Biscuits Butter Honey Coffee Milk	Tuna-noodle casserole Cabbage slaw Bread Butter or margarine Canned fruit Cookies Milk	Hash Green lima beans Harvard beets Bread Butter or margarine Cherry pudding Coffee Milk
Fruit Fried ham and eggs Fried potatoes Bread Butter or Margarine Coffee Milk	Broiled cheese sandwiches Egg and beet salad Peach dumplings Coffee Milk	Pork loaf Escalloped potatoes Glazed carrots Bread Butter or margarine Lemon cake pudding Milk

Utensils

The cooking utensils used in this study are shown in figure 1.

Utensils for top-of-range cooking were of aluminum of a gage heavy enough so that they would not be likely to become bent or warped during the course of the study. All had flat bottoms and were of sizes most suitable for the types and amounts of food cooked. All were large enough to cover the electric range units with the exception of the coffeemaker which was a little smaller than some units. The usual coffeemaker with a diameter that covers small electric units of every range would be too large for a family of four. Pans for cooking vegetables had straight sides and well-fitting covers.

Oven utensils were of aluminum, tinware, and glass, of sizes suitable for quantities of foods to be baked.

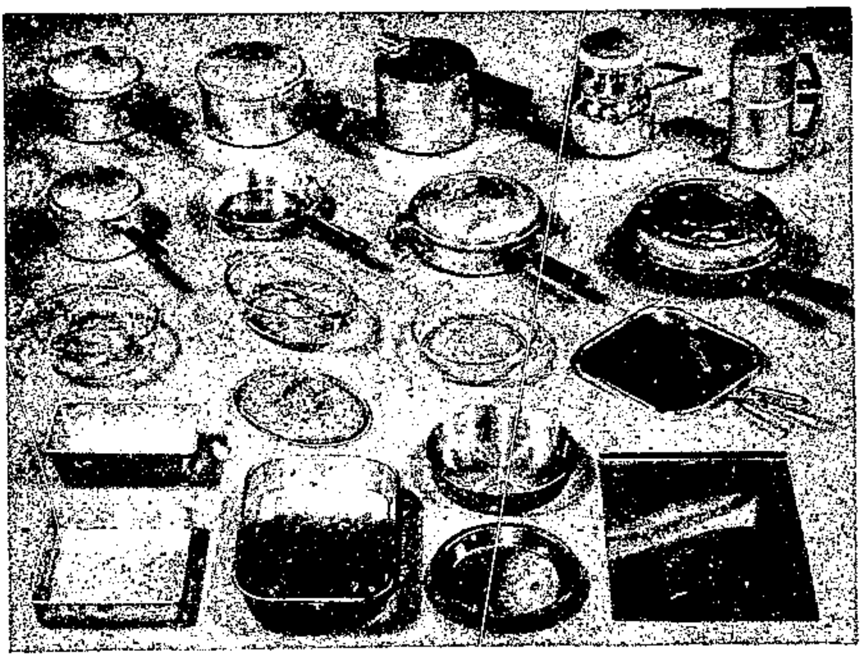

Figure 1.—The set of utensils used for all cooking.

The Laboratory and Equipment

The meals were prepared and cooked in a home-type kitchen, set up within a laboratory (fig. 2). Both gas and electric connections were provided at locations for range and refrigerator so that all ranges and all refrigerators were used in the same positions. Gas meters and kilowatt-hour meters were mounted near the appliances. The L-shape of the kitchen left open space for moving portable potentiometers into positions near the appliances. A table equipped with a constantly running electric clock and three switch-controlled electric timers was conveniently placed for the timing of cooking operations and keeping of records. (For description of all instruments used see Appendix, p. 53.)

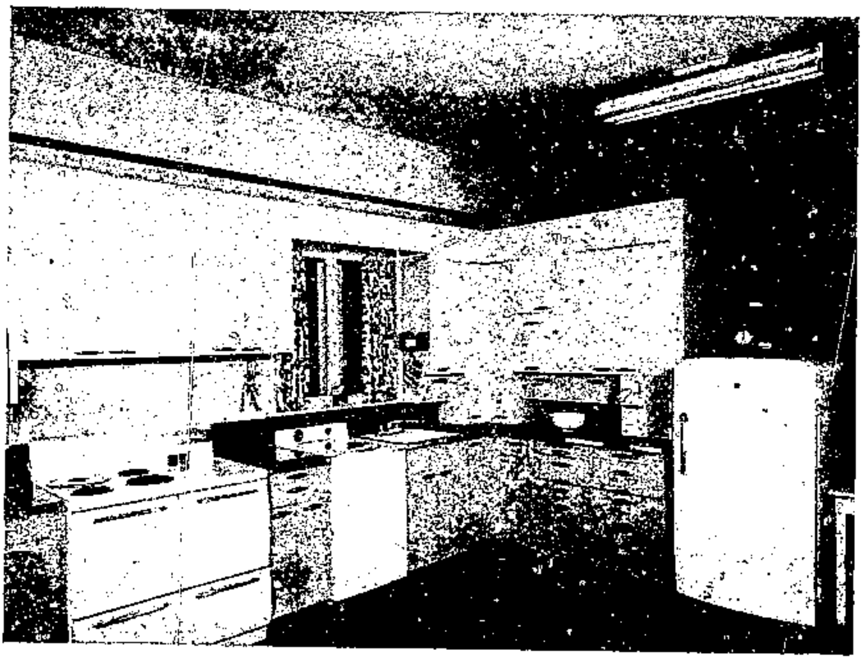

Figure 2.—Kitchen laboratory in which electric and LP-gas ranges and refrigerators were studied.

ELECTRIC RANGES

Electric ranges were selected on the basis of type of surface unit. Makes equipped with representative types of high-efficiency sheathed heating elements were chosen by lot from a list supplied by the National Electrical Manufacturers Association. Three of the ranges chosen were equipped with 3 units and a well cooker, 1 with 4 top-of-range units.

The units are illustrated in figure 3. Lamps on ranges which came so equipped were disconnected so that the meters would record only energy for actual cooking. For a description of the four ranges see tables 2, 3, and 4.

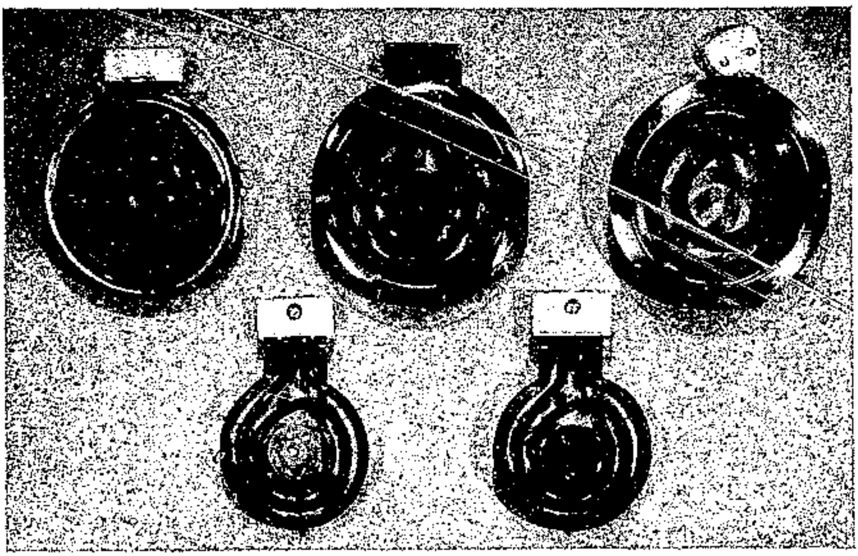

FIGURE 3.—Top units from the four electric ranges; two lower units were from the same range.

GAS RANGES

Gas ranges were selected mainly on the basis of type of top-of-range burners, from lists supplied by the American Gas Association Laboratories and the Gas Appliance Manufacturers Association.

At the time the research was initiated, a change in inputs of surface burners of LP-gas ranges was taking place. A recommended change in the American Standard was to become effective January 1, 1953. The new recommendations called for an input of 7,000 B. t. u. per hour for standard burners, 9,000 for giant

TABLE 2.—*Description of electric ranges*

Range	Top					Oven				
	Description of units	Number of heats	Arrangement of units	Distance between units (center to center)		Type of units	Dimensions			Number of rack positions
				Side to side	Front to back		Width	Height	Depth	
				Inches	*Inches*		*Inches*	*Inches*	*Inches*	
A	One, 7½ inch; two, 6 inch; well cooker.	7	Divided	----------	10⅛	Open	16¾	16¼	19	10
B	One, 7½ inch; two, 5¾ inch; well cooker.	5	Left cluster	11½	10¼	Open	16	20	19	12
C	Two, 7½ inch; two, 5¾ inch.	5	Left cluster	10¾	11	Open	16	15	20	12
D	One, 7½ inch; two, 5½ inch; well cooker.	5	Left cluster	11⅝	10¼	Open	16⅝	15⅞	19½	7

TABLE 3.—*Power inputs of top-of-range electric units*

Unit	Range A			Range B			Range C			Range D		
	Switch marking	Manufacturer's rating	Meter reading [1]	Switch marking	Manufacturer's rating	Meter reading [1]	Switch marking	Manufacturer's rating	Meter reading [1]	Switch marking	Manufacturer's rating	Meter reading [1]
		Watts	*Watts*		*Watts*	*Watts*		*Watts*	*Watts*		*Watts*	*Watts*
RF (large)	High	2,100		High	2,050	2,000	High	2,050		High	2,090	
	2	1,200	1,188	Medium high	1,060	1,160	Second	1,000	1,048	Medium high	1,365	1,368
	3	900	938	Medium low	720	796	Third	510	528	Medium	485	492
	4	525	536	Low	265	297	Low	250	263	Low	345	349
	5	300	297	Simmer	150	198	Warm	100	136	Simmer	120	125
	6	225	239									
	Simmer	131	133									
RR (small)	High	1,250	1,324	High	1,250	1,430	High	1,600	1,560	High	1,260	1,268
	2	675	712	Medium high	720	818	Second	690	656	Medium high	720	710
	3	575	596	Medium low	500	570	Third	400	368	Medium	300	310
	4	313	328	Low	180	214	Low	170	170	Low	175	183
	5	169	180	Simmer	125	142	Warm	100	96	Simmer	80	80
	6	144	150									
	Simmer	78	81									
LF (small)	High	1,200	1,320	High	1,250	1,420	High	1,250	1,240	High	1,250	1,250
	2	600	694	Medium high	720	800	Second	690	696	Medium high	675	703
	3	500	608	Medium low	500	568	Third	310	300	Medium	375	424
	4	300	325	Low	180	215	Low	170	175	Low	244	276
	5	150	172	Simmer	125	142	Warm	75	77	Simmer	100	135
	6	110	153									
	Simmer	50	81									

[1] Obtained with a dual-range, single-phase wattmeter, 0 to 500 and 0 to 2,000 watts.

TABLE 4.—*Power inputs of electric oven units: Manufacturers' ratings*

Range	Preheat	Bake		Broil
		Top unit	Bottom unit	
	Watts	*Watts*	*Watts*	*Watts*
A	4,900	----------	2,000	2,900
B	5,500	620	2,800	3,350
C	3,800	800	3,000	4,000
D	3,700	700	3,000	3,800

burners. However, several major producers of LP-gas ranges had gone beyond the recommendations and were already equipping their ranges with burners having inputs that approached or met those for city gas (9,000 and 12,000 B. t. u.). A spot check showed that ranges with these high-input burners were available in most parts of the country and represented the majority of 1952 sales in several large areas where LP-gas is used extensively. In fact, a 1949 survey[6] showed that more than half the national farm consumption of LP-gas occurred in these same areas.

One of the ranges used had surface burner inputs of about 7,000 and 9,000 B. t. u.; the 3 others, burners with inputs closer to 9,000 and 12,000 B. t. u. All surface burners were of double-throat type and were controlled by valves having simmer positions (fig. 4).

Three ranges had constant-burning gas pilots for top burners, one had electric ignition. None of the ovens had constant-burning pilots.

For outline descriptions of the four ranges see tables 5 and 6.

REFRIGERATORS

Each refrigerator selected had a horizontal freezing compartment across the interior top of the food cabinet.

Two of the four electric refrigerators had storage capacities of approximately 9 cubic feet, the other two, 8 cubic feet. Makes to be used were chosen by lot. Since there was only 1 make of gas refrigerator on the market, 2 models of that make were used—one of approximately 9-foot capacity, the other 8. Each of these two refrigerators was used twice in the series of cooking tests. For outline descriptions of refrigerators see table 7.

[6] Brodell, A.P., and Kendall, A.R. Farm consumption of liquefied petroleum gases. U. S. Bur. Agr. Econ. FM 87, 7 pp. [processed.] 1951.

TABLE 5.—*Description of gas ranges*

Range	Top					Oven			
	Finish of burner heads	Number and diameter of burners	Arrangement of burners	Distance between burners (center to center)		Dimensions			Number of rack positions
				Side to side	Front to back	Width	Height	Depth	
				Inches	*Inches*	*Inches*	*Inches*	*Inches*	
E	Enamel	One, 3⅞ inch; three, 3⅜ inch.	Left cluster (one pilot).	9⅜	9⅛	16	13¼	19	3
F	Aluminum	Two, 3¾ inch; two, 3⅛ inch.	Divided (two pilots)	----------	9½	16	13¼	19	4
G	Enamel	Two, 3⅝ inch; two, 3⅜ inch.	Divided (two pilots).	----------	8⅝	16½	13	20½	4
H	Aluminum	Two, 3¾ inch; two, 3⅛ inch.	Divided (electric ignition).	----------	10½	17	15	20	4

TABLE 6.—*Gas burner B. t. u. inputs as determined in laboratory*[1]

Burner and valve position [2]	Range E	Range F	Range G	Range H
	B. t. u.	*B. t. u.*	*B. t. u.*	*B. t. u.*
Top-of-range:				
Giant:				
High	11,135	12,925	9,580	11,375
Second	6,570	8,225	4,515	6,300
Third	2,305	2,805	2,275	2,995
Low	1,270	1,140	1,800	1,295
Standard:				
High	8,915	9,195	6,950	10,205
Second	5,280	6,410	4,220	6,300
Third	2,255	2,630	2,260	1,945
Low	1,270	1,115	1,960	1,250
Oven: Preheat	21,045	19,240	17,370	17,615

[1] For method used for measuring inputs see p. 18.
[2] For method used for determining valve positions see p. 19.

TABLE 7.—*Description of refrigerators*

Refrigerator	Cubic foot storage capacity	Horsepower	B. t. u./hr.
Electric:			
J	9	1/6	
K	9	1/8	
L	8.22	1/8	
M	8	1/8	
Gas:			
N	8		2,600
O	9.4		2,800

STANDARDIZATION OF INSTRUMENTS, EQUIPMENT, AND METHODS OF WORK

INSTRUMENTS

Wet-test gas meters were calibrated at the National Bureau of Standards. As an additional check on the accuracy of the large meter in registering the small amount of gas used by a range pilot, a smaller meter was connected in series with it and records of the gas used by a single pilot were made for 72 hours. The 5-percent difference between the readings of the 2 meters at such a slow rate of flow of gas was considered negligible.

Kilowatt-hour meters were checked against a standard watt-hour meter, to ascertain the correction factor for each meter.

EQUIPMENT

POWER INPUTS OF TOP-OF-RANGE ELECTRIC UNITS

Each electric range was connected into a circuit which included a voltage regulator, a voltmeter, and an indicating wattmeter. Connections were made across 118 or 236 volts as needed to secure an input reading for each unit at each switch position. Inputs were then charted as a means of finding comparable units and switch positions on all ranges so that any one cooking operation could be carried on from range to range with amounts of heat as similar as possible. (See table 3.) For simplicity in setting up work sheets and keeping records, the four switch positions used for all cooking were designated *high*, *second*, *third*, and *low*. These were the first four switch positions on Ranges B, C, and D, and the first, second, fourth, and fifth positions on Range A.

B. T. U. INPUTS OF TOP-OF-RANGE GAS BURNERS

Each gas range was connected into the supply and incoming gas passed through a wet-test gas meter with a capacity of 80 cubic feet per hour. Gas pressure was maintained at 11 inches of water when 3 range burners were on full. Since gas pressure was affected by the number of burners in operation at any one time, inputs obtained with a single burner in operation were higher than those usually prevailing during cooking tests when from 1 to 3 burners were in use at any one time.

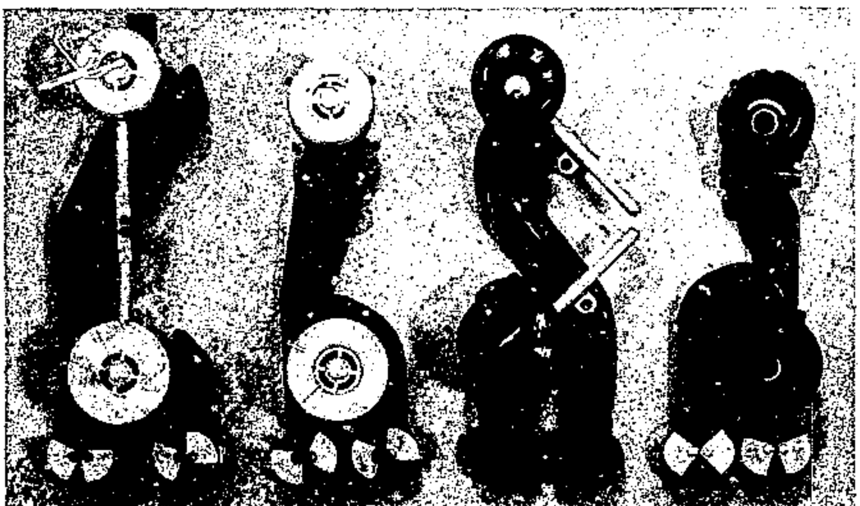

FIGURE 4.—Top burners from the four LP-gas ranges.

Each top-of-range burner on the 4 ranges had 2 definite positions of the valve handle. These gave maximum flame of the entire burner and maximum flame of the center simmer burner. Tests showed that two more positions could be located repeatedly with reasonable accuracy; these were the points at which a noticeable reduction of the flame could be seen as the handle was turned slowly from the full-on position, and the lowest point to which the handle could be turned before the click of the valve indicated a change to the center simmer burner only. For simplicity and uniformity in keeping records these four positions were given the same designations used for switch positions of electric units: *high, second, third,* and *low*. At each of these four positions of the valve handle for each burner, the time required for the meter to register a specific amount of gas was recorded. From this figure and the B. t. u. content of the gas during cooking tests with that range, the input per hour was calculated.

In measuring these inputs, gas consumed by the constant-burning pilot or pilots was included. Gas consumption figures were then obtained from overnight and weekend records when the only gas passing through the meter was used by pilots. The hourly pilot figure was calculated and subtracted from the calculated figures for burner inputs. Table 6 shows burner inputs at the four operating positions of the valve handles. These burner inputs were used as a means of comparing heat available at different valve handle positions.

CALIBRATION OF OVEN THERMOSTATS

Recording potentiometers were used for checking oven temperatures. Thermocouples were placed in electric ovens in accordance with the American Standard, ASA, C71.1–1950, American Standard Test Procedure for Household Electric Ranges, and thermostats were calibrated according to these procedures. For gas ranges, the thermocouples were placed and thermostats calibrated according to procedures in American Standard, ASA Z21.1–1948, Approval Requirements for Domestic Gas Ranges.

PREHEATING OF OVENS

All foods were put into ovens after the preheat period. On the electric ranges the oven was considered preheated when the signal light went off. Since the gas ranges had no such visible signals, it was necessary to make preliminary determinations of preheat times. With thermocouples placed as for thermostat calibration, the time was noted for heating each oven from a cold start to each of the six temperatures that were to be used in the cooking of meals. This was done three times for each temperature, and the average of the three used as the standard time for preheating the oven in the test meals.

DETERMINATION OF TEMPERATURE CONTROL SETTINGS FOR REFRIGERATORS

Since all refrigerators were to be operated at an average temperature between 34° and 38° F., it was necessary to determine the control setting for each one that would produce the desired temperature. This was done for each refrigerator at the beginning of its kitchen-use test. When the refrigerator was placed in the kitchen, thermocouples were located in the cabinet in accordance with American Standards Association specifications for determining average interior cabinet temperature. (See page 43.) The temperature control was first set according to the manufacturer's directions for normal operation and then adjusted as necessary until the average temperature fell in the desired range.

METHODS OF WORK

Methods of work for all operations incident to cooking the series of meals were determined by preliminary tests. Work sheets were then prepared giving detailed information such as specific amounts of food and water, methods of combining ingredients, pans and units or burners to be used, cooking temperatures and times, switch or valve positions, oven rack positions, and exact placement of food on racks. These work sheets were used throughout the laboratory tests so there was no deviation of procedure from one appliance to another. A sample work sheet is given on page 22.

PROCEDURES

SETTING UP EQUIPMENT

On the Friday prior to the start of each 4-week test period the range and refrigerator to be used were moved into the kitchen and connected to electric or gas lines. The weekend period permitted the refrigerator to reach a steady operating condition so that temperature adjustments could be made on Monday before food was put in.

Since the cooking of meals did not start until Tuesday, it was possible on the first Monday to check or adjust ranges as needed.

DAILY INSTRUMENT READINGS

Room temperature and refrigerator meter readings were recorded each morning and evening. When gas equipment was in use the range meter was read evening and morning to determine pilot consumption; barometric pressure and gas pressure were read twice a day, temperature of gas at the meter three times to obtain data necessary in determining a daily correction factor for gas consumption.

Complete time records were kept for all cooking, and range meters were read at the beginning and end of each oven operation and each group of top operations.

RANGE PROCEDURES

SCHEDULING THE COOKING

All top-of-range cooking was done on 3 units or burners—1 large and 2 small. In the preparation of meals consisting of several foods to be cooked at one time, units or burners were assigned according to their suitability for cooking each food.

In order to obtain separate energy consumption figures for top and oven cooking, the two were never carried on simultaneously. For any meal in which there were both baked and surface-cooked foods, the baking was done first. As soon as the oven was turned off the meter was read and then the top-of-range cooking (usually consisting of short-time processes) was started.

In a few cases it was necessary to use an electric surface unit for a second operation so soon after the first that there might have been some retained heat. In such instances the same lapse of time was always maintained between the same two operations on every range. The oven was always preheated from room temperature except when the broiling of cheese sandwiches followed the baking of peach dumplings for use in the same lunch. In that case, a 5-minute lapse was allowed between operations, during which the oven door was kept closed. This practice was observed for all ranges. At other times a fan was used to cool the oven if there was insufficient time between operations for natural cooling. The baking of bread and cookies was shifted to the extra day in the week to ease the schedule and permit cooling of the oven between uses.

CONTROL OF TEMPERATURE OF FOOD AT START OF COOKING

With all ranges, the temperature of the food at the start of cooking was always the same. Food such as meat, milk, and eggs were taken from the refrigerator just before cooking. Meats from 0° F. storage were placed in the main food compartment of the refrigerator 2 days before use so they would reach refrigerator temperature. Frozen vegetables were moved from 0° storage to the frozen-food compartment of the refrigerator the day before use and were put on to cook without thawing. Potatoes, carrots, and onions were at room temperature prior to cooking. The temperature of water used in making coffee or tea or for cooking vegetables was always 80° F. This temperature was used to simplify laboratory procedures. A large pan was filled with 80° water each morning. Because this was approximately room temperature, little heating or cooling of the water was necessary at the time of each use.

Sample work sheet—DAY 7

Menu item and ingredients	*Utensils*	*Procedure*	*Setting*[1]	*Unit or burner*
		BREAKFAST		
BISCUITS				
2 c. biscuit mix. ⅔ c. milk.	Bowl. Fork. Rolling pin and frame. 2-inch cutter. Spatula. Cooky sheet.	Add milk to dry mix and mix thoroughly. Knead 10 times on lightly floured board. Roll, using frame as thickness guide.		
		Preheat oven here.	450°	Oven.
		Cut biscuits with floured cutter. Bake on ungreased sheet for 10 minutes.		
GRITS				
4 c. 80° water. ½ tsp. salt. ¾ c. grits.	3-quart saucepan and lid.	Heat salted water to 212°. Slowly stir in grits and heat to 150°.	High.	Small.
		Turn down heat and cover. Simmer 30 minutes stirring frequently.	Low.	
COFFEE				
4 c. 80° water. 6 tbsp. coffee.	Drip coffee-maker.	Assemble top of coffee-maker with coffee in basket. Heat water to 212° in bottom pot, pour into top, and quickly place top on pot.	High.	Small. (speed unit on C and D).
BACON				
½ lb. sliced bacon.	10-inch fry pan.	Put bacon in cold pan and heat to 325°.	High.	Large.
		Turn down heat. Fry 5 minutes. Pour fat from pan.	Second.	
EGGS				
3 tbsp. bacon fat. 4 eggs.	Pan used for bacon.	Put fat in pan. At 300° put in eggs. Fry to 350°.	Third.	Large.
		NOON MEAL		
TUNA-NOODLE CASSEROLE				
2 qt. 80° water. 1 tsp. salt. 1 pkg. noodles (8 oz.).	4-qt. saucepan and lid.	Heat salted water to 212°. Add noodles, cover, and heat to 212°.	High.	Large.
		Turn down heat and cook 9 minutes, stirring twice. Drain.	Low.	
TUNA-NOODLE CASSEROLE				
Cooked noodles. 1 7-oz. can tuna. 1 can mushroom soup. 1 tsp. salt. 1 tbsp. butter. 1 c. crushed corn flakes.	2-qt. casserole.	Preheat oven.	400°	Oven.
		Grease casserole. Place noodles and tuna in layers, salting each. Top with corn flakes and butter. Bake 40 minutes.		

Sample work sheet—DAY 7 (*Continued*)

Menu item and ingredients	*Utensils*	*Procedure*	*Setting* [1]	*Unit or burner*
		EVENING MEAL		
CHERRY PUDDING				
1 tbsp. shortening. ½ c. sugar. 1 c. flour. 1 tsp. baking powder. ½ c. milk. 1 can cherries (No. 2). ½ c. sugar.	Bowls. Wooden spoon. Shallow casserole.	Cream shortening and ½ c. sugar. Sift flour and baking powder and add to creamed mixture alternately with milk. Beat until smooth.		
		Preheat oven here.	350°	Oven.
		Pour batter into greased casserole. Mix cherries (and their juice) with ½ c. sugar and pour over cake batter. Bake 45 minutes.		
HASH				
2 tbsp. meat drippings. 2 tbsp. flour. 1 c. 80° water. 2 c. cold roast beef, chopped. 1½ lb. cold boiled potatoes, chopped.	10-inch fry pan.	Heat drippings to 275°. Stir in flour for 20 seconds. Add water slowly, stir and cook to 212°. Add meat and potatoes. Cover and heat to 212°.	High.	Large.
		Turn down heat and cook 15 minutes.	Low.	
HARVARD BEETS				
1 can sliced beets (No. 2). 2 tbsp. flour. ⅓ c. sugar. ¼ c. juice from beets. ¼ c. vinegar. ½ tsp. salt. 2 tbsp. butter.	2-qt. saucepan without lid.	Drain beets, save ¼ c. juice. Mix flour and sugar in pan, add beet juice and vinegar. Cook to 212° stirring occasionally. Add salt, butter, beets.	Second.	Small.
		Turn down heat and cook 5 minutes.	Third.	
COFFEE				
4 c. 80° water. 6 tbsp. coffee.	Drip coffeemaker.	Same as at breakfast.		
LIMA BEANS				
½ c. 80° water. ¼ tsp. salt. 1 pkg. frozen lima beans.	2-qt. saucepan and lid.	Heat salted water to 212°. Add limas, heat to 212°, remove cover and break beans apart.	High.	Small.
		Turn down heat and cook 8 minutes.	Low.	

[1] Only 4 settings of switch or valve handle were used for top units or burners. The laboratory designations of high, second, third, and low, used for both gas and electric ranges, do not correspond in most cases to switch or valve designations on ranges.

TEMPERATURE MEASUREMENTS IN COOKING

A recording potentiometer and thermocouple were used to measure temperatures of all top-of-range cooking processes except frying. In the cooking of vegetables the thermocouple was located in the vapor above the water and the food. The thermocouple wire entered each covered saucepan through a small hole made available by the removal of 1 of 2 screws which fastened the knob to the cover. Water for coffee or tea was heated in the lower part of the drip coffeemaker. The thermocouple was led in through a small steam hole in the cover and immersed in the water or in such foods as white sauce and gravy which were cooked uncovered.

Temperatures for fried foods were measured by means of a griddle thermometer.

Since oven thermostats were adjusted to give the same temperature for the same setting, no further temperature measurements were used for baked products.

CONTROL OF HEAT IN TOP-OF-RANGE COOKING

Highest heat was used to start most top-of-range cooking operations. When the desired cooking temperature was reached the switch or valve handle was turned to the position determined in preliminary tests to be the lowest that would maintain the cooking temperature.

TIMING OF COOKING OPERATIONS

In all top-of-range cooking a part of the time is used for heating the food to cooking temperature—for instance, the boiling point. If that temperature is then maintained, the time to complete the cooking is the same no matter what the source of heat. The time variable between ranges then is the time necessary to heat food to the required temperature. In oven cooking the time variable between ovens is in the preheating period, and baking time for any one food from range to range is the same as long as temperatures are the same.

Since most recipes give a spread of cooking time to cover differences in food and individual preferences, it was necessary to establish a time-at-cooking-temperature for each food. By preliminary tests with each item a specific time within the spread was decided on. To determine roasting time for beef a thermocouple was inserted in the center of lean muscle of one of the roasts. The time for cooking this piece of meat to an internal temperature of 150° F. (medium well done) was followed thereafter.

Electric timers were used to time cooking operations precisely. To avoid confusion when more than one food was cooking, a label showing food and time was placed by each timer in use.

REFRIGERATOR PROCEDURES

TEMPERATURE MEASUREMENTS

A potentiometer was used to record temperatures of each refrigerator throughout the period of its use. The three thermocouples in the main food-storage cabinet, placed according to American Standards Association specification were so connected that an average temperature of the three points was recorded. (For details, see p. 43.) A fourth thermocouple was used in an ice tray to record temperatures during the making of ice. The potentiometer was run continuously for the first 4 days. For each, a temperature-time curve was plotted from the potentiometer record and the area under the curve was measured with a planimeter to obtain the average temperature for the day. After the fourth day an automatic interval timer was used so that the potentiometer recorded only 5 minutes of each hour.

DOOR OPENINGS

All food was placed in and removed from the refrigerator according to a definite plan. Foods for each meal were listed and divided into groups that would be moved in or out of the refrigerator at one time. By this means the number of door openings was determined. One extra opening was included in the schedule for each meal. Three openings were allowed in the evening meal schedule for loading food for the next day. The schedule of door openings for the series of meals is shown in table 8.

TABLE 8.—*Schedule of refrigerator door openings*

Day	Morning	Noon	Evening	Total
1	8	11	13	32
2	7	9	10	26
3	5	9	12	26
4	6	8	10	24
5	7	14	12	33
6	7	7	10	24
7	9	8	11	28
8	7	12	11	30
Total	56	78	89	223

A work sheet for each day, showing foods to be moved in or out at each door opening was posted near the refrigerator for guidance of the workers. (See sample, p. 26.) If the extra door opening was not used in the course of a meal, the door was simply opened and closed to keep the number of openings constant from one refrigerator to another.

Sample guide for refrigerator door openings and movement of food—DAY 7

Morning		Noon		Evening	
Out	In	Out	In	Out	In
1. Milk		1. Butter or margarine.		1. Roast beef, fat	
2.	Milk.	2. Cabbage, carrots, dressing.		2. Potatoes	
3. Bacon, eggs		3.	Cabbage	3. Butter or margarine.	
4. Cooking fat		4. Fruit, milk		4. Lima beans	
5. Butter or margarine, milk, cream.		5. Ice		5. Milk	
6. Fruit	Eggs.	6.	Milk, dressing	6. Cream	
7.	Milk, cream.	7.	Tray of water	7.	Butter, milk, cream.
8.	Butter, fat.	8. Extra		8.–10. Loading	
9. Extra					
				11. Extra	

No attempt was made to control the time between door openings or the number of seconds the door was open each time. However, the total time that the door was open was recorded. The refrigerator lamp was removed and its socket used for the connection of a clock and counter setup (located outside the refrigerator) so that the switch which normally controls the lamp would cause the clock to run whenever the door was open. The counter served as a check against the planned schedule of door openings. A separate meter was used for this instrument setup so that the energy it used would not be charged to the refrigerator. Allowance was made in calculations for the energy that would have been used by the refrigerator lamp during the time the door was open.

DEFROSTING

At the beginning of the study, refrigerators did not need defrosting during the 4-week period of use. Frost collected more rapidly as the weather became more humid and the two refrigerators used last were defrosted at the midpoint of the test period. The defrosting was done on the extra day of the week and the internal temperature had time to reach equilibrium before in-use readings were resumed.

MAKING ICE

The plan of work called for making one tray of ice after the noon meal each day, and recording the length of freezing time. This was done regularly throughout the tests. However, a study of the potentiometer charts from the first refrigerators showed that no definite point could be located at which freezing was complete. It was evident that a separate series of tests was required in which certain conditions could be controlled more closely than was possible during regular use of the refrigerators. Consequently, ice-making tests were made after the conclusion of the cooking series.

The freezing tests were accomplished in a comparatively short span of time so that there was little variation in room temperature from one test to another. The ambient temperature averaged 80° F.

The temperature setting of each refrigerator was the same as used in the regular run. Each refrigerator was operated for at least 48 hours prior to the freezing test. During that time one tray of ice was made to determine which cube in the tray was the last to freeze. That grid cell was the one used as the location for the thermocouple.

One tray of water was frozen at a time. In four of the refrigerators there were no divisions in the freezing compartments and in each of these the tray was placed on the right side. In each of the other two, which had freezing shelves within the compartments, the tray was placed on the shelf as recommended by the manufacturer.

Each tray was filled with 1¾ pounds of 80° F. water, which brought the level to within one-eighth inch of the top. The bottom of the tray was wetted and the tray placed in position on the freezing surface, which was free from frost and dry.

A thermocouple junction was placed in the center of the predetermined grid cell. The thermocouple was held by a jaw-type clamp on a tripod stand. The point at which the water was frozen was shown by a drop in the temperature record after a constant 32° F. Visual inspection was used as a check on the potentiometer record. During the test the refrigerator door was opened only as necessary to make the visual checks. The bond between tray and freezing surface was never broken during a test.

Two freezing tests were made in each refrigerator.

Results

UTILIZATION OF ENERGY BY RANGES

Two complete sets of figures were obtained for energy consumption by each range for the cooking of meals for 8 days. One set shows energy use when Worker 1 did the cooking, the other set was obtained when Worker 2 cooked the meals. The two sets, which were always close, were averaged to give a single set of figures for each range.

The data on energy consumption were analyzed by amounts used for actual cooking on top of the range, in the oven, and for top and oven combined. Energy consumption for constant-burning pilots was also included in gas range analyses since most users are willing to pay the extra cost of operation for the convenience that pilots afford.

ELECTRIC RANGES

The four electric ranges used about the same amounts of energy for top-of-range cooking. Range B, with the highest energy figure, used only 5 percent more B. t. u. than Range A, with the lowest figure.

Ovens showed more variation. Range B—again with the highest energy figure—used 23 percent more than Range D, which was lowest. When top and oven figures were combined, Range B was found to use 14 percent more energy than Range D; the other two fell in between. For total energy used by electric ranges see table 9.

In the ratio of top to oven operations used in the test meals, electric ranges used a little less than half of their total energy for top-of-range cooking (table 10). Of the total energy used by the electric ovens 33 to 39 percent was used in preheating (table 11).

TABLE 9.—*Energy consumption by electric ranges for cooking 8 days' meals*

Range and worker	Kilowatt-hours			British thermal units [1]		
	Top	Oven	Top and oven	Top	Oven	Top and oven
Range A:						
Worker 1	16.555	18.991	35.546	56,535	64,854	121,390
Worker 2	16.398	19.660	36.058	55,999	67,139	123,138
Average	16.476	19.326	35.802	56,267	65,996	122,264
Range B:						
Worker 1	17.309	20.393	37.702	59,110	69,642	128,752
Worker 2	17.428	20.414	37.842	59,517	69,714	129,230
Average	17.368	20.404	37.772	59,314	69,678	128,991
Range C:						
Worker 1	16.444	17.621	34.065	56,156	60,176	116,332
Worker 2	16.760	17.472	34.232	57,235	59,667	116,902
Average	16.602	17.546	34.148	56,696	59,922	116,617
Range D:						
Worker 1	16.520	16.747	33.267	56,416	57,191	113,607
Worker 2	16.586	16.303	32.889	56,641	55,675	112,316
Average	16.553	16.525	33.078	56,528	56,433	112,962

[1] 1 kw.-hr. = 3,415 B. t. u. Applying this figure to kilowatt-hour averages does not necessarily give the exact B. t. u. averages shown, because the former have been rounded in some instances.

TABLE 10.—*Energy used for top-of-range and oven cooking as percent of total energy for cooking 8 days' meals*

Range	Top	Oven
Electric:	*Percent*	*Percent*
A	46.0	54.0
B	46.0	54.0
C	48.6	51.4
D	50.0	50.0
Average	47.6	52.4
Gas (not including pilots):		
E	37.1	62.9
F	35.4	64.6
G	40.4	59.6
H	36.2	63.9
Average	37.3	62.7
Gas (including pilots):		
E	[1] 40.4	59.6
F	[2] 46.4	53.6
G	[2] 50.0	50.0
H	[3] 37.3	62.7
Average	43.5	56.5

[1] 1 pilot.
[2] 2 pilots.
[3] Based on total including B. t. u. for electric ignition.

TABLE 11.—*Time and energy used in preheating as percent of total time and energy used by oven in cooking 8 days' meals*

Range	Time	Energy
	Percent	*Percent*
Electric:		
A	9.4	39.2
B	7.6	33.0
C	9.3	34.0
D	9.3	35.9
Average	8.9	35.5
Gas:		
E	15.8	31.6
F	8.6	20.9
G	10.7	25.0
H	10.1	23.4
Average	11.3	25.2

GAS RANGES

Among the gas ranges there was more variation in energy used for top-of-range than for oven cooking (table 12). Range G used 21 percent more B. t. u. for top cooking than did Range F, which used the lowest amount.

A comparison of burner inputs to energy used for top cooking indicates that an increase in burner input results in lower use of energy:

Range	*Sum of inputs of giant and standard burner at four valve positions (B. t. u. per hour)*	*Energy used for top cooking 8 days' meals (B. t. u.)*
G	33,560	89,312
E	39,000	82,456
H	40,370	75,411
F	44,415	73,549

The four gas ovens were much closer together in their use of energy: Range E, with the highest consumption, used 6 percent more than did Range G; the figures for Range F and H fell in between.

When figures for top and oven were combined Range E was found to use 7 percent more energy than Range H.

Since gas used by constant-burning pilots was metered along with gas for top or oven cooking, pilot usage was subtracted to obtain energy figures for actual cooking. However, in considering cost of operation of ranges the gas used by pilots must be calculated on a 24-hour basis. Table 13 shows the energy used by pilots on the different ranges during the test period of 8 cooking days.

The single pilot of Range E burned with a very small flame and used less than a third as much gas as did the two pilots of either Range F or G. (Range H had electric ignition instead of gas pilots.)

TABLE 12.—*Energy consumption by gas ranges for cooking 8 days' meals*

Range and worker	Gas in cubic feet					B. t. u. values [1]				
	Top	Top and 24-hr. pilot	Oven	Top and oven	Top, oven, and 24-hr. pilot	Top	Top and 24-hr. pilot	Oven	Top and oven	Top, oven, and 24-hr. pilot
Range E:										
Worker 1	32.51	37.34	55.26	87.77	92.60	81,990	94,171	139,366	221,356	233,537
Worker 2	32.88	37.73	55.52	88.40	93.25	82,923	95,155	140,021	222,945	235,176
Average	32.70	37.54	55.39	88.08	92.92	82,456	94,663	139,694	222,150	234,356
Range F:										
Worker 1	29.86	47.01	53.84	83.70	100.85	74,232	116,867	133,846	208,078	250,713
Worker 2	29.31	46.50	54.08	83.39	100.58	72,865	115,599	134,443	207,308	250,042
Average	29.58	46.76	53.96	83.54	100.72	73,549	116,233	134,144	207,693	250,377
Range G:										
Worker 1	35.80	52.85	53.99	89.79	106.84	89,249	131,755	134,597	223,846	266,352
Worker 2	35.85	52.89	51.80	87.65	104.69	89,374	131,855	129,137	218,511	260,992
Average	35.82	52.87	52.90	88.72	105.76	89,312	131,805	131,867	221,178	263,672
Range H:										
Worker 1	30.36	(2)	52.99	83.35	----------	75,748	[3] 79,081	132,210	207,958	[3] 211,291
Worker 2	30.09	(2)	52.97	83.06	----------	75,074	[4] 78,400	132,160	207,235	[4] 210,561
Average	30.22	(2)	52.98	83.20	----------	75,411	78,740	132,185	207,596	210,926

[1] Heating value of gas used in B. t. u. per cubic foot: Range E, 2,522; F, 2,486; G, 2,493; H, 2,495. Applying these figures to cubic-foot averages does not necessarily give exact B. t. u. averages shown because the former have been rounded in some instances.

[2] Range equipped with electric ignition instead of pilot.

[3] Includes 0.976 kw.-hr. or 3,333 B. t. u. for electric ignition.

[4] Includes 0.974 kw.-hr. or 3,326 B. t. u. for electric ignition.

TABLE 13.—*Energy consumption by gas range pilots during eight 24-hour periods*

Range and worker	Gas in cubic feet	B. t. u. values
Range E (1 pilot):		
Worker 1	4.83	12,181
Worker 2	4.85	12,232
Average	4.84	12,206
Range F (2 pilots):		
Worker 1	17.15	42,635
Worker 2	17.19	42,734
Average	17.17	42,685
Range G (2 pilots):		
Worker 1	17.05	42,506
Worker 2	17.04	42,481
Average	17.04	42,493

Table 12 shows, in addition to energy for cooking, the energy used by each range during the 8 days, with pilot use included.

Comparing energy used by pilots with that used for cooking only for the 8 days, the following percentages were found:

Range	*Pilot use as percent of energy for top cooking*	*Pilot use as percent of energy for top and oven cooking*
E	14.8	5.5
F	58.0	20.6
G	47.6	19.2

When only the energy for actual cooking was considered, gas ranges were found to use 37 percent of the total for top-of-range cooking, 63 percent for the oven. When pilot consumption was included, the percentages for top and oven were 44 and 56, respectively (table 10).

Gas ovens used from 21 to 32 percent of the total energy for preheating (table 11).

COMPARATIVE UTILIZATION OF ENERGY BY ELECTRIC AND GAS RANGES

Amounts of energy used by electric and gas ranges in cooking the 8 days' meals may be compared in different ways to yield ratios for utilization of energy. Ratios are shown in the accompanying comparisons for three types of energy use: Top, oven, and combined top and oven cooking. B. t. u. figures in these comparisons are from tables 9 and 12.

For each of the three types of energy use, consumption figures are compared to show ratios between (1) the highest gas and the lowest electric figures, (2) the lowest gas and highest electric figures, (3) the highest and lowest electric figures, and (4) the highest and lowest gas figures.

RATIOS BETWEEN GAS AND ELECTRIC RANGES

Top-of-range cooking (gas pilots not included)

$$\frac{\text{Range G (highest gas)}}{\text{Range A (lowest electric)}} = \frac{89{,}312}{56{,}267} = 1.59$$

$$\frac{\text{Range F (lowest gas)}}{\text{Range B (highest electric)}} = \frac{73{,}549}{59{,}314} = 1.24$$

$$\frac{\text{Range B (highest electric)}}{\text{Range A (lowest electric)}} = \frac{59{,}314}{56{,}267} = 1.05$$

$$\frac{\text{Range G (highest gas)}}{\text{Range F (lowest gas)}} = \frac{89{,}312}{73{,}549} = 1.21$$

Top-of-range cooking (including gas pilots)

$$\frac{\text{Range G (highest gas)}}{\text{Range A (lowest electric)}} = \frac{131{,}805}{56{,}267} = 2.34$$

$$\frac{\text{Range E (lowest gas)}}{\text{Range B (highest electric)}} = \frac{94{,}663}{59{,}314} = 1.60$$

$$\frac{\text{Range G (highest gas)}}{\text{Range E (lowest gas)}} = \frac{131{,}805}{94{,}663} = 1.39$$

Oven cooking

$$\frac{\text{Range E (highest gas)}}{\text{Range D (lowest electric)}} = \frac{139{,}694}{56{,}433} = 2.48$$

$$\frac{\text{Range G (lowest gas)}}{\text{Range B (highest electric)}} = \frac{131{,}867}{69{,}678} = 1.89$$

$$\frac{\text{Range B (highest electric)}}{\text{Range D (lowest electric)}} = \frac{69{,}678}{56{,}433} = 1.23$$

$$\frac{\text{Range E (highest gas)}}{\text{Range G (lowest gas)}} = \frac{139{,}694}{131{,}867} = 1.06$$

Combined top and oven cooking (gas pilots not included)

$$\frac{\text{Range E (highest gas)}}{\text{Range D (lowest electric)}} = \frac{222{,}150}{112{,}962} = 1.97$$

$$\frac{\text{Range H (lowest gas)}}{\text{Range B (highest electric)}} = \frac{207{,}596}{128{,}991} = 1.61$$

$$\frac{\text{Range B (highest electric)}}{\text{Range D (lowest electric)}} = \frac{128{,}991}{112{,}962} = 1.14$$

$$\frac{\text{Range E (highest gas)}}{\text{Range H (lowest gas)}} = \frac{222{,}150}{207{,}596} = 1.07$$

Combined top and oven cooking (including gas pilots)

$$\frac{\text{Range G (highest gas)}}{\text{Range D (lowest electric)}} = \frac{263{,}672}{112{,}962} = 2.33$$

$$\frac{\text{Range E (lowest gas)}}{\text{Range B (highest electric)}} = \frac{234{,}356}{128{,}991} = 1.82$$

$$\frac{\text{Range G (highest gas)}}{\text{Range E (lowest gas)}} = \frac{263{,}672}{234{,}356} = 1.12$$

COOKING TIME

METHOD OF ANALYSIS

Time for cooking was first analyzed by the sum of single operations as though they had been performed one at a time. This is an accurate analysis in terms of time required by the ranges. The totals so obtained are the greatest that would be found in cooking the foods in the test meals, and therefore show up most clearly the differences between ranges.

However, timing on a single-operation basis is not typical of the way a homemaker uses her range. She normally cooks several foods simultaneously, using oven and top units or burners as needed. With such overlapping of operations the total time that she spends in cooking the same foods is reduced. For this reason a second analysis was made, based on times actually used in the laboratory as cooking was done with some top-of-range operations overlapping. The figures obtained in this analysis give a better indication of the time that would be used by a homemaker than those obtained in the first analysis, but they are still not wholly typical of home cooking since laboratory procedures permitted no overlapping of top and oven operations in order to obtain separate energy figures for the two. For time totals obtained by the two methods of analysis see tables 14 and 15.

Oven times were the same for both analyses since each use of an oven was considered one operation, regardless of the number of foods cooked in the oven at one time.

ELECTRIC RANGES

The total times required for oven cooking on electric ranges in the 8 days' meals were comparatively close, with a maximum difference between ranges of less than one-half hour. In top-of-range cooking there was a greater time spread among ranges—about 1-1/2 hours on the basis of overlapping operations, 1-3/4 hours on the basis of single operations (table 14). Range B was the fastest of the four in both top and oven cooking; it also used more energy for both types of cooking than did the other electric ranges.

GAS RANGES

The times used in oven cooking were rather close for three of the gas ranges; the difference between the extremes was less than one-half hour. The fourth range, E, required considerably more time for oven cooking because of the preheating characteristic of the oven. The thermostat cut down the oven flame of this range before the desired temperature was reached; the temperature then rose slowly and never overshot the thermostat setting. In the other three ovens the thermostat did not cut down the full flame of the burner until the desired temperature was

TABLE 14.—*Time taken to cook 8 days' meals on electric ranges*

Range and worker	On basis of single operations									On basis of overlapping operations								
	Top			Oven			Top and oven			Top			Oven			Top and oven		
	Hr.	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*
Range A:																		
Worker 1	21	30	51	17	19	34	38	50	25	16	11	18	17	19	34	33	30	52
Worker 2	21	31	56	17	21	38	38	53	34	16	40	33	17	21	38	34	02	11
Average	21	31	24	17	20	36	38	52	00	16	25	56	17	20	36	33	46	32
Range B:																		
Worker 1	19	37	33	16	56	20	36	33	53	14	52	05	16	56	20	31	48	25
Worker 2	19	53	10	16	57	40	36	50	50	15	04	49	16	57	40	32	02	29
Average	19	45	22	16	57	00	36	42	22	14	58	27	16	57	00	31	55	27
Range C:																		
Worker 1	20	51	56	17	16	12	38	08	08	16	02	40	17	16	12	33	18	52
Worker 2	21	04	38	17	14	47	38	19	25	16	14	14	17	14	47	33	29	01
Average	20	58	17	17	15	30	38	13	46	16	08	27	17	15	30	33	23	56
Range D:																		
Worker 1	20	49	44	17	13	11	38	02	55	16	05	37	17	13	11	33	18	48
Worker 2	21	05	50	17	15	59	38	21	49	16	14	26	17	15	59	33	30	25
Average	20	57	47	17	14	35	38	12	22	16	10	02	17	14	35	33	24	36
Over-all average	20	48	12	17	11	55	38	00	08	15	55	43	17	11	55	33	07	38

TABLE 15.—*Time taken to cook 8 days' meals on gas ranges*

Range and worker	On basis of single operations									On basis of overlapping operations								
	Top			Oven			Top and oven			Top			Oven			Top and oven		
	Hr.	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*	*Hr.*	*Min.*	*Sec.*
Range E:																		
Worker 1	19	42	07	18	40	23	38	22	30	15	01	58	18	40	23	33	42	21
Worker 2	19	51	27	18	37	49	38	29	16	15	12	44	18	37	49	33	50	33
Average	19	46	47	18	39	06	38	25	53	15	07	21	18	39	06	33	46	27
Range F:																		
Worker 1	17	56	42	17	07	01	35	03	43	13	58	08	17	07	01	31	05	09
Worker 2	18	22	21	17	09	54	35	32	15	14	24	21	17	09	54	31	34	15
Average	18	09	32	17	08	28	35	17	59	14	11	14	17	08	28	31	19	42
Range G:																		
Worker 1	21	27	57	17	31	23	38	59	20	16	17	19	17	31	23	33	48	42
Worker 2	21	49	14	17	31	30	39	20	44	16	39	49	17	31	30	34	11	19
Average	21	38	36	17	31	26	39	10	02	16	28	34	17	31	26	34	00	00
Range H:																		
Worker 1	18	07	17	17	26	05	35	33	22	14	13	08	17	26	05	31	39	13
Worker 2	18	22	24	17	27	09	35	49	33	14	24	49	17	27	09	31	51	58
Average	18	14	50	17	26	37	35	41	28	14	18	58	17	26	37	31	45	35
Over-all average	19	27	26	17	41	24	37	08	50	15	01	32	17	41	24	32	42	56

reached. The latter method resulted in a temperature above the thermostat setting. Since gas ovens were not considered preheated until the desired temperature was recorded by the potentiometer, the time for preheating the oven of Range E was always longer than for the others. This might account for most of the higher use of energy by this oven.

Gas ranges showed a difference of almost 3 1/2 hours between the shortest and longest times required for top-of-range cooking, when computed by single operations and more than 2 hours on the basis of overlapping operations (table 15). The reason for this was the difference in the B. t. u. inputs of the burners (table 6). When ranges are ranked from fast to slow by time for top cooking the order is the same as when they are ranked from high to low by the combined B. t. u. inputs of the giant and standard burners. The 3 fastest ranges were the 3 with the new high-input burners. When the 3 ranges with the high-input burners were considered by themselves the time spread for top cooking on the basis of single operations became a little over 1 1/2 hours, and became less than 1 hour on the basis of overlapping operations.

TIME COMPARISON—ELECTRIC AND GAS

To compare electric cooking times with gas, figures for the two workers were averaged.

Top cooking on electric ranges required more time than on gas ranges (table 16). The difference was less when computed on the basis of actual overlapping operations during the study than when based on the sum of single operations. The difference was also less when times for all 4 gas ranges were averaged than when only the 3 with high-input burners were included.

In oven cooking the electric ranges proved to be faster than the gas. When top and oven times were combined, gas ranges were faster by a small amount. When the 8 ranges (4 electric and 4 gas) were ranked according to the time for cooking the 8 days' meals, the 2 types were intermingled, with a gas range at the top and another at the bottom:

Ranges in order of time	*Average time* *Hr.*	*Min.*	*Sec.*
F (LP-gas)	35	17	59
H (LP-gas)	35	41	28
B (Electric)	36	42	22
D (Electric)	38	12	22
C (Electric)	38	13	46
E (LP-gas)	38	25	53
A (Electric)	38	52	00
G (LP-gas)	39	10	02
Average			
LP-gas	37	08	50
Electric	38	00	08

TABLE 16.—*Time difference between electric and gas ranges in cooking of 8 days' meals*[1]

Basis of comparison	By single operations					By overlapping operations				
	Time difference			Percent difference [2]	Type range with longer cooking time	Time difference			Percent difference [2]	Type range with longer cooking time
	Hr.	*Min.*	*Sec.*	*Percent*		*Hr.*	*Min.*	*Sec.*	*Percent*	
Average for 4 electric and 4 gas ranges:										
Top	1	20	46	6.9	Electric	0	54	10	6.0	Electric.
Oven	0	29	29	2.9	Gas	0	29	29	2.9	Gas.
Top and oven	0	51	17	2.3	Electric	0	24	42	1.3	Electric.
Average for 4 electric and 3 high-input gas ranges:										
Top	2	04	30	11.1	Electric	1	23	11	9.5	Electric.
Oven	0	32	48	3.2	Gas	0	32	48	3.2	Gas.
Top and oven	1	31	41	4.2	Electric	0	50	22	2.6	Electric.

[1] Average of 2 workers.

[2] Based on the shorter cooking time.

Several representative cooking operations, each of which was done at least four times on each range, were studied for time differences (table 17). Time for cooking shows variations from range to range using the same type of energy as well as differences between ranges of the two types.

A comparison of the proportion of total time used for top and for oven cooking (table 18) shows a fairly even division between the two types of cooking by electric ranges when considered on

TABLE 17.—*Average time for cooking specified menu items*[1]

Range	Coffee		Lima beans		Potatoes		Bacon		Sausage	
	Min.	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*
Electric:										
A	10	22	13	44	32	40	8	56	22	44
B	8	12	11	53	31	14	8	59	21	30
C	[2] 8	42	13	50	34	02	9	04	22	16
D	[2] 8	51	12	36	32	59	8	58	23	04
Gas:										
E	6	59	14	01	33	10	8	51	20	44
F	5	51	12	14	30	20	7	29	19	56
G	10	09	13	36	35	33	8	38	23	17
H	5	38	11	13	30	34	7	50	19	26

[1] Each item was cooked at least 4 times on each range.
[2] Speed unit used.

TABLE 18.—*Time for top-of-range and oven cooking as percent of total time for cooking 8 days' meals*

	On basis of single operations		On basis of overlapping operations	
	Top	Oven	Top	Oven
	Percent	*Percent*	*Percent*	*Percent*
Electric ranges:				
Range A	55.4	44.6	48.6	51.4
Range B	53.8	46.2	46.9	53.1
Range C	54.9	45.1	48.3	51.7
Range D	54.9	45.1	48.4	51.6
Average	54.7	45.3	48.1	51.9
Gas ranges:				
Range E	51.5	48.5	44.8	55.2
Range F	51.4	48.6	45.3	54.7
Range G	55.3	44.7	48.5	51.5
Range H	51.1	48.9	45.1	54.9
Average	53.3	47.7	45.9	54.1

the basis of overlapping operations. On the basis of single operations, a higher proportion of the time was consumed for top cooking. Among gas ranges, the time required for oven cooking was greater than that for top cooking. Comparison of the sums of single operations shows a nearly even division of time among the ranges.

UTILIZATION OF ENERGY BY REFRIGERATORS

From refrigerator meter readings which were taken evening and morning, consumption figures were obtained for overnight periods (during which the refrigerator door was never opened) and for daytime use. As far as possible, readings were taken so that the overnight period was 16 hours; the daytime period, 8 hours. When such a timing of readings was not possible, hourly averages were calculated for both night and day periods and the consumption figures adjusted to the 16- and 8-hour bases. There were four normal-use days each week. By taking readings for four corresponding overnight periods, records for four 24-hour periods per week were obtained. In 4 weeks of kitchen use, energy-consumption figures were thus obtained for sixteen 24-hour periods (tables 19 and 20).

Refrigerators were used during the months beginning with December and ending with July. The difference in energy used by gas refrigerators in the first and second test periods, which were 3 months apart in each case, definitely shows the effect of the higher room temperature during the second period (table 21). Some of the increase in energy use by the electric refrigerators presumably was the result of room temperature but since all four refrigerators were different it is impossible to say how much of the difference, if any, may be attributed to room temperature changes.

Energy figures obtained in kitchen use of refrigerators were not compared directly because of certain variable factors: refrigerators were of different sizes, room temperature varied, and though cabinet temperatures were kept within defined limits, the average temperatures maintained were not identical from one refrigerator to another. For this reason, engineering tests were used to determine relative energy values. (pp. 45).

MAKING ICE

The exact time of freezing of water into ice is difficult to determine for three reasons: (1) the potentiometer will usually record temperatures that indicate a frozen state when visual inspection shows that freezing of the cube is not complete; (2) the recorded temperature drop from 32° F. is a gradual change so the exact minute a frozen state is reached cannot be determined; and (3) the rate of temperature drop is different in different refrigerators so that corresponding points are hard to determine. The American Standards Association specifications allow an error of ± 10 percent. Times shown therefore are approximate.

TABLE 19.—*Energy consumption by electric refrigerators during 16 days of use*

Refrigerator	Kilowatt-hours			British thermal units				
	8-hour daytime operation	16-hour overnight operation	Combined 24-hour operation	8-hour daytime operation	16-hour overnight operation	Combined 24-hour operation	Electric lamp consumption	24-hour operation plus electric lamp
J	8.681	13.935	22.616	29,646	47,588	77,234	102	77,336
K	8.383	13.815	22.198	28,628	47,178	75,806	174	75,980
L	4.800	7.498	12.298	16,392	25,606	41,998	191	42,189
M	7.447	10.020	17.467	25,432	34,218	59,650	133	59,783

TABLE 20.—*Energy consumption by gas refrigerators during 16 days of use*

Refrigerator	Cubic feet			British thermal units				
	8-hour daytime operation	16-hour overnight operation	Combined 24-hour operation	8-hour daytime operation	16-hour overnight operation	Combined 24-hour operation	Electric lamp consumption	24-hour operation plus electric lamp
N (1)	84.699	145.783	230.482	213,611	367,665	581,276	120	581,396
N (2)	85.717	153.581	239.298	213,864	383,185	597,049	123	597,172
O (1)	103.020	185.844	288.864	256,108	462,008	718,116	116	718,232
O (2)	115.628	201.190	316.818	288,260	501,567	789,827	109	789,936

In ambient temperatures averaging 80° F., and with refrigerator temperature controls set at the points used in kitchen tests (described on page 20), time for making a tray of ice in each refrigerator was as follows:

	Hours	*Minutes*
Electric:		
J	1	50
K	2	25
L	5	45
M	2	45
Gas:		
N	3	50
O	3	45

TABLE 21.—*Refrigerator storage capacity, month of use, temperature, and energy consumption*

Refrigerator	Approximate storage capacity	Month in use [1]	Average room temperature		Average cabinet temperature	Energy consumption during 16 days of use
			Morning	Afternoon		
	Cubic Feet		*°F.*	*°F.*	*°F.*	*B. t. u.*
Electric:						
J	9	July	84.3	85.8	37.9	77,336
K	9	May	78.2	79.2	35.5	75,980
L	8	January	74.6	77.5	35.9	42,189
M	8	March	76.1	77.6	37.5	59,783
Gas:						
N	8	December	73.4	74.9	37.6	581,276
		April	77.9	78.9	38.2	597,049
O	9	February	75.7	77.4	38.1	718,116
		June	80.6	83.9	38.2	789,827

[1] Month indicated is that in which the major portion of use fell. See p. 5 for exact dates of use.

ENGINEERING TESTS OF REFRIGERATORS AND WATER HEATERS

No-load energy-requirement tests were conducted on refrigerators according to the specifications and recommendations in American Standard, ASA B38.2–1944, American Standard Test Procedures for Household Electric Refrigerators (Mechanically Operated).

Delivery performance tests were conducted on water heaters according to the specifications in American Standard, ASA C72.1–1949, American Standard for Household Electric Storage-Type Water Heaters. In addition, energy consumptions were determined for drawoffs of 38 and 78 gallons.

The Laboratory

The tests were conducted in a room in which temperature could be maintained within ± 1° of any specified value between 65° and 115° F. The vertical temperature gradient in the room conformed to the requirements of American Standard test specifications of not more than 0.5° F. per foot. Two calibrated kilowatt-hour meters, one for the 236-volt and the other for the 118-volt supply, were installed in the constant-temperature room for the duration of the tests.

Two wet-test gas meters, with capacities of 80 and 20 cubic feet per hour, were installed in the water-heater and refrigerator supply lines, respectively. Because of serious condensation difficulties in the supply line at the refrigerator when the meters were in the temperature-controlled test room, they were located in an adjoining room. A water trap placed at a low point in the line near the water-heater meter prevented any condensation difficulty in that line.

Refrigerators

METHOD OF TEST

For the engineering tests, the 6 refrigerators (table 7) were placed in the constant-temperature room, 2 at a time; gas and electric, gas and electric, and 2 electrics.

When a gas and an electric refrigerator were in the room they were tested simultaneously. When the two electric refrigerators were in the room together, tests were run alternately because only one 118-volt kilowatt-hour meter was included in the setup. In this case readings were made on one refrigerator while the other was reaching a temperature equilibrium after the change in dial setting.

Three thermocouples, each weighted by means of a brass cylinder to the equivalent of 5 grams of water, were located in the refrigerator according to standard specifications. All refrigerators had horizontal evaporators across the top of the cabinet and two vegetable pans at the bottom with an essentially continuous solid shelf directly above them. The distance between this shelf and the bottom of the evaporator was divided into thirds. One thermocouple was placed one third of the distance below the evaporator, another at the two-thirds point, and the third 1 inch above the shelf. All three thermocouples were located in the vertical center line from side to side and back to front. In electric refrigerators, a fourth thermocouple was placed against the evaporator tubing.

The two refrigerators were separated from each other by a small table which held the recording potentiometer. A mercury thermometer and a thermocouple—used to determine ambient temperature—were held by a stand on the table. They were placed equidistant from the sides of the two refrigerators, midway between front and back, and about one third of the way down from the tops of the refrigerators.

Test runs were of 24-hour duration. With gas refrigerators, which have no operating cycle, exact timing was possible. With electric refrigerators, time and meter readings were taken always at the same point in the cycle—just as the motor started. The exact time of starting was determined by noting the beginning of rotation of the kilowatt-hour meter disk. The thermocouple located on the evaporator tube made it possible to determine roughly the time for the beginning of a cycle; hence it was not necessary to watch the meter for relatively long periods. Energy requirements were then prorated to a 24-hour period.

American Standard test procedures recommend determination of energy requirements at cabinet temperatures of 38°, 43°, and 46° F. in ambient temperatures of 70°, 90° and 110°, respectively. As suggested in the standard procedure, instead of attempting to adjust the controls to give exact cabinet temperatures in ambient temperatures of 70° and 90°, determinations were made with the temperature control at the coldest setting, the warmest setting, and an intermediate setting giving a temperature near that desired for the cabinet. In an ambient temperature of 110°, the procedure was varied by using only the coldest setting and an intermediate one giving a temperature near that desired. Kilowatt-hour and cubic-foot requirements were plotted against cabinet temperatures. At all ambient temperatures the energy requirements at the appropriate specified cabinet temperatures were obtained from the resulting straight-line curves.

COMPARATIVE UTILIZATION OF ENERGY BY REFRIGERATORS

The energy requirements of the six refrigerators are shown in tables 22 and 23. Refrigerator N did not reach a cabinet temperature as low as 46° F. in an ambient of 110°. Refrigerator L was considerably below any other in its energy use at all three ambient temperatures. The rate of increase in energy use with increased ambient temperature was greater for the electric refrigerators than for the gas, with a resultant decrease in the ratio of energy utilization.

Since 1 gas and 2 electric refrigerators were of approximately 8-cubic-foot capacity and the others of 9, comparisons of energy use were made on the basis of size as well as ambient temperature. For each size of refrigerator and ambient temperature the B. t. u. figure for gas was compared with the high and low figures for electricity. The figures for the two electric refrigerators in each category were also compared. These ratios are shown on page 45.

RATIOS BETWEEN GAS AND ELECTRIC REFRIGERATORS

8-cubic-foot refrigerators in 70° F. ambient

$$\frac{\text{Refrigerator N (gas)}}{\text{Refrigerator M (high electric)}} = \frac{26{,}800}{2{,}561} = 10.5$$

$$\frac{\text{Refrigerator N (gas)}}{\text{Refrigerator L (low electric)}} = \frac{26{,}800}{1{,}455} = 18.4$$

$$\frac{\text{Refrigerator M (high electric)}}{\text{Refrigerator L (low electric)}} = \frac{2{,}561}{1{,}455} = 1.8$$

8-cubic-foot refrigerators in 90° F. ambient

$$\frac{\text{Refrigerator N (gas)}}{\text{Refrigerator M (high electric)}} = \frac{42{,}381}{4{,}508} = 9.4$$

$$\frac{\text{Refrigerator N (gas)}}{\text{Refrigerator L (low electric)}} = \frac{42{,}381}{2{,}612} = 16.2$$

$$\frac{\text{Refrigerator M (high electric)}}{\text{Refrigerator L (low electric)}} = \frac{4{,}508}{2{,}612} = 1.7$$

8-cubic-foot refrigerators in 110° F. ambient

$$\frac{\text{Refrigerator M (high electric)}}{\text{Refrigerator L (low electric)}} = \frac{7{,}445}{4{,}235} = 1.8$$

9-cubic-foot refrigerators in 70° F. ambient

$$\frac{\text{Refrigerator O (gas)}}{\text{Refrigerator K (high electric)}} = \frac{39{,}139}{2{,}390} = 16.4$$

$$\frac{\text{Refrigerator O (gas)}}{\text{Refrigerator J (low electric)}} = \frac{39{,}139}{2{,}271} = 17.2$$

$$\frac{\text{Refrigerator K (high electric)}}{\text{Refrigerator J (low electric)}} = \frac{2{,}390}{2{,}271} = 1.0$$

9-cubic-foot refrigerators in 90° F. ambient

$$\frac{\text{Refrigerator O (gas)}}{\text{Refrigerator K (high electric)}} = \frac{44{,}730}{4{,}200} = 10.6$$

$$\frac{\text{Refrigerator O (gas)}}{\text{Refrigerator J (low electric)}} = \frac{44{,}730}{3{,}654} = 12.2$$

$$\frac{\text{Refrigerator K (high electric)}}{\text{Refrigerator J (low electric)}} = \frac{4{,}200}{3{,}654} = 1.1$$

9-cubic-foot refrigerators in 110° F. ambient

$$\frac{\text{Refrigerator O (gas)}}{\text{Refrigerator K (high electric)}} = \frac{54{,}421}{7{,}513} = 7.3$$

$$\frac{\text{Refrigerator O (gas)}}{\text{Refrigerator J (low electric)}} = \frac{54{,}421}{6{,}249} = 8.7$$

$$\frac{\text{Refrigerator K (high electric)}}{\text{Refrigerator J (low electric)}} = \frac{7{,}513}{6{,}249} = 1.2$$

TABLE 22.—*Cabinet temperatures and 24-hour energy consumption of electric and gas refrigerators at specified dial settings and ambient temperatures*

Refrigerator used and ambient temperature (Fahrenheit)	Dial Setting					
	Coldest		Warmest		Intermediate	
	Cabinet temperature	Energy consumption	Cabinet temperature	Energy consumption	Cabinet temperature	Energy consumption
Electric:	*°F.*	*Kw.-hr.*	*°F.*	*Kw.-hr.*	*°F.*	*Kw.-hr.*
Refrigerator J:						
70° F.	22.5	1.138	44.0	0.559	37.5	0.651
90° F.	28.0	1.821	51.0	.838	43.0	1.032
110° F.	34.0	2.845			47.0	1.756
Refrigerator K:						
70° F.	30.0	1.004	49.0	.389	37.0	.769
90° F.	36.0	1.616	56.0	.715	39.0	1.471
110° F.	39.0	2.541			48.0	2.154
Refrigerator L:						
70° F.	28.5	.728	50.0	.239	38.0	[1] .406
90° F.	30.0	1.359	52.5	.526	41.0	.807
110° F.	31.0	2.250			42.0	1.458
Refrigerator M:						
70° F.	32.0	.915	52.0	.449	35.0	.854
90° F.	39.0	1.401	55.0	.798	42.0	1.363
110° F.	43.0	2.252			48.0	2.035
Gas:		*Cu. ft.*		*Cu. ft.*		*Cu. ft.*
Refrigerator N:						
70° F.	24.0	13.850	55.0	9.366	42.5	10.682
90° F.	36.0	21.790	60.0	10.557	39.0	17.242
110° F.	48.0	22.623			48.0	22.669
Refrigerator O:						
70° F.	21.5	18.784	54.0	13.006	37.5	16.202
90° F.	29.0	24.033	53.0	15.191	41.0	17.986
110° F.	41.5	24.122			47.0	21.770

[1] Weighted average of two runs at ambient temperatures of 66° and 72° F.

TABLE 23.—*Computed 24-hour energy consumption by electric and gas refrigerators at standard cabinet and ambient temperatures*

Refrigerator	Storage capacity	Ambient, 70° F. Cabinet, 38° F.	Ambient, 90° F. Cabinet, 43° F.	Ambient, 110° F. Cabinet, 46° F.	Ambient, 70° F. Cabinet, 38° F.	Ambient, 90° F. Cabinet, 43° F.	Ambient, 110° F. Cabinet, 46° F.
Electric:	*Cu. ft.*	*Kw.-hr.*	*Kw.-hr.*	*Kw.-hr.*	*B. t. u.* [1]	*B. t. u.* [1]	*B. t. u.* [1]
J	9	0.665	1.07	1.83	2,271	3,654	6,249
K	9	.700	1.23	2.20	2,390	4,200	7,513
L	8	.426	.76	1.24	1,455	2,612	4,235
M	8	.750	1.32	2.18	2,561	4,508	7,445
Gas:		*Cu. ft.*	*Cu. ft.*	*Cu. ft.*			
N	8	10.75	17.0	(2)	26,800	42,381	(2)
O	9	15.75	18.0	21.9	39,139	44,730	54,421

[1] 2,493 B. t. u. per cu. ft. for refrigerator N. 2,485 B. t. u. per cu. ft. for refrigerator O.

[2] Cabinet temperature of 46° F. could not be obtained in 110° ambient.

WATER HEATERS

Four electric and four gas water heaters, described in table 24, were tested. The capacity of the tanks was determined by weighing the water obtained from a complete draining of the tanks. In conformance with standard industry practices, which recognize general restrictions as to electrical energy input in the interests of economical and practical operation, the electric water heaters of nominal 66-gallon storage capacity were selected for comparison with gas heaters of nominal 30-gallon capacity.

TABLE 24.—*Description of water heaters*

Water heater	Type	Rated input			Tank capacity
		Electric		Gas burner	
		Upper unit	Lower unit		
Electric:		*Watts*	*Watts*	*B. t. u./hr.*	*Gallons*
S	Wrap-around	2,000	1,250		62
T	do	2,000	1,250		65.8
U	Immersion	2,000	1,250		63.8
V	do	2,000	1,250		64.1
Gas:					
W	Internal flue			30,000	29.7
X	External flue			30,000	27.4
Y	Internal flue			30,000	26.5
Z	External flue			25,000	28.0

TEST SETUP

One gas and one electric water heater were tested simultaneously in a 70° F. constant-temperature room. The setup was such that the temperature of the incoming water was brought to a constant value before being admitted to either tank. An industrial thermometer with separable brass well was located in the water-outlet pipe from each heater as close as possible to the tank. A pressure-relief valve was placed in each outlet line ahead of two flow-regulation valves. One of these was a 90-degree fast-action valve by means of which the flow for the drawoffs was turned on and off. The other was a slow-action valve. Standard procedure specifications call for a drawoff rate of 5 gallons per minute. With the fast-action valve wide open, the slow-action valve was adjusted for each heater test to give the desired rate of flow and left in the determined position during the test, the flow being turned on and off by the fast-action valve. See figure 5.

The instantaneous average temperature of the water in the tanks was obtained by 6 parallel-connected thermocouples so located as to give the temperatures at the vertical centers of 6 equal zones. Tank plugs were drilled to receive 3/8-inch (outside diameter) copper tubing which was brazed to the plugs.

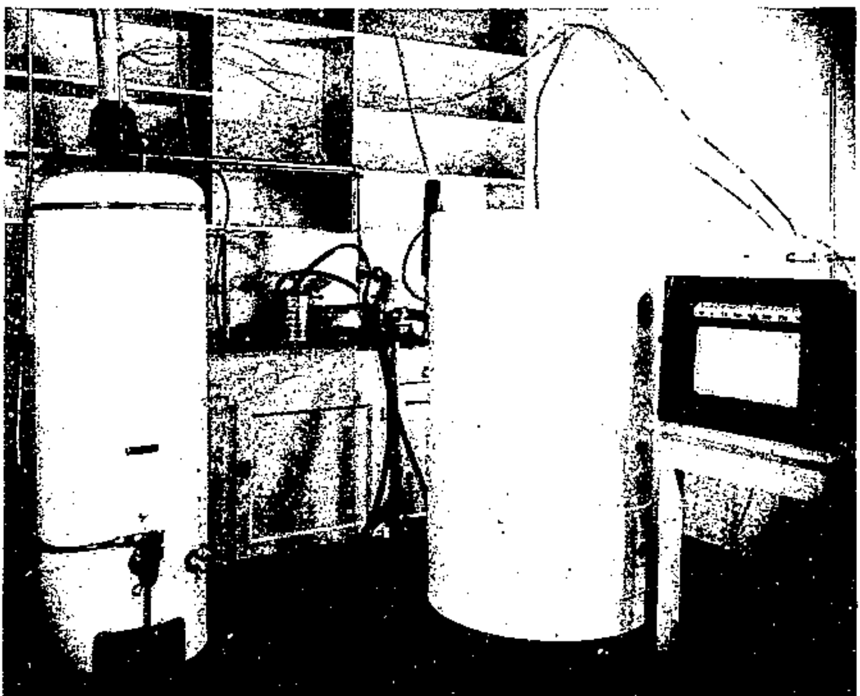

FIGURE 5.—Test setup for gas and electric water heaters.

The tubing was sealed at the lower end and the thermocouple junctions brought out through holes drilled in the tubing and soldered in place to seal the opening. Where possible the tubing was located in the center line of the tank. If there was no tank opening in the center of the top, the tubing was located, by means of a tee, directly beneath the hot-water outlet from the tank.

METHOD OF TEST

The cold-start efficiency of each heater was determined. In the 70° F. room, water was allowed to flow at a steady rate through each heater until the average water temperature in the heater had been at the temperature of the incoming water for several hours. The water was then shut off; and after about an hour temperature and meter readings were taken. The electric heater was then turned on and the gas ignited at the gas-heater burner. Meter readings were taken again immediately after the first operation of the thermostat had shut off the heat supply. The efficiency was determined from the weight of water and its temperature rise and the number of British thermal units required to heat the water to the highest temperature reached during the initial heating.

Each drawoff test was of 24-hour duration. Three drawoff schedules were used. One represented a normal use, the second a laundry-day use, and the third an ASA Standard withdrawal based on 1.7 times the capacity of the larger nominal tank size used, namely, 66 gallons. The laundry-day use was represented by the superimposition of two automatic-washing-machine loads (one right after the other) on the normal use. The drawoffs of 38, 78, and 112 gallons, respectively, were concluded in 16 hours according to the schedule below. Drawoffs from the electric heaters were always made after those from the gas heaters, at times 5 minutes later than those given in the schedule.

Time	*Normal-day drawoff*	*Laundry-day drawoff*	*ASA Standard drawoff*
	Gallons	*Gallons*	*Gallons*
8:15	8	8	12
9:15	3	3	6
9:45	2	14	19
10:00	0	8	0
10:30	0	12	0
10:45	2	10	16
11:45	3	3	15
12:45	2	2	4
1:45	3	3	4
2:45	0	0	8
6:45	0	0	3
7:45	3	3	4
9:15	4	4	6
12:15	8	8	15
	38	78	112

Before each scheduled withdrawal, the incoming water was bypassed into a receiver in which a thermometer was placed to determine the final constant temperature. When this temperature equilibrium was reached, the bypass was closed and withdrawals as indicated were made. Temperature of outlet water was taken at the end of each gallon withdrawn.

CALCULATIONS

Calculations were made on a basis of 100-degree rise in water temperature. Since incoming water was at a temperature of approximately 60° F., the tests were based on supplying 160-degree water. Calculations for the electric heater were made in the following manner: The kilowatt-hour requirements for the period were determined from the meter readings. Corrections were made (1) for the difference in average tank temperature at beginning and end of test, (2) to adjust water-temperature rise to 100 degrees, and (3) for the calibration factor of the meter.

Calculations for the gas heater were made in the same manner except that the correction factor to reduce cubic-foot reading to standard conditions of gas pressure and temperature was used before corrections for tank temperatures and water-temperature rise were made.

The following is a sample calculation based on the data obtained from a 38-gallon drawoff from Heater S.

Data:	Initial average tank temperature	164.0° F.
	Final average tank temperature	161.0° F.
	Temperature of incoming water	60.0° F.
	Cold-start efficiency	95.8 percent
	Tank capacity	62.0 gallons
	Drawoff	38.0 gallons
	Average temperature of drawoff	158.9° F.
	Initial meter reading	482.492 kw.-hr.
	Final meter reading	493.622 kw.-hr.

Uncorrected energy consumption. $493.622 - 482.492 = 11.130$ kw.-hr.

Correction for change in average tank temperature.

Kw.-hr. required to raise 1 gallon of water 1° F. = 0.00242

$$\frac{.00242 \times 62 \times (164.0-161.0)}{0.958} = 0.470 \text{ kw.-hr.}$$

$11.130 + 0.470 = 11.600$ kw.-hr.

Correction for 100° F. temperature rise.

$$\frac{11.600\ (100-98.9)}{98.9} = 0.129 \text{ kw.-hr.}$$

$11.600 + 0.129 = 11.729$ kw.-hr.

Correction for meter factor.

Meter factor = 0.994

$0.994 \times 11.729 = 11.659$ kw.-hr.

Conversion to B. t. u.

One kw.-hr. = 3,415 B. t. u.

$11.659 \times 3{,}415 = 39{,}814$ B. t. u.

COMPARATIVE UTILIZATION OF ENERGY BY ELECTRIC AND GAS WATER HEATERS

The energy consumptions of the eight water heaters are shown in table 25. Although the figures for the electric heaters were very close to each other for all the drawoff schedules, Heater V had the lowest in each case, with Heater T the highest for the 38- and 78-gallon drawoffs and Heater S for the 112-gallon drawoff.

TABLE 25.—*Energy consumption by electric and gas water heaters during 24 hours*

Water heater and drawoff	Cold start efficiency	Temperature of incoming water	Average temperature of drawoff	Water temperature rise	Average tank temperature (from chart)		Energy consumption per 24 hours	
					Initial	Final		
Electric:	*Percent.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Kw.-hr.*	*B. t. u.*[1]
Heater S:								
38 gallons	95.8	60.0	158.9	98.9	164.0	161.0	11.659	39,814
78 gallons	95.8	60.0	156.0	96.0	161.0	162.0	20.997	71,706
112 gallons	95.8	60.0	150.9	90.9	161.0	167.0	29.234	99,832
Heater T:								
38 gallons	92.7	61.0	162.1	101.1	163.0	162.0	11.878	40,564
78 gallons	92.7	61.0	158.5	97.5	162.0	162.0	21.204	72,412
112 gallons	92.7	61.0	148.5	87.5	157.0	162.0	28.924	98,777
Heater U:								
38 gallons	95.3	59.5	146.8	87.3	151.5	142.0	11.795	40,279
78 gallons	95.3	59.5	140.9	81.4	143.0	142.0	20.940	71,509
112 gallons	95.3	60.0	154.5	94.5	162.0	161.0	28.693	97,986
Heater V:								
38 gallons	90.5	61.5	160.4	98.9	162.0	158.0	11.528	39,368
78 gallons	90.5	61.5	158.6	97.1	158.0	158.0	20.784	70,976
112 gallons	90.5	61.5	156.0	94.5	158.0	161.0	28.247	96,465
Gas:							*Cu. ft.*	
Heater W:								
38 gallons	69.2	60.0	159.6	99.6	157.0	159.0	35.677	87,323
78 gallons	69.2	60.0	160.2	100.2	158.0	157.5	51.583	125,612
112 gallons	69.2	60.0	163.3	99.6	157.0	156.0	71.315	167,096
Heater X:								
38 gallons	68.0	61.0	164.1	103.1	165.0	160.5	33.065	79,294
78 gallons	68.0	61.0	159.5	98.5	171.0	170.0	48.810	119,760
112 gallons	68.0	61.0	166.4	105.4	172.0	167.0	68.460	155,258
Heater Y:								
38 gallons	63.2	61.5	158.5	97.0	155.0	152.0	31.579	77,055
78 gallons	63.2	61.5	155.8	94.3	151.0	151.0	45.700	114,119
112 gallons	63.2	61.5	160.7	99.2	151.0	153.0	62.220	148,695
Heater Z:								
38 gallons	62.5	59.5	150.2	90.7	153.5	148.0	27.542	74,900
78 gallons	62.5	59.5	139.2	79.7	148.0	148.0	43.021	128,355
112 gallons	62.5	60.0	151.2	91.2	153.0	148.0	65.315	167,576

[1] The B. t. u. value for the cubic feet consumed by gas heaters was 2,485.

There was more variation among the gas heaters than among the electrics. Heater Z used the least energy for the 38-gallon and the most for the 78- and 112-gallon drawoffs. Heater Y used the least energy for the 78- and 112-gallon drawoffs, and Heater W the most for the 38-gallon drawoff.

For each drawoff, consumption figures were compared to show ratios between the highest gas and lowest electric, the lowest gas and highest electric, highest and lowest electric, and highest and lowest gas figures.

The ratios between the gas and electric heaters show that the rate of increase in energy use with increase in drawoff was less for the gas heaters than for the electric heaters.

RATIOS BETWEEN GAS AND ELECTRIC HEATERS

38-gallon drawoff

$$\frac{\text{Water heater W (highest gas)}}{\text{Water heater V (lowest electric)}} = \frac{87{,}323}{39{,}368} = 2.22$$

$$\frac{\text{Water heater Z (lowest gas)}}{\text{Water heater T (highest electric)}} = \frac{74{,}900}{40{,}564} = 1.85$$

$$\frac{\text{Water heater W (highest gas)}}{\text{Water heater Z (lowest gas)}} = \frac{87{,}323}{74{,}900} = 1.16$$

$$\frac{\text{Water heater T (highest electric)}}{\text{Water heater V (lowest electric)}} = \frac{40{,}564}{39{,}368} = 1.03$$

78-gallon drawoff

$$\frac{\text{Water heater Z (highest gas)}}{\text{Water heater V (lowest electric)}} = \frac{128{,}355}{70{,}976} = 1.81$$

$$\frac{\text{Water heater Y (lowest gas)}}{\text{Water heater T (highest electric)}} = \frac{114{,}119}{72{,}412} = 1.58$$

$$\frac{\text{Water heater Z (highest gas)}}{\text{Water heater Y (lowest gas)}} = \frac{128{,}355}{114{,}119} = 1.12$$

$$\frac{\text{Water heater T (highest electric)}}{\text{Water heater V (lowest electric)}} = \frac{72{,}412}{70{,}976} = 1.02$$

112-gallon drawoff

$$\frac{\text{Water heater Z (highest gas)}}{\text{Water heater V (lowest electric)}} = \frac{167{,}576}{96{,}465} = 1.74$$

$$\frac{\text{Water heater Y (lowest gas)}}{\text{Water heater S (highest electric)}} = \frac{148{,}695}{99{,}832} = 1.49$$

$$\frac{\text{Water heater Z (highest gas)}}{\text{Water heater Y (lowest gas)}} = \frac{167{,}576}{148{,}695} = 1.13$$

$$\frac{\text{Water heater S (highest electric)}}{\text{Water heater V (lowest electric)}} = \frac{99{,}832}{96{,}465} = 1.03$$

APPENDIX. DESCRIPTION OF INSTRUMENTS[7]

U-tube water manometer. To measure gas pressure at point where supply enters laboratory.

Wet-test gas meters, American Meter Company. A. L. 19-100.56, A. L. 19-100.58, and A. L. 19-100.57, capacity 80 cubic feet per hour, reading to 1/100th cubic foot. First two used to meter gas to ranges in kitchen, third to water heaters in test room.

A. L. 18-100.50 and A. L. 18-6706, capacity 20 cubic feet per hour, reading to 1/1000th cubic foot. First used to meter gas to refrigerators in kitchen, second to refrigerators in test room.

Induction voltage regulators, Type AIRS, Form M, General Electric Company. Used to maintain constant voltages of 236 and 118. Serial No. 7570810 used for ranges and refrigerators in kitchen. Serial No. 6794533 used for water heaters and refrigerators in test room.

Voltmeter, Weston, Model 433, No. 26352, range 0 to 300 volts. Connected in line to range as a check on the regulator.

Recording potentiometers, Brown Instrument Division, Minneapolis Honeywell Regulator Company. Model No. 153X65P16-X-1F, Serial No. 338831, range 0° to 600° F. Used to record oven temperatures. Model No. 153X65P16-X-1, Serials Nos. 315939, 324771, 338890, and 324772, range −50° to 300° F. First two used to record temperatures at ranges in kitchen, third to record temperatures at refrigerators in kitchen, fourth to record temperatures at refrigerators and water heaters in test room. One thermocouple of each was used to record room or ambient temperature.

Mercury thermometer, Taylor Instrument Company, No. 21412, range −30° to 120° F., reading to 2° F. Used to measure temperature of water used for cooking and freezing.

Mercury thermometer, C. J. Tagliabue Division, Portable Products Corporation. No. 1754181, 3-inch immersion, range 0° to 220° F., reading to 2° F. Used to determine temperature of incoming water to water heaters.

Mercury industrial thermometers (2), Taylor Instrument Company, No. 11ES510, with separable brass well, 1¾-inch standard thread, range 29° to 150° F., reading to 1° F. Used to determine temperature of drawoff water.

Griddle meter, West Bend. A small round device, 2 inches in diameter and ½ inch thick, having three points on the bottom of the metal case which make contact with pan or griddle. Heat is conducted to a metal coil, the expansion of which causes a pointer to move across a scale. The scale reads in degrees from 275° to 525° F. Used to measure temperatures for all frying operations.

Electric clock and timers. Electric kitchen clock with second hand, Sessions. Used in recording start and finish time of all operations in kitchen.

Electric desk clock with second hand, General Electric Company. Used in recording start and finish times of runs and individual operations in test room.

Electric timers, Standard Electric Time Company. Timers have minute and second hands and are controlled by hand switches. Used for timing mixing and cooking operations.

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[7] Mention of instruments or manufacturers does not imply indorsement by the Department of Agriculture, or discrimination against other products.

Combination counter and timer (for refrigerator door openings). In this ensemble, powered from the lamp socket in the refrigerator, were (1) an electromagnetic relay and a light bulb to supply current for its action, (2) a counter and a desk clock (General Electric) operated by the relay so that the counter registered each door opening and the clock ran while the door was open, and (3) a watt-hour meter (Westinghouse, Type OC, Serial 90149F, reading to 1/100th kilowatt-hour) to record the energy used by the ensemble.

Kilowatt-hour meters, General Electric, two-element, Type V2S, reading to 1/100th kw.-hr. (estimated to thousandths).

Model AC153, Serial No. 21286519. Used on refrigerators in kitchen.

Model AJ1, Serial No. 21254129. Used on ranges.

Model AE 253, Serial No. 30518454. Used on water heaters in test room.

Model AC153, Serial No. 19860768. Used on refrigerators in test room.

Wattmeter, General Electric, single-phase, Type P3, Serial No. 1181773, dual range, 0 to 500, and 0 to 2,000. Used for determining power inputs of range units.

Watt-hour meter, Westinghouse, portable single-phase, style number 718305, Serial No. 1167327 (a standard meter). Used for calibrating kilowatt-hour meters used.

Time control, Automatic Temperature Control Company, Type 4101-A, Serial No. T-11465. Used to control the operation of the potentiometer at the refrigerator so the temperature record could be made for 5 minutes out of each hour.

Water meter, Buffalo Meter Company, Model DF1, reading to 0.25 gallons. Used in incoming-water line for measuring drawoffs from water heaters.

Platform Scales, Fairbanks, Morse and Company, Number 1204, capacity 400 pounds, sensitive to 0.25 ounce. Used to weigh water in determining tank capacity of heaters.

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