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A STUDY OF CERTAIN FACTORS IN GAS HEATING AFFECTING THE EFFICIENCY OF ALUMINUM KETTLES

by

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INTRODUCTION

Problem

The problem of standardization of household equipment though recognized for more than two decades has only recently been actively engaging the attention of the home consumer. Because of its relative newness it is not surprising that the question of standardization for cooking utensils has had as yet little attention. Any standardization of size of cooking utensil, which will be suited to the amount of food to be cooked and the burner to be used, must consider how heat can be utilized best and how waste of fuel can be eliminated. This study was made as an attempt to establish certain relations between the size of kettles of a given type, the mass of water to be heated, the kind of natural gas burners used, and the gas consumption under certain gas pressures.

Review of Literature

Previous investigations emphasize that in making any study of utensil efficiencies it is impossible to separate utensil efficiency from that of the stove, and the conditions under which it is operated. The construction and operation of the stove are vital factors in producing uniform results in kettles. For example the position of the burner relative to the utensil has a marked effect on the efficiency of the utensil. The Bureau of Standards (3) found that as the distance between utensil and burner is increased there is a decrease in efficiency due to flame contact. The decrease in efficiency caused by moving the utensil from 3/4 inches to a position 1½ inches away, amounts to about 15% irrespective of velocity of gas. Should the velocity of gas be increased at the 3/4 inch position there is a lowering of efficiency. This is due to loss of heat by radiation and convection when the flame extends to the sides of the utensil. Figure 1 shows the temperatures of the various parts of a gas flame as is given by McPherson and Henderson. (10)

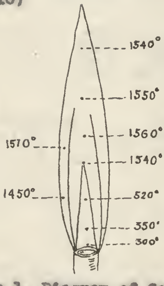


Figure 1. Diagram of Gas Flame

If the burner is adjusted so that the flame extends to the sides of the kettle, the hottest part of the flame is not in contact with the kettle. A good flame depends on the adjustment of the air shutter, the velocity of the gas and condition in the mixing chamber. All ordinary fuel gases are a mixture of naturally occurring or artificial gases. Natural gas was used in this experiment, and by far the larger per cent is methane. The following equation given by McPherson and Henderson (10) shows the relationship of volumes necessary for maximum combustion:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

$$1 \text{ vol} + 2 \text{ vol} \rightarrow 1 \text{ vol} + 2 \text{ vol}$$

Since air is only about 1/5 oxygen it is obvious that approximately 10 volumes of air are necessary for complete combustion of 1 volume of the natural gas. The composition of the gas determines the volume of air necessary to properly support combustion. The Bureau of Standards (3-4) cites the position, length, shape and size of the orifice, the design of the injection tube, dimension and shape of burner head and the total area of the flame ports as factors which affect the heating value of a gas flame. If these factors are controlled it is then possible to determine the conditions for the maximum efficiency of the utensil.

Landreth and Hutchinson (9) in studying the effect of the weight of the kettle used five aluminum kettles of varying weights on an electric stove. They found that the thermal efficiency of heavy and light weight aluminum kettles with practically the same capacity and diameter was approximately the same. They also found that evaporation of water from the kettle depends upon the tightness of fit of the lid rather than on the weight of the kettle. They conclude also that waterless cooking may be done in light weight kettles as well as heavy provided the lid fits well. Good (6) in making similar tests on a gas stove with four four-quart stew kettles, one of light and one heavy weight aluminum and one of heavy and one of light weight enamel, found the slight difference of 3% in thermal efficiency of the light and heavy weight enamel kettles. For the aluminum kettle the heavy weight showed the greater efficiency. It is interesting to note that after the light weight aluminum kettle was roughened with sand paper it showed an increase of 1.6% in efficiency, while the same kettle blackened on the bottom showed an increase of 5.3% in efficiency. This was probably due to reflection of heat by the brighter surface. Brigham (2) found in her study of electric stoves that an ordinary enameled or nickled copper kettle held heat better than one of aluminum and she reports also that it absorbed heat more slowly on an open coil than for a closed coil.

She makes the statement that straight sided kettles present less surface for radiation and are more efficient, and that flat bottom pans of the proper size and type are a saving of electricity. A pan with a diameter at the heating surface equal to or a trifle larger than the heating unit is best. The kettle should be heavy enough to prevent buckling so that it will at all times fit flat on the heating unit. Brigham also found that the heavier kettle heats as quickly as the lighter one and that it holds the heat longer. She brings out the fact that close fitted covers are an economy of time and fuel.

Balderston (1) makes the statement that efficiency is not due to the thickness of material of which the utensil is made but rather to size of kettle in relation to size of the burner. She, however, does not cite proof for the statement.

Kloeffler (8), 1917, in his work with electric stoves shows that covering a kettle while heating water gives a gain of from 10 to 25 per cent in efficiency in the utensil. In his test he used two aluminum kettles 6 inches in diameter and 5 inches in depth. One kettle was new while the other was discolored and dented. On the open unit the new kettle showed an increase of 2.45% in efficiency over the other while on the enclosed unit the difference in efficiency was much greater, 13.8%. He considers that this difference is due to absorption of heat by the old kettle on the open unit while the bright surface of the new one reflects back some of the heat.

INVESTIGATION

Apparatus

In testing the fuel value of gas a Sargent Automatic Gas Calorimeter, No. 2756, a Sargent Wet Test Gas Meter, a Laboratory balance, a Torsion balance, style 4420, 35 lbs. capacity graduated to .01 of a pound, a mercury barometer and Fahrenheit thermometer were used. For all the tests a gas stove of standard make, with closed manifold, was used. The burners were star shaped and the tests were made on the two at the front. The diameter of the regular burner was 4-1/4 inches and that of the giant burner was 5½ inches. The giant burner used was next to the oven. The burners were 2-3/16 inches from the utensil. The mixer and cock showing the speed and orifice are illustrated in Plate No. 1. The orifice, one of the adjustable, channel type, was 1/16 inch in diameter and fitted with a spud which regulated the volume of gas going to the mixer head. The air shutters were also adjustable. The temperature of the flame was tested by means of an iron constantan thermocouple and a Leeds & Northup potentiometer. The kettles were of medium weight aluminum with convex sides and flat bottoms. The characteristics of the kettles are showing in Table I.

TABLE I. KETTLE CHARACTERISTICS

Ket-tle	Diam. Bottom Inches	Area Bot-tom Sq. In.	Diam. Top Inches	Depth Inches	Weight Pounds	Thick-ness mm	Commer-cial Lab. Cap. Quart	Actual Cap. Quart
A	9	28.3	11-1/15	7-1/16	1.761	1.625	12	11.215
B	7	22.0	7-7/8	4-3/4	.8135	.995	4	3.834
C	5.5	17.3	7-1/4	3-3/8	.535	1.045	2	2.136

The apparatus was arranged in a corner of the laboratory where there were no windows and surrounded by a screen of pressed wood, seven feet high. Plate No. II shows the arrangement of apparatus. The time was recorded from a stop watch.

Procedure

The fuel value of gas is essential in obtaining the desired evaporation in utensil efficiencies. Checks on the calorimeter showed that running the gas at 2 inches pressure gave the highest fuel value. As the fuel value of the gas changes from time to time it was necessary to make the test often. At least two tests were made each day and a slight variation in B. T. U. was found each time the test was made. In order to get the greatest heat from the burner the temperature of the flame was tested with the thermocouple while the shutter governing the volume of air was being adjusted. A blue flame without yellow tips gave the greatest heat, and at the same time did not blacken the kettle. A room had to be arranged to reduce air currents to a minimum because the slightest current caused a noticeable drop in temperature. The three kettles used were tested with varying amounts of water. Kettle A with 3, 6, 9, 12, 15 and 18 pounds. B with 1½, 3 and 6 pounds and C with 1½ and 3 pounds. The first set of tests were made on the regular burner with lids on the kettle. A hole was made in the lid through which the thermometer, inserted in a cork, was suspended. Each kettle was weighed with lid, thermometer and cork, and the water was then weighed after the temperature of 70° was obtained. The burner had previously been tested and lighted, and the gas rate obtained with a stop watch and wet test gas meter. The tests were made with 3 and 7 inches of pressure. As the kettle was placed on the flame the stop watch was started and meter reading taken. The water in the kettle was heated to 209 degrees, this being the average boiling point for this attitude. When the boiling point was reached the watch was stopped and meter cut off. The water was quickly weighed to determine the amount of evaporation. To determine the rate of heating the temperature of the water was noted at intervals. Each run was repeated at least three times. The temperature of gas, temperature of room and barometric pressure were recorded for each run. Each gas volume was reduced to 60° F. and 30 inches of mercury pressure. The following formula was used for calculating the efficiency of the kettle:

$$\text{Efficiency} = \frac{W \times S(t_2 - t_1)}{\text{cu. ft. gas} \times \text{BTU per cu. ft.}}$$

W = water heated

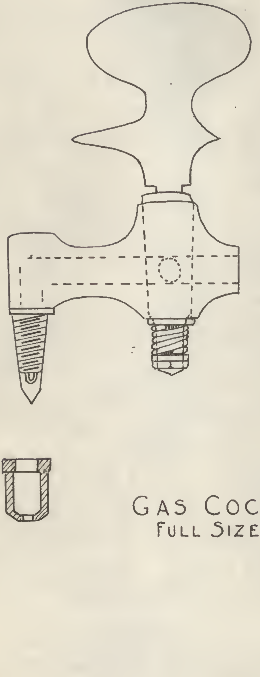
S = specific heat of water which is 1

t_2 = highest temperature to which the water was heated which was 209°F

t_1 = beginning temperature of 70°F

Tests with the same kettles uncovered were made in a similar way. The thermometer bulb in all cases was kept at the center of the mass of water.

PLATE No. 1.



GAS COCK
FULL SIZE

Plate No. 2

Plate No. 3

Plate No. 4

Discussion of Results

In the tests made using the three aluminum kettles on the regular burner, it was found that the efficiency in each case was greater with three inches of gas pressure than with 6.2 inches. This was due, evidently, to the fact that more heat was utilized when the flame was shorter. With the higher pressure the flame was longer. The Bureau of Mines (7) classify this longer flame as an effective but wasteful one because so much of the total heat produced is lost to the surrounding atmosphere by being sent outward and down. Kettle C and B showed a greater rate of increase in efficiency with three pounds of water when changing from 6.2 inches of gas pressure to three inches than did kettle A. Kettle C showed a greater increase in efficiency than did B. The lesser increase for A may be due principally to greater surface area which allows more evaporation. This evaporation loss may be noted by comparing data in Tables IV, VII and XV; also Tables III, IX and XIV. There was also greater surface of the kettle to radiate and reflect heat. In using three inches of gas pressure a longer time was required to heat the water but less gas was utilized. For example, in heating six pounds of water in kettle A with the cover on, it took an average of 3.8 minutes longer to heat the water from 70° F. to 200° F. with three inches of gas pressure, and an average of .4 of a cubic foot of gas less than with 6.2 inches of gas pressure.

All kettles covered showed greater efficiency than uncovered. When a closed kettle is heated according to Preston (11) there is a point reached at which the molecules which have escaped from the surface of the water are reflected from the sides and from each other in such a way that many find their way back into the water lessening the rate at which evaporation takes place. When the kettle is uncovered the molecules escaping from the surface of the water are carried away by the atmosphere above and at the same time take a larger amount of heat. The Bureau of Standards (3) estimates that with each five drops of water that is taken off as steam it takes from the water enough heat to cool about a pound of water 1° F. This means that an uncovered kettle requires a longer time to raise the temperature to the desired point.

The tests show that there is a limit to the increase in efficiency with the increase in pounds of water heated. For example the efficiency of kettle A covered increased as the water was increased up to 12 pounds. After this point it remained practically at a level. When the kettle was uncovered the increase in efficiency noted stopped at nine pounds.

There was an increase in efficiency with an increase in diameter of the kettle. This may be noted especially from Table XVII for three pounds of water. The larger area of surface probably explains this fact.

All the kettles showed lowered efficiency on the giant burners due to the fact that the area of the burner was larger and a greater percentage of the heat was carried away by the surrounding air and not absorbed. The giant burner requires slightly longer time and more gas to reach a given temperature in all the tests as yet made.

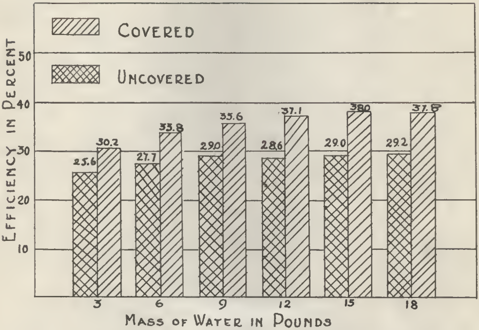


Figure 2 Comparison of Efficiencies of Kette A on Regular Burner 6.2 inches Gas Pressure.

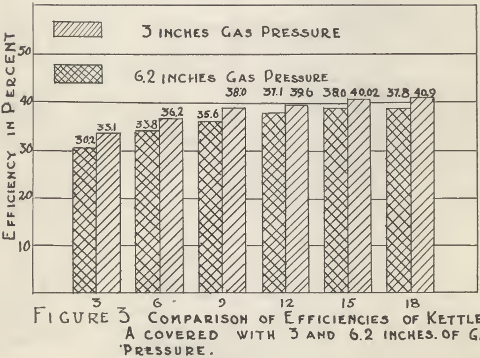


Figure 3 Comparison of Efficiencies of Kettle A covered with 3 and 6.2 inches. of Gas Pressure.

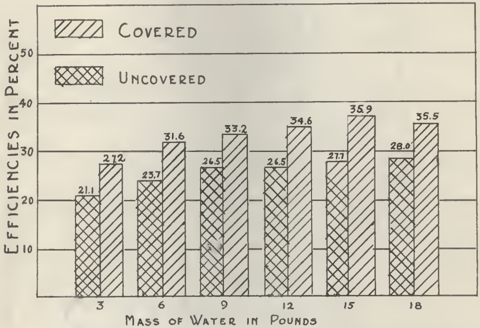


Figure 4 Comparison of Efficiencies of Kettle A on Giant Burner 6.2 inches of Gas Pressure.

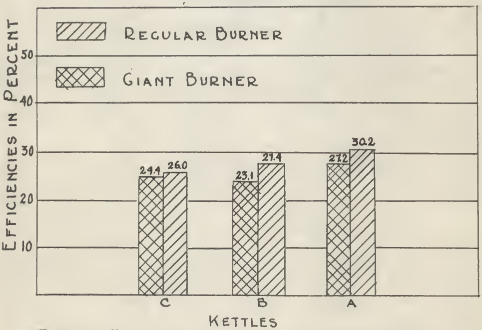


Figure 5 Comparison of Efficiencies of all Kettles Covered with 3 Pounds of Water and 6.2 inches of Gas Pressure.

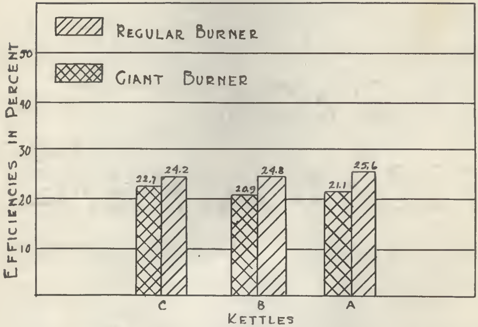


Figure 6 Comparison of Efficiencies of all Kettles Uncovered with 3 Pounds of Water and 6.2 inches of Gas Pressure.

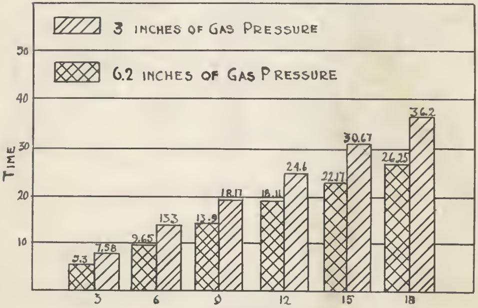


Figure 7 Comparison of Time of Heating Water in Kettle A covered with 3 and 6.2 inches of Gas Pressure.

TABLE II. KETTLE A COVERED ON REGULAR GAS BURNER
(3 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
3	.040	1.425	8.33	10.75	30.4
	.039	1.346	7.10	11.30	33.3
	.082	1.396	7.56	11.00	33.2
	.040	1.341	7.34	10.90	33.4
6	.042	2.350	13.50	10.38	37.1
	.041	2.421	13.11	11.20	36.3
	.067	2.378	13.74	10.35	35.1
	.031	2.341	13.11	10.70	36.1
9	.155	3.380	19.00	10.80	37.4
	.135	35.20	19.00	10.70	36.7
	.046	3.450	18.80	11.02	38.9
	.032	32.60	18.31	10.70	38.9
12	.041	4.390	24.90	10.65	39.4
	.069	4.440	24.10	11.02	40.0
	.042	4.375	25.55	10.32	40.0
	.028	4.320	24.08	10.17	39.0
15	.045	5.370	31.25	10.45	40.0
	.036	5.300	31.03	10.33	41.7
	.034	5.240	30.50	10.34	41.8
	.032	5.340	29.90	10.70	38.9
18	.027	6.130	36.00	10.35	42.4
	.039	6.399	36.30	10.57	41.2
	.038	6.270	36.15	10.60	40.1
	.036	6.620	37.00	10.70	40.0

TABLE III. KETTLE A UNCOVERED ON REGULAR GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
3	.204	1.805	7.03	15.35	23.9
	.153	1.582	6.28	15.13	28.1
	.180	1.805	6.86	15.62	24.7

6	.312	3.23	12.33	15.80	26.7
	.365	3.42	12.73	16.10	26.4
	.261	3.12	11.57	16.20	28.5
9	.472	4.77	18.73	15.30	27.2
	.369	4.50	16.95	15.90	30.0
	.383	4.41	16.92	15.60	30.2
12	.588	6.17	24.34	15.20	28.0
	.556	6.18	23.42	15.68	29.2
	.517	6.18	23.10	16.05	28.7
15	.821	7.87	24.20	15.30	27.4
	.800	7.69	29.98	15.43	29.3
	.565	7.33	28.05	15.75	30.3
18	.988	9.23	36.15	15.32	28.2
	.903	8.99	35.60	15.15	30.1
	.761	9.09	34.90	15.60	29.3

TABLE IV. KETTLE A COVERED ON REGULAR GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
3	.044	1.395	5.26	16.00	31.6
	.044	1.435	5.28	16.26	30.1
	.051	1.530	5.62	16.30	28.9
	.046	1.565	5.98	15.65	30.4
6.	.064	2.560	9.73	15.80	34.0
	.048	2.615	9.59	16.35	33.4
	.044	2.618	9.75	16.25	34.2
	.042	2.541	9.55	16.35	33.7
9	.048	3.680	13.80	16.05	35.7
	.041	3.670	13.80	15.95	35.8
	.045	3.790	14.25	16.05	35.5
	.042	3.703	13.86	16.02	35.3
12	.052	4.700	18.28	15.45	36.7
	.041	4.740	18.15	15.65	37.2
	.036	4.700	17.90	15.75	37.2
	.040	4.780	18.12	15.75	37.4

15	.034	5.850	22.68	15.47	37.5
	.049	5.740	22.10	15.50	38.5
	.045	5.750	22.15	15.56	37.6
	.036	5.740	21.75	15.80	38.2
18	.020	6.960	26.62	15.70	37.7
	.045	6.850	26.10	15.78	37.8
	.030	6.850	26.33	15.70	38.5
	.030	7.020	26.25	16.32	37.3

TABLE V. KETTLE A COVERED ON GIANT GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
3	.051	1.63	6.00	16.25	27.6
	.051	1.64	5.95	16.41	26.8
	.051	1.55	5.62	16.48	27.2
6	.048	2.84	10.56	16.10	31.6
	.042	2.82	10.03	16.90	31.1
	.055	2.74	10.11	16.32	32.2
9	.041	3.89	14.85	16.13	33.8
	.039	4.01	14.45	16.55	32.2
	.032	3.95	14.26	16.25	33.7
12	.034	5.08	18.08	16.15	34.2
	.030	5.02	18.38	16.41	34.9
	.035	5.13	18.51	16.50	34.6
15	.028	6.04	22.30	16.32	36.3
	.029	6.07	22.20	16.36	36.0
	.027	6.29	22.81	16.42	35.3
18	.035	7.43	27.30	16.30	36.0
	.021	7.16	26.25	16.31	35.4
	.032	7.25	26.10	16.40	36.1

TABLE VI. KETTLE A UNCOVERED ON GIANT BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
3	.209	2.040	7.72	15.90	21.6
	.246	2.215	8.20	16.15	20.1
	.171	1.980	7.28	16.35	21.7
6	.318	3.580	13.30	16.15	23.9
	.380	3.720	13.90	16.05	23.7
	.335	3.750	14.00	16.05	23.8
	.366	3.660	13.60	16.20	23.2
9	.374	5.030	18.50	16.35	26.7
	.358	4.940	17.95	16.50	26.5
	.349	4.770	17.50	16.28	27.5
	.465	5.000	18.92	16.10	25.3
12	.470	6.260	22.80	16.20	27.9
	.425	6.420	23.85	16.10	27.2
	.638	6.970	25.20	16.50	25.3
	.648	6.740	25.10	16.20	25.4
15	.576	7.680	27.73	16.55	28.4
	.565	7.740	28.48	16.21	28.6
	.777	8.420	30.75	16.30	26.2
18	.632	8.970	32.95	16.20	29.3
	.755	9.220	33.67	16.40	28.8
	.965	9.850	36.60	16.15	25.9

TABLE VII. KETTLE B COVERED ON A REGULAR GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.020	.935	3.49	16.00	23.4
	.020	.926	3.47	16.00	23.8
	.036	.906	3.41	16.00	24.5
	.030	.912	3.43	15.98	23.6

3	.016	1.631	5.91	16.55	26.9
	.017	1.569	6.00	15.85	28.1
	.030	1.590	6.00	16.00	27.1
	.022	1.600	6.06	15.85	27.5
6	.012	2.961	10.76	16.45	29.7
	.020	2.900	10.85	16.10	30.0
	.017	2.950	11.12	15.90	30.2
	.026	2.921	10.95	16.05	29.7

TABLE VIII. KETTLE B COVERED ON REGULAR GAS BURNER
(3 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.017	.796	4.35	10.96	27.4
	.017	.792	4.30	11.02	27.6
	.020	.732	4.24	10.36	28.8
	.016	.758	4.10	11.10	28.4
3	.017	1.416	7.81	10.85	30.8
	.016	1.372	7.60	10.90	31.2
	.017	1.404	7.86	10.70	30.8
	.042	1.425	8.33	10.75	30.4
6	.016	2.540	14.62	10.65	34.0
	.023	2.640	15.12	10.45	33.9
	.011	2.610	14.30	10.95	33.2
	.043	2.665	15.15	10.60	32.7

TABLE IX. KETTLE B UNCOVERED ON REGULAR GAS BURNER
(5.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.061	1.051	3.87	16.03	21.1
	.063	.999	3.85	15.85	22.1
	.065	1.038	3.93	15.86	21.1
	.052	.990	3.74	15.72	22.0

3	.089	1.730	6.63	15.88	25.1
	.089	1.720	6.53	15.70	25.5
	.093	1.842	6.92	16.00	24.1
	.093	1.810	6.90	15.76	24.4
6	.134	3.260	12.38	15.80	27.2
	.094	3.330	12.60	16.05	26.1
	.136	3.170	12.17	15.30	27.8

TABLE X. KETTLE B UNCOVERED ON GIANT GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.059	1.150	4.28	16.42	20.0
	.078	1.187	4.43	16.10	18.4
	.058	1.128	4.17	16.30	19.4
3	.091	2.140	7.78	16.23	20.9
	.096	2.153	7.88	16.40	20.8
	.096	2.120	7.617	16.58	20.9
6	.152	3.700	13.81	16.11	23.9
	.145	3.800	13.85	16.45	23.0
	.155	3.830	14.38	16.20	22.7

TABLE XI. KETTLE B COVERED ON GIANT GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.023	1.013	3.82	15.90	21.2
	.021	1.013	3.84	16.01	21.5
	.021	1.113	4.02	16.52	19.0
3	.020	1.890	6.94	16.45	22.7
	.016	1.885	6.92	16.32	22.8
	.034	1.782	6.83	16.15	23.8

6	.012	3.370	12.46	16.11	25.6
	.061	3.290	12.25	16.25	25.7
	.020	3.310	12.30	16.10	26.0

TABLE XII. KETTLE C UNCOVERED ON GIANT GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.068	1.145	4.17	16.45	18.6
	.065	1.135	4.22	16.15	18.7
	.085	1.025	3.83	16.05	20.7
3	.065	1.830	6.71	16.30	24.6
	.085	2.020	7.33	16.38	21.0
	.079	1.860	6.82	16.38	22.5

TABLE XIII. KETTLE C COVERED ON GIANT GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.023	.958	3.51	16.52	23.3
	.017	.933	3.50	16.00	22.3
3	.029	1.815	6.73	16.10	25.7
	.016	1.715	6.12	16.36	24.7
	.023	1.905	6.96	16.30	22.7

TABLE XIV. KETTLE C UNCOVERED ON REGULAR GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.057	1.029	3.83	16.13	21.6
	.050	1.010	3.77	16.20	22.0
	.052	.990	3.74	15.72	22.0

3	.073	1.865	7.03	15.85	23.5
	.071	1.795	6.63	16.25	24.7
	.069	1.850	6.87	16.20	24.2

TABLE XV. KETTLE C COVERED ON REGULAR GAS BURNER
(6.2 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.011	.872	3.25	16.00	24.7
	.021	.878	3.29	16.05	24.5
	.013	.918	3.48	15.85	23.5
	.018	.895	3.35	16.05	24.1
3	.022	1.717	6.48	15.80	25.1
	.014	1.642	6.16	16.06	26.8
	.012	1.675	6.29	16.00	25.7
	.015	1.640	6.18	15.92	26.3

TABLE XVI. KETTLE C COVERED ON REGULAR GAS BURNER
(3 Inches Gas Pressure)

Pounds HOH	Pounds Vapor	Cubic Feet Gas	Time Minutes	Cubic Feet Per Hour	Per Cent Efficiency
1½	.016	0.737	4.32	11.05	27.5
	.016	0.802	4.25	11.30	27.3
	.019	0.797	4.35	10.98	27.2
	.016	0.775	4.12	11.10	27.7
3	.016	1.460	7.87	11.23	30.0
	.011	1.475	7.94	11.20	29.7
	.013	1.435	7.90	11.06	30.0
	.015	1.425	7.67	11.15	30.3

TABLE XVII. TABLE OF EFFICIENCIES OF ALL KETTLES

Kettle	Inches Pressure	Burner	Cover	HOH 1½ lb	HOH 3 lb	HOH 6 lb	HOH 9 lb	HOH 12 lb	HOH 15 lb	HOH 18 lb
A	6.2	Regular	On		30.2	33.8	35.6	37.1	38.0	37.8
B	6.2	Regular	On	23.8	27.4	29.9				
C	6.2	Regular	On	24.2	26.0					
A	3.0	Regular	On		33.1	36.2	38.0	39.6	40.6	40.9
B	3.0	Regular	On	28.1	30.8	33.4				
C	3.0	Regular	On	27.4	30.0					
A	6.2	Regular	Off		25.6	27.2	29.1	28.6	29.0	29.2
B	6.2	Regular	Off	21.6	24.8	27.1				
C	6.2	Regular	Off	21.9	24.1					
A	6.2	Giant	On		27.2	31.6	33.2	34.6	35.9	35.5
B	6.2	Giant	On	20.6	23.1	25.8				
C	6.2	Giant	On	23.1	24.4					
A	6.2	Giant	Off		21.1	23.7	26.5	26.5	27.7	28.0
B	6.2	Giant	Off	19.2	20.9	23.2				
C	6.2	Giant	Off	19.3	22.7					

Summary of Results

1. Although from 20 to 25% more time was required when the regular burner was used, the efficiencies were greater for three inches of gas pressure than for 6.2 inches. With the lower pressure the efficiency of kettle A was about 7% greater while the efficiencies of kettles B and C were from 11 to 15% higher.

2. The covered kettles on the regular burner showed greater efficiencies than the uncovered with both the 3 and 6.2 inches of gas pressure. The efficiencies of kettle A increased from 20 to 30% when the cover was used. For kettles B and C covered the increase ranged from 8 to 14%.

3. The efficiency of kettle A uncovered on both burners with 6.2 inches of gas pressure remains about the same for nine pounds or more of water.

4. Kettle A covered showed only a slight increase in efficiencies for masses of water of 12 or more pounds when three inches of gas pressure were used.

5. With three pounds of water and 6.2 inches of gas pressure the efficiency of the kettle with largest area was greater than that of the two kettles with the lesser areas except when the largest kettle was used uncovered with the giant burner.

6. Kettles B and C containing 1½ pounds of water showed little difference in efficiencies under the same conditions.

7. The covered kettles showed lower efficiencies on the giant burner with 6.2 inches of gas pressure. For kettle A on the regular burner the efficiency was about 4% greater with the larger amounts of water and 15 to 20% greater with the smaller amounts. For the smaller kettles the increase ranged from 8 to 20% when the regular burner was used. The giant burner utilized more gas throughout the test. There was a slight saving of time when the giant burner was used with the smaller kettles.

CONCLUSIONS

1. On the regular burner three inches of gas pressure gave greater efficiencies than 6.2 inches but required longer time.

2. In contrasting the regular burner with the giant burner greater efficiencies in all cases were found with the regular burner when 6.2 inches of gas pressure were used.

3. The covered kettles in all cases showed greater efficiencies than the uncovered ones.

4. The kettle having the largest diameter was more ef-

ficient than the smaller ones except when used uncovered with the giant burner.

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