TEMPERATURE *and* HUMIDITY STUDIES

Effects of Using Electric Range Surface Units for a Medium-Length Cooking Process

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TEMPERATURE *and* HUMIDITY STUDIES

*Effects of Using Electric Range Surface Units for a Medium Length Cooking Process**

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SUMMERS in the Southeastern States are typically long, warm, and humid, especially near the coast. Maintenance of summer comfort in the home is often difficult. When the house is kept cool by shading and opening it to the breezes, atmospheric moisture condenses on the cooler surfaces. Mold and mildew often follow in the wake of the condensation.

When the house is closed against heat from the outside, internally produced heat and moisture become a problem. If air conditioning is employed to cool the house, heat and moisture add to the load of the cooling system and increase operating costs.

Heat production is the function of some household appliances. Since none performs with 100 per cent efficiency, heat from appliances contributes to the heat of the house. Processes carried out in connection with some appliances produce moisture.

In winter, heat transmitted from appliances to the house is useful. When the general heating system performs in such a way as to reduce humidity to uncomfortably low levels, some production of atmospheric moisture adds to the winter comfort of homes. However, excessive humidity in winter causes condensation on cold surfaces, such as window panes and uninsulated outer walls. In both summer and winter, interiors of closets and other large storage spaces may be the coolest part of the house. If so, excessive atmospheric moisture tends to be adsorbed on surfaces in these places, and promotes growth of mildew and mold, and production of musty odors.

Two approaches to the solution of temperature and humidity problems are control of production of heat and moisture and overcoming the results. For both, a knowledge of production is of first importance.

When a homemaker cooks she is usually more interested in the results in terms of food than in what happens to the temperature and humidity of the house. Such practices as using plenty of water so the pan will not boil dry, moving the pan to the side of the unit to keep it from boiling over, choice of kind and size of pan, and type of lid might conceivably affect not only temperature and humidity levels, but also input requirements of the range.

This report is a part of a study planned to determine the effects of using selected home appliances on temperature and humidity conditions. Cooking appliances were studied first. The process first selected for study was boiling a vegetable requiring a medium-length cooking time. This was studied in three series of tests.

Series A was largely exploratory. Comparisons were made among units of various types and sizes and having different controls, use of different input programs, different pans, and different amounts of water. Series B used one pan and unit and compared two kinds of lids and centering or decentering pans on the unit at three input levels. In Series C two pressure pans and regular pans with two amounts of water were used on each of four units. Units having regular controls were compared with one having thermostatic control and one having speed heat start, infinite control.

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** Resigned.

Laboratory and Instrumentation

BUILDING AND TEST ROOM

The project was conducted in a wood frame building on a concrete slab floor, the perimeter walls of which were covered with drop siding, and inside with T&G V-siding. There was no insulation in the outer walls. Inside this building, a well-insulted test room was built on blocks. The top of the test room was lower than the ceiling of the outer building. Thus, air could circulate below and above the test room. Floor plans of main building and test room are shown in Figure 1. Details of structure and insulation, and vertical dimensions of test room and ambient room are given in Figure 2. Various views of the test room are shown in Figure 3. Test room doors were wide to allow large appliances to be moved in and out. An entrance hall, or anteroom, provided insulation for the doorway, Figure 1. Spring bronze weather stripping was used to make both sets of doors close tightly.

HEATING, AIR CIRCULATION, AND HUMIDITY CONTROL

The main building was heated by two vented and thermostatically controlled gas space heaters each having a capacity of 85,000 BTU per hour. Fans of these heaters cycled thermostatically or operated continuously according to switch setting. Two large fans circulated the air around the test room. Two small fans moved the air above and below the test room. A dehumidifier was used in summer to reduce humidity as necessary in the main building during tests and in the test room between tests for series B and C.

COOLING SYSTEMS

The outer building was not air conditioned for the series reported here. However, the roof was shaded by trees in summer and the attic was vented by an attic fan that could be used also for drawing outside air through the ambient room.

Three 1-ton air conditioners were installed in the walls of the test room. The thermostats of these air conditioners were replaced by special ones that could be located at distances up to 11 feet from the left end of each air conditioner. The special thermostats could be set to maintain average temperatures at any level between 66° and 94° F. For the three series of tests reported here, one air conditioner was used at a time for cooling the test room after a test was completed or for circulating air in the test room during tests. The air stream flowing from the air conditioner used during tests was directed by three sets of louvers in the air conditioner and a curved baffle on the ceiling in such a way that air was circulated about the test room without excessive drafts and with a minimum of undisturbed air space as indicated by streamers of thin paper fastened in various locations.

CIRCUITS FOR ELECTRIC METERING AND VOLTAGE CONTROL

Meters and voltage control for appliances were located outside the test room. Wiring from the distribution panel was brought to receptacles attached outside test room walls. Receptacles inside were connected by rubber-covered cables passed through the wall and connected to out-

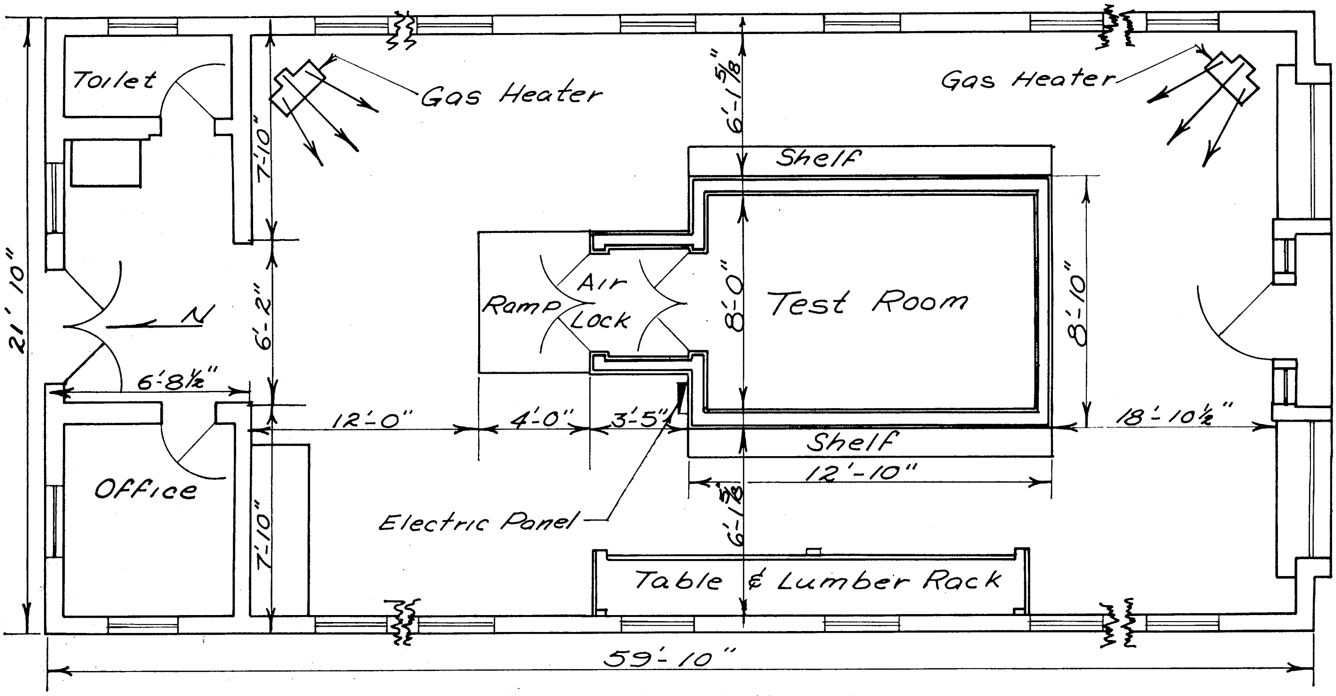

FIGURE 1. Floor plans of main building and test room.

side receptacles by attachment plugs. Any appliance inside the test room could be energized or disconnected outside the room. Metering sets and voltage regulating devices also could be interposed between the electric supply and the appliance under consideration. Figure 4 shows the set prepared to regulate voltage and measure watt-hour consumption of the range. Later a recording ammeter with two current transformers was interposed in the set at points X and X′.

The wiring diagram is given in Figure 5. The method of connecting transformers with ammeter shown in this figure allows currents on both 115-volt circuits to operate additively in deflecting the meter pen, as indicated by arrows. The current of the 230-volt circuit is thus registered twice by the ammeter. However, if wattage values are desired, the recorded value for amperes may be multiplied by 115 (or the voltage of each leg of the circuit) to give volt-amperes. For resistance circuits, this value is considered practically equal to watts.

The ceiling lamp in the test room was metered separately.

TEMPERATURE MEASURING SYSTEM

Copper-constantan thermocouples were used with a 16-point electronic temperature recorder. This instrument had an accuracy of ± 0.2 per cent of scale span or ± 0.35° F. Three 10-point selector switches were connected in series for use with the temperature indicator, Figure 6. It had an accuracy of ± 0.5 per cent of scale span or ± 2° F. Neither of these ranges includes the inaccuracies of thermocouples. The recorder was used for observations inside the test room and for air temperatures ambient to it. The indicator was used for observations of temperatures within the walls and ceiling of the test room and of the air above and below it.

Temperatures of the test room were measured in panels at various points on the walls and ceiling, on the surface of the range, in the air, and within the walls and ceiling at locations interior and exterior to the insulating batts. For series C, a temperature measurement was made in a 4 × 5-inch copper float ball, painted dull black and suspended in front of the range. The thermocouple at the north end of the west wall was diverted for use in the globe. Ambient air temperatures were measured outside the test room at each corner. Thermocouple locations are shown in Figure 7.

For measuring wall and ceiling temperatures, panels approximately 5½ × 6 inches were cut from finished hardboard wall covering like that used on the test room walls. This material was 3/16 inch thick. At mid-point along one edge, a hole 1 inch deep was drilled edgewise and centered between the two surfaces with a 5/64-inch drill. The thermocouples were wound with tape about ¼ inch from their junctions. When the couples were inserted to full depth of the holes, the tapes served as plugs to hold the couples in place. The panels were attached to walls and ceiling with masking tape. Those on the ceiling were also secured with two metal screws to hold them in place.

Thermocouples attached to the surface of the range and other items were fastened to thin aluminum strips with sealing wax. The strips were placed on the surface of the range, held in place and covered with two small adhesive bandages and two layers of masking tape. Since

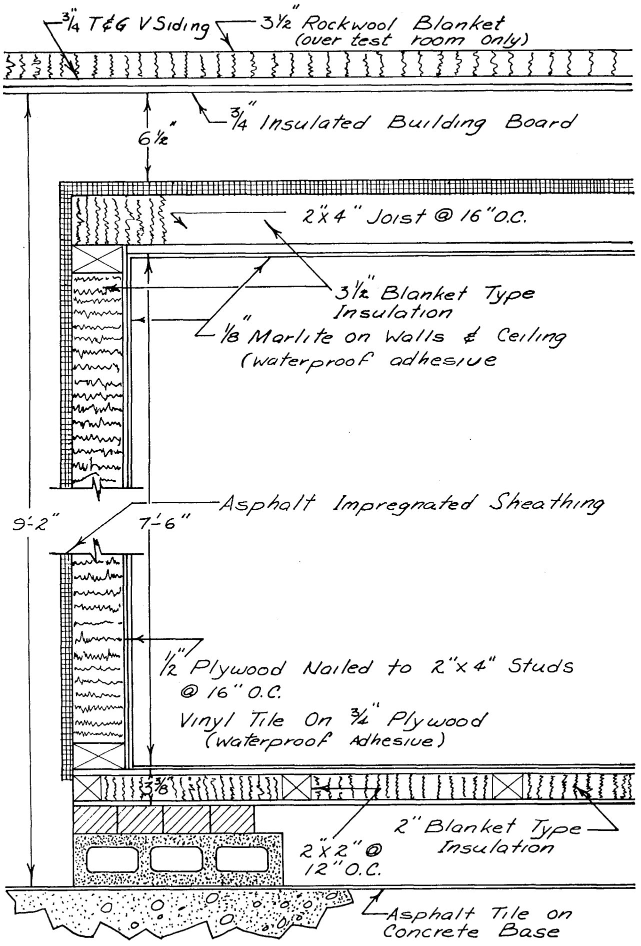

FIGURE 2. Section of test room showing floor and ceiling of main building.

the two ranges were used alternately for series A, the thermocouples of each were led to a connecting board and from it to the temperature recorder.

For measuring temperatures within the walls and ceiling of the test room, holes were drilled through the outside sheathing of the walls to receive ¼-inch glass tubing. In each wall one hole was drilled through the outer sheathing only and another through the sheathing and the insulating batt but not into the inner sheathing. The glass tubes, open at both ends, had stops to position them at desired depths. A thermocouple was inserted in each tube so that its junction just reached the inner end of the tube. Tape wound on each thermocouple served to position it in the tube as well as for a stopper. Thermocouples for measuring temperatures within the test room ceiling were installed similarly from the underside of the ceiling.

Junctions of thermocouples used for measuring air temperatures of the ambient room were covered with cellophane tape and wrapped in heavy aluminum foil. This much weighting reduced sensing of fluctuations caused by nonuniformity in air temperatures, but allowed operators to anticipate thermal overshoots of heated air in time to prevent undesirably high temperatures by manual operation of heater thermostats and other means. (See Appendix p. 50.)

In the walls and ceiling of the ambient room, thermo-

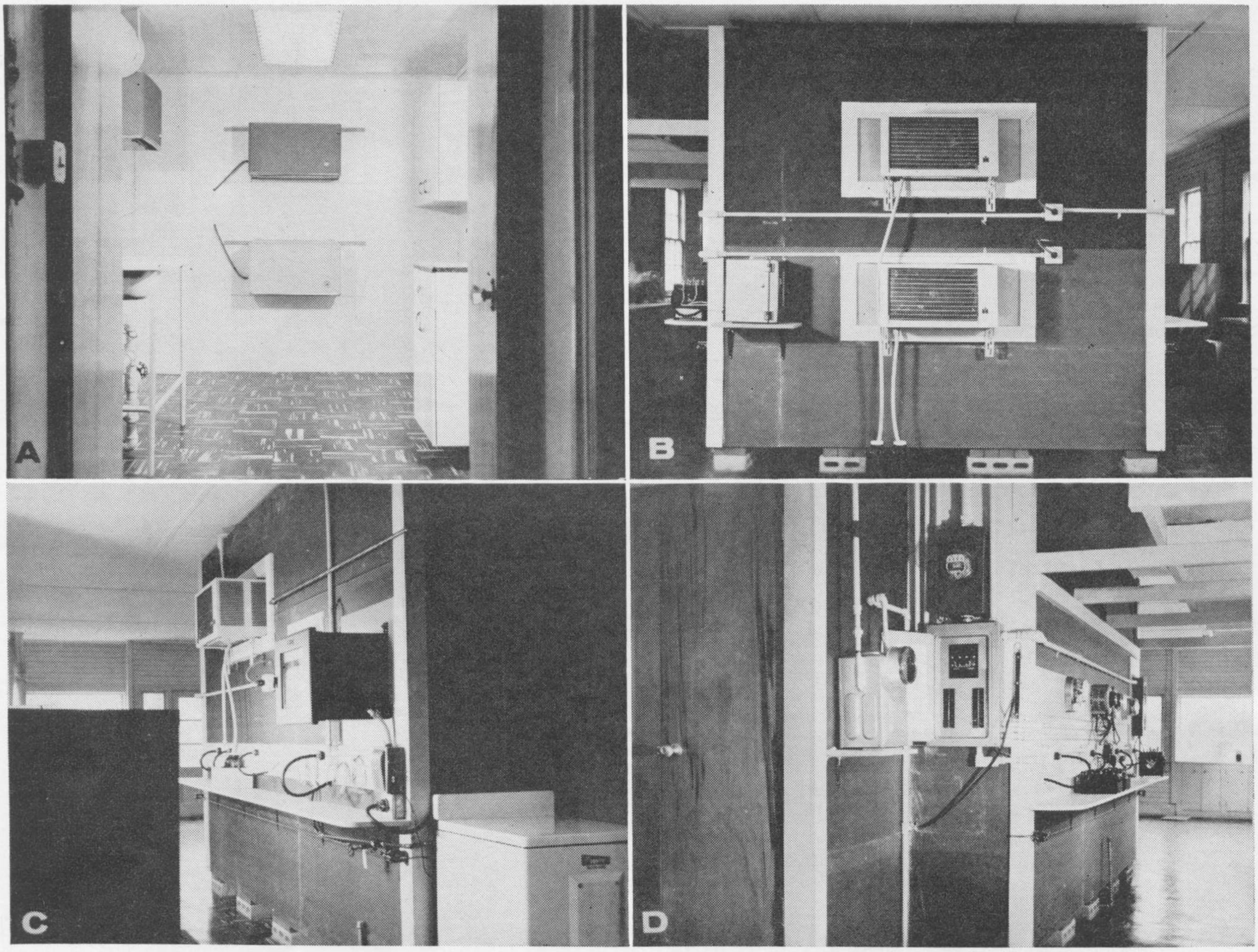

FIGURE 3. Test room: (A) interior as seen from north and before room was completely equipped; (B) exterior from south end; (C) exterior east side showing temperature recorder near northeast corner; and (D) exterior west side showing gas meter, electric meter and circuit breaker in foreground, voltage control, and electric metering arrangement along wall.

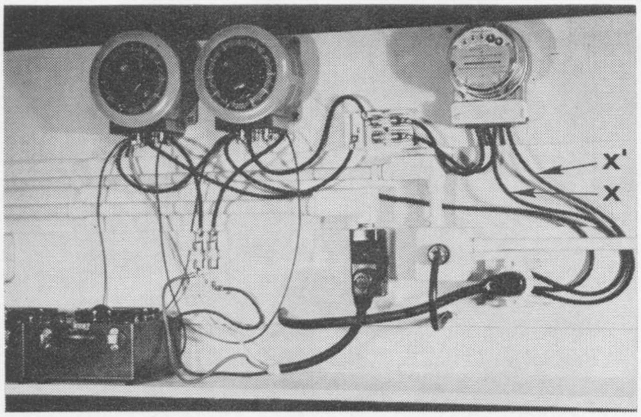

FIGURE 4. Instruments and connections for regulating voltage and measuring watt-hour consumption. Recording ammeter with current transformers was added at points X and X′.

couple junctions were inserted in holes drilled in the surface material. Thermocouples in these locations were used to predict the possibility of having temperatures suitable for carrying out tests.

Temperatures in the cooking pans, except pressure pans, were taken for series A by means of a thermocouple the junction of which was placed in a glass tube sealed at one end. The tube was inserted through a hole in the lid of the pan and held in place at least ¼ inch above the bottom of the pan by tape attached to tube and lid. Since the glass tube retarded sensing temperature changes, boiling was often observed visually before it registered on the temperature indicator.

For series B and C a thermocouple with a metal protecting tube was fitted into a rubber stopper, Figure 8, which rested on the lid and held the tube in position in the pan. To hold the tube in readiness for use and to prevent tipping when in the pan, the tube was suspended from ceiling hooks suitably located for each unit used. Suspension was by a nylon fish line with one end attached to the tube, the other to a counterweight.

The protecting tube was readily sensitive to temperature changes. It was held away from the potatoes by a cylindrical cage made of ¼-inch mesh hardware cloth. Two cages approximately 2 inches in diameter were made. The one for the sauce pan was about 3¼ inches high, the other for the frypan, about 2½ inches high. Each had two

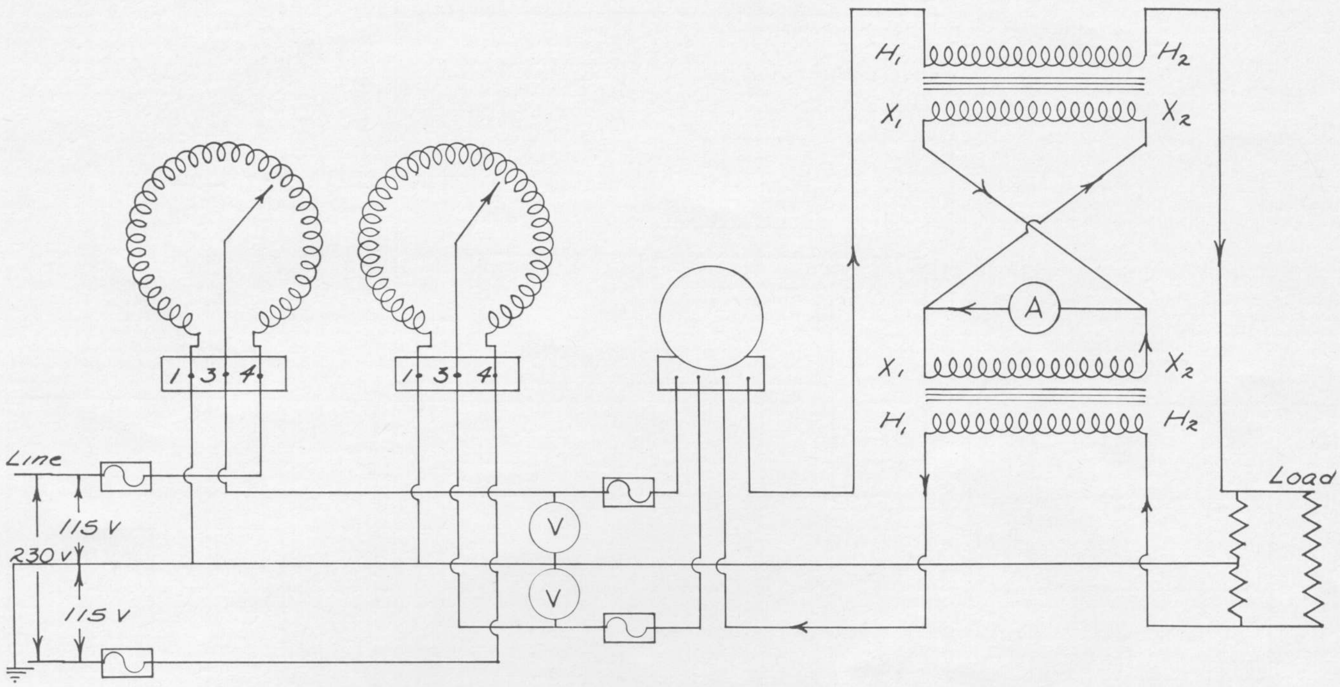

FIGURE 5. Wiring connections for regulating voltage and for electric metering.

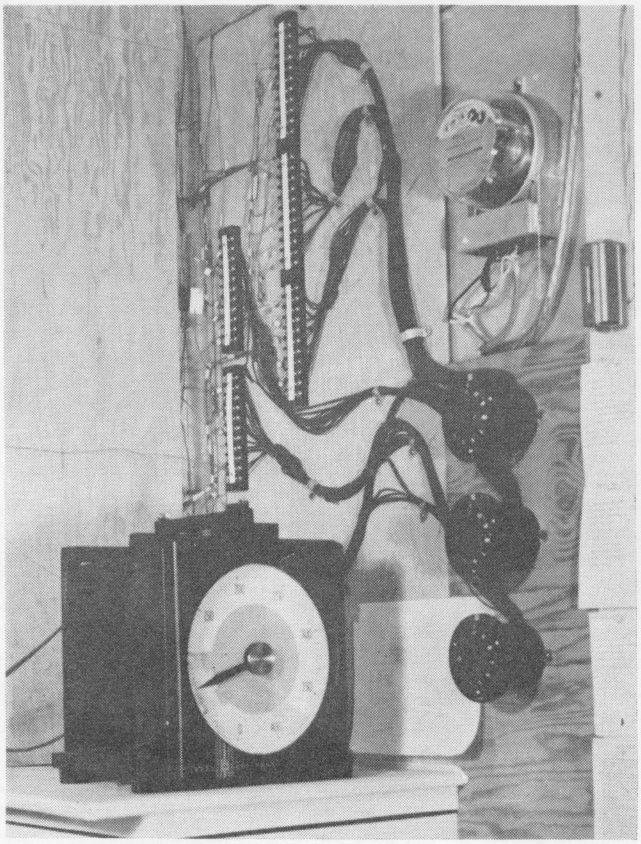

FIGURE 6. Temperature indicator, switches, and connections are shown here.

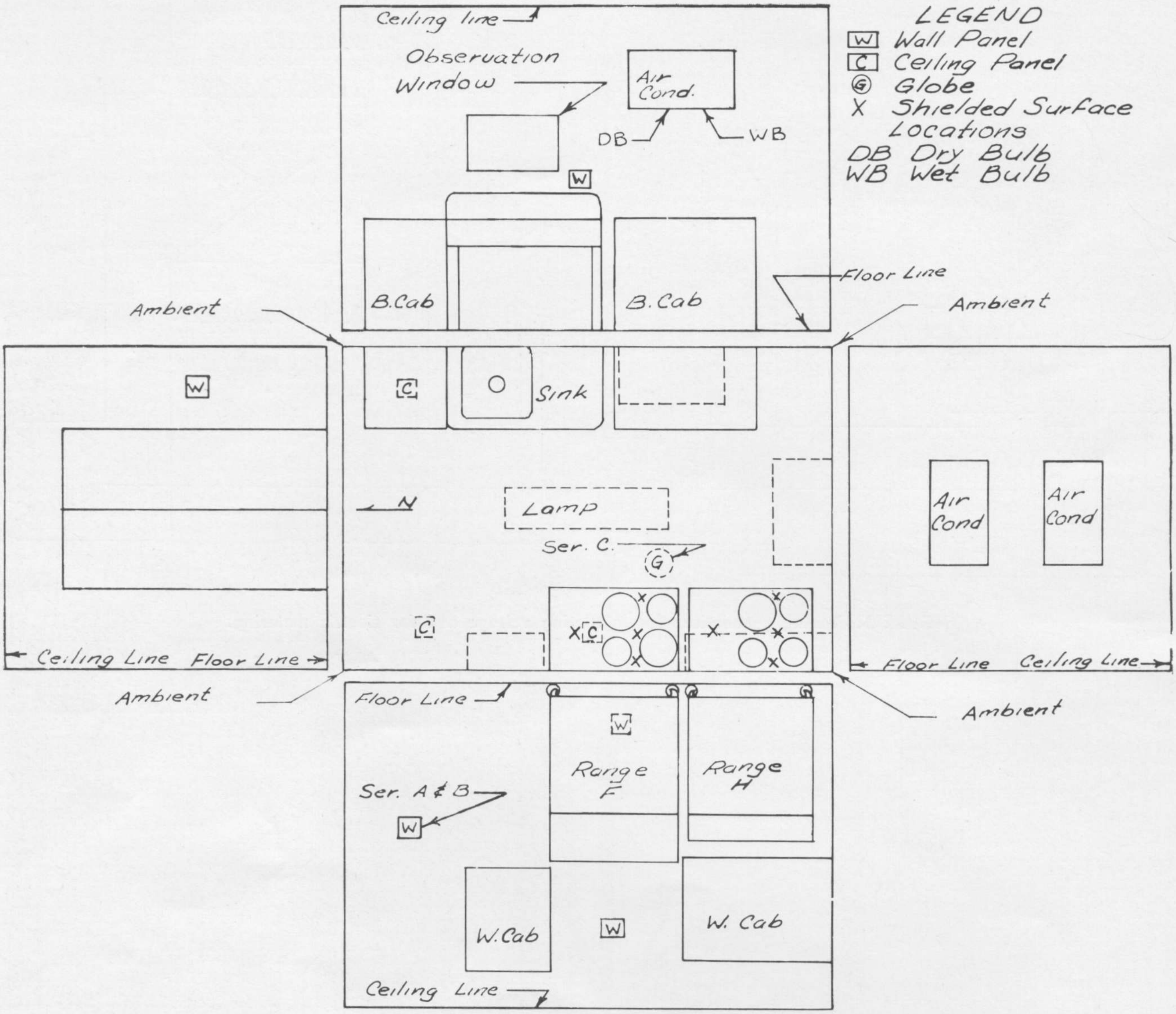

FIGURE 7. Diagram showing thermocouple locations.

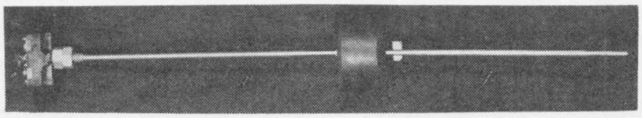

FIGURE 8. Thermocouple protecting tube with stopper for positioning tube in pan.

pairs of threads that crossed near the center of the cage. When the thermocouple tube was put in the pan, it was inserted between the two pairs of threads.

HUMIDITY MEASURING DEVICE

Wet- and dry-bulb temperatures for determining humidity were observed by means of two thermocouples the junctions of which were covered by glass tubes with one end sealed. One of these was covered at the closed end with a tubular wick that was kept moistened with distilled water. Both of the tubes with thermocouples were clamped into the air conditioner so that they were held in the return air stream at the same angle. Both extended into the air conditioner for the same distance.

Appliances and Pans

For series A, two electric ranges were used, Figure 9. For series B and C, only Range F was used. Range H was a standard model with two-tube units. The one large unit was rated at 2600 watts; the small ones used were rated at 1250 watts. These units operated at five heats by means of a six-position rotary switch. The control positions were marked *high, second, third, low* and *warm.*

Range F, a *de luxe* model, had one-tube units, all of which had rotary switches. The large left rear unit, rated at 1600 watts and located at the bottom of a deep well, was a lift-up unit that could also be used for surface cooking. The two rear units each had six-position switches that provided five levels of input: *high, medium high, medium low, low,* and *simmer.*

The small left front speed-heat unit was marked like the two rear units, but the control could be set at any point between these marks. Rated 1250 watts at 118 volts, it operated at 5000 watts and 236 volts for 27 to 35 seconds after it was turned on from a cold start. The manufacturer describes the operation of this unit as follows:

> At the end of the initial period the control automatically converts the electrical supply to the unit back to 118 volts and 1250 watts. On *high* heat there is no interruption in this supply and the full rated wattage of the unit is in constant use. On lesser heats a bimetal controlled contact in the control opens and closes to provide heat comparable to a lesser wattage. The lower the control is set the more *off* time is recorded for the contacts in the control.[1]

The initial use of 5000 watts heated the bimetal control so that at settings other than *high* no input was supplied this unit for a period long enough that temperature of the contents of the pan dropped. Thus, in spite of the speed start, the unit had to be set at *high* to start boiling in the pan. When the setting was reduced, the current was interrupted for a long enough time that boiling stopped.

The right front unit, rated at 2050 watts and 118 volts, was thermostatically controlled by a sensing element located in the center of the unit and in contact with the cooking vessel. It had words and numbers to indicate levels of control. They were: *warm,* 1, 2, 3; *boil,* 4, 5; *fry,* 6, 7, 8, 9. The manufacturer describes the control of this unit as a combination of thermostatic control at two levels and a pulsing relay that operates at two levels, giving a total of four levels. This control supplied the full 2050 watts for 10 seconds at the beginning of a cold start, then switched to the pulsing relay at a lower level. However, it had an anticipating control that reduced the wattage further when the vessel reached a temperature 25° F below the setting selected. It cycled at higher levels when the setting was within the *fry* part of the dial, and at lower levels when the setting was lower than *fry.*[2]

The pans used in these three series are shown in Figure 10. Their descriptions are given in Table 1, which also lists the series in which each was used. The sauce pan, chosen to use on small units, conforms with the standards for cooking pans used in testing performance of electric range surface units as set forth by the National Electric Manufacturers Association[3] with the exception that its sides are slightly curved rather than vertical. The frypan meets NEMA standards with the same exception. It was chosen to use on large units because sauce pans of the correct diameter were unnecessarily deep for the amount of food used.

FIGURE 9. Thermocouples are shown in place on surfaces of Range H (above) and Range F (below).

FIGURE 10. Pans, top row: deep-well inset and cooker-fryer. Bottom row: pressure pan B, pressure pan A, sauce pan, and frypan.

[1] *Frigidaire Service Teck-Talk.* Vol. V, No. 7A, Nov., 1954. Model RV Frigidaire Electric Ranges, pp. 154-156.

[2] Ibid.

[3] National Electric Manufacturers Association. *American Standard Household Electric Ranges.* Publication No. ER 1-1950. June 1950. Paragraph 10.2.1, p. 12.

Table 1. Description of Pans

Pan	Diameter	Capacity	Weight[1]	Gage of material[2]	Used in series
	In.	*Qt.*	*Gm.*		
Frypan	9	1½	970	8	A,C
Sauce pan	7½	3	896	10	A,B,C
Deep-well inset	8½	6	834	16[3]	A
Pressure pan A	8⅝	4	2165	5[3]	A,C
Pressure pan B	8¼	4	2166	8[3]	C
Cooker-fryer[4]	9½[5]	6	3295	5[3]	A

[1] Including lid. For pressure pans, includes also trivet, gasket, and regulator.
[2] All pans of stamped aluminum including well of cooker-fryer. Jacket of cooker-fryer of chrome-plated steel.
[3] Estimated by measurement.
[4] With self-contained electric unit.
[5] Diameter of cooking well.

The pressure pans were sealed by means of V-type gaskets held in place by locking the flange of the lid over the flange of the pan. Pressure pan A had a rocking regulator. Regulation of pressure could be reduced from a maximum of 15 pounds to 10 and 5 pounds by removal of weight rings. The air exhaust and safety plug was made of rubber with a center metal piece that was pushed against the rubber when pressure began to build in the pan.

The regulator of pressure pan B had three cylindrical cavities with indentations of three sizes at the interior end. Use of the cavity with the smallest indentation gave a pressure of 15 pounds, and use of the larger ones 10 and 5 pounds. Excess pressure lifted the regulator and allowed air and/or steam to escape. The safety plug was made of fusible metal.

The 6-quart electric cooker-fryer, used in series A tests, was thermostatically controlled and was rated at 1400 watts. Selection of this appliance was based on preliminary trials of it and an electric frypan. Of the two, the cooker-fryer could be regulated to maintain boiling temperatures with lower evaporative loss.

Food—Selection, Preparation, and Storage

A simple cooking process was considered desirable for the first experiments of this study. White potatoes were selected as representative of vegetables requiring a medium-length cooking time. They were boiled because this process does not require lifting the lid from the pan. Idaho potatoes were used since they are available for a great part of the year. They were cooked unpeeled to further simplify preparation.

Enough potatoes were purchased at one time for one replication of each treatment of a series plus enough for three or four extra treatments. The potatoes were weighed individually at the market to 6 ± 1 ounces. At the laboratory they were weighed in batches of six potatoes. The batches for series A and the first replication of series B were weighed to 1000 ± 5 grams on the assumption that after storage and cleaning they would have weights between 990 and 1000 grams. However, decreases were greater than anticipated and adjustments were made. For the second replication of series B, batches weighing 1015 ± 2 grams at the time of storage had the desired weight range at time of cooking. For series C, potatoes of the desired size were so scarce that heavier ones had to be purchased. Weights of these batches at time of cooking ranged from 999-1010 grams, which was heavier than desired.

After each batch was weighed, it was placed in a plastic bag and stored in a refrigerator until used. The batch for each test was randomly selected as needed. Batches left over at completion of a replication were separated and distributed among batches for the next replication or series.

General Preliminary Tests

Before any of the series of experiments with cooking food was attempted, methods were devised for stabilizing temperatures in the test room and controlling temperatures in the ambient room.[4] Experiments were done to determine whether known differences in heat input would produce observable differences in temperatures of the test room. Finally, an experiment using high and low levels of input for boiling water and holding it at boiling for 30 minutes with and without a lid on the pan showed that under these circumstances readily observable changes in both temperatures and humidity of the test room were produced.

[4] These methods are given in the Appendix, page 50. Temperature specifications are given in Table 2, page 11.

Preliminary Tests for Each Series

When the design for a series of tests was made and the general conditions for each treatment had been set up, preliminary tests were carried out to determine specifications for each treatment. Two of the specifications – pattern for control settings of the range unit and amount of water to be used – were to some extent interdependent. The control pattern, unless otherwise specified, was the one with the lowest input that would perform the cooking operation. The amount of water, unless specified otherwise, was the least that would cook the food and was always sufficient to prevent the pan from boiling dry without addition of more during the cooking period.

In addition to these specifications, a manual of procedure was developed. The procedure was basically the same for all tests but had to be modified as required for the tests of each series. Also some alterations were made as improvements in instrumentation and technique were put into effect.

General Procedure

The treatments of each series were done in random order except that all the treatments of the first replication were completed before those of the second were started, and so on, each set of replicates being completed before the next was started. This was done to avoid as far as possible effects of weather or other cumulative effects on any treatment.

The general procedure for carrying out treatments was:

1. Control temperatures of ambient room.

2. Stabilize temperatures and humidity[5] of the test room at specified levels, Table 2.[6]

3. Perform the cooking operation according to specifications.

4. Measure evaporative loss from pan, power consumption of appliance and lamp.

5. Record during entire test (a) operation pattern of appliance, (b) temperatures at specified locations, (c) humidity of test room, (d) time operator is in test room, and (e) any subjective feelings about the comfort of the test room.

6. Estimate heat output of worker for period she is in the test room.

Temperatures of test room were held as stable as possible between tests by maintaining correct temperatures in ambient room, operation of test-room air conditioner in warm weather, and energizing electric lamps in the test room in cold weather. For 30 minutes or more before tests, the test-room air conditioner was operated at *fan only,* and any necessary cooling was done with pans of ice or cans of frozen *Scotch Ice* and *Magic Cold.*

An attempt was made to maintain humidity at desired levels in damp seasons, first by exposing bags of calcium chloride and later by using a dehumidifier. The latter was more effective. The two methods were used in the test room between tests and in the ambient room during tests. Use of either had a heating effect on the room and at times it was difficult to stabilize temperature and humidity concurrently. During the seasons when heaters were used in the ambient room, humidity was increased by exposing pans of water and wet towels in the test room.

Potatoes to be cooked were taken from storage, prepared, and placed in test room in the afternoon before a test. Water to be used was kept in a covered container in the test room. Thus, these materials were at room tem-

Table 2. Temperature and Humidity Specifications

Location	Thermocouple	Temperature
	Number	*Degrees F.*
		Starting Tests
Wall and ceiling panels inside test room	1,3,5,7,9,11,13,15[1]	80
Range surfaces	4,8,12,16	80
Water tank surface	A-8, -9	80 ± ¼
Globe temperature	5 (Series C only)	80
Interior air	A-10	80 ± ¼
Within walls and ceiling of test room		
Inner points	A-1, -2, -3, -4, -5	80 ± ¼
Outer points	B-1, -2, -3, -4, -5	80 ± ¼
Outer points when outdoor temperature is 80° F or more	B-1, -2, -3, -4, -5	78 ± 1¼
Ambient air		
Middle level	2,6,10,14	80 ± 1
Middle level when outdoor temperature is 80° F or over	2,6,10,14	79 ± 2
Between ceilings	B-10	80 ± 1
Under test room	C-1	79 ± 1
Air lock	C-7	80 ± 1
Ambient air		**During Tests**
Middle level	2,6,10,14	80 ± 2
Between ceilings	B-10	80 ± 1
Humidity for Starting Tests (Series B and C only) 6-7 grains per cubic foot		

[1] Thermocouple 5 was used here in series A and B only.

[5] Humidity was not stabilized for series A treatments.

[6] The temperature specifications of Table 2 had ranges smaller than the range of accuracy of the instruments. However, it had been ascertained in preliminary trials that, in order to have reproducibility of results, the temperatures indicated by the instruments had to be within the ranges specified in the table with few exceptions permitted for each test.

perature at beginning of tests. Pan assembly, food, and water were weighed before and after cooking to determine evaporative loss.

Before a test was started, the circuit to the appliance was de-energized, the pan of food carefully placed on the unit, the thermocouple placed and adjusted, and the dial preset at the first control setting for the test. At the beginning of the test, a worker designated as *inside operator* entered the test room when another designated as *outside operator* energized the appliance circuit. From this time the inside operator controlled the appliance according to specifications, and removed and weighed pan at end of test. The outside operator controlled the voltage and the temperature of the ambient room, and read the temperature indicator.

During tests the air conditioner in test room was operated at *fan only*. Panel temperatures at some locations might have risen higher without the air motion. On the other hand in some tests in which temperature and humidity were high, the inside operator might not have been comfortable enough to think clearly, although she wore a sleeveless, low-necked uniform to compensate for the high temperature and humidity levels. Also, operation of the air conditioner fan provided air circulation required for humidity observations.

Voltage of appliance was controlled during tests to $118 \pm 1/236 \pm 2$ volts for range, 115 ± 1 volts for small appliance. Operation pattern of appliance was recorded by a curve-drawing ammeter.

The inputs of the appliance and lamp, obtained by readings of the watt-hour meters, were converted to BTU's by using the factor of 3.412 BTU's per watt-hour.

Temperatures and humidity were recorded as explained on pages 5 through 8.

Estimate of the heat output of worker was calculated according to Taylor, MacLeod, and Rose[7] as follows:

Total calories = Basal + Activity allowance + S.D.A. allowance,

in which Basal = Cal./sq. m./hr. × surface area × time. Cal./sq. m./hr., obtained from table, = 34.4 (for age 20-30). Surface area, obtained from chart, was based on weight and height.

Activity allowance = cal./kg./hr. × weight × hours Cal./kg./hr., obtained from table, = 6 (paring potatoes).

S.D.A. allowance = (Basal + Activity allowance) × .10.

The total calories obtained in this manner were converted to BTU's by the formula Cal. × 3.968 = BTU's.

The more specific manual of procedure is given in the appendix.

Since the design and procedure of each succeeding series was more or less determined by results and conclusions of the preceding series, each of the three series is discussed separately.

Analysis of Data

Temperature records of locations on the range, walls, and ceiling, and in the air test room were graphically analyzed by means of temperature-time charts. These served to present a general view of the temperature patterns resulting from each treatment and to show the maximum temperatures at each location.

Bar graphs were also made for various measures (power consumption, evaporative loss, gain in humidity, and maximum temperatures observed at each location) for each treatment and in some series for each test. These were used to help visualize relationships between treatments and between various measures when interpreting the results.

Statistical analysis of data was also made. For series A the various effects of pairs of treatments for each measure (power consumption, evaporative loss, gain in humidity, and maximum temperatures at various locations in the test room) were analyzed by Student's t-test. This method of analyzing pairs gave more precise results, but presentation of results of such tests failed to show clearly the relationship among all the treatments of the series. Although for this series comparisons of results of every pair were not especially desirable, many comparisons were needed. Use of Duncan's New Multiple Range Test permitted comparison of results of any pair of treatments. This test was used to determine differences in ranked treatment means for each measure. As method of analysis, it was considered especially useful in the case of series A, which was exploratory in nature. It was advantageous to make many individual comparisons between the several treatments as well as to determine the relative position of average observations in a set.

This test was done after an analysis of variance table was constructed for each measure. The error mean square was obtained from this table and used to compute the standard error of a treatment mean. This result was multiplied by values from tables for Significant Studentized Ranges at the 5 and 1 per cent levels of significance to obtain the shortest significant ranges. These ranges were then compared to differences in the array of means. A line was shown adjacent to each group of means that were not significantly different. Any pair of means not included in the range of any one line is considered to differ significantly; that is, unless a 1-in-20 or 1-in-100 chance of sampling (or less) has occurred a true difference exists between the two means. The means without adjacent lines are declared significantly different from all other means.

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[7] Clara M. Taylor, G. MacLeod, and M. S. Rose. *Foundations of Nutrition.* 5th Edition N.Y. The Macmillan Co. 1956.

Series A Experiments

DESIGN

The treatments of series A were planned to explore various practices in using electric range units that might be expected to cause measurable and significantly different temperatures and humidities in the test room. Practices considered were choice of: type, size, and control of unit; an alternate electric cooking appliance; input level; and pan.

A series of 11 treatments was planned to compare the effects of the following pairs of factors—

Input level: Highest and lowest inputs that would maintain a boil.

Unit type: Two-tube and monotube units.

Unit size: Large and small units with appropriate pans for each.

Lift-up unit: Use of this unit for deep-well and surface cooking.

Controls: Regular six-position control and speed heat start, infinite control. Regular six-position control and thermostatic control. Thermostatic and speed heat infinite control.

Pans: Pressure pan and regular pan.

Appliance: Alternate electric appliance and range units with pans.

Through an error in copying specifications, another comparison developed. In one treatment, 240 grams of water was to be used. However, 480 grams was written by error into the specifications. This treatment, done twice before the mistake was discovered, was repeated twice with the correct amount of water. By this means it was possible to compare the effects of using different amounts of water under otherwise equal conditions.

SPECIFICATIONS

The specifications for series A treatments are given in Table 3. These specifications were arrived at by preliminary study and testing on the basis of the following descriptive outline:

1. Cook six potatoes on small 1250-watt unit of range F. Use *high* setting until water boils and then lowest setting that will maintain a boil for 30 minutes.
2. Repeat 1, except use range H.
3. Repeat 1, except use *high* setting for 30 minutes after the water boils.
4. Repeat 3, except use range H.
5. Repeat 1, except use large regular unit (1600 watts) of range F.
6. Repeat 1, except use large regular unit (2600 watts) of range H.
7. Repeat 5, except use deep-well inset.
8. Repeat 1, except use the speed-heat unit of range F.
9. Repeat 1, except use thermostatically controlled unit of range F, setting the control at the lowest position that will maintain boiling. Let the unit adjust itself. Bring to boil and boil for 30 minutes.
10. Cook six potatoes in the pressure pan according to manufacturer's instructions. Choose unit with regular control that fulfills requirements of these instructions.
11. Cook potatoes in the cooker-fryer according to 9.

For each treatment the amount of water had to be determined. Amounts used were sufficient to complete the process without the pan boiling dry. Most of the treatments required 240 grams, or 1 cup, of water.[8] For others, the water requirement was determined to the nearest ¼ cup. Time required to boil could be predetermined, but time to get pressure in the pressure pan could not. Therefore, the timing of the 10 minutes at pressure was begun when the weight was observed to start rocking. The manufacturer recommended starting the pressure pan at *high* setting, reducing to *low* and adjusting as required to

[8] A cup of water weighs 236.5 grams, but for practical reasons, 240 grams per cup was used in this study.

TABLE 3. SPECIFICATIONS FOR TREATMENTS, SERIES A

Treatment	Range	Units								Pans[2]	Size	Water
		Tubes	Diam.	Max. rating	Control[1]	Settings						
						Level	Duration	Level	Duration			
No.		*No.*	*In.*	*Watts*			*Minutes*		*Minutes*		*Qt.*	*Grams*
1	F	1	6	1250	Reg.	High	5	Low	30	SP	3	240
2	H	2	6	1250	Reg.	High	4	3rd	30	SP	3	240
3	F	1	6	1250	Reg.	High	37	----	----	SP	3	900
4	H	2	6	1250	Reg.	High	37½	----	----	SP	3	900
5	F	1	8	1600	Reg.	High	6	Low	30	FP	1½	240
6a	H	2	8	2600	Reg.	High	2	Low	30	FP	1½	240
6b	H	2	8	2600	Reg.	High	3	Low	30	FP	1½	480
7	F	1	8	1600	Reg.	High	5	Low	30	DWI	6	240
8	F	1	6	1250[3]	SH	High	4	M-Low	30	SP	3	240
9	F	1	8	2050	Ts	2½-3	34	----	----	FP	1½	240
10	H	2	8	2600	Reg.	High	[4]	3rd	10	PPA	4	240
11	--	--	--	1400	Ts	210°	35½	----	----	C-F	6	600

[1] Controls are: Reg.—regular; SH—speed heat start, infinite control; Ts—thermostatic.
[2] Pans are: SP—sauce pan; FP—frypan; DWI—deep-well inset; PPA—pressure pan A; C-F—cooker-fryer.
[3] Although rated at 1250 watts, start is at 5000 watts.
[4] Until weight rocks.

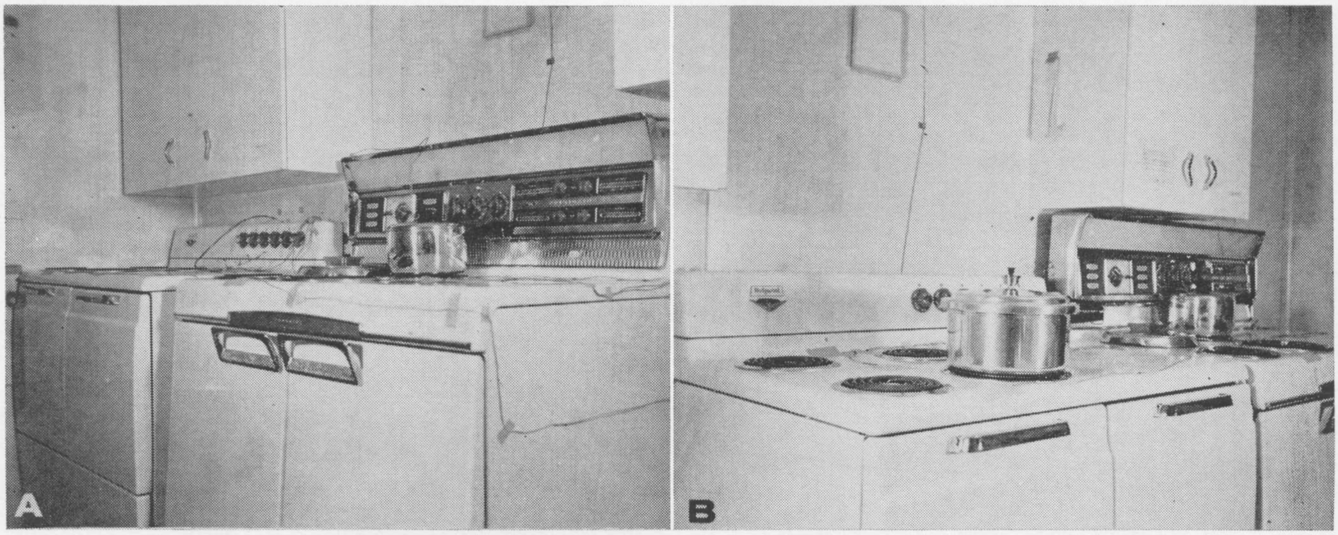

FIGURE 11. Ranges placed for use in series A tests: (A) Range F in position; (B) Range H in position.

maintain pressure. It was found that when *third* setting was used to maintain pressure, no further adjusting was necessary.

Three replications of each treatment were planned.

SPECIAL LABORATORY ARRANGEMENTS

The use of two ranges when treatments were done in random sequence required that they be easily moved and positioned. Correct positioning was necessary to have temperatures at each thermocouple location in the test room comparable from treatment to treatment. The ranges were mounted on caster dollies and arranged along the wall, with range H to the right and range F to the left. The base cabinets along that wall were removed. When range F was used, range H was pushed under the cabinet at the right, Figure 11. This cabinet was raised a few inches to permit the tall back splasher to slide under it. The cooker-fryer was used at the center of the right side of range H.

RESULTS

The tests were completed between November 3, and December 19, 1958. There were three replications of all tests, except 6a and 6b for which there were two replications each. The replications of 6b were done during the first two sets, and those of 6a during the last two.

Deviations from Specifications

Weights of potatoes

Weights of potatoes just before cooking ranged from 984 to 1001 grams per batch of six. Average weight of batches per treatment ranged from 989.5 to 997.3 grams.

Timing

Timing of the period required for bringing the water to boiling temperature was specified from preliminary tests except for treatment 10, in which the pressure pan was used. When the water failed to boil within the specified time, as happened in three tests, the time on *high* setting was continued until boiling occurred. Also in one test the boil occurred sooner than the specified time and the time on *high* setting was shortened.

Temperatures

The temperature specifications for starting tests given in Table 2, page 11, were usually met. The deviations usually did not exceed ¼° as indicated by the instruments used. The 100 deviations represent approximately 10 per cent of 986 individual specified temperatures. Four deviations of temperatures were observed during tests. These were not continuous during the tests, but each deviant average temperature was observed for one or more intervals.

Effects of Treatments

Power consumption

Power consumption of an appliance is important to the consumer, since it is the basis of operation cost. In this study, the influence of power consumption on the temperature and humidity of the test room was the basis of its importance. For this reason, and to make it comparable with heat production of other fuels, it was converted to BTU's.

Other sources of heat in the test room were the light and the operator who remained in the test room during tests. The heat from these two sources usually varied with the time the operator was in the test room during a test. However, it was nearly the same from treatment to treatment, except that Treatment 10, in which the pressure cooker was used, was of shorter duration than the others.

When power consumption of the appliance under study was small, heat produced by operator and lamp had relatively great importance, being responsible in some instances for nearly half the total heat input, Table 4. The general effect was that the temperatures of the test room, except the range-top temperatures, tended to vary less between treatments with higher and lower power consumption than they would had the appliance alone been responsible for observed temperatures. However, if the cook remains in the kitchen while food cooks, and if a lamp is used, the situation in the home kitchen in similar to that in the test room, except that in practice more than one item usually is cooked at a time.

Analysis of variance of power consumption indicated real differences among the various treatments (P < .005). Ranked means, nonsignificant ranges, and descriptions of treatments, Table 5, show the range of observations, analysis of differences, and their source.

INPUT LEVEL (Treatments 1 and 3, 2 and 4)[9]. The small regular units of both ranges were operated at the lowest input that would cook the potatoes and at the highest input available for these units. The lower input program in each pair required a smaller power consumption (P < .01). This was the expected response. It is also pointed out that the average observations for one of these pairs (1 and 3) occupied the extreme positions in the ranked means and that each of these two average observations differed from all other observations in the set (P < .01, except 1 and 7 P < .05).

TWO-TUBE AND MONOTUBE UNITS (Treatments 1 and 2, 4 and 3). At low input level the monotube unit required lower power consumption than the two-tube unit (P < .01). This was attributable to the fact that the two-tube unit (2) would not support boiling on *low* setting, and *third* setting had to be used after the initial heating period, Table 3, page 13. This provided a higher level of heating than was required. At highest input levels, the two-tube unit (4) required lower power consumption (P < .01), although its operation pattern specified a slightly longer heating period. The wattages of these units as measured were 1227 and 1416, although the nameplate of each carried the 1250-watt rating. Since this was the case, the differences caused by the two types of unit structure could not be meaningfully studied.

UNIT SIZE (Treatments 1 and 5, 2 and 6a). Comparisons of power consumption of large and small units at lowest practical control settings show differences for monotube units (P < .01) and no significant difference for two-tube units. The nonsignificance in the latter case is prob-

[9] In the discussions of these and the following differences in measures related to each pair of factors, the treatment or factor with the lower mean is mentioned first in each pair. The reader is referred to page 12 for an interpretation of nonsignificant ranges.

TABLE 4. AVERAGE HEAT INPUT PER TREATMENT AND APPLIANCE INPUT AS A PER CENT OF TOTAL, SERIES A

Number	Description of treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Heat input, av. each treatment: Operator	Lamp	Appliance	Total	Appliance input: total input
	No.		*In.*			*Gm.*		*BTU*	*BTU*	*BTU*	*BTU*	*Pct.*
1	1	1250	6	Reg.	SP	240	Low	306.3	266.4	739.9	1312.6	56.4
2	2	1250	6	Reg.	SP	240	Low	298.0	217.4	815.0	1330.4	61.3
3	1	1250	6	Reg.	SP	900	High	316.2	269.8	2993.8	3579.8	83.6
4	2	1250	6	Reg.	SP	900	High	313.5	264.1	2634.1	3211.7	82.0
5	1	1600	8	Reg.	FP	240	Low	302.0	225.4	885.6	1413.0	62.7
6a	2	2600	8	Reg.	FP	240	Low	352.9	278.3	840.1	1471.3	57.1
6b	2	2600	8	Reg.	FP	480	Low	295.7	245.9	956.2	1497.8	63.8
7	1	1600	8	Reg.	DWI	240	Low	344.4	240.2	803.7	1388.3	57.9
8	1	1250	6	SH	SP	240	Low	302.0	252.7	994.9	1549.6	64.2
9	1	2050	8	Ts	FP	240	Low	306.3	252.7	910.7	1469.7	62.0
10	2	2600	8	Reg.	PP	240	Low	217.5	177.6	1102.0	1497.1	73.6
11	--	1400	--	Ts	C-F	600	Low	296.7	269.8	1391.0	1957.5	71.1

[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, SH—speed heat start, infinite control, Ts—thermostatic.
[3] Pans are: SP—sauce pan, FP—frypan, DWI—deep-well inset, PP—pressure pan, C-F—cooker-fryer.

TABLE 5. ANALYSIS OF POWER CONSUMPTION BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of Treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		*In.*			*Grams*		*BTU*		
3	1	1250	6	Reg.	SP	900	High	2993.833		
4	2	1250	6	Reg.	SP	900	High	2634.133		
11	--	1400	--	Ts	C-F	600	Low	1391.033		
10	2	2600	8	Reg.	PP	240	Low	1102.033		
8	1	1250	6	SH	SP	240	Low	994.933		
6b	2	2600	8	Reg.	FP	480	Low	956.200		
9	1	2050	8	Ts	FP	240	Low	910.700		
5	1	1600	8	Reg.	FP	240	Low	885.633		
6a	2	2600	8	Reg.	FP	240	Low	840.100		
2	2	1250	6	Reg.	SP	240	Low	815.033		
7	1	1600	8	Reg.	DWI	240	Low	803.667		
1	1	1250	6	Reg.	SP	240	Low	739.900		

Standard error of the mean, Treatments 6a, 6b, = 21.7916; other treatments = 17.7925.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, C-F—cooker-fryer, PP—pressure pan, FP—frypan, DWI—deep-well inset.

ably because of the lack of flexibility in control settings as previously explained.

Type of heat control (Treatments 5 and 9, 1 and 8, 9 and 8). Surface units are usually controlled manually with a rotary switch or with push-buttons. Thermostatic control and speed-heat start, infinite control usually come only on *de luxe* models. Since special controls cost more, the expenditure should be compensated by some positive value such as lower power consumption.

Comparison of the means for regular and thermostatic control (5 and 9) shows no significant difference. Means for regular control are lower than those for speed heat start, infinite control (1 and 8) ($P < .01$). Means for thermostatic control are lower than those for speed heat start, infinite control (9 and 8) ($P < .01$).

If the thermostatic control setting had been adjusted during the cooking process, it is possible that it might have given better performance. However, one purpose of using this control was to avoid readjusting.

Lift-up unit (Treatments 7 and 5). Presumably, use of the deep-well inset should require lower power consumption than use of the lift-up unit with another pan at range-top level. Comparison of means for the lift-up unit as a deep-well and as a surface unit shows that there is a difference ($P < .01$) and that a saving is realized when the inset is used.

Pressure pan (Treatment 10). Cooking in a pressure pan requires less time after pressure is reached than boiling the same food after it has started to boil. Although the total pressure-cooking process requires less time than boiling, the time difference is less than might be inferred from the time tables because it requires a longer time to attain the pressure than to start boiling. Also, some time is required for reducing pressure. In this series the power consumption for pressure cooking (10) was greater than any method on range units except those using high input levels ($P < .01$). However, in accordance with the manufacturer's instructions, a large regular unit was used.

Separate appliance (Treatment 11). Since the cooker-fryer contained its heating unit within the outer jacket, it might be expected to perform the cooking operation with a minimum of power consumption. However, it was difficult to adjust the control level of its thermostat to maintain boiling. The self-limiting nature of boiling temperatures when water is used makes it extremely difficult to find the correct control setting to cause a simple bimetal thermostat to maintain a boil. For settings below boiling, the temperature is too low; and for those at boiling or above, the thermostat does not cycle off. The multiple range test shows that (11) in which the cooker-fryer was used, had a higher mean than any other treatment except those in which high input levels were used (Treatments 3 and 4) ($P < .01$). Its power consumption was lower than those of 3 and 4 ($P < .01$).

Amount of water. Presumably, using more water than necessary would require greater power consumption. A difference of 240 grams of water would theoretically require a difference of approximately 70 BTU's if the pan-unit combination were operating at 100 per cent efficiency in transmitting heat to the contents of the pan. This great a difference would be significant. The means of Treatments 6a and 6b differ by 116.1 BTU's and the difference, according to the multiple range test, is a real one ($P < .01$) and supports the theoretical contention.

Evaporative loss

The homemaker usually needs to keep evaporative losses at lowest levels. Water evaporated from the pan contributes to the humidity of the room in addition to requiring extra fuel for the cooking process. For each pint of water boiled off, 0.284 kilowatt-hour of energy is consumed.

Analysis of variance showed considerable differences in evaporative loss for the treatments of this series ($P < .005$). The differences are also evident in the wide range of means, Table 6. The scale used for weighing pan and contents had a capacity too small for treatments requiring 900 grams of water (3 and 4) and those requiring use of pressure pan and cooker-fryer (Treatments 10 and 11). Weights before cooking were determined separately and added. Those after cooking were determined by a spring scale. The latter was less accurate than desirable for comparison of small differences.

Table 6. Analysis of Evaporative Loss by Duncan's New Multiple Range Test, Series A

Number	Description of treatments							Ranked means	Nonsignificant ranges	
	Units				Pans[3]	Water amt.	Input level		(5% level)	(1% level)
	Tubes	Watts[1]	Diam.	Control[2]						
	No.		*In.*			*Grams*		*Grams*		
4	2	1250	6	Reg.	SP	900	High	799.00		
3	1	1250	6	Reg.	SP	900	High	795.67		
11	--	1400	--	Ts	C-F	600	Low	335.33		
8	1	1250	6	SH	SP	240	Low	138.00		
6b	2	2600	8	Reg.	FP	480	Low	124.00		
10	2	2600	8	Reg.	PP	240	Low	122.83		
2	2	1250	6	Reg.	SP	240	Low	118.00		
6a	2	2600	8	Reg.	FP	240	Low	103.00		
5	1	1600	8	Reg.	FP	240	Low	69.33		
9	1	2050	8	Ts	FP	240	Low	53.00		
7	1	1600	8	Reg.	DWI	240	Low	50.00		
1	1	1250	6	Reg.	SP	240	Low	47.33		

Standard error of the mean, Treatments 6a, 6b, 7 = 15.8837; other treatments = 12.9694.

[1] Rated wattage, the actual wattage was not always as rated.

[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.

[3] Pans are: SP—sauce pan, C-F—cooker-fryer, FP—frypan, PP—pressure pan, DWI—deep-well inset.

INPUT LEVEL (Treatments 2 and 4, 1 and 3). Use of high inputs on small regular units was responsible for greatest evaporative losses ($P < .01$). The mean for the treatment in which the low input program was used was in each comparison lower than the one in which high input was used ($P < .01$).

UNIT SIZE (Treatments 1 and 5, 6a and 2). When evaporative losses were evaluated by group analysis and the multiple range test, no significant difference was shown for units of different sizes. However, when losses for each pair of treatments were analyzed separately, greater losses were indicated for the larger unit of each pair ($P < .05$). This disparity arises from a difference in error terms. In group analysis the error term was derived from all of the treatments including those in which the less accurate scale was used in determining the loss. In the separate analysis the error term for each comparison was derived only from the two treatments for which the more accurate scale was used.

TYPE OF HEAT CONTROL (Treatments 9 and 5, 1 and 8, 9 and 8). Since thermostatic control presumably adjusts the input level to maintain the desired temperature in the pan, it might be expected to hold evaporative losses to low levels. The mean for the treatment using the thermostatically controlled range unit, Table 6, is among the lowest. When this mean is compared with the one for the manually controlled unit of the same size on the same range (9 and 5), although it is lower, the difference is not significant. The large regular unit (5) had a low wattage, probably because it was designed to use in a deep-well. The 8-inch unit on the other range had a higher wattage. Comparison of the means for the thermostatically controlled unit with this unit (9 and 6a) shows that the evaporative loss for the thermostatically controlled unit to be lower ($P < .05$).

In the case of the speed heat unit, flexibility of control levels between highest and lowest available might be assumed to provide a level of input that could be adjusted to provide for low evaporative losses. High input at the start should not cause cold water to evaporate excessively. However, the cycling of the control made it necessary to use a somewhat high input level to maintain boiling in the pan. Treatments using this unit produced higher evaporative losses than any others using range units, with the exception of those for which highest input programs were specified. The comparison of means for treatments using the monotube unit with regular controls and the speed heat unit (1 and 8) show that the evaporative losses caused by using the speed heat unit were truly larger ($P < .01$). The two-tube unit with regular controls produced smaller mean evaporative loss than the speed heat unit but not significantly smaller (2 and 8).

Although the thermostatically controlled unit was larger than the speed heat unit, its use caused lower evaporative losses ($P < .01$) as shown by comparison of means (9 and 8).

LIFT-UP UNIT (Treatments 7 and 5). Since use of the deep-well required significantly lower power consumption than use of the same unit at range-top level, it might be expected that the deep-well would have smaller evaporative losses. Comparison of means for treatments shows that this was true, but the difference was not significant.

PRESSURE PAN (Treatments 6a and 10). Use of the pressure pan required greater power consumption than use of the regular pan on the same unit. Although the means for evaporative loss for Treatments 6a and 10 indicate that use of the pressure pan brought about greater evaporative losses, the difference is not significant by the multiple range test nor by individual analysis. It is probable that the values obtained by use of the spring scale for weighing the pressure pan affected this comparison. Also the pressure pan used was somewhat erratic in the time required to bring pressure to designated levels. The metal piece that shuts off the air exhaust could not be pre-positioned in the rubber plug, yet its position seemed to affect the time of the exhaust. This, in turn, affected time to get pressure.

SEPARATE APPLIANCE (Treatment 11). The treatment using the cooker-fryer differed from all the others. The mean for evaporative loss, like the mean for power consumption, was smaller than those for the tests in which high input levels were used ($P < .01$) (Treatments 3 and 4) and larger than all the others ($P < .01$).

AMOUNT OF WATER (Treatments 6a and 6b). Although the use of a greater amount of water required a significantly greater power consumption, it was not necessarily expected that the evaporative loss would be greater. Comparison of means for treatments in which 240 and 480 grams of water were used (6a and 6b), shows the mean evaporative loss when 240 grams were used to be smaller, but not significantly smaller. Tests of significance in which only these two treatments were considered also showed the differences not to be significant.

Gain in humidity

On the whole, gain in humidity should be directly influenced by evaporative loss. However, water evaporated is not necessarily retained entirely in the air. At higher levels of humidity, there is a tendency for atmospheric moisture to become adsorbed on surfaces. Indeed, when air temperatures exceed temperatures of surfaces and relative humidity approaches saturation, atmospheric moisture may condense on surfaces and even trickle down cool vertical surfaces in the room. Also, in some tests escaping vapor condensed on the back splash of the range when the pan was on a rear unit. Analysis of observed values for gain in humidity, Table 7, indicates highly significant differences among treatments and this is also indicated by the range of the ranked means.

INPUT LEVEL (Treatments 2 and 4, 1 and 3). Greatest increases in humidity were observed for treatments using high input programs (4 and 3). These two treatments had means significantly greater than any others of the series ($P < .01$). There was a much greater difference between the means of treatments using monotube units (1 and 3) than those using two-tube units (2 and 4). This difference was probably attributable to factors other than the structures of the units.

SIZE OF UNIT (Treatments 1 and 5, 6a and 2). As indicated by the multiple range test, no significant differences in means for gain in humidity between treatments with large and small units were observed. In fact, for one comparison (1 and 5) means for the larger unit were greater, whereas for the other comparison (6a and 2) the means for the smaller unit were greater.

TABLE 7. ANALYSIS OF GAIN IN HUMIDITY BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		In.			Grams		Grains/cu.ft.		
3	1	1250	6	Reg.	SP	900	High	7.993		
4	2	1250	6	Reg.	SP	900	High	7.930		
11	--	1400	--	Ts	C-F	600	Low	4.423		
2	2	1250	6	Reg.	SP	240	Low	2.720		
8	1	1250	6	SH	SP	240	Low	2.593		
6b	2	2600	8	Reg.	FP	480	Low	2.190		
5	1	1600	8	Reg.	FP	240	Low	2.120		
6a	2	2600	8	Reg.	FP	240	Low	1.950		
10	2	2600	8	Reg.	PP	240	Low	1.870		
7	1	1600	8	Reg.	DWI	240	Low	1.583		
9	1	2050	8	Ts	FP	240	Low	1.350		
1	1	1250	6	Reg.	SP	240	Low	1.280		

Standard error of the mean, Treatments 6a, 6b = .45754; other treatments = .37357.
[1] Rated wattage, the actual wattage was not always as rated
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, C-F—cooker-fryer, FP—frypan, PP—pressure pan, DWI—deep-well inset.

TYPE OF HEAT CONTROL (Treatments 9 and 5, 9 and 8, 1 and 8). When analyzed by the multiple range test, humidity gains for thermostatic and manually controlled units (9 and 5) did not differ significantly. The same was true of thermostatically controlled and speed heat units (9 and 8). However, the gains for the manually controlled unit were smaller than those for the speed heat unit (1 and 8) ($P < .05$). Separate analysis of the gains of these pairs of treatments showed that those of the thermostatically controlled and manually controlled units were smaller than those of the speed heat unit (9 and 8) (1 and 8) ($P < .01$). As previously mentioned (p. 17), separate analysis avoids the experimental error of treatments other than the ones for which the comparisons were made.

LIFT-UP UNIT (Treatments 7 and 5). No significant difference in gain in humidity was found between using the lift-up unit as a deep-well or a surface unit.

PRESSURE PAN (Treatments 10 and 6a). Differences resulting from using pressure pan and regular pan were not significant.

SEPARATE APPLIANCE (Treatment 11). Use of the cooker-fryer caused gain in humidity greater than any of the other treatments except those in which high input programs were used ($P < .01$). These high inputs caused greater gains than use of the cooker-fryer ($P < .01$).

AMOUNT OF WATER (6a and 6b). The slightly higher mean associated with use of 480 grams of water did not differ significantly from that associated with use of 240 grams.

Temperatures of range surface

Temperature of the range surface affects the comfort of the person working near it. Since these temperatures are sometimes higher than body temperature, radiation from the range surface may be a source of great discomfort to the worker, especially when she is performing a task at the range. The increases in temperature of range surface are caused by heat from the unit that is not transmitted to the pan. Increases in range-top temperatures are thus an indication of the efficiency of the process. Although

TABLE 8. ANALYSIS OF MAXIMUM RANGE-TOP TEMPERATURES, CENTER OF UNIT CLUSTER, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
10	2	2600	8	Reg.	PP	240	Low	104.200		
3	1	1250	6	Reg.	SP	900	High	104.100		
4	2	1250	6	Reg.	SP	900	High	96.600		
7	1	1600	8	Reg.	DWI	240	Low	95.133		
5	1	1600	8	Reg.	FP	240	Low	94.100		
8	1	1250	6	SH	SP	240	Low	90.267		
9	1	2050	8	Ts	FP	240	Low	90.000		
6b	2	2600	8	Reg.	FP	480	Low	87.150		
6a	2	2600	8	Reg.	FP	240	Low	86.800		
2	2	1250	6	Reg.	SP	240	Low	86.200		
1	1	1250	6	Reg.	SP	240	Low	85.367		
11	--	1400	--	Ts	C-F	600	Low	82.767		

Standard error of the mean, Treatments 6a, 6b = 1.24054; other treatments = 1.01373.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: PP—pressure pan, SP—sauce pan, DWI—deep-well inset, FP—frypan, C-F—cooker-fryer.

thermocouple locations were distributed over various parts of each range, none of them was equally distant from all units. Thermocouple 8 had its junction at the center of the unit cluster, but it was nearer the 8-inch units than the 6-inch ones. Also this location was not near the cooker-fryer, which was used on the other half of the range.

Certain incidents interfered with obtaining comparable results. During some tests, condensation collected on the back splash and ran down on the range surface. This would have cooled the surface. Also, the procedure for this series did not provide for definite locations of the operator who worked in the test room. It is believed that she might deflect air currents toward or away from a thermocouple location on the range, exposing it to greater air flow and causing lower temperature observations or shielding the location and causing higher observations. Temperatures at each location were recorded at 4-minute intervals on the strip chart. Temperature-time curves indicated that some maximum temperatures may have occurred between the times when the temperatures were recorded.

Analysis of temperatures on the surface of the range at the center of the cluster of units is given in Table 8. Analysis of variance indicated real differences among the various treatment means ($P < .005$). The range of the ranked means shows the extent of the observed differences.

Maximum temperatures at center of cluster of range units

INPUT LEVEL (Treatments 1 and 3, 2 and 4). Use of low input programs brought about lower temperatures at center of the unit cluster than high input programs ($P < .01$). Temperature-time curves showed that the maximum temperature occurred less than 10 minutes after the unit was turned down for the low input program with the monotube unit (1) and at the end of the cooking period for the like program with the two-tube unit (2). However, for both treatments the temperature at this location stayed within 1° of maximum for the entire time after the initial rise caused by the *high* setting at the start. Temperatures at this point for *high* input programs (4 and 3) occurred after the range was turned off at end of the cooking period. There was usually a continuous rise. Irregularities in some curves were probably caused by condensation running across the range top and by the effect of the operator's position on air currents. However, the differences in range-top temperatures attributable to low and high input programs were so great that these experimental errors did not affect the tests for significance.

UNIT SIZE (Treatments 1 and 5, 2 and 6a). Use of smaller units rather than larger ones might be expected to bring about lower range-top temperatures. This was the case with the monotube units (1 and 5) ($P < .01$), but not with the two-tube units. The cause of disparity is probably related to the difference in wattage of the large units. The large monotube unit, rated at 1600 watts, required 6 minutes on high setting to produce boiling temperatures, whereas the large two-tube unit, rated at 2600 watts, produced a boil in 2 minutes. Also the large monotube unit was the lift-up one. It had no reflector pan and the deep-well was not insulated. Heat from the unit may have been absorbed by the jacket of the well and radiated to the range top. The maximum temperatures associated with the large monotube unit (5) occurred soon after the initial *high* setting was reduced, and those associated with the large two-tube unit (Treatment 6a) were after the range was turned off.

TYPE OF HEAT CONTROL (Treatments 9 and 5, 1 and 8, 9 and 8). Use of the thermostatically controlled unit kept the range top cooler than did the large regular unit, as shown by comparison of means for 9 and 5 ($P < .05$). However, comparison with the large lift-up unit gives the advantage to the thermostatically controlled unit. In comparison with the large unit on the other range, the thermostatically controlled unit caused higher temperatures (Treatments 6a and 9) ($P < .05$). When the thermostatically controlled unit was used, the maximum temperature occurred early, shortly after the unit began to cycle at a lower level.

Use of the speed heat unit with infinite control produced higher range-top temperatures than use of a unit of the same size with regular control (1 and 8) ($P < .01$). Maximum temperatures (8) occurred after the speed-heat unit was turned off.

Comparison of maximum range-top temperatures from use of the thermostatically controlled unit and the speed-heat unit (9 and 8) shows that they do not differ significantly.

LIFT-UP UNIT (Treatment 7). Comparison of means for treatments using lift-up unit at the surface and in deep-well (Treatments 5 and 7), Table 9, indicates that they did not differ significantly.

PRESSURE PAN (Treatment 10). Use of pressure pan caused higher temperatures at center of the unit cluster than any other treatment except the one in which the small monotube unit was used at high input level ($P < .01$). Maximum temperatures occurred shortly after the temperature control setting was reduced.

SEPARATE APPLIANCE (Treatment 11). Since the separate appliance was used on the right side of the range and remote from the location on the left side, comparison of means of Treatment 11 with those of other treatments given in Table 9 is not meaningful. However, a thermocouple was located directly under the cooker-fryer when it was used. The temperature mean of this thermocouple for the treatment using the cooker-fryer is approximately the same as that for Treatment 2 in Table 8.

AMOUNT OF WATER (Treatments 6a and 6b). The amount of water made little difference in temperatures at the location at the center of the unit cluster, as shown by comparison of means for treatments in which 240 and 480 grams of water were used.

Ceiling and wall temperatures

Temperatures of walls and ceiling of a room affect the comfort of the person in the room. If these surfaces are warmer than body temperature, which does not often happen, they radiate heat to the person(s) in the room. Even when ceiling and wall temperatures are lower than body temperature, the rate at which the body radiates heat to them is affected by the difference between ceiling (or wall) and body temperatures, greater temperature differences being associated with more rapid radiation. Subjectively, the occupant of a room with warm panels

TABLE 9. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL OVER RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
3	1	1250	6	Reg.	SP	900	High	89.533		
4	2	1250	6	Reg.	SP	900	High	87.200		
10	2	2600	8	Reg.	PP	240	Low	83.700		
11	--	1400	--	Ts	C-F	240	Low	82.100		
9	1	2050	8	Ts	FP	240	Low	82.100		
7	1	1600	8	Reg.	DWI	240	Low	81.933		
5	1	1600	8	Reg.	FP	240	Low	81.933		
6b	2	2600	8	Reg.	FP	480	Low	81.900		
8	1	1250	6	SH	SP	240	Low	81.867		
6a	2	2600	8	Reg.	FP	240	Low	81.800		
2	2	1250	6	Reg.	SP	240	Low	81.767		
1	1	1250	6	Reg.	SP	240	Low	81.533		

Standard error of the mean, Treatments 6a, 6b = .67806; other treatments = .55363.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, PP—pressure pan, C-F—cooker-fryer, FP—frypan, DWI—deep-well inset.

TABLE 10. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL AT NORTHWEST CORNER, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
3	1	1250	6	Reg.	SP	900	High	85.266		
4	2	1250	6	Reg.	SP	900	High	83.133		
9	1	2050	8	Ts	FP	240	Low	81.933		
10	2	2600	8	Reg.	PP	240	Low	81.767		
11	--	1400	--	Ts	C-F	600	Low	81.633		
6a	2	2600	8	Reg.	FP	240	Low	81.550		
6b	2	2600	8	Reg.	FP	480	Low	81.500		
8	1	1250	6	SH	SP	240	Low	81.367		
7	1	1600	8	Reg.	DWI	240	Low	81.200		
5	1	1600	8	Reg.	FP	240	Low	81.133		
1	1	1250	6	Reg.	SP	240	Low	81.133		
2	2	1250	6	Reg.	SP	240	Low	80.933		

Standard error of the mean, Treatments 6a, 6b = .21373; other treatments = .1745.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, FP—frypan, PP—pressure pan, C-F—cooker-fryer, DWI—deep-well inset.

TABLE 11. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL AT NORTHEAST CORNER, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		In.			Grams		Degree F.		
3	1	1250	6	Reg.	SP	900	High	84.200		
4	2	1250	6	Reg.	SP	900	High	83.200		
6b	2	2600	8	Reg.	FP	480	Low	81.650		
11	--	1400	--	Ts	C-F	600	Low	81.633		
9	1	2050	8	Ts	FP	240	Low	81.600		
6a	2	2600	8	Reg.	FP	240	Low	81.550		
10	2	2600	8	Reg.	PP	240	Low	81.533		
8	1	1250	6	SH	SP	240	Low	81.433		
7	1	1600	8	Reg.	DWI	240	Low	81.200		
5	1	1600	8	Reg.	FP	240	Low	81.200		
1	1	1250	6	Reg.	SP	240	Low	81.200		
2	2	1250	6	Reg.	SP	240	Low	81.000		

Standard error of the mean, Treatments 6a, 6b = .21689; other treatments = .17708.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, FP—frypan, C-F—cooker-fryer, PP—pressure pan, DWI—deep-well inset.

has a feeling of being "surrounded" and unable to escape the warmth.

Temperatures at locations on walls and ceiling continued to rise throughout each test. At some locations, especially those more remote from the range and the one low on the wall behind the range, temperatures continued to rise after the unit was turned off.

Ceiling temperatures

For panels at comparable distances from the range unit, ceiling temperatures were higher than wall temperatures. They were recorded for three locations, Figure 7. Analyses of maximum ceiling temperatures are given in Tables 9, 10, and 11. Analysis of variance in each instance indicated differences among the several treatments ($P < .005$). Inspection of treatment means of Tables 9, 10, and 11 and comparison of their ranges with that of Table 8 shows that the range of ceiling temperatures was much smaller than those of the range top.

Combined coincident maximum ceiling temperatures were calculated by finding for each test the 4-minute interval in which the average of the temperatures at the three ceiling locations was highest and using this average of observations in the analysis. Because maximum temperatures of the three locations did not always occur at the same time, the observations that were averaged for each combined coincident maximum temperature were not neccessarily the same observations that were used in the analyses in Table 9, 10, and 11, although in many instances they were the same. Coincident temperatures were considered desirable to represent an evaluation of the complete situation at any given instant. Analysis of these temperatures is given in Table 12.

INPUT LEVEL (Treatments 1 and 3, 2 and 4). High input caused considerably higher ceiling temperatures at all three locations ($P < .01$). This is shown in the analysis in Tables 9 through 11. The combined maximum ceiling temperatures (Table 12) are thus higher for treatments using high rather than low input programs ($P < .01$).

UNIT SIZE (Treatments 1 and 5, 2 and 6a). Use of different size units did not bring about much difference in maximum ceiling temperatures. No significant differences in maximum ceiling temperatures at any of the three locations or in the combined coincident temperatures for these locations were found as a result of using 6- or 8-inch monotube units (1 and 5). Use of the 6-inch two-tube unit gave lower temperatures at the northwest corner of the ceiling (2 and 6a) ($P < .05$), but not at other ceiling locations.

TYPE OF HEAT CONTROL (Treatments 5 and 9, 1 and 8, 8 and 9). The treatment using the thermostatically controlled unit produced higher temperatures at the northwest corner of the ceiling than the regular unit of like size and construction (5 and 9) ($P < .01$), Table 10. Differences in temperature caused by these two units at the other ceiling locations and for combined ceiling locations were not significant, Tables 9, 11, and 12. However, separate analysis indicated that the thermostatically controlled unit caused higher temperatures than the regular monotube unit at northwest and northeast ceiling locations and for combined ceiling locations ($P < .05$). In addition to greater heat output of the thermostatically controlled unit, its location nearer the north corners of the ceiling and the northerly direction of air currents in the test room favored its association with the higher temperatures.

Means for treatments involving use of the speed heat and the manually controlled units of like size and construction were not significantly different for any ceiling location (1 and 8).

Means for treatments in which the thermostatically controlled unit and the speed heat unit were used did not differ significantly at any ceiling location according to the multiple range test. However, at the northwest ceiling location, the mean for the thermostatically controlled unit was higher ($P < .05$) by analysis of variance of all treatments and also higher ($P < .01$) by individual analysis. Again the thermostatically controlled unit was nearer the north end. Although real, the difference was a small one.

LIFT-UP UNIT (Treatments 5 and 7). Use of the lift-up unit in the up or down position made no significant difference in ceiling temperatures.

TABLE 12. ANALYSIS OF MAXIMUM COMBINED COINCIDENT CEILING TEMPERATURES BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments							Ranked means	Nonsignificant ranges	
	Units				Pans[3]	Water amt.	Input level			
	Tubes	Watts[1]	Diam.	Control[2]					(5% level)	(1% level)
	No.		*In.*			*Grams*		*Degrees F.*		
3	1	1250	6	Reg.	SP	900	High	86.20		
4	2	1250	6	Reg.	SP	900	High	84.37		
10	2	2600	8	Reg.	PP	240	Low	82.17		
9	1	2050	8	Ts	FP	240	Low	81.87		
6b	2	2600	8	Reg.	FP	480	Low	81.70		
11	--	1400	--	Ts	C-F	600	Low	81.63		
6a	2	2600	8	Reg.	FP	240	Low	81.60		
8	1	1250	6	SH	SP	240	Low	81.53		
7	1	1600	8	Reg.	DWI	240	Low	81.43		
5	1	1600	8	Reg.	FP	240	Low	81.40		
2	2	1250	6	Reg.	SP	240	Low	81.23		
1	1	1250	6	Reg.	SP	240	Low	81.23		

Standard error of the mean, Treatments 6a, 6b = .37233; other treatments = .30401.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, PP—pressure pan, FP—frypan, C-F—cooker-fryer, DWI—deep-well inset.

PRESSURE PAN (Treatments 6a and 10). Use of the pressure pan brought about higher temperatures at the ceiling location over the range than use of an ordinary pan on the same unit ($P < .05$). Temperature differences at other ceiling locations were not significant.

SEPARATE APPLIANCE (Treatment 11). Use of the cooker-fryer did not produce ceiling temperatures significantly different from those of either the thermostatically controlled unit or the small regular monotube unit. Use of this appliance produced higher temperatures at the northeast and northwest corners of the ceiling than the small two-tube unit ($P < .05$).

AMOUNT OF WATER (Treatments 6a and 6b). Use of 480 rather than 240 grams of water made no significant difference in ceiling temperatures.

Wall temperatures

Temperatures of walls were recorded at five locations, Figure 7. Analyses of the means for maximum temperatures at these locations are given in Tables 13 through 17. Analysis of maximum combined coincident wall temperatures for these locations is given in Table 18. Analysis of variance of maximum temperatures at each location and for combined coincident wall temperatures indicated differences among the various treatments ($P < .005$). Comparison of treatment means shows the range for each set to be rather narrow, less than 6°.

INPUT LEVEL (Treatments 1 and 3, 2 and 4). High input level was responsible for highest temperatures at every wall location. Differences in means are indicated for high and low input programs at each wall location and for maximum combined coincident temperatures for all wall locations ($P < .01$), as shown in Tables 13 through 18.

UNIT SIZE (Treatments 5 and 1, 2 and 6a). Apparently size of unit made little difference in maximum temperatures of walls. None of the comparisons of wall temperatures for treatments using the small and large monotube units showed significant differences. In the case of treat-

TABLE 13. ANALYSIS OF MAXIMUM TEMPERATURES, PANEL HIGH ON WALL BEHIND RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
4	2	1250	6	Reg.	SP	900	High	87.100		
3	1	1250	6	Reg.	SP	900	High	86.100		
10	2	2600	8	Reg.	PP	240	Low	83.533		
9	1	2050	8	Ts	FP	240	Low	82.200		
6b	2	2600	8	Reg.	FP	480	Low	82.150		
7	1	1600	8	Reg.	DWI	240	Low	82.100		
8	1	1250	6	SH	SP	240	Low	82.000		
6a	2	2600	8	Reg.	FP	240	Low	82.000		
11	--	1400	--	Ts	C-F	600	Low	81.933		
1	1	1250	6	Reg.	SP	240	Low	81.933		
5	1	1600	8	Reg.	FP	240	Low	81.767		
2	2	1250	6	Reg.	SP	240	Low	81.700		

Standard error of the mean, Treatments 6a, 6b = 1.10854; other treatments = .90511.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, PP—pressure pan, FP—frypan, DWI—deep-well inset, C-F—cooker-fryer.

TABLE 14. ANALYSIS OF MAXIMUM WALL TEMPERTAURES, PANEL LOW BEHIND RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments: Units: Tubes	Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
3	1	1250	6	Reg.	SP	900	High	83.933		
4	2	1250	6	Reg.	SP	900	High	82.867		
7	1	1600	8	Reg.	DWI	240	Low	81.933		
10	2	2600	8	Reg.	PP	240	Low	81.533		
9	1	2050	8	Ts	FP	240	Low	81.267		
8	1	1250	6	SH	SP	240	Low	81.267		
6b	2	2600	8	Reg.	FP	480	Low	81.150		
5	1	1600	8	Reg.	FP	240	Low	81.133		
1	1	1250	6	Reg.	SP	240	Low	81.033		
6a	2	2600	8	Reg.	FP	240	Low	81.000		
11	--	1400	--	Ts	C-F	600	Low	80.933		
2	2	1250	6	Reg.	SP	240	Low	80.933		

Standard error of the mean, Treatments 6a, 6b = .1895; other treatments = .15472.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, DWI—deep-well inset, PP—pressure pan, FP—frypan, C-F—cooker-fryer.

TABLE 15. ANALYSIS OF MAXIMUM WALL TEMPERATURES, PANEL OPPOSITE RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments							Ranked means	Nonsignificant ranges	
	Units				Pans[3]	Water amt.	Input level			
	Tubes	Watts[1]	Diam.	Control[2]					(5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
3	1	1250	6	Reg.	SP	900	High	83.533		
4	2	1250	6	Reg.	SP	900	High	83.100		
11	--	1400	--	Ts	C-F	600	Low	81.767		
10	2	2600	8	Reg.	PP	240	Low	81.767		
9	1	2050	8	Ts	FP	240	Low	81.767		
6b	2	2600	8	Reg.	FP	480	Low	81.650		
6a	2	2600	8	Reg.	FP	240	Low	81.650		
1	1	1250	6	Reg.	SP	240	Low	81.433		
8	1	1250	6	SH	SP	240	Low	81.367		
7	1	1600	8	Reg.	DWI	240	Low	81.367		
5	1	1600	8	Reg.	FP	240	Low	81.200		
2	2	1250	6	Reg.	SP	240	Low	81.133		

Standard error of the mean, Treatments 6a, 6b = .1719; other treatments = .14036.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, C-F—cooker-fryer, PP—pressure pan, FP—frypan, DWI—deep-well inset.

TABLE 16. ANALYSIS OF MAXIMUM WALL TEMPERATURES, PANEL, EAST END OF NORTH WALL, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments							Ranked means	Nonsignificant ranges	
	Units				Pans[3]	Water amt.	Input level			
	Tubes	Watts[1]	Diam.	Control[2]					(5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
3	1	1250	6	Reg.	SP	900	High	83.267		
4	2	1250	6	Reg.	SP	900	High	82.933		
6b	2	2600	8	Reg.	FP	480	Low	81.650		
9	1	2050	8	Ts	FP	240	Low	81.600		
6a	2	2600	8	Reg.	FP	240	Low	81.550		
11	--	1400	--	Ts	C-F	600	Low	81.533		
10	2	2600	8	Reg.	PP	240	Low	81.467		
8	1	1250	6	SH	SP	240	Low	81.367		
7	1	1600	8	Reg.	DWI	240	Low	81.300		
5	1	1600	8	Reg.	FP	240	Low	81.200		
2	2	1250	6	Reg.	SP	240	Low	81.200		
1	1	1250	6	Reg.	SP	240	Low	81.133		

Standard error of the mean, Treatments 6a, 6b = .1665; other treatments = .13594.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, FP—frypan, C-F—cooker-fryer, PP—pressure pan, DWI—deep-well inset.

TABLE 17. ANALYSIS OF MAXIMUM WALL TEMPERATURES, PANEL, NORTH END OF WEST WALL, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments							Ranked means	Nonsignificant ranges	
	Units				Pans[3]	Water amt.	Input level			
	Tubes	Watts[1]	Diam.	Control[2]					(5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
3	1	1250	6	Reg.	SP	900	High	83.000		
4	2	1250	6	Reg.	SP	900	High	82.300		
11	--	1400	--	Ts	C-F	600	Low	81.633		
9	1	2050	8	Ts	FP	240	Low	81.600		
8	1	1250	6	SH	SP	240	Low	81.367		
10	2	2600	8	Reg.	PP	240	Low	81.200		
7	1	1600	8	Reg.	DWI	240	Low	81.200		
6b	2	2600	8	Reg.	FP	480	Low	81.150		
6a	2	2600	8	Reg.	FP	240	Low	81.150		
1	1	1250	6	Reg.	SP	240	Low	81.133		
5	1	1600	8	Reg.	FP	240	Low	81.033		
2	2	1250	6	Reg.	SP	240	Low	80.800		

Standard error of the mean, Treatments 6a, 6b = .13312; other treatments = .10867.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, C-F—cooker-fryer, FP—frypan, PP—pressure pan, DWI—deep-well inset.

TABLE 18. ANALYSIS OF MAXIMUM COMBINED COINCIDENT WALL TEMPERATURES BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments							Ranked means	Nonsignificant ranges	
	Units				Pans[3]	Water amt.	Input level		(5% level)	(1% level)
	Tubes	Watts[1]	Diam.	Control[2]						
	No.		*In.*			*Grams*		*Degrees F.*		
3	1	1250	6	Reg.	SP	900	High	83.70		
4	2	1250	6	Reg.	SP	900	High	83.37		
10	2	2600	8	Reg.	PP	240	Low	81.70		
9	1	2050	8	Ts	FP	240	Low	81.70		
6b	2	2600	8	Reg.	FP	480	Low	81.55		
11	--	1400	--	Ts	C-F	600	Low	81.53		
7	1	1600	8	Reg.	DWI	240	Low	81.53		
8	1	1250	6	SH	SP	240	Low	81.50		
6a	2	2600	8	Reg.	FP	240	Low	81.50		
1	1	1250	6	Reg.	SP	240	Low	81.33		
5	1	1600	8	Reg.	FP	240	Low	81.23		
2	2	1250	6	Reg.	SP	240	Low	81.17		

Standard error of the mean, Treatments 6a, 6b = .20337; other treatments = .16604.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, PP—pressure pan, FP—frypan, C-F—cooker-fryer, DWI—deep-well inset.

ments using small and large two-tube units, means for maximum temperatures on the wall opposite the range were higher for the larger unit ($P < .05$). However, the small unit used (2) was a rear one and the large unit used (6a) was a front one. It is possible that the difference in distances of these two from the opposite wall may have been to some extent responsible for the temperature difference observed.

TYPE OF HEAT CONTROL (Treatments 5 and 9, 1 and 8, 8 and 9). The large monotube unit with regular control caused lower maximum temperatures than did the thermostatically controlled unit at the north end of the west wall ($P < .01$) and at the wall location opposite the range ($P < .05$). Maximum temperatures at other locations and for combined locations did not differ significantly. Again there was a difference in location that may have made the unit with regular control seem to have held temperatures at cooler levels. However, the two-tube unit of the same size and with regular controls (Treatment 6a) had the same relative position as the thermostatically controlled unit. Comparison of its means with those of the thermostatically controlled unit (9) shows a similar pattern.

Differences in maximum wall temperatures attributable to using regular and speed heat infinite controls with units of the same size and construction (1 and 8) were not significant at any wall location nor for combined wall locations. However, if the two-tube unit of corresponding size and with regular controls is used in the comparison (Treatments 2 and 8), the mean for the speed heat unit is higher for the location at north end of the west wall ($P < .05$).

No significant differences in maximum wall temperatures were noted as a consequence of using the speed heat unit with infinite control and the unit with thermostatic control (8 and 9).

LIFT-UP UNIT. The wall low behind the range was made warmer by using the lift-up unit at bottom of the deep-well rather than as a surface unit ($P < .01$), as shown by comparison of means (Treatments 5 and 7), Table 14. No significant difference in maximum temperatures for these two treatments was noted at other wall locations or for combined wall locations. The location low behind the range would have little effect on the worker in the kitchen during meal preparation, but it was a wall location that cooled slowly. It might have the effect of absorbing heat during the time of meal preparation, and of extending the overall period of higher kitchen temperatures.

PRESSURE PAN (Treatments 6a and 10). At the wall panel low behind range, temperatures were higher from use of pressure pan than those from use of the regular pan ($P < .05$) (6a and 10). This, however, was not the case at any other wall location. The reason for this is not clear, since the same range unit was used for both treatments and it was located at the front of the range. However, the difference in means was only 0.5°.

SEPARATE APPLIANCE (Treatment 11). When mean for the treatment in which the cooker-fryer was used is compared with that in which the thermostatically controlled range unit was used (Treatments 11 and 9), differences are not significant for any wall location. Comparison of mean for the cooker-fryer treatment with those for either small regular unit (Treatments 1 and 11, 2 and 11) shows the temperatures for the cooker-fryer to be higher at the wall location at the northwest corner of test room ($P < .01$).

AMOUNT OF WATER (Treatments 6a and 6b). No significant difference in wall temperatures was noted between means for treatments using 240 and 480 grams of water on the same range unit.

Maximum air temperatures

Air temperatures affect the comfort of the worker inasmuch as the ability of the body to lose heat by convection is partially dependent on the difference between body and air temperatures.

When the air of a room is heated by a small source such as those used in the cooking processes under study, the temperatures of air currents tend to be "streaky." The

TABLE 19. ANALYSIS OF MAXIMUM AIR TEMPERATURES BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES A

Number	Description of treatments: Units — Tubes	Units — Watts[1]	Units — Diam.	Units — Control[2]	Pans[3]	Water amt.	Input level	Ranked means	Nonsignificant ranges (5% level)	(1% level)
	No.		In.			Grams		Degrees F.		
3	1	1250	6	Reg.	SP	900	High	86.100		
4	2	1250	6	Reg.	SP	900	High	85.100		
10	2	2600	8	Reg.	PP	240	Low	83.167		
9	1	2050	8	Ts	FP	240	Low	83.100		
6a	2	2600	8	Reg.	FP	240	Low	82.900		
8	1	1250	6	SH	SP	240	Low	82.750		
6b	2	2600	8	Reg.	FP	480	Low	82.866		
11	--	1400	--	Ts	C-F	600	Low	82.600		
5	1	1600	8	Reg.	FP	240	Low	82.433		
1	1	1250	6	Reg.	SP	240	Low	82.367		
2	2	1250	6	Reg.	SP	240	Low	82.267		
7	1	1600	8	Reg.	DWI	240	Low	81.933		

Standard error of the mean, Treatments 6a, 6b = .27432; other treatments = .22396.
[1] Rated wattage, the actual wattage was not always as rated.
[2] Controls are: Reg.—regular, Ts—thermostatic, SH—speed heat start, infinite control.
[3] Pans are: SP—sauce pan, PP—pressure pan, FP—frypan, C-F—cooker-fryer, DWI—deep-well inset.

thermocouples used could sense these small fluctuations. Thus, the air temperature observed may not have always been the average of room air temperatures at the time of observation.

Analysis of maximum air temperatures is given in Table 19. Analysis of variance indicated differences among treatment means (P < .005). The ranked means suggest a relatively large range of temperatures for the various treatments.

According to the multiple range test, treatments using high input programs produced maximum air temperatures higher than all other treatments (P < .01). In the case of all other meaningful comparisons tested there was no significant difference between treatment means.

Series B Experiments

DESIGN

This series was designed to test the temperature and humidity effects of centering or not centering the pans on the unit, using the lid designed for the pan or one that was purchased separately, and three levels of input. The highest input was lower than *high* as used in series A. Twelve treatments were required as shown below.

Lid	*Position*	*Input* — *Low*	*Medium*	*High*
Good	Centered	1	5	9
Good	Uncentered	2	6	10
Poor	Centered	3	7	11
Poor	Uncentered	4	8	12

The numbers given were used to identify the treatments. Two replications of each treatment, a total of 24 tests, allowed each lid and position to be repeated 12 times and each input 8 times.

The same range unit (small regular unit of range H) and pan (3-quart sauce pan) were used for all tests of series B. Centering was studied to test a theory that developed as a possible explanation of varied response between replications of the same treatments of series A. In each test of series A, it had been assumed that the pan was to be centered, but no special method for centering had been developed. It was believed that differences in centering the pan might have occurred and that these might have been responsible for some differences in temperatures observed on range top, walls, and ceiling between replications of the same treatment.

CENTERING

For series B, a special method of centering was developed. A line was drawn on the surface of the range to the right of the unit and in line with its center. Thus, if the line were continued to the left, it would pass through the center of unit. A line was also drawn on the side of the pan vertically from the center of the cross section of the handle to bottom of pan. A large sewing needle was suspended from the free-swinging hanger loop on the pan handle. The thread holding the needle was adjusted so that the point of the needle just cleared the range top when the pan sat on the unit. The pan was carefully centered on the unit with the handle to the right so that the needle hung above the line on the range surface. Adjustment was made so that the mirror image of the line on the range coincided with the line marked on the pan when a sighting was made from beyond the needle toward the pan. Also the needle and thread appeared to coincide with the line on the pan. After rechecking the right-to-left centering of pan, a line was drawn across the line on the range at the point below the needle. The intersection made a reference point for centering the pan.

A second reference line was drawn to intersect line on range at a point ¾ inch to the left of reference point for centering pan. By repeating the centering process with needle over intersection of second crossline, the pan was decentered by ¾ inch. This was the position designated as uncentered.

LIDS

Lids were studied because it was believed that poorly fitting ones might affect evaporative loss from the cooking pan. Some pans, usually more costly ones, have lids made especially for them. For pans that do not, lids may be purchased but they do not necessarily fit well. Homemakers may improvise, using a pie tin or whatever is available as a substitute for a lid. Also battered lids may not fit well.

Of the lids used in series B, the one identified as *good* was that made for the pan. It was slightly domed and fit inside the pan, Figure 12. The lid designated as *poor* was a new and relatively flat one stamped from sheet aluminum of light gauge, Figure 13. It rested on top of the pan, Figure 12.

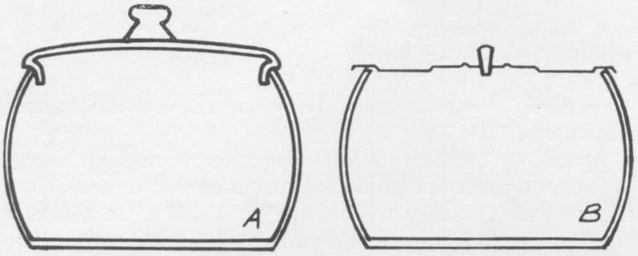

FIGURE 12. Sections of pan with (A) good and (B) poor lids.

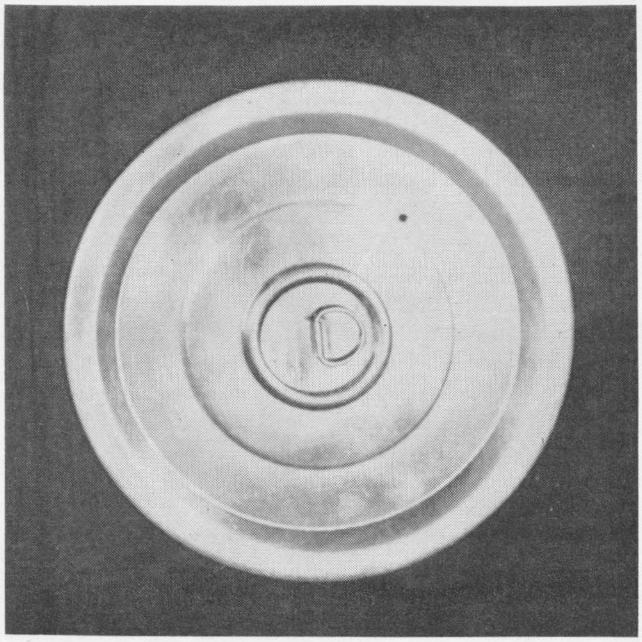

FIGURE 13. Lid designated as "poor."

SPECIFICATIONS

Inputs in series A included the highest the unit provided and the lowest that would cook the food. Those used in series B included the lowest that would cook the food but not the highest input of the unit.

The input programs were planned on the basis of preliminary trials. The water and potatoes were brought to a boil on *high* setting, after which the setting was changed for the 30-minute period to *low*, *medium-low*, or *medium-high*, respectively, for low, medium, and high inputs. However, for the low input program it was found that, although the water boiled in 3 minutes, the setting had to remain at *high* for 4 minutes. Otherwise, when the setting was reduced, the water ceased boiling for so long the potatoes were not done after the 30-minute cooking period.

Preliminary trials showed that the input programs and amounts of water should be the same within input levels. The specifications were as follows:

Input level	*Grams of water*	*Minutes at high setting*	*Setting for cooking period*
Low	180	4	Low
Medium	300	4	Med. low
High	480	5	Med. high

CHANGES IN METHOD AND INSTRUMENTATION

For this series the general procedure was changed to specify the location of the inside operator at all times during tests. The humidity was controlled as far as possible to give a level between 6 and 7 grains per cubic foot at the beginning of tests. This was done in summer by exposing calcium chloride or using a dehumidifier in the test room between tests. Also, for these tests the metal thermocouple protecting tube was put into use. Figure 14 shows the two pan-lid combinations on the range with the thermocouple in place.

RESULTS

The tests were completed between July 7, and October 14, 1959.

Deviations and Specifications

No deviations from timing of the cooking processes were made. Weight of batches of potatoes deviated very little from the specified 1000 grams $\pm$ 5 at the time of cooking. Weights ranged from 988 to 1005.5 grams. Deviant weights of batches were 988, 992, 993, and 1005.5 grams. Batches of the first replication were lighter in weight than those of the second except for two treatments.

Of the temperatures specified for starting tests, those at several locations were correct for all tests of series B. These were: panel at north end of west wall, water tank surface (two locations), within walls and ceiling of test room (five inner locations), and air above and below test room. Also temperatures of air ambient to the test room were maintained during tests as specified. The 81 deviations from temperature specifications represent 10.9 per cent of a possible 744. Nine of the 81 deviations are greater than $\frac{1}{4}°$.

Three deviations in humidity were observed: 5.86, 7.16, and 7.22 grains per cubic foot.

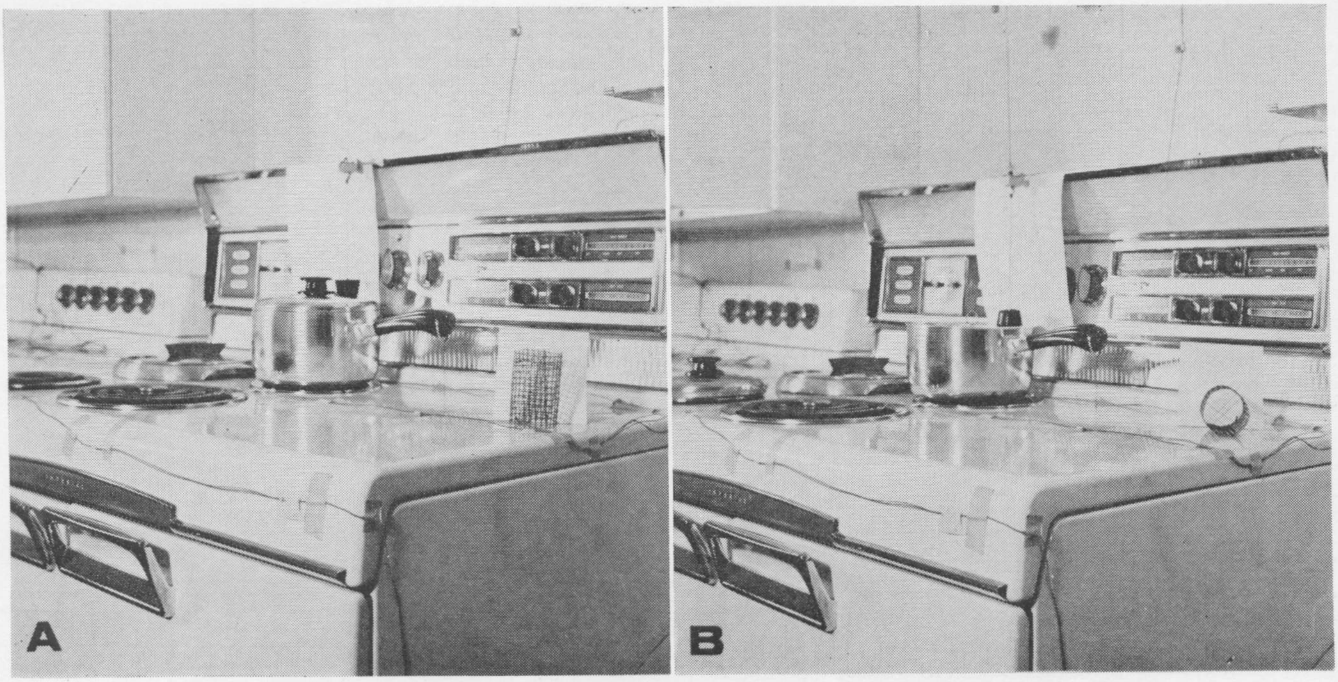

FIGURE 14. (A) Pan with "good" lid is in centered position on unit with the thermocouple in place; the wire cage for the thermocouple is at lower right in photo. (B) Pan with "poor" lid is in an uncentered position on unit with the thermocouple in place. End view of the wire cage for the thermocouple is at the lower right.

Effects of Treatments

Power consumption

Power consumption of the range unit is determined almost entirely by the input program when manual control is used. In this series, input level was one of the factors studied. From the specifications, page 26, it was obvious that input was the only factor expected to cause significant differences in power consumption. Therefore, the results for power consumption were not analyzed. Some temperatures were subject to the effects of heat inputs of operator and lamp, as well as that of the appliance. Also the operator may have contributed moisture to the air of the test room. Given in Table 20 are the average heat inputs per treatment and the heat input of the range as a per cent of the total in each case. It was noted that appliance input varied among tests and treatments of each input level more than was expected from experimental error. Therefore, the meter was tested and adjusted after this series. Data in Table 20 show that the proportion of total input supplied by appliance is about 2/3, 3/4, and 4/5, respectively, for low, medium, and high input programs.

Evaporative loss

Analysis of variance of evaporative loss showed differences attributable to the various treatments of the series ($P < .005$). Both input patterns and position of pan on the unit were responsible for differences in evaporative loss ($P < .005$). Input was more effective than position in causing the differences. It had been proposed that fit of lid might affect evaporative loss, but within each input, differences caused by lids were not significant.

The ranked means, Table 21, show that average evaporative loss per treatment varied from an almost negligible

TABLE 20. AVERAGE HEAT INPUT PER TREATMENT AND APPLIANCE INPUT AS A PER CENT OF TOTAL, SERIES B

Treatment	Input level	Position	Lid	Heat input, av. each treatment				Appliance input: total input
				Operator	Lamp	Appliance	Total	
No.				*BTU*	*BTU*	*BTU*	*BTU*	*Pct.*
1	Low	C	Good	208.7	184.4	642.0	1035.1	62.0
2	Low	U	Good	208.7	191.2	635.2	1035.1	61.4
3	Low	C	Poor	208.7	177.6	614.7	1000.9	61.4
4	Low	U	Poor	208.7	172.5	659.1	1040.2	63.4
5	Med.	C	Good	208.7	199.8	1164.5	1572.9	74.0
6	Med.	U	Good	208.7	184.4	1171.3	1564.4	74.9
7	Med.	C	Poor	208.7	162.2	1167.9	1538.8	75.9
8	Med.	U	Poor	208.7	179.3	1096.2	1484.2	73.9
9	High	C	Good	214.7	170.8	1594.8	1980.2	80.5
10	High	U	Good	214.7	194.7	1591.4	2000.7	79.5
11	High	C	Poor	217.7	203.2	1618.7	2039.6	79.4
12	High	U	Poor	214.7	204.9	1618.7	2038.3	79.4

TABLE 21. ANALYSIS OF EVAPORATIVE LOSS BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Grams*		
11	High	C	Poor	378.75		
9	High	C	Good	371.00		
12	High	U	Poor	338.00		
10	High	U	Good	338.00		
7	Med.	C	Poor	219.75		
5	Med.	C	Good	216.50		
8	Med.	U	Poor	197.50		
6	Med.	U	Good	192.50		
1	Low	C	Good	23.75		
4	Low	U	Poor	14.25		
2	Low	U	Good	10.00		
3	Low	C	Poor	6.75		

Standard error of the mean = 3.2656.

6.75 grams (less than 2 teaspoons) to 378.75 grams (more than 1½ cups). The means are stratified by input, higher inputs causing the greater evaporative losses. For medium and high inputs, means are also stratified by positions, centered pans having higher evaporative losses than uncentered ones. Lines indicating nonsignificant ranges show that each of the three input levels produced evaporative losses different from the other levels ($P < .01$) and that centering produced greater evaporative losses at the two higher input levels ($P < .01$). At low input levels evaporative losses were relatively small and did not differ greatly by lid and position.

Stratification of positions within the two higher inputs and lack of stratification of positions at low input was indicated by interaction of position and input ($P < .005$), that is, the higher the unit is turned the more the evaporative loss may be decreased by positioning the pan off center. The usefulness of this observation is limited; it is more sensible to turn down the unit to prevent excessive evaporation. However, if it were impossible to maintain boiling in the pan when the unit is turned down, evaporation might be reduced by placing pan slightly off center when using the next higher setting.

Gain in humidity

As in the case of evaporative loss, analysis of variance of gain in humidity showed differences for treatments ($P < .005$). Differences were caused by input and position ($P < .005$). Differences caused by lids were not significant. Input was found to be more effective than position in causing differences in humidity gain.

The ranked means, Table 22, show the gains in humidity stratified by input level. Lines indicating nonsignificant ranges show that the differences between input levels are significant ($P < .01$). There is some stratification by position within medium and low input levels, but the strata are not significantly different according to the nonsignificant ranges. Failure of humidity gains to follow the exact pattern of evaporative losses is to some extent attributable to greater condensation at higher input levels. When evaporative losses are highest, condensation and probably adsorption of moisture on surfaces is greatest. Operators' comments written during tests indicate clammy feelings and visible condensation on range surface and on the observation window when higher input levels were used. These comments were more frequent for high than for medium inputs.

TABLE 22. ANALYSIS OF GAIN IN HUMIDITY BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Grains/cu. ft.*		
9	High	C	Good	4.825		
10	High	U	Good	4.655		
11	High	C	Poor	4.620		
12	High	U	Poor	4.465		
7	Med.	C	Poor	3.520		
5	Med.	C	Good	3.360		
8	Med.	U	Poor	3.280		
6	Med.	U	Good	2.910		
1	Low	C	Good	.975		
3	Low	C	Poor	.970		
4	Low	U	Poor	.630		
2	Low	U	Good	.610		

Standard error of the mean = .12186.

Temperatures of surface of range

Since the right rear unit was used for all treatments of series B, the temperatures at each of the thermocouple locations may be meaningfully compared between treatments. Temperature-time curves of range surfaces showed several characteristics of the tests and indicated differences between replications of the same treatment. The four locations had clearly different temperatures. These were, from highest to lowest: (a) left side, rear, between units; (b) left side, center of unit cluster; (c) right side, center; (d) left side, center front. This was also in order of distance from the unit. Differences caused by input were evident at each location. Temperatures at rear of left side and at center of the unit cluster climbed rapidly for the first 12 minutes. At low input level they then either leveled or dropped with an occasional slight rise at the end of the cooking period. At medium and high levels, the temperature increase was less rapid after the initial rise, but the increase continued throughout the test. Temperatures at center of the right side and at center front of left side increased less rapidly and the curve was more nearly linear than at the other two locations. Temperatures at the location at center of unit cluster were consistently higher for the second replication of each treatment. This difference between replicates was supported by analysis of variance. Differences were shown in maximum temperatures at center of the unit cluster and at center front of the left side ($P < .005$), but not at other locations. After a great deal of searching for a reason, a review of daily records revealed that the dark enameled broiler pan, normally stored just beneath the drip pan under the units, had been removed at approximately the time of the change in replications. Evidently when it was there it acted as a heat absorber. This accounted for the consistent differences in temperature at center of the units. The difference at center front of the left side was too small to be evident from the line graphs. This also might be accounted for by the removal of the broiler pan.

A temperature difference between treatments for the location at rear of the left side was believed to be caused by condensation that ran down the back splasher. This was purely random for replications. In spite of these experimental errors, differences for treatments were indicated at all four range-top locations ($P < .005$).

Input and position caused temperature differences at each of the four range locations ($P < .005$). Input was more effective than position in producing these differences. It may be noted from the ranked means, Tables 23 through 26, that the centered pans caused lower range-top temperatures, whereas in the cases of evaporative loss and gain in humidity, Tables 21 and 22, the centered pans were associated with higher values. Analysis of variance showed temperature differences were caused by lids for the location at the center rear of the left side ($P < .025$). Good lids were associated with lower temperatures.

The ranked means show that the range-top temperatures were stratified by input levels. Except for the location at center front, left side, at low input, they were also stratified within inputs by position. For the exception mentioned, mean maximum temperatures were identical for all low inputs.

Table 23. Analysis of Maximum Temperatures, Center Rear, Left Side of Range Top, by Duncan's New Multiple Range Test, Series B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
12	High	U	Poor	95.10		
10	High	U	Good	94.50		
9	High	C	Good	93.85		
11	High	C	Poor	93.75		
8	Med.	U	Poor	92.25		
6	Med.	U	Good	90.90		
7	Med.	C	Poor	90.75		
5	Med.	C	Good	90.35		
4	Low	U	Poor	88.10		
2	Low	U	Good	87.90		
3	Low	C	Poor	87.85		
1	Low	C	Good	87.15		

Standard error of the mean = .4025.

Table 24. Analysis of Maximum Temperatures, Center of Unit Cluster, Range Top, by Duncan's New Multiple Range Test, Series B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
12	High	U	Poor	91.00		
10	High	U	Good	90.75		
11	High	C	Poor	89.90		
9	High	C	Good	89.50		
8	Med.	U	Poor	87.85		
6	Med.	U	Good	87.85		
7	Med.	C	Poor	87.40		
5	Med.	C	Good	87.40		
2	Low	U	Good	85.60		
4	Low	U	Poor	85.50		
3	Low	C	Poor	84.60		
1	Low	C	Good	84.60		

Standard error of the mean = .1803.

Table 25. Analysis of Maximum Temperatures, Center of Right Side of Range Top, by Duncan's New Multiple Range Test, Series B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
12	High	U	Poor	87.20		
10	High	U	Good	87.00		
11	High	C	Poor	86.60		
9	High	C	Good	86.20		
8	Med.	U	Poor	85.35		
6	Med.	U	Good	85.20		
7	Med.	C	Poor	84.80		
5	Med.	C	Good	84.80		
4	Low	U	Poor	83.80		
2	Low	U	Good	83.65		
3	Low	C	Poor	83.50		
1	Low	C	Good	83.35		

Standard error of the mean = .14142.

Table 26. Analysis of Maximum Temperatures, Center Front, Left Side of Range Top, by Duncan's New Multiple Range Test, Series B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
12	High	U	Poor	84.20		
10	High	U	Good	84.20		
11	High	C	Poor	84.10		
9	High	C	Good	83.90		
8	Med.	U	Poor	83.50		
6	Med.	U	Good	83.50		
5	Med.	C	Good	83.10		
7	Med.	C	Poor	83.00		
4	Low	U	Poor	82.35		
3	Low	C	Poor	82.35		
2	Low	U	Good	82.35		
1	Low	C	Good	82.35		

Standard error of the mean = .067082.

Lines indicating nonsignificant ranges show that temperatures are different for different input levels ($P < .01$, except Table 23, $P < .05$). However, these lines indicate differences in temperature for position within input levels in only three instances, Table 24, high and low inputs ($P < .01$), and Table 26, medium input ($P < .01$). Possibly the experimental error associated with removal of the broiler pan is responsible for some of the lack of significance shown by the multiple range test.

Ceiling temperatures

Temperature-time curves of ceiling temperatures were more nearly linear than those of range temperatures. Maximum temperatures were reached at the end of tests.

Analysis of variance of maximum ceiling temperatures showed differences for replications at the northwest corner ($P < .025$), over the range, and in the northeast corner ($P < .005$). Since the first replications were done in late

TABLE 27. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL ABOVE RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
10	High	U	Good	82.75		
12	High	U	Poor	82.65		
11	High	C	Poor	82.65		
9	High	C	Good	82.50		
6	Med.	U	Good	82.20		
8	Med.	U	Poor	82.10		
7	Med.	C	Poor	82.00		
5	Med.	C	Good	81.90		
3	Low	C	Poor	81.35		
2	Low	U	Good	81.35		
1	Low	C	Good	81.25		
4	Low	U	Poor	81.20		

Standard error of the mean = .1.

TABLE 28. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL IN NORTHWEST CORNER OF TEST ROOM, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
12	High	U	Poor	82.20		
11	High	C	Poor	82.20		
10	High	U	Good	82.10		
9	High	C	Good	82.00		
6	Med.	U	Good	81.65		
8	Med.	U	Poor	81.50		
7	Med.	C	Poor	81.50		
5	Med.	C	Good	81.50		
3	Low	C	Poor	81.15		
4	Low	U	Poor	80.90		
2	Low	U	Good	80.90		
1	Low	C	Good	80.90		

Standard error of the mean = .13964.

TABLE 29. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL IN NORTHEAST CORNER OF TEST ROOM, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
11	High	C	Poor	82.00		
12	High	U	Poor	81.80		
10	High	U	Good	81.75		
9	High	C	Good	81.75		
6	Med.	U	Good	81.50		
8	Med.	U	Poor	81.35		
7	Med.	C	Poor	81.20		
5	Med.	C	Good	81.20		
3	Low	C	Poor	81.00		
4	Low	U	Poor	80.90		
2	Low	U	Good	80.90		
1	Low	C	Good	80.75		

Standard error of the mean = .10954.

July and early August and the second replications in late September and early October, it is quite possible that ceiling temperatures may have been affected by seasonal changes. Temperature differences for treatments were indicated for all three ceiling panels ($P < .005$). Differences for input were likewise indicated ($P < .005$), but differences for position and lid are not significant. In view of the distance of the ceiling panels from the source of heat and of the differences between replicates, it might be expected that lesser differences would not be observed in ceiling panels.

Ranked means, Tables 27, 28, and 29, show the temperatures of all ceiling panels to be stratified by input. However, the lines indicating nonsignificant ranges show that the means were not altogether distinct for inputs. In the panel over the range, the lowest temperature for high input is not significantly different from the highest temperature for medium input according to lines of nonsignificant ranges. Temperatures of the panel at the northwest and northeast corners show successively greater overlapping according to the lines of nonsignificance, but temperatures for high and low inputs are in each case significantly different from each other.

Ranked means show very little stratification within inputs. Inspection of means and nonsignificant ranges show that when there is apparent stratification, differences caused by position or lid are not significant when they exist.

Interactions were not significant. Evidently differences are between inputs only.

Wall temperatures

Wall temperatures were taken in panels: two behind the range, one high and one low; one opposite the range; one in the northwest corner, and one in the northeast, Figure 7. Temperature-time curves for wall panels, like those for ceiling panels, were more nearly linear than those for the range surface. However, the temperature of the panel high behind the range rose more rapidly at the beginning of the test than did the temperatures of other wall panels. The temperatures of this panel remained higher than the others; thus, its temperature-time curves were less nearly linear.

The temperatures of the panels behind the range were higher than those of the other three panels, whose maximum temperature means per treatment were almost identical. Greatest variations among the three panels were at low input levels. The maximum temperatures of the five wall panels were analyzed together. Analysis of variance showed temperature differences between replicates ($P < .005$). As in the case of ceiling temperatures, this is probably because of changes in weather. Air temperatures in the ambient room were controlled, but temperatures of the walls in the ambient room were subject to changes attributable to weather. Radiation from these walls may have affected temperatures of test-room walls.

Temperature differences between treatments were also indicated ($P < .005$). However, treatment differences were attributable to input levels, which brought about differences in temperature ($P < .005$). Temperatures were not significantly different for positions or lids.

No interactions of position, lid, and input were significant; therefore, it may be assumed that input alone was effective in causing temperature differences. Temperature

Table 30. Analysis of Combined Maximum Wall Temperatures, Panels at Five Locations in Test Room, by Duncan's New Multiple Range Test, Series B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
12	High	U	Poor	82.16		
11	High	C	Poor	82.12		
10	High	U	Good	82.05		
9	High	C	Good	81.95		
8	Med.	U	Poor	81.59		
6	Med.	U	Good	81.58		
7	Med.	C	Poor	81.43		
5	Med.	C	Good	81.37		
3	Low	C	Poor	81.09		
2	Low	U	Good	81.07		
4	Low	U	Poor	81.05		
1	Low	C	Good	80.96		

Standard error of the mean = .081486.

Table 31. Analysis of Maximum Air Temperatures, Return Air Stream of Air Conditioner, by Duncan's New Multiple Range Test, Series B

Treatment	Input level	Position	Lid	Ranked means	Nonsignificant ranges (5% level)	Nonsignificant ranges (1% level)
Number				*Degrees F.*		
11	High	C	Poor	83.75		
10	High	U	Good	83.65		
12	High	U	Poor	83.60		
9	High	C	Good	83.40		
8	Med.	U	Poor	83.00		
6	Med.	U	Good	83.00		
7	Med.	C	Poor	82.50		
5	Med.	C	Good	82.15		
4	Low	U	Poor	82.15		
3	Low	C	Poor	82.10		
2	Low	U	Good	81.24		
1	Low	C	Good	81.24		

Standard error of the mean = .25788.

differences attributable to location were indicated ($P < .005$), as might be expected, since two locations were near the range and three at a distance from it. An interaction indicated between input and location ($P < .005$) may be interpreted thus: the influence of input level on temperatures was more effective at locations near the range than at more remote locations. No other interactions were significant.

The ranked means of Table 30 are stratified by input levels. Lines indicating nonsignificant ranges show that the means for each level of input differed from the others but that differences within input were not significant.

Air temperatures

Temperatures observed in the return air stream of the air conditioner were read from the temperature indicator for series B. Therefore, they were recorded less frequently and with less regularity than temperatures of range, walls, and ceiling. Analysis of variance showed differences in maximum temperatures of replicates ($P < .005$). The low specific heat of air makes it extremely sensitive to temperature changes of surrounding surfaces. Thus, weather changes may have been responsible for these differences. Also, experimental error inherent in reading the temperatures and timing of readings may account for some differences. Air temperatures of the second replications were higher with two exceptions.

Differences were indicated for treatments ($P < .005$). Further analysis showed these treatment differences were caused by input patterns ($P < .005$), but no significant air temperature differences were associated with position and lids.

The ranked means, Table 31, show that maximum air temperatures were stratified by input levels. However, the lines indicating nonsignificant ranges show that there was overlapping of temperatures for medium input with high on the one hand and with low on the other. Air temperatures for high inputs were distinct from those for low inputs.

Nonsignificant ranges show the mean air temperatures for good lids at low input to be lower than all others ($P < .05$).

Series C Experiments

DESIGN

Series C was designed to show in terms of comfort factors whether use of pressure pans or ordinary pans was more desirable for cooking processes of moderate length, and whether the amount of water used in nonpressure cooking made any significant difference. Four different range units were used for each pan and water combination; thus, a comparison of the effects of the units could be made. However, it was considered more useful to rate pan-unit combinations in terms of the factors studied.

Results of series A had indicated that use of the pressure pan required greater power consumption, caused greater evaporative loss, and was associated with higher temperatures on the range surface than use of the ordinary pan. However, because only one pressure pan and one range unit had been used in series A to study pressure cooking, it seemed that further investigation should be made. Results of series A had also indicated that use of minimum amounts of water were favorable to lower power consumption in cooking, but that the amount of water had not affected comfort factors significantly. This, too, apparently needed further study. By combining the two objectives, it was possible to have results from tests using the ordinary pan with minimum amount of water as a control for comparing results from tests using excess water and those using pressure pans.

To attain the objectives, the following 16 treatments were required:

Range units	*Pressure pan A*	*Pressure pan B*	*Regular pan min. H_2O*	*Regular pan excess H_2O*
Small regular	1	5	9	13
Speed heat	2	6	10	14
Large regular	3	7	11	15
Thermostatic	4	8	12	16

The same range was used for all tests. Pressure pans are described on page 10, where the differences in the air exhausts are explained. As with previous treatments, the frypan was used with 8-inch units, the sauce pan with 6-inch units when *regular pan* was specified. Two replications of each treatment were done.

IMPROVEMENTS IN EQUIPMENT AND TECHNIQUES

During the analysis of the results of series A, it was apparent that when different range units were used differences in distance between the unit and the location of the thermocouple junction caused differences not attributable to treatments, especially at locations relatively near the units. In series B the same unit was used so that this problem was avoided. For series C, a thermocouple junction was placed in a blackened copper globe, which was suspended from the ceiling with its equator 47½ inches from the floor. The range was on a dolly that raised its surface to a height of about 39 inches; thus the globe was slightly higher than the top of the pan sitting on the unit. For each test the globe was suspended so that it was 18 inches forward of the center of whichever unit was in use.

Larger balances were procured before this series was begun. These permitted weighing each complete pressure pan assembly, including the food and water, for a test. Weighing was done outside the test room. This reduced the time after tests that lamp and operator added to the heat input of the room. Also, the starting of tests was easier since the presence of operator and lamp during weighing had made the stabilization of temperatures before tests difficult.

SPECIFICATIONS

Specifications for amounts of water and timing of range unit control settings were made on the basis of preliminary trials. In each instance the timing and control settings were planned to give the lowest power consumption that would cook the potatoes. Input programs for pressure pans were planned to obtain 15 pounds pressure as rapidly as possible and to maintain that pressure long enough to cook the potatoes. When a longer time was required to reach pressure, a shorter time was required at pressure. The minimum amount of water was the smallest that was practical for all pans and units used. The excess amount of water was the largest that could be used without boiling over in either pan. Amounts were held to the nearest multiple of ¼ cup (60 grams). The specifications are given in Table 32.

RESULTS

Tests for treatments of series C were done in May and June, 1960.

Deviations from Specifications

There were few deviations from the temperatures specified in Table 7. Of the 11 deviations none exceeded ¼° F. as indicated by instruments used. No deviations were noted in ambient temperatures during tests and none for beginning humidity.

TABLE 32. SPECIFICATIONS FOR TREATMENTS, SERIES C[1]

Treatment	Range units									Pans[3]	Size	Water
	Diam.	Max. rating	Control[2]	Setting I		Setting II		Setting III				
				Level	Duration	Level	Duration	Level	Duration			
No.	*In.*	*Watts*			*Min.*[4]		*Min.*		*Min.*		*Qt.*	*Grams*
1	6	1250	Reg.	Hi	10	M-Lo	15	--	--	PPA	4	240
2	6	1250[7]	SH	Hi	Pr+4	M-Hi	11[5]	--	--	PPA	4	240
3	8	1600	Reg.	Hi	Pr	M-Lo	15	--	--	PPA	4	240
4	8	2050	Ts	4 →5	Pr+10	4 † 5	5	--	--	PPA	4	240
5	6	1250	Reg.	Hi	7[6]	M-Hi	5	M-Lo	12	PPB	4	240
6	6	1250[7]	SH	Hi	Pr+4	M-Hi	11[5]	--	--	PPB	4	240
7	8	1600	Reg.	Hi	8[6]	M-Hi	4	M-Lo	12	PPB	4	240
8	8	2050	Ts	4 →5	Pr+10	4 † 5	6	--	--	PPB	4	240
9	6	1250	Reg.	Hi	4	M-Lo	4	Lo	26	SP	3	240
10	6	1250[7]	SH	Hi	B+1	M-Hi	3	M-Lo	26	SP	3	240
11	8	1600	Reg.	Hi	6	Lo	30	--	--	FP	1½	240
12	8	2050	Ts	2 →3	B+30	--	--	--	--	FP	1½	240
13	6	1250	Reg.	Hi	5	M-Lo	5	Lo	25	SP	3	600
14	6	1250[7]	SH	Hi	B+½	M-Hi	4	M-Lo	25½	SP	3	600
15	8	1600	Reg.	Hi	B	Lo	30	--	--	FP	1½	600
16	8	2050	Ts	2 →3	B+30	--	--	--	--	FP	1½	600

[1] All treatments of this series were done on one-tube units.
[2] Controls are: Reg.—regular; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: PPA—pressure pan A; PPB—pressure pan B; SP—sauce pan; FP—frypan.
[4] Abbreviations in this column as follows: Pr—minutes required to get pressure; B—minutes required to bring to a boil.
[5] If pressure goes down when setting is changed, note how long, and extend time to allow 15 minutes at pressure.
[6] If pressure has been reached, otherwise when pressure is reached.
[7] Name plate rating is 1250 watts, but start is at 5000 watts.

Effects of Treatments

Power consumption

Analysis of variance of power consumption showed differences for units and for pans and water ($P < .005$). Pans and water were more effective of the two in producing differences. The units with regular control required lower power consumption than those with special controls ($P < .005$), and the small (6-inch) units required lower power consumption than the large (8-inch) ones ($P < .005$). Controls were more effective than size of unit.

The sauce pan with 240 grams of water required lower power consumption than the pressure pans ($P < .005$), the smaller amount of water required lower power consumption than the larger amount ($P < .005$), and pressure pan B required lower power consumption than pressure Pan A ($P < .01$).

The ranked means and the lines of nonsignificant ranges, Table 33, further elucidate the foregoing analysis and show the order of power consumption requirements of various pan-unit and pan-unit-water combinations. The descriptive columns and nonsignificant ranges show the relative importance of various factors in this connection. In general, pressure pans required higher power consumption than regular pans, but within pressure pans the means are stratified by units. From lowest to highest these are: 6-inch regular, 8-inch regular, speed heat, and thermostatic. These strata differ ($P < .05$) with the exception that power consumption of 6- and 8-inch regular units are not entirely distinct. Also, within units except for the large

TABLE 33. ANALYSIS OF POWER CONSUMPTION BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means
	Watts[1]	Diam.	Control[2]			
No.		*In.*			*Grams*	*BTU*
4	2050	8	Ts	PPA	240	1547
8	2050	8	Ts	PPB	240	1472
2	1250[4]	6	SH	PPA	240	1386
6	1250[4]	6	SH	PPB	240	1352
7	1600	8	Reg.	PPB	240	1246
3	1600	8	Reg.	PPA	240	1212
1	1250	6	Reg.	PPA	240	1202
16	2050	8	Ts	FP	600	1165
14	1250[4]	6	SH	SP	600	1144
5	1250	6	Reg.	PPB	240	1079
12	2050	8	Ts	FP	240	1001
15	1600	8	Reg.	FP	600	997
10	1250[4]	6	SH	SP	240	997
11	1600	8	Reg.	FP	240	820
13	1250	6	Reg.	SP	600	796
9	1250	6	Reg.	SP	240	703

Nonsignificant ranges (5% level) and (1% level) are shown on the page as vertical lines beside the ranked means.

Standard error of the mean = 21.7466.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

TABLE 34. AVERAGE HEAT INPUT PER TREATMENT AND APPLIANCE INPUT AS A PER CENT OF TOTAL, SERIES C

Number	Description of treatments					Heat input, av. each treatment				Appliance input: total input
	Range units			Pans[3]	Water amt.	Operator	Lamp	Appliance	Total	
	Watts[1]	Diam.	Control[2]							
		In.			*Grams*	*BTU*	*BTU*	*BTU*	*BTU*	*Pct.*
1	1250	6	Reg.	PPA	240	167.9	141.7	1202.1	1511.7	79.5
2	1250[4]	6	SH	PPA	240	181.3	148.6	1386.5	1716.4	80.8
3	1600	8	Reg.	PPA	240	164.1	133.2	1212.3	1509.6	80.3
4	2050	8	Ts	PPA	240	153.3	122.9	1547.0	1823.3	84.8
5	1250	6	Reg.	PPB	240	163.5	124.6	1079.1	1367.3	78.9
6	1250[4]	6	SH	PPB	240	177.3	131.5	1352.3	1661.1	81.4
7	1600	8	Reg.	PPB	240	167.8	133.2	1246.5	1547.5	80.5
8	2050	8	Ts	PPB	240	155.1	112.7	1471.9	1739.7	84.6
9	1250	6	Reg.	SP	240	230.2	162.2	703.5	1095.9	64.2
10	1250[4]	6	SH	SP	240	226.8	181.0	997.2	1405.0	71.0
11	1600	8	Reg.	FP	240	244.0	189.5	819.6	1253.1	65.4
12	2050	8	Ts	FP	240	243.7	189.5	1000.6	1433.8	69.8
13	1250	6	Reg.	SP	600	246.9	204.9	795.7	1247.5	63.8
14	1250[4]	6	SH	SP	600	242.3	192.9	1144.0	1579.2	72.4
15	1600	8	Reg.	FP	600	258.0	208.3	997.2	1463.5	68.1
16	2050	8	Ts	FP	600	261.5	206.6	1164.5	1632.6	71.3

[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: PPA and B—pressure pans A and B; SP—sauce pan; FP—frypan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

regular unit pressure pan B required the lower power consumption. An interaction of large regular and thermostatic units with the pressure pans (P < .025) was associated with this reversal. The difference in type of air exhaust may have been partially responsible for the higher power consumption required for pressure pan A. This pan had a separate exhaust, the valve of which required a relatively long time to close. Pressure could not build as high as required until the valve closed.

For each range unit the smaller amount of water required the lower power consumption (P < .01). The amount of power consumption of units with the regular pans was in the same order as it was with pressure pans.

The focus of this study is on the results of the power consumption of the appliance in terms of evaporative loss, gain in humidity, and increase in temperatures. However, since temperatures other than those of the range top and surfaces near the range may also have been increased by the heat produced by lamp and operator in the test room, averages per treatment of all known heat inputs are given in Table 34. This table also gives the averages of total input per treatment and the appliance input as a per cent of the total input for each treatment. Results in Table 34 show that for the treatments using pressure pans the appliance input as a per cent of total was greater, ranging from about 4/5 to 5/6 of the whole. Within pressure pan treatments, it was ranked in order of units as follows: thermostatic, speed heat, 8-inch regular, 6-inch regular. Within regular pan treatments this per cent ranged from approximately ⅔ to ¾ of the total. The order of units was: speed heat, thermostatic, 8-inch regular, 6-inch regular. In general, the per cent input due to appliance was greater for the larger rather than the smaller amount of water for regular pans. In general, the treatments having higher range inputs had proportionally lower per cent of input from sources other than the range.

Evaporative loss

Analysis of variance indicated that units were responsible for differences in evaporative loss (P < .005). Use of 6-inch and 8-inch units did not cause significantly different evaporative losses. This was because the 6-inch regular unit caused lower evaporative losses than the 8-inch regular unit, while the 6-inch speed heat unit, for each pan-water combination except pressure pan A, was associated with higher evaporative losses than the 8-inch thermostatically controlled unit.

The regular pan with minimum amount of water was associated with lower evaporative losses than the pressure pans (P < .005). Pressure pan B had lower evaporative losses than pressure pan A (P < .005). Differences in evaporative losses between smaller and larger amounts of water were not significant.

The ranked means and nonsignificant ranges, Table 35, show that the pressure pans and regular pans were not stratified as they were for power consumption. Means of treatments with the speed heat unit ranked high, but means of treatments with the thermostatically controlled unit were distributed among the means. This distribution was associated with the pans in this order: pressure pan A, pressure pan B, regular pan with excess water, regular pan with minimum water. Nonsignificant ranges show that the means for evaporative loss within speed heat unit did not differ significantly, except that the lowest mean differed from the two highest. In general, the units with regular controls were associated with lower means for evaporative loss. In the case of each unit except the 6-inch regular one, the smaller amount of water in the regular pan was associated with lower evaporative losses according to the multiple range test. The differences were significant only in the case of the large regular unit.

Gain in humidity

Analysis of variance of gain in humidity indicated a difference for replicates (P < .05) that was probably caused by changing weather. The tests were done during the season of change from artificial to natural heat. When heaters were in use, the humidity had to be increased by evaporating water. It was then that smaller increases were observed for tests.

TABLE 35. ANALYSIS OF EVAPORATIVE LOSS BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Grams*		
4	2050	8	Ts	PPA	240	171.50		
2	1250[4]	6	SH	PPA	240	135.50		
14	1250[4]	6	SH	SP	600	132.00		
10	1250[4]	6	SH	SP	240	127.25		
6	1250[4]	6	SH	PPB	240	113.00		
8	2050	8	Ts	PPB	240	105.75		
1	1250	6	Reg.	PPA	240	90.00		
3	1600	8	Reg.	PPA	240	85.75		
15	1600	8	Reg.	FP	600	85.50		
5	1250	6	Reg.	PPB	240	75.00		
16	2050	8	Ts	FP	600	72.50		
7	1600	8	Reg.	PPB	240	67.75		
11	1600	8	Reg.	FP	240	65.50		
12	2050	8	Ts	FP	240	64.75		
9	1250	6	Reg.	SP	240	39.75		
13	1250	6	Reg.	SP	600	31.75		

Standard error of the mean = 5.81324.

[1] Rated wattage; actual watts not always as rated.

[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.

[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.

[4] Although rated at 1250 watts, start is rated at 5000 watts.

Table 36. Analysis of Gain in Humidity by Duncan's New Multiple Range Test, Series C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Grains/cu. ft.*		
4	2050	8	Ts	PPA	240	2.89		
10	1250[4]	6	SH	SP	240	2.05		
2	1250[4]	6	SH	PPA	240	2.04		
14	1250[4]	6	SH	SP	600	1.99		
15	1600	8	Reg.	FP	600	1.86		
6	1250[4]	6	SH	PPB	240	1.83		
1	1250	6	Reg.	PPA	240	1.78		
8	2050	8	Ts	PPB	240	1.72		
3	1600	8	Reg.	PPA	240	1.45		
5	1250	6	Reg.	PPB	240	1.35		
16	2050	8	Ts	FP	600	1.33		
11	1600	8	Reg.	FP	240	1.06		
12	2050	8	Ts	FP	240	1.03		
7	1600	8	Reg.	PPB	240	1.02		
9	1250	6	Reg.	SP	240	0.88		
13	1250	6	Reg.	SP	600	0.51		

Standard error of the mean = .2567.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

Values for gain in humidity followed the general pattern of those for evaporative loss, but the humidity differences were less sharply defined, as shown by the multiple range test, Table 36. Longer nonsignificant ranges indicate that fewer differences in means for humidity gains were significant. However, Treatment 4, in which pressure pan A was used on the thermostatically controlled unit, stands out as different from all others ($P < .05$). Fewer differences were expected since evaporative loss is not the only factor responsible for changes in humidity.

Temperatures of surface of range

Range temperatures were recorded at four locations, but only the location at the center of the unit cluster was considered useful for comparison. However, the highest temperatures per treatment for the thermostatically controlled unit and most of the highest temperatures for the large regular unit were observed at this location. The highest temperatures for the speed heat unit were observed at the center front of left side and those for the small regular at the center rear of left side. This temperature distribution was caused by the size and arrangement of the units. However, temperature distribution for units with reference to the thermocouple locations needs to be considered in connection with the results. Comparisons of range temperatures at the center of the unit cluster between 6-inch and 8-inch units are in some respects not valid.

Temperature-time curves of temperatures at the center of the unit cluster differed between pressure pans and regular pans because of differences in length of the cooking period and higher temperatures required for getting and maintaining pressure. The temperatures rose to a high peak, dropped slightly when input was reduced, then more steeply when the unit was turned off. The rise in temperature was more rapid than the drop. For regular pans on the 8-inch units, the rise was rapid but not as high as that for pressure pans. The drop after the input was reduced was shorter and less abrupt and was followed by a period of little or no decrease until the range was turned off. The rise was higher for regular unit and for the larger amount of water. The curves for regular pans on small regular and speed heat units were fairly similar, except that after the initial rise (which was smaller for the small regular unit) the temperatures of the small regular unit declined slightly, whereas those for the speed heat unit rose gradually so that the highest temperature was observed at approximately the time the range was turned off. For these two small units, higher temperatures were observed also when the larger amount of water was used.

At locations more remote from the unit in use, temperature-time curves were lower and smoother. For treatments using pressure pans, they rose much less abruptly than did the temperatures at locations near the unit, continued to rise at a slower rate, and reached their highest point in most instances after the range was turned off. Their decline was very gradual. Curves for the treatments with regular pans had more gradual rises and longer times at high levels. Their decline was almost imperceptible, probably because heat was being transferred from the warmer areas until the temperature of the entire range top had become equal.

Analysis of variance indicated a difference in temperatures at the center of the unit cluster for replicates ($P < .05$). Since this location is very near the source of heat, it seems unlikely that these temperature differences were caused by weather conditions. A slight difference in timing of the adjustment of controls could have caused a difference in the recorded maximum temperatures since records were made at 4-minute intervals. Curves show that some maximum temperatures fell in the interval between recordings. Differences were indicated for units ($P < .005$). The small regular unit caused lower maximum temperature than the speed heat unit ($P < .005$), the large regular lower than the thermostatically controlled unit ($P < .005$), and the two small units lower than the two large ones ($P < .005$). Pressure pans were associated with higher maximum temperatures than regular pans with the smaller amount of water ($P < .005$), 240 grams

Table 37. Analysis of Maximum Range-Top Temperatures, Center of Unit Cluster, by Duncan's New Multiple Range Test, Series C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Degrees F.*		
8	2050	8	Ts	PPB	240	108.4		
7	1600	8	Reg.	PPB	240	107.3		
2	1250[4]	6	SH	PPA	240	107.0		
4	2050	8	Ts	PPA	240	104.5		
3	1600	8	Reg.	PPA	240	103.9		
6	1250[4]	6	SH	PPB	240	103.8		
1	1250	6	Reg.	PPA	240	101.8		
15	1600	8	Reg.	FP	600	97.7		
11	1600	8	Reg.	FP	240	95.6		
5	1250	6	Reg.	PPB	240	94.2		
16	2050	8	Ts	FP	600	93.6		
10	1250[4]	6	SH	SP	240	91.2		
12	2050	8	Ts	FP	240	91.2		
14	1250[4]	6	SH	SP	600	91.1		
13	1250	6	Reg.	SP	600	85.3		
9	1250	6	Reg.	SP	240	84.6		

Standard error of the mean = .53292.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

of water with lower temperatures than 600 grams ($P < .005$), and pressure pan B with lower temperatures than pressure pan A ($P < .05$).

Ranked means and nonsignificant ranges, Table 37, reinforce the results of analysis of variance and show the extent of the temperature differences. All except one of the treatments with pressure pans are at the top of the ranked means. The regular pan used with the small manually controlled unit is responsible for means that are lower than all others of the series ($P < .01$).

Lower temperatures were caused by using the smaller amount of water on the thermostatically controlled unit ($P < .01$) and the large regular unit ($P < .05$).

Analysis of variance showed pressure pan A to have been associated with higher means than pressure pan B. However, the ranked means and nonsignificant ranges show that, while this was true for the small regular ($P < .01$) and speed heat units ($P < .01$), the reverse was true for the large regular ($P < .01$) and thermostatic units ($P < .01$). Assuming high range-top temperatures are an index of efficiency of heat use by a pan-unit combination, the 8-inch units must have been more efficiently used with pressure pan A, and the 6-inch units more efficiently used with pressure pan B. The reason for this may be associated with the relation of the shape of the bottoms of the pans to the sizes of the units. The bottom of pressure pan B had a depression approximately 1/16 inch deep and 6 inches in diameter, which may have increased its contact with 6-inch units, whereas the bottom of pressure pan A had somewhat the shape of a flattened cone with a height of approximately 1/16 inch. It probably made equally good contact with the outer edge of both units, but for the large unit the total contact area was probably greater.

Ceiling temperatures

Temperatures were recorded for three panels on the ceiling, Figure 7. Locations of the panels were: west side over range, northwest corner, and northeast corner. Their distance from the range was in the order mentioned. Temperatures were also in this order. Temperature-time curves for ceiling locations were more nearly linear than those for the range surface. For treatments using pressure pans and those using regular pans on the large unit with manual control, the curves for the location over the range were distinctly higher than those of the other ceiling locations. For treatments in which the regular pan was used on the small unit with regular control, there was little difference among the curves of the three locations. For treatments in which the regular pan was used with speed heat and thermostatically controlled units, the curves of the three locations were intermingled. In general, the curves rose gradually until the range was turned off after which they remained level for some time. However, for treatments with pressure pans on the thermostatically controlled unit, the temperature over the range rose rapidly and leveled off or declined slightly before the range was turned off.

Analysis of variance showed no significant differences for replicates, but differences for units and pans were indicated for all three locations ($P < .005$). Of the units, the small ones caused lower maximum temperatures than the large, and the large regular caused lower maximum temperatures than the thermostatically controlled unit at all locations ($P < .005$); the small regular unit produced lower temperatures than the speed heat unit at the location over the range ($P < .005$) and in the northeast corner ($P < .05$), but no difference was indicated at the northwest corner. Location may have been responsible for lack of difference in the last instance since the speed heat unit, of higher power consumption, was farther from the northwest corner than the small regular unit. The regular pan with 240 grams of water was associated with lower temperatures than the pressure pans at all three locations ($P < .005$), but temperature differences associated with the two pressure pans and with the two amounts of water were not significant.

The ranked means and nonsignificant ranges, Tables

38, 39, and 40, show that locations nearer the range had higher temperatures and that pressure pans were associated with higher temperatures than regular pans, especially at locations at a distance from the range. For the location above the range, treatments using regular pans are stratified by units. Within units the smaller amount of water is associated with the lower temperatures. However, the differences for amount of water are not significant. At locations more remote from the range, differences are smaller and lower significance is indicated by the longer lines of nonsignificant ranges.

Wall temperatures

Wall temperatures were recorded for panels at four locations. Two on the wall behind the range (one above splasher and one at a level lower than the units), one at the east side of the north wall, and one opposite the range, Figure 7. Temperature-time curves for each treatment show that the temperatures of the panel high behind the range were always higher than those of the other panels. This difference was more evident for pressure pans than for regular pans. The highest temperatures were for treatments using pressure pans with the thermostatically controlled unit. For these treatments the location high behind the range had much higher temperatures than the other wall locations. When wall temperatures rose rather high, as in the case of those of the panel high behind the range for treatments using pressure pans, they fell less rapidly than they increased. In instances of their slow rise they fell even more slowly.

TABLE 38. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL OVER RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Degrees F.*		
8	2050	8	Ts	PPB	240	84.1		
4	2050	8	Ts	PPA	240	84.0		
7	1600	8	Reg.	PPB	240	82.9		
3	1600	8	Reg.	PPA	240	82.5		
2	1250[4]	6	SH	PPA	240	82.3		
5	1250	6	Reg.	PPB	240	82.1		
6	1250[4]	6	SH	PPB	240	82.1		
1	1250	6	Reg.	PPA	240	82.1		
16	2050	8	Ts	FP	600	82.0		
12	2050	8	Ts	FP	240	81.9		
15	1600	8	Reg.	FP	600	81.9		
11	1600	8	Reg.	FP	240	81.8		
14	1250[4]	6	SH	SP	600	81.7		
10	1250[4]	6	SH	SP	240	81.6		
13	1250	6	Reg.	SP	600	81.3		
9	1250	6	Reg.	SP	240	81.2		

Standard error of the mean = .07071.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

TABLE 39. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL AT NORTHWEST CORNER, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Degrees F.*		
8	2050	8	Ts	PPB	240	82.3		
4	2050	8	Ts	PPA	240	82.3		
16	2050	8	Ts	FP	600	81.8		
12	2050	8	Ts	FP	240	81.8		
1	1250	6	Reg.	PPA	240	81.5		
2	1250[4]	6	SH	PPA	240	81.4		
5	1250	6	Reg.	PPB	240	81.4		
7	1600	8	Reg.	PPB	240	81.3		
6	1250[4]	6	SH	PPB	240	81.2		
3	1600	8	Reg.	PPA	240	81.2		
15	1600	8	Reg.	FP	600	81.1		
14	1250[4]	6	SH	SP	600	81.1		
10	1250[4]	6	SH	SP	240	81.1		
11	1600	8	Reg.	FP	240	81.0		
13	1250	6	Reg.	SP	600	81.0		
9	1250	6	Reg.	SP	240	81.0		

Standard error of the mean = .089442.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

TABLE 40. ANALYSIS OF MAXIMUM CEILING TEMPERATURES, PANEL AT NORTHEAST CORNER, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Degrees F.*		
4	2050	8	Ts	PPA	240	81.8		
8	2050	8	Ts	PPB	240	81.7		
16	2050	8	Ts	FP	600	81.4		
12	2050	8	Ts	FP	240	81.4		
2	1250[4]	6	SH	PPA	240	81.3		
7	1600	8	Reg.	PPB	240	81.2		
6	1250[4]	6	SH	PPB	240	81.2		
3	1600	8	Reg.	PPA	240	81.2		
15	1600	8	Reg.	FP	600	81.2		
1	1250	6	Reg.	PPA	240	81.2		
11	1600	8	Reg.	FP	240	81.1		
14	1250[4]	6	SH	SP	600	81.1		
10	1250[4]	6	SH	SP	240	81.1		
5	1250	6	Reg.	PPB	240	81.1		
9	1250	6	Reg.	SP	240	81.0		
13	1250	6	Reg.	SP	600	80.9		

Standard error of the mean = .07746.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

Sometimes they remained the same for a long period before falling.

Analysis of variance of maximum wall temperatures indicated no significant differences for replicates. Temperature differences among units were indicated for all wall panels, except the one low behind the range ($P < .005$). The regular pan with 240 grams of water caused lower temperatures than pressure pans in the panels high and low behind the range ($P < .005$), in panels opposite the range, and at the northeast corner ($P < .05$). Differences associated with the two pressure pans and the two amounts of water were not significant.

The ranked means and nonsignificant ranges, Tables 41, 42, 43, and 44, show that highest temperatures and greatest numbers of significant differences were found for the panel on the wall high behind the range. Next in order of significant differences was the panel opposite the range, although temperatures of this panel were slightly lower than those of the panel low behind the range. At the two panels near the range, the pressure pans were usually associated with highest temperatures, whereas, at the two panels more remote from the range, maximum temperatures were highest for the thermostatically controlled unit, and lowest for the 6-inch unit with manual control. This is in line with the analysis of variance, except that for the panel high behind the range. It is possible that the position of the units on the range is associated with the greater significance of temperature difference among units.

TABLE 41. ANALYSIS OF MAXIMUM WALL TEMPERATURES, PANEL HIGH BEHIND RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Degrees F.*		
8	2050	8	Ts	PPB	240	84.2		
4	2050	8	Ts	PPA	240	83.9		
2	1250[4]	6	SH	PPA	240	82.5		
7	1600	8	Reg.	PPB	240	82.5		
6	1250[4]	6	SH	PPB	240	82.4		
1	1250	6	Reg.	PPA	240	82.3		
3	1600	8	Reg.	PPA	240	82.3		
12	2050	8	Ts	FP	240	82.2		
16	2050	8	Ts	FP	600	82.2		
5	1250	6	Reg.	PPB	240	82.1		
11	1600	8	Reg.	FP	240	81.9		
15	1600	8	Reg.	FP	600	81.9		
10	1250[4]	6	SH	SP	240	81.8		
14	1250[4]	6	SH	SP	600	81.8		
9	1250	6	Reg.	SP	240	81.7		
13	1250	6	Reg.	SP	600	81.6		

Standard error of the mean = .074162.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

TABLE 42. ANALYSIS OF MAXIMUM WALL TEMPERATURES, PANEL OPPOSITE RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		In.			Grams	Degrees F.		
4	2050	8	Ts	PPA	240	81.6		
8	2050	8	Ts	PPB	240	81.5		
16	2050	8	Ts	FP	600	81.2		
12	2050	8	Ts	FP	240	81.2		
2	1250[4]	6	SH	PPA	240	81.2		
11	1600	8	Reg.	FP	240	81.1		
6	1250[4]	6	SH	PPB	240	81.1		
7	1600	8	Reg.	PPB	240	81.0		
15	1600	8	Reg.	FP	600	81.0		
10	1250[4]	6	SH	SP	240	81.0		
3	1600	8	Reg.	PPA	240	81.0		
14	1250[4]	6	SH	SP	600	80.9		
5	1250	6	Reg.	PPB	240	80.9		
1	1250	6	Reg.	PPA	240	80.9		
9	1250	6	Reg.	SP	240	80.7		
13	1250	6	Reg.	SP	600	80.7		

Standard error of the mean = .10954.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

TABLE 43. ANALYSIS OF MAXIMUM WALL TEMPERATURES, PANEL LOW BEHIND RANGE, BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		In.			Grams	Degrees F.		
1	1250	6	Reg.	PPA	240	81.8		
4	2050	8	Ts	PPA	240	81.7		
3	1600	8	Reg.	PPA	240	81.7		
2	1250[4]	6	SH	PPA	240	81.7		
8	2050	8	Ts	PPB	240	81.7		
7	1600	8	Reg.	PPB	240	81.7		
11	1600	8	Reg.	FP	240	81.6		
6	1250[4]	6	SH	PPB	240	81.6		
14	1250[4]	6	SH	SP	600	81.5		
5	1250	6	Reg.	PPB	240	81.5		
16	2050	8	Ts	FP	600	81.5		
15	1600	8	Reg.	FP	600	81.5		
12	2050	8	Ts	FP	240	81.3		
13	1250	6	Reg.	SP	600	81.0		
9	1250	6	Reg.	SP	240	81.0		
10	1250[4]	6	SH	SP	240	80.9		

Standard error of the mean = .20494.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

Table 44. Analysis of Maximum Wall Temperatures, Panel East End of North Wall, by Duncan's New Multiple Range Test, Series C

Treatment	Range units: Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Ranked means	Nonsignificant ranges (5% level)	(1% level)
No.		In.			Grams	Degrees F.		
4	2050	8	Ts	PPA	240	81.6		
8	2050	8	Ts	PPB	240	81.4		
16	2050	8	Ts	FP	600	81.3		
12	2050	8	Ts	FP	240	81.3		
2	1250[4]	6	SH	PPA	240	81.3		
10	1250[4]	6	SH	SP	240	81.1		
15	1600	8	Reg.	FP	600	81.1		
14	1250[4]	6	SH	SP	600	81.1		
11	1600	8	Reg.	FP	240	81.1		
7	1600	8	Reg.	PPB	240	81.1		
6	1250[4]	6	SH	PPB	240	81.1		
3	1600	8	Reg.	PPA	240	81.1		
1	1250	6	Reg.	PPA	240	81.0		
5	1250	6	Reg.	PPB	240	81.0		
13	1250	6	Reg.	SP	600	80.8		
9	1250	6	Reg.	SP	240	80.8		

Standard error of the mean = .089442.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

Globe temperatures

Since the globe was movable and was suspended so as to be always the same distance from the center of the unit in use, presumably it would avoid as far as possible temperature differences caused by location of units. However, when the rear units were used, more heat may have been reflected towards the globe than when front units were used.

Also the globe temperatures were presumably affected by the total situation in a manner similar to that experienced by a worker at the range, that is, by radiation from all sides and by air temperatures. Temperature-time curves of the globe thermocouple had a shape and height intermediate between those of the range and wall. Curves for regular pans were flatter than those for pressure pans. Not much difference was evident between curves of treatments using larger and smaller amounts of water.

In addition to analyzing maximum globe temperatures and in order to study the total situation, the concept of degree-minutes above 80° was developed. This was essentially equivalent to studying the area between the temperature-time curve and the 80-degree base line, using minutes for the horizontal dimension and degrees for the vertical. This was done for the cooking and serving period. The latter was arbitrarily set as the duration of the cooking period plus 5 minutes for regular pans and the duration of the cooking period plus 10 minutes for pressure pans. More time was allowed for pressure pans

Table 45. Analysis of Maximum Globe Temperatures, Location in Front of Range, by Duncan's New Multiple Range Test, Series C

Treatment	Range units: Watts[1]	Diam.	Control[2]	Pans[3]	Water amt.	Ranked means	Nonsignificant ranges (5% level)	(1% level)
No.		In.			Grams	Degrees F.		
8	2050	8	Ts	PPB	240	85.0		
4	2050	8	Ts	PPA	240	84.7		
7	1600	8	Reg.	PPB	240	84.4		
2	1250[4]	6	SH	PPA	240	84.3		
6	1250[4]	6	SH	PPB	240	84.1		
5	1250	6	Reg.	PPB	240	83.8		
1	1250	6	Reg.	PPA	240	83.8		
3	1600	8	Reg.	PPA	240	83.6		
16	2050	8	Ts	FP	600	83.5		
12	2050	8	Ts	FP	240	83.4		
14	1250[4]	6	SH	SP	600	82.9		
15	1600	8	Reg.	FP	600	82.8		
11	1600	8	Reg.	FP	240	82.8		
10	1250[4]	6	SH	SP	240	82.8		
13	1250	6	Reg.	SP	600	82.5		
9	1250	6	Reg.	SP	240	82.3		

Standard error of the mean = .12042.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

because pressure had to be reduced before the food could be served. Since observations were made at 4-minute intervals, the formula for calculating degree-minutes was as follows:

$$2(\text{Obs}_1 + \text{Obs}_n) + 4\sum_{i=2}^{n-1} \text{Obs}_i + A_1 + A_2 = \text{Total degree-minutes}$$

In which

Obs. = temperature observation minus 80 degrees

A_1 = area under the curve before observation 1. (The first observation was made less than 4 minutes after zero time.)

A_2 = area under the curve between observation n and the end of the period under consideration. (The last observation did not necessarily fall at the end of the period considered.)

The average temperature of the cooking and serving period was found by dividing the degree-minutes by the total minutes included.

When maximum temperatures were used, no account was taken of the shorter time required by the pressure pans. Presumably degree-minutes would remove this disadvantage by taking the length of time into consideration. However, this assessment of the total period does not represent an existing situation at any time.

Use of average temperatures did not remove the time factor, but reduced the importance of the maximum temperature. For pressure pans, the lines of average temperature cut the temperature-time curves as they ascended to maximum and as they decended, whereas for regular pans the lines of average temperature kept fairly near to the temperature-time curves. In all tests the average temperature did not differ greatly from the temperature at the end of the cooking and serving period.

Degree-minutes and average temperatures were calculated for the eating period also. This was defined as the 30-minute interval following the cooking and serving period. This was intended to represent a time during which the effects of the cooking process are evident to the family that eats in the kitchen. Thirty minutes represents a minimum time for eating. Since temperatures changed very gradually during this period, the temperature-time curve kept rather near to the line of average temperatures.

Analyses of variance of maximum globe temperatures, degree-minutes during the cooking and serving period, average temperatures during the cooking and serving period, and average temperatures during the eating period showed differences attributable to units, kinds of pans, and amounts of water ($P < .005$). Units with regular controls caused lower maximum globe temperatures than those with special controls, small units caused lower temperatures than large units, and regular pans caused lower temperatures than pressure pans ($P < .005$). Pressure pan A caused lower temperatures than pressure pan B ($P < .025$).

The ranked means and nonsignificant ranges, Tables 45, 46, 47, and 48 show that within units the values for pressure pans were in each comparison higher than for regular pans for maximum globe temperatures ($P < .01$). The same trend was evident for average globe temperatures for cooking and serving period, and eating period; and degree minutes for the cooking and serving period. However, fewer differences were significant.

The thermostatically controlled unit was associated with highest means for each pan and pan-water combination. The 6-inch unit with manual control was lowest for each pan and pan-water combination, except for pressure pan A, which for all measures during the cooking period had lowest values when used on the large regular unit.

Although temperature differences were small (the range of maximum globe temperatures was only 2.7°), the lines of nonsignificant ranges are of short enough length to show that many differences were significant.

TABLE 46. ANALYSIS OF DEGREE-MINUTES OBSERVED DURING COOKING AND SERVING PERIOD BY DUNCAN'S NEW MULTIPLE RANGE TEST, SERIES C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Degree-Minutes*		
8	2050	8	Ts	PPB	240	114.000		
16	2050	8	Ts	FP	600	111.100		
4	2050	8	Ts	PPA	240	108.125		
12	2050	8	Ts	FP	240	100.025		
6	1250[4]	6	SH	PPB	240	97.025		
7	1600	8	Reg.	PPB	240	96.825		
2	1250[4]	6	SH	PPA	240	94.000		
15	1600	8	Reg.	FP	600	88.625		
1	1250	6	Reg.	PPA	240	83.060		
11	1600	8	Reg.	FP	240	79.825		
3	1600	8	Reg.	PPA	240	76.825		
5	1250	6	Reg.	PPB	240	76.475		
14	1250[4]	6	SH	SP	600	73.125		
10	1250[4]	6	SH	SP	240	70.925		
13	1250	6	Reg.	SP	600	68.300		
9	1250	6	Reg.	SP	240	61.775		

Standard error of the mean = 3.1978.

[1] Rated wattage; actual watts not always as rated.

[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.

[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.

[4] Although rated at 1250 watts, start is rated at 5000 watts.

Table 47. Analysis of Average Globe Temperatures for Cooking and Serving Period by Duncan's New Multiple Range Test, Series C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Degrees*		
8	2050	8	Ts	PPB	240	83.560		
4	2050	8	Ts	PPA	240	83.380		
7	1600	8	Reg.	PPB	240	82.805		
6	1250[4]	6	SH	PPB	240	82.735		
16	2050	8	Ts	FP	600	82.585		
2	1250[4]	6	SH	PPA	240	82.575		
12	2050	8	Ts	FP	240	82.500		
1	1250	6	Reg.	PPA	240	82.445		
5	1250	6	Reg.	PPB	240	82.285		
3	1600	8	Reg.	PPA	240	82.260		
15	1600	8	Reg.	FP	600	82.085		
11	1600	8	Reg.	FP	240	82.000		
10	1250[4]	6	SH	SP	240	81.865		
14	1250[4]	6	SH	SP	600	81.830		
13	1250	6	Reg.	SP	600	81.690		
9	1250	6	Reg.	SP	240	81.605		

Standard error of the mean = .081055.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

Table 48. Analysis of Average Globe Temperatures for Eating Period by Duncan's New Multiple Range Test, Series C

Treatment	Range units			Pans[3]	Water amt.	Ranked means	Nonsignificant ranges	
	Watts[1]	Diam.	Control[2]				(5% level)	(1% level)
No.		*In.*			*Grams*	*Degrees*		
8	2050	8	Ts	PPB	240	82.300		
4	2050	8	Ts	PPA	240	82.270		
7	1600	8	Reg.	PPB	240	82.065		
12	2050	8	Ts	FP	240	81.945		
16	2050	8	Ts	FP	600	81.930		
2	1250[4]	6	SH	PPA	240	81.925		
3	1600	8	Reg.	PPA	240	81.875		
6	1250[4]	6	SH	PPB	240	81.845		
1	1250	6	Reg.	PPA	240	81.810		
11	1600	8	Reg.	FP	240	81.795		
15	1600	8	Reg.	FP	600	81.775		
10	1250[4]	6	SH	SP	240	81.705		
14	1250[4]	6	SH	SP	600	81.630		
5	1250	6	Reg.	PPB	240	81.620		
13	1250	6	Reg.	SP	600	81.415		
9	1250	6	Reg.	SP	240	81.350		

Standard error of the mean = .070071.
[1] Rated wattage; actual watts not always as rated.
[2] Controls are: Reg.—regular or manual; SH—speed heat start, infinite control; Ts—thermostatic.
[3] Pans are: FP—frypan, PPA and B—pressure pans A and B, SP—sauce pan.
[4] Although rated at 1250 watts, start is rated at 5000 watts.

Summary

This report presents the first three of a series of experiments in which the temperature and humidity effects of using selected home appliances were studied.

PHYSICAL SET-UP

Electric range surface units and one separate electric cooker-fryer were used to cook whole potatoes by boiling and by pressure cooking. Various practices were studied.

Cooking was done in a tightly built test room that was well provided with thermal insulation, and finished and furnished with nonporous materials. The test room was located inside a building and so situated as to provide for free air circulation below, above and on all sides. Four fans were used to ensure this circulation.

The outer building was provided with two gas space heaters with fans. Trees shaded the roof of the outer building in summer and a ventilating fan was available for cooling attic space or drawing air through the building. The attic floor above the test room was covered with insulating batts. Test room temperatures were controlled between tests by air conditioners and electric lamps. During tests an air conditioner fan was used to circulate air in the test room. Humidity was reduced as necessary first by use of calcium chloride, and next by a dehumidifier before tests of series B and C.

Provision was made outside the test room for electric metering and voltage control of appliances used inside this room. Power consumption was measured and current recorded. The latter was used as a check on input pattern of appliances.

Temperatures were measured by copper-constantan thermocouples connected to a 16-point electronic strip-chart recorder and to an electronic indicator with three 10-point switches. Humidity was calculated from temperatures obtained by two glass-encased thermocouples located in the return air stream of the air conditioner. The cover of one of these thermocouples was kept wet by means of a water supply and wick arrangement. The ranges used provided units with two conformations, three types of control, and two diameters. There was one lift-up unit with a deep-well inset. Two pans were sized to fit 6- and and 8-inch units. Two pressure pans had differing venting devices and regulators.

FOOD

Potatoes were carefully selected for uniformity of variety, shape, size, and weight. They were stored in batches of six, from which random selection was made before each test.

PRELIMINARY STUDY

Methods of controlling ambient room temperatures and stabilizing test room temperatures were established through preliminary study. Each series of treatments was designed, and the specifications and procedures for each treatment were determined through preliminary tests, after which a manual of procedure was compiled for the guidance of laboratory workers. The manual was revised as necessary for each succeeding series.

GENERAL PROCEDURE

General procedure consisted of stabilizing test-room temperatures to 80 or 80 ± ¼° F. (as measured by the instruments used) according to location, stabilizing humidity (for series B and C treatments) at 6 to 7 grains per cubic foot, performing the cooking operation, and recording results. Ambient room temperatures were controlled to 80 ± 2 degrees during tests. For each series each set of treatments in the two replications was done in random sequence. Each set was completed before the next was begun. Data were analyzed graphically and statistically.

SERIES A

Design

Treatments of series A were planned to explore the temperature and humidity effects of using the following pairs of practices for doing the cooking task previously described: (a) high and low input levels; (b) monotube and two-tube units, (c) large and small units; (d) thermostatic control and regular six-position manual control; (e) speed heat start, infinite control, and regular six-position manual control; (f) use of same unit on surface and as deep-well; (g) pressure pan and regular pan; (h) range unit with pan, and separate appliance; and (i) large and small amounts of water.

Twelve treatments were required to make these comparisons. Three replications were done for all except two treatments. For these, two replications were done.

Results

Analysis of data yielded the following results in terms of these measures: power consumption of appliance; evaporative loss from cooking pan; gain in humidity of test room; and maximum temperatures of range surfaces, walls, ceiling, and air of test room.

Input level

Results indicated that the greatest differences were those that existed between use of the same unit with high and low input patterns. Low input was associated with lower values for every measure studied including maximum combined coincident temperatures of walls, of ceiling, and of walls and ceiling. Wall and ceiling temperatures were the measures most subject to influences from outside the test room.

Also the treatments using high inputs usually caused results that were higher than those of treatments using low inputs, that is, there was little intermingling of mean values coming as a result of using low and high inputs.

One- and two-tube units

Although study of differences between monotube and two-tube units had been planned, it was found that the wattage and reflectors of the units differed sufficiently to make such comparisons unmeaningful.

Unit size

Two pairs of treatments were used to test unit size. These produced conflicting results. Those in which the *monotube* units were used showed the small unit to have significantly lower means for power consumption, evaporative loss, and range-top temperatures, whereas those in which *two-tube* units were used showed no significant difference in means for these values. The lack of significance in the latter instance may be attributable to the fact that the small two-tube unit would not maintain boiling at *low* setting and was operated at *third* for the cooking period. It appears that the switch positions of this unit provided no suitable setting for the operation. Evidence of association between unit size and comfort factors was not conclusive.

Type of control

The thermostatically controlled unit required slightly higher power consumption than the unit of the same size and construction with manual control. The difference was not great enough to be evident in group analysis, but it was revealed in separate analysis of the two treatments. Thermostatic control was associated with higher temperatures at the northwest corner, at ceiling locations, on range top, and wall opposite the range.

The speed heat unit required higher power consumption than the regular unit of the same size and construction. This unit was also associated with higher evaporative loss, gain in humidity, and range-top temperatures. Although the speed heat unit had an infinite number of settings between the lowest and highest, the cycling of the unit interrupted the boiling process unless a fairly high setting was used. The cycling was in response to a bimetal controlled contact in the control panel. The bimetal control had no connection with the pan but was heated by a small resistance that was energized concurrently with the unit.

Comparison of means of thermostatically controlled and speed heat units showed the latter to be associated with higher power consumption and evaporative loss.

Treatments of series A gave rise to some questions concerning the value of these special controls. Although the results were not considered sufficiently conclusive to warrant any recommendations, further study of control devices was indicated.

Use of lift-up unit

The lift-up unit required lower power consumption when it was used as a deep-well rather than when used as a surface unit. However, as a deep-well unit, it caused higher temperatures on the range top and the wall low behind the range. Otherwise little difference was observed in effects of the two positions of the unit. Evidently the deep-well inset and the unit were built for doing this process with efficient use of current. Yet, since the well was not insulated, it heated the range top and the wall low behind the range.

Pressure pan

The pressure pan required higher power consumption than the regular pan used on the same unit. Means for evaporative loss and for temperatures of range top, ceiling over range, and wall low behind range were also higher for the pressure pan. The treatment for the pressure pan required a shorter time than any other; consequently, the heat added to the test room by the operator and the lamp was the lowest for the pressure pan treatment (Table 4, p. 15). In fact, the totals of the three heat inputs for each of these two treatments (6a and 10) were more nearly alike than the input of appliance only. Operator and lamp inputs affected range-top temperatures little if at all. Apparently the high range temperatures caused by the relatively long initial period at high control setting resulted in higher temperatures on the ceiling over the range and the wall low behind the range but not at other locations. However, the shorter time required by the pressure pan would have the added advantage of lower heat production from sources other than the range unit, especially in kitchens in which artificial lighting is required.

Separate appliance

The simple bimetal thermostat used as heat control for the separate appliance was not as effective as properly adjusted manual control or the special controls of surface units for holding power consumption to low levels. However, the simple thermostat did control the input and evaporative loss from the pan considerably better than is the case when the homemaker forgets to turn down the control setting of a range unit after the water boils. This is indicated by the ranked means for power consumption, evaporative loss, and gain in humidity of the treatment for separate appliance (Treatment 11) and other treatments. The mean for the separate applicance in each of these measures was lower than those for treatments with high input programs but higher than all others.

The separate appliance was responsible for a few wall and ceiling temperatures that were higher than those caused by the small regular units.

Although this separate appliance did cause much higher evaporative loss and humidity gain than the thermostatically controlled surface unit, differences in temperatures of ceiling, wall, and air between treatments for these two were not significant.

Amount of water

Using 240 rather than 480 grams of water required lower power consumption. However, the amount of water appeared to make no difference as far as comfort factors were concerned, since no significant difference in means for evaporative loss, gain in humidity, or temperatures in test room was found.

SERIES B

Design

Series B was designed to study the effects of using two different pan lids and centering or not centering pans at three input levels, all of which were lower than the high input level of series A. The same range unit and pan were used for all treatments. Twelve treatments were required for this design. Two replications of each treatment allowed each lid and position to be repeated 12 times and each input level 8 times.

Results

Data are expressed in the same measures as those of series A. Analysis showed that input level was more effective than the specified pan positions and lids in bringing about differences in evaporative loss, humidity gain, and temperatures of range, wall, ceiling, and air. The importance of input brought out in series B not only reinforced the results of series A but also showed that the smallest input differences available for the small unit with a 6-position switch had a marked effect on comfort factors.

Results indicate that position was second in importance. Placing the pan ¾ inch off center caused lower evaporative loss, gain in humidity, but higher range top temperatures. While there was an apparent tendency for the centered pans to be associated with lower wall and ceiling temperatures at some locations, the differences were not significant. This may have been the result of variations in the environment ambient to the test room, a situation that could not be completely controlled. However, small heating effects are not expected to be as effective at locations remote from the source of heat as those near the source.

The lids had no significant effects except that for the location at the center rear left side of the range top the poor lids were associated with higher temperatures than good lids. However, these differences were small. The lid designated as *poor* was not warped or bent and made a good contact with the pan. If it had been an ill-fitting lid, the results might have been otherwise.

SERIES C

Design

Series C was designed to study more thoroughly the differences resulting from use of pressure pans and regular pans, minimum and larger amounts of water in ordinary pans, and units with manual, thermostatic, and infinite controls. The four units of one range were used with regular pans and with two pressure pans. Sixteen treatments were required. Two replications of each treatment were done.

Results

Data are expressed in the same measures as those of series A and B. In addition, globe temperatures were taken at a location approximately 47½ inches above the floor and 18 inches forward of whichever unit was in use. For the globe temperatures, the maximum, the average during cooking and serving period and during the eating period, and the degree-minutes above 80° F. during these two periods were calculated for each test and analyzed.

Kind of pan and amount of water were more effective than the different units in causing differences in power consumption, and maximum temperatures of range surface, ceiling over range, wall low behind range and maximum globe temperatures. The most important of the differences caused by kinds of pan and amount of water was that pressure pans were associated with higher values than regular pans. Besides the measures mentioned, differences were found in evaporative loss, gain in humidity, and all maximum ceiling and wall temperatures. Pressure pan A caused higher values than pressure pan B for power consumption, evaporative loss, gain in humidity, and maximum temperatures of range surface. The larger amount of water in regular pans caused higher power consumption and higher maximum range temperatures than the smaller amount.

Units were more effective than pans in bringing about differences in evaporative loss, gain in humidity, most of the wall and ceiling temperatures, average globe temperatures, and degree-minutes above 80° F. globe temperature. Units with manual control usually caused values lower than those of the same diameter with mechanical controls, except that the thermostatically controlled unit produced lower range-top temperatures than the large regular unit. Large units were associated with higher values than small ones, except for evaporative loss, gain in humidity, and wall temperatures low behind the range.

Of the pan-unit combinations the small manually controlled unit and ordinary pan with either amount of water was always associated with lowest values; the thermostatically controlled unit pressure pan A combination and frequently pressure pan B also were associated with highest values. These values, both high and low, frequently differed significantly from all others.

ALL SERIES

It is useful to consider whether, in spite of their statistical significance, differences were great enough to have practical effects. The compilation shows the extent of differences observed in the three series included in this report. Some of the measures given were observed in only one or two series.

Measure	*Treatment Means*	
	Highest	*Lowest*
Power input, BTU's	2994	603
Evaporative loss, grams	799	7
Humidity gain, grains per cubic foot	7.99	0.51
Maximum temperatures		
Range, center of units, degrees	108.4	83.4
Ceiling over range, degrees	89.5	81.2
Ceiling, northeast, degrees	84.2	80.8
Ceiling, northwest, degrees	85.3	81.0
Wall above range, degrees	87.1	81.6
Wall behind range, degrees	82.9	80.9
Wall opposite range, degrees	83.5	80.7
Wall, northeast, degrees	83.3	80.8
Wall, northwest, degrees	83.0	80.8
Air, degrees	86.1	81.2
Globe, degrees	85.0	82.3
Degree-minutes above 80° F.		
Cooking and serving period	114.	61.
Average globe temperatures		
Cooking and serving period, degrees	83.6	81.6
Eating period, degrees	82.3	81.4

In comparing temperatures, the increase above 80° F. should be considered since the beginning temperature was 80°. Cooking a vegetable such as potatoes represents only part of the heat-producing operations in preparing a meal. Therefore, the total increase caused by cooking a whole meal would be greater. The lowest values in the compilation are associated with use of the ordinary pan on the small manually controlled unit with the lowest input program. The highest are usually associated with use of the same unit and pan with the unit left on *high* for the entire cooking period. The latter is what happens when the user forgets to turn down the unit. However, other high values were observed with units not manually controlled, especially when such units were used with pressure pans.

In addition to the observations of temperature and humidity, reactions of the laboratory workers recorded during tests showed that difference in comfort factors of the extreme cases and some intermediate ones were observable subjectively, but that fine distinctions could not be clearly made by this method.

Conclusions

The following conclusions are made on the basis of observations of power consumption; evaporative loss; maximum temperatures of surfaces and air in the test room; and globe temperatures, including maximum, average during the cooking-serving period and during the 30 minutes thereafter; and the calculated degree-minutes above 80° F. for these periods:

The extent of the differences shows that the choices available to the homemaker in doing such a simple cooking operation as boiling potatoes on an electric range or with a separate electric appliance are worth consideration. The homemaker's choice among ways of performing this operation may be the deciding factor between a comfortable and an uncomfortable kitchen and incidentally may affect the cost of fuel for cooking.

Manual control of surface units offers the opportunity of producing both the best and the worst effects. Properly managed, it is the best of methods studied. However, this "best method" required three control settings properly timed. Leaving the unit on *high* control setting for the entire cooking period was the worst possible method, but one that may be used inadvertently by the forgetful homemaker or erroneously by the one who believes that this method will hasten the cooking process.

Thermostatic control of surface units is decidedly poorer than the best manual control but much better than poor manual control. For the forgetful cook or for the one who must be away from the kitchen during the cooking process, it would be the better and safer method. The thermostatic control does do as well as manual control at keeping evaporative loss to a minimum when units are the same size.

The thermostatically controlled surface unit, because of the anticipating nature of its control, is preferable to a separate appliance with a simple bimetal control for processes where boiling is specified. The separate appliance, probably because of the difficulty of control at the boiling point, was associated with very high evaporative loss, and consequently high power consumption.

The speed heat unit with infinite control, and operated at three control settings, ranked between the best manual control and thermostatic control, except that the thermostatically controlled unit was superior to the speed heat unit in holding evaporative loss to low levels when ordinary pans were used.

For the process studied, small units are superior to large ones. However, this may be associated with the pan as well the unit. For larger amounts of food, this may not be a valid conclusion.

For a process of this kind, pressure pans are a poor choice for holding kitchen temperatures and humidity to low levels. The cooking time is considerably shorter than for boiling, but when the entire process including time to reduce pressure is considered, even this difference is smaller than might be inferred from cooking time tables. Even the use of degree-minutes during the cooking and serving period, a measure designed to take time requirements into account, leads to the conclusion that the pressure pan is the poorer choice. It is possible that lack of flatness in the bottoms of the pressure pans was a factor in this result.

No great advantage could be assigned to either pressure pan. Any advantage seemed to be associated with the combination between pan and unit. Pressure pan B seemed to have some advantage over pressure pan A when used with the small regular unit and the thermostatically controlled unit. On the other hand pressure pan A appeared to have a slight advantage when used with the large regular unit.

Using less water had no great general advantage, except that it required lower power consumption.

Centering a pan on a unit is of some importance in reducing heat loss to the room, but it causes greater evaporative loss than when pan is off center. The higher the input supplied the greater is the difference in evaporative loss between centered and uncentered pans. This shows the importance of centering the pan and holding input to low levels. A pan might be set off center to prevent undesirable evaporative loss when control settings lack sufficient flexibility to give the desired input.

If a lid fits even if it merely sits on top of the pan, it is for all practical purposes as effective in preventing evaporative loss and consequent high fuel requirement as a lid made for the pan. This is not necessarily true of a battered or ill-fitting lid.

When the lift-up unit is used as a deep-well, a saving of power consumption is realized; the surface of the range will become slightly warmer, but no important difference in comfort factors will be noted.

It was not possible to study differences associated with monotube and two-tube units with the ranges used in these series.

The use of Duncan's New Multiple Range Test provided a means of compact presentation of results. Use of ranked means and nonsignificant ranges made it possible to visualize relationships among an entire set of values. On the other hand, in this method or any method that analyzes a set of values as a group the experimental error of each treatment affects the analysis of the entire set. Thus, if experimental error is considerably greater for some treatment(s) than for others, group methods may fail to show some true differences that would be revealed by separate analysis. Consequently, there is also a possibility that group comparisons may show differences that separate analysis would indicate are not real. However, inconsistencies of this nature did not occur in these tests.

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APPENDIX

INSTRUMENTS

Graphic ammeter, The Esterline-Angus Company, Model AW AC, Serial No. 123733, 0 to 5 amp. capacity. Hand-wound spring chart drive with feed ¾, 1½, 3, 6, and 12 inches per hour and per minute. (Twelve inches per hour used.) Used for checking timing of various settings and to record current used by cooking appliances.

Instrument current transformers, General Electric Company, Type JP-1, Model No. 9JP1 F AB 2, Serial Nos. A875287 and A897413, 25 to 60 cycles, with self-contained primary for ratios 10:5, 20:5, 50:5 and 100:5. Higher ratios, obtainable by passing a cable through an opening in the case, were not required in this study. Used in connection with graphic ammeter.

Voltage regulators, Powerstat Variable Autotransformer, Superior Electric Company. Type 136. Serial Nos. 3490 and 3466. Input 120 V, single phase, 50/60 cyc., 20 amp., 2.8 KVA. Used to maintain constant voltage for appliances.

Voltmeters, General Electric Company, Type P-3, Model 8AP3VAV1, Nos. 3743605 and 3731848, dual range 0 to 150 volts and 0 to 300 volts. Used as a check on voltage regulators.

Watt-hour meters, General Electric Company, single phase, reading to 1/100 kwh (estimated to thousandths).

Type 1-55-A, Model No. AR152, Serial No. 35969073, 3-wire. Used to measure current of cooking appliances.

Type 1-50-A, Model BA15a, Serial No. 35969068, 2-wire. Used to measure current of test room light.

Temperature indicator, Speedomax, Leeds and Northrup Company, Type H, Catalog No. 1-01-00-015-6-00-0, Serial No. 55-29084-1-1, range 0° to 400° F. Used for measuring test room and ambient temperatures.

Selector switches, 10-point, Leeds and Northrup Company, No. 8240, Serial Nos. 1503915, 1503958 and 1165899. Used in connection with temperature indicator.

Temperature recorder, sixteen-point Electronik strip chart potentiometer recorder; Brown Instrument Division, Minneapolis-Honeywell Regulator Company; Model No. 153X64P 16-X-42; Serial No. 6625-N; range -25° to + 150° F.; chart speed, 2 inches per hour with change gears for 4, 6, and 8 inches per hour. (Eight inches per hour used.) Used to record ambient and test room temperatures.

Electric kitchen clocks with second hands, General Electric, Telechron, and Harmony House, manufactured by E. Ingraham Company. Used in recording start and finish time of all operations in kitchen.

Stopwatches, Clico, Northeast Instrument, and Fisher Scientific Companies; (Minute and second hands controlled by hand switches). All used for timing cooking operations.

Heavy duty solution balance, Ohaus Scale Corporation, Model No. 1195, capacity 20 kg.

Weighing scale, Speedweigh, Toledo Scale Company, Model 1901D, Serial No. 7668, capacity 2,500 gr. Both were used to weigh food and pan assembly before and after cooking.

APPLIANCES

Electric range, Hotpoint Model No. 108RB67, Serial No. 9584221, 11.3 KW, 60 cycles, 115/230-120/240 V, Installation form 0.

Electric range, Frigidaire, Model No. RI-60-56, Serial No. 24053417, 14.6 KW, 60 cycles, 115/230-120/240 V, Installation form 0.

Air conditioners, International Harvester, Model A1000D 15 amp., 230 V, 1 H.P., capacity 10,600 BTU/Hr., Air delivery, 300 CFM.

MANUAL OF PROCEDURE

Preliminary Preparation

Before each series

Purchase food, divide into batches, store.

DAY BEFORE TEST

1. Check test to be done.
2. Note descriptive data on large data sheet, and appropriate field books.
3. Place pads by watt-hour meters, set up book for temperature indicator.
4. Set out appropriate pan and assembly. For nonpressure pans check tape over hole in lid to see that hole in tape has not been marred.
5. Suspend globe temperature thermocouple from hook corresponding to unit used. (See procedure for placing globe temperature apparatus page 49.)
6. When nonpressure pan is used, suspend pan thermocouple from hook corresponding to unit used. Adjust stopper to depth of pan that is to be used. (See procedure for placing thermocouples, page 49.)
7. Select and prepare food, reweigh, place in test kitchen or appropriate storage place.[1] If two tests are expected, prepare two batches of food. Also set out one extra batch to provide for minor difficulties.
8. Set out a container (nonmetal surface) of water to use in test. Cover.
9. See that ammeter is prepared, clock wound, chart in place and labelled with ratio and chart speed.
10. See that transformers are set up with correct ratio for unit used (50:5 for speed heat unit).
11. See that preparations are made for having temperature and humidity for day of test as nearly correct as possible.

DAY OF TEST. First thing in the morning turn on fans in ambient room, note temperatures and humidity, adjust as necessary. (See instructions *To Regulate Temperatures,* page 50, and *To Regulate Humidity,* pages 49-50.

While temperatures and humidity are adjusting, make frequent checks, note rate of progress, and decide whether there will be time for test to proceed. When it is clear that a starting point can be made, go on with preparations as given below. This outline is set up for either one or two operators until about 15 minutes before the test. After that time two operators are required.

OUTSIDE PREPARATION.

1. Set date and numbering stamps.
2. Label charts except for time of day.
3. Get out stopwatches.
4. Weigh item to be cooked, record weight.
5. Weigh pan assembly (less lid), record. Set scale for pan assembly plus the amount of water for treatment to be used.
6. Add food. Weigh pan, lid, cage[2] (or rack and regulator for pressure pan), water and food, record.

[1] When uncured potatoes must be used, note whether spoilage has occurred or may occur overnight. If it has, get out and wash other potatoes to substitute for spoiled ones. Make the substitution just before the test.

[2] The cages are small cylinders of hardware cloth, one 3¼ inches long and 2 inches in diameter, and one 2¾ inches long and 2 inches in diameter, with devices at the center of each for holding thermocouple.

7. Inform inside operator that pan assembly is in readiness for the test.

8. See that circuits 9, 10 (range) and 15 (ceiling lamp) are off.

9. Check voltmeters for level and connections and turn on. Run the temperature recorder at intervals as necessary to keep informed about temperatures.

10. Start clock to Esterline-Angus ammeter. (Do inside preparation here if one person is doing preliminary preparation.)

11. Read kilowatt-hour meters; have another person read independently. If readings do not check, both persons should read again and agree on the correct values.

12. While the temperature recorder runs, read the temperature indicator (all points), record. At this time record outdoor temperature of thermometers.

13. When it is believed a test can be started, unless the temperature recorder has been running steadily, run a complete cycle and come back to 16. With stopwatch in hand let No. 1 come up; stop after 11 seconds or just before it gets ready to print.

INSIDE PREPARATION.

1. Before going into test room see that circuits 9, 10 (range), and 15 (ceiling lamp) are off. Use small wattage lamps in preparation. Avoid using ceiling light. If temperature is on 80° F. or very near, carry into test room *one* can of ice per person. Place ice on lower air conditioner if wall and ceiling temperatures are high. If range temperatures are high, place ice on upper air conditioner and turn on fan.

2. Carry complete weighed assembly in readiness for cooking into test room and place on proper unit. (For positioning see *Procedure for Centering Pan,* page 49.)

3. Turn unit to proper setting. Check transformer ratio. If unit is to be turned down, mark position to which it is to be turned.

4. If thermocouple is used, place it in pan, recheck for distance from bottom of pan for security. (For positioning, see *Procedure for Placing Thermocouple,* page 49.)

5. Check the humidity apparatus to see that wick is wet and in the proper position, and that water in wick tube is at the proper level. Note also whether there is sufficient water in the flask.

6. Turn off the fan of the accessory air conditioner, turn on the fan of the one that is to be used.

7. On going out, carry out ice if it was used, turn off whatever inside light was used.

8. If salt bags or dehumidifier were used, remove just before the test.

Test Proper

Outside operator

1. Start temperature recorder at an even minute by second hand of clock, note clock time on chart. This time is called 0-4 minutes. Inform inside operator. (At this point inside operator is reading the temperature recorder.)

2. At 0-3 minutes (one minute after temperature recorder was started) mark appliance ammeter chart for start. Record time on chart.

3. At 0-1 minute inform inside operator of the time and see that temperatures are still in line for a start.

4. (Inside operator reports to air lock.) At 0-5 *seconds* turn on lamp. (Circuit 15.)

5. At 0 minutes turn on appliance and start stopwatch. (Circuits 9 and 10.)

6. Go to voltmeters at once. Adjust voltage. Continue to adjust voltage for first few minutes. Adjust again after the current for the appliance drops to a lower level. Go back and check it at intervals during tests.

7. Note any changes in ambient temperatures as shown on recorder and indicator, make adjustments as necessary. (See instructions *To Regulate Temperatures,* Page 50.)

8. Read the temperature indicator and record at 0+10 minutes, and 0+20 minutes. The readings will be taken more often when the pressure pans are used. Also record indicator Switch A, Nos. 6 and 7 just after inside operator signals that heating appliance has been turned off. (Read all if time.)

9. Between readings keep the temperature indicator at C-9 (pan thermocouple). Note any deviations from boiling.

10. After inside operator leaves test room, continue to note temperature until temperatures of all points in test room have leveled or dropped.

11. Read the watt-hour meters for appliance and lamp.

12. Turn off voltmeters, replace covers.

13. Stop appliance ammeter. Remove chart and rewind.

14. Turn off circuits 9, 10 (range), and 15 (ceiling lamp). If it looks as if another test will follow the same day, start procedures for next test.

15. When no further temperature increases are noted at points inside test room, consider test at an end. Note the time on temperature record chart.

16. If humidity of test room is above 7 grains per cu. ft. open doors when ambient room is dry. If humidity of test room is below 6 grains per cu. ft. do not open doors.

17. If general humidity conditions are above 7 grains per cu. ft. reclose test room and take measures to reduce humidity to a level between 6 and 7 grains per cu. ft.

18. After humidity has reached proper levels recool test room. Take whatever measures are necessary to keep ambient temperatures within prescribed limits. If ambient temperatures are high, lower air tunnel and use fan to direct heated air from air conditioner out window.

Inside operator

1. At about 0-6 minutes or earlier get into uniform for test.

2. When outside operator is ready to start temperature recorder, read temperature indicator for all points. Call this 0-5 minutes for start of these readings.

3. Between 0-1 minute and 0-5 *seconds* go into air lock carrying stopwatches, instructions, and recording sheet. See that light switch is up.

4. Ceiling light will come on at 0-5 seconds, then go into test room, and start watch when *range light* comes on. This is 0 time.

5. Take position on stool at the north end in front of the door on east side.

6. At predetermined time go to position at right of range. Operate range according to instructions for treatment.

7. If pressure pan is used, write a note to outside operator, giving time pressure was reached and time for end of test.

8. Make appropriate notes, as evidences of boiling, pressure, execessive evaporation, condensation, and subjective feelings about temperature, humidity and other comfort factors.

9. Turn off unit at proper time, leaving your station 15 seconds before and taking position at right of range.

10. Write a note informing outside operator of this, if requested.

11. Leave room carrying pan of food, turn out ceiling light, close doors.

After leaving test room

1. Weigh pan and contents. Record.

2. Remove lid, pour off water. Test potatoes for doneness. Note burst places. Record.

3. Read watt-hour meter for lamp and appliance at once. Check with outside operator's readings.

4. Watch temperature recorder and indicator; continue with indicator readings.

5. After the test room door has been opened by outside operator (page 48), the problem is to get the conditions in the test room ready for the next test by controlling the humidity and temperature as far as possible.

6. Stop recorder, noting time it was stopped. Remove chart, and stamp.

7. Help mark charts and file ready for calculating, recording, etc.

8. Clean up utensils and test room.

Procedure for Centering Pans

1. Set pan on unit so that handle is above the line drawn through the center of the unit,[3] and the pan appears to be centered.

2. See that the two needles on the pan handle are hanging vertically from the center axis of the handle.

3. When the needle at the outer end of the handle is just above the cross line that corresponds to the pan used, and the two needles line up visually with each other and the line on the range, the pan is centered.

Procedure for Placing Globe Temperature Apparatus

1. Keep in mind that this contains a thermocouple and handle with care.

2. For each test the apparatus must be placed on the hook that corresponds to the range unit to be used.

3. See that the ridge at the equator of the globe is about 47¼ inches above the floor. (Use folding rule.)

Procedure for Placing Thermocouple in Pan

1. This is not done for pressure pans. For nonpressure pans procedure begins the day before test. Place the pan that is to be used in the correct position on the unit. See that the pan lid is correctly placed. Insert the thermocouple in the pan, being sure the tagged side of the stopper is near the lid handle. Adjust the thermocouple through the stopper so that it just touches the pan bottom and is practically vertical. While the stopper is resting on the lid, place a piece of masking tape on the thermocouple as a flag or tag just above the stopper. Raise the thermocouple so that the tag is ¼ inch above the stopper. If the same pan is used next, this setup need not be changed.

2. During *weighing procedure* 5, the next step takes place. Cage must be placed correctly at this time. Place cage in pan so that the end with the crossed threads is up. Rotate cage so that the crossed threads are as far from center of pan as possible. Place cage by mark on pan. Red mark is for front unit, blue mark for back unit.

3. Place lid on pan so that hole will be above cage. When marks on lid and pan are matched, hole should be in desired position.

4. After pan is centered, (*see Procedure for Centering Pans* above), check to see that thermocouple C-9 is on correct hook above pan. Pull thermocouple down and insert into hole in lid. Raise lid, maintaining horizontal position, (do not tilt) to see that thermocouple goes between the pairs of crossed threads in the cage.

5. Replace lid as before. Check to see that tag is still ¼ inch above stopper.

[3] Pressure pan A has such a wide flange that it cannot be centered front to back on the RR unit of Range F. For this unit, an extra line is drawn for this pan. By substituting this line for the center line side to side centering is obtained. Since the bottom of the pan is larger than the unit, this much de-centering probably does not cause loss of heat from this 6-inch unit.

6. Fasten thermocouple leads (wires) so that they will not be moved by the air currents.

Procedure for Weighing

1. If Ohaus scale is used, get zero balance.

2. Weigh potatoes, record weight.

3. Weigh pan (and trivet); check with posted values.

4. Set scale for amount of water to be weighed (see values, on this page). Add water to balance scales.

5. Place (cage and) potatoes in pan. For MH3Q or MHFP, arrange so all potatoes are in water. When thermostatic unit is used, see that no potato is on exact center of pan so it will be over sensing element.

6. Place lid (and regulator) on pan. (If pressure pan is used, do not tighten lid until pan is off scales.) Weigh this entire assembly. It contains pan, trivet or cage, water, food, lid, needles (and regulator if pressure pan is used). Check weight with posted value plus weight of potatoes.

7. Remove from scales. Tighten lid if pressure pan is used, being certain that needle is on lower handle.

8. After finishing tests, take all weights off scales (both kinds) but do not leave at zero. The beam should not continue to move up and down.

9. Always keep weighing platforms and beam clean. Sweep with 2-inch camel's-hair brush.

Items	*MHPP*	*Mirro PP*	*MH3Q*	*MHFP*
Pan (and trivet), g.	1383.5	1188.5	720.0	753.0
Pan, (trivet), water 240 g.	1623.5	1428.5	960.0	993.0
Total assembly, incl. 240 g. water less potatoes	2401.5	2403.5	1155.0	1227.0
Pan (trivet), water, 600 g.	----	----	1320.0	1353.0
Total assembly, incl. 600 g. water less potatoes	----	----	1515.0	1587.0

To Regulate Humidity

To raise humidity

In Test Room—

1. If calcium chloride has been used remove from room.

2. Place open pans of water in room. Hot water raises humidity more rapidly than cold, *but* it also increases temperatures. Let fan blow over surface of exposed water.

3. In humid weather open test room doors provided ambient room heaters are not in use.

4. Hang wet towels in test room. Placing them in a draft helps. The net effect of evaporation is to reduce temperatures but using a fan raises them.

In Ambient Room—

1. Put pans of water on heaters or boil water on hotplate.

2. Expose a pan of water in front of fan. Hot water works faster.

3. If outdoor temperatures are near 80° F. and humidity outdoors is greater than indoors, open doors.

4. Do not run dehumidifier.

To lower humidity

In Test Room—

1. Run dehumidifier after tests to bring humidity within specified limits.

2. Keep well-filled bags of calcium chloride in test room

when tests are not under way. In extremely humid times calcium chloride may be spread in flat pans.

3. Keep test room doors tightly closed; close as quickly as possible when entering and leaving room.

4. Run dehumidifier if temperatures are below 80° F. CAUTION. The dehumidifier raises temperatures; therefore just before a test watch temperatures carefully. Remove dehumdifier from test room when it is not running; collected water can re-evaporate.

5. Do not expose water or wet items in room unnecessarily. Wipe up spilled liquids and carry wet cloths out of room.

6. Having ambient room dry helps keep test room dry.

In Ambient Room—

1. Run the dehumidifier but remember to empty it often enough to prevent spilling. Always empty after turning it off.

2. Do not expose open pans of water and the like.

3. On rainy days avoid unnecessary traffic from outdoors.

4. Keep doors and windows closed.

To Regulate Temperatures

For starting tests

1. Start fans (2 room fans, fans above and below test room, air conditioner fan).

2. Start and standardize temperature recorder. Let it run one or two complete cycles.

3. While temperature recorder runs, read temperature indicator switches A, B, and C. Record.

4. Check all temperatures and decide whether desired level can be attained. If so, note each place where temperature is low or high, and take necessary steps to attain desired temperature levels.
(See list, Table 2, page 11.)

5. Continue to read recorder and indicator at intervals frequent enough to attain control. Often this keeps one person fairly busy with reading and following up with necessary adjustment.

6. In making adjustments, particularly when about to balance at the desired level, be extra careful to avoid overshoots and undershoots.

7. In warm seasons consider whether the sun is affecting the warming process. Try to anticipate this and to take advantage of it or to avoid it as the situation requires.

8. Exact temperatures are most important inside the test room and within its walls and ceiling. Ambient air and wall temperatures may vary more, but remember that they affect test room temperatures.

9. Whenever the person reading and regulating temperatures is uncertain as to whether progress is as desired or as to how to proceed she should discuss the problem with another as soon as convenient.

10. Remember that it is of no use to note incorrect temperatures unless you follow up with action to control the situation as needed.

During tests

1. As soon as the voltage has leveled off, check ambient temperatures on the recorder and proceed as needed to keep temperatures within prescribed limits.

2. Read the indicator as soon as necessary measures have been taken.

3. Remember that now temperatures within test room and in test room walls, especially interior ones, are increasing because of the test. The ones to be regulated are ambient air, air above test room, and air below test room.

4. These ambient temperatures must be kept within 2 degrees of prescribed levels, but it is desirable to keep within 1 degree. Some difficulty is usually experienced with the air above and below test room. Endeavor to keep these in line, but give them greater leeway.

Ways of Cooling Test Room

1. If ambient room is cooler than test room, open doors and put fan in doorway blowing inward.

CAUTION. Humidity must be considered. (a) When heaters are on, the ambient air will be too dry to do this. (b) When heaters are not on and the weather is humid, the ambient air will be too moist to do this.

2. Ice or Scotch ice, may be placed in the draft from the air conditioner or fan.

CAUTION. This will reduce the humidity, since moisture condenses on these cold surfaces.

3. Cold water or moist towels may be placed in a draft.

CAUTION. This, especially the moist towels, will usually increase humidity.

4. *Do not* turn the test room air conditioner to cool, unless it is the day before a test. The air conditioner quickly overcools, and there is no way of disposing of the extra cooling effect in time to do a test.

Ways of Heating Test Room

1. Use light bulbs of the wattage needed. If light bulbs do not furnish enough wattage, use heat lamps (250 watts) or even heat cones (1000 watts). When doing this in the morning before a test, turn on the air conditioner fan to circulate heated air. It is better to use several small heat units than one large one of equal wattage.

2. The starter and ballast of the center light generate a great deal of heat, and the ceiling, which is relatively easy to heat, is easily overheated when this lamp is used.

3. A very slight rise in temperature can be brought about by the use of the air conditioner fan only.

Ways of Cooling Ambient Room

1. Turn on fans to circulate air before beginning to cool room.

2. If outside air is cooler than inside, open a door. Greater cooling is obtained if front and back doors are opened.

CAUTION. If humidity is high it may be inadvisable to open outside doors.

3. Use window shades as necessary to keep out sun.

4. See that heater pilots are off in hot weather.

5. Close small office door in afternoon.

6. If ceiling is warm and attic air is warmer than outdoor air, turn on attic fan.

7. Turn out unnecessary lights.

Ways of Heating Ambient Room

1. Turn on all fans to help to keep temperatures as even as possible.

2. Turn on lights.

3. Use heat lamp or heat cones for small heating effects.

4. Use heaters. Be sure heater fans are switched to run continuously. When tests are about to start or in progress turn heater thermostats up and down manually leaving heaters on for short intervals (½ to 1 minute) to avoid wide fluctuations in temperature.

5. Use panels and fans to direct heated air currents.

6. On cool days close doors to small office and bathroom.

7. Raise shades on sunny days, but *do not* let sun shine on walls of test room.