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A Study of Washing Machines

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TABLE OF CONTENTS

SUMMARY

The purpose of this investigation was to study the performance and constructional features of various types of washing machines. The machines studied were of four types, classified on the basis of mechanical construction. The types were dolly, gyrator, cylinder, and vacuum.

Eight machines were studied, four of the gyrator type, two of the dolly type, one of the cylinder type, and one of the vacuum type. The material reported in this bulletin includes the following: (1) cleansing action of various washing machines and relation of cleanness of fabric to length of washing period, temperature of water, and size of load; (2) wear on fabric; (3) heat retention; (4) constructional features adding to convenience of operation.

To study the cleansing action of different machines, they were used to wash test specimens of fabric which had been soiled under uniform conditions. The machines were operated under uniform conditions of time, temperature and load, and amount and hardness of water and soap solution. The washed specimens were dried under uniform conditions and tested for whiteness or brightness by a photometric method. The brightness, which was the measure of cleanness of the washed specimens, was determined by comparison with a new, unwashed specimen of the same fabric, assumed to be 100 per cent clean.

Results show that the maximum brightness of test specimens washed in the cylinder and vacuum machines was highest, and from the dolly machines lowest. The difference in maximum brightness of specimens washed in the cylinder and vacuum machines as compared with those from the gyrators was slight.

In general, specimens washed in the gyrator machines reached maximum brightness in less time than in other types. Specimens washed in one dolly-type machine reached maximum brightness in less time than in the gyrator machines. Specimens washed in the cylinder and vacuum types required longest to reach maximum brightness. Specimens washed in one dolly machine required longer to reach maximum brightness than in the gyrator machines, but less than in the cylinder and vacuum types.

Each machine appears to have an optimum washing period, which depends upon the character of the dirt used in soiling and is affected by temperature of the water. Washing clothing longer than the optimum period apparently results in redistributing the dirt over the fabric.

Medium temperatures (around 125° F.) gave best results in this study. Higher temperatures tend to cook or "set" the dirt into the meshes of the cloth.

There appears to be an optimum load for each machine. A decreased or increased load did not in general give as satisfactory results as did the optimum load.

To determine comparative wear on fabric, strips of test material were washed under uniform conditions for the same length of time in the different machines. Samples, uniform in thread count, were cut from the test strips, conditioned as to moisture content, and tested for breaking strength by a Scott tester. Breaking strength of the washed samples was compared with the breaking strength of samples of the new, unwashed material of the same thread count, conditioned in the same way. Results show that the gyrator machines caused less wear than other types and the dolly machines the most. Differences in wear were of slight significance except for one dolly machine, which produced relatively great wear.

To determine the comparative heat retention of different machines, they were filled with water at the same temperature and allowed to cool under uniform conditions of room temperature and draft. The temperature of the water was taken at ten-minute intervals for a period of one hour. The machines were kept closed except to insert the thermometer.

Results show little difference in cooling rate for the different machines. The machine with the lowest cooling rate was double walled and finished both inside and out in white porcelain enamel. The machine with the highest cooling rate was a cylinder type. The walls were copper plated inside and enameled outside. It had a large opening in addition to the opening into the cylinder.

The machines were also tested for heat retention under actual washing conditions. The machine having the highest cooling rate was the cylinder type mentioned above, with large openings in both outside tub and inside cylinder. On the machine next highest in cooling rate, the opening was equal in area to the surface area of water, and the outside was corrugated. The machine was made of nickel-plated copper and was double walled with a steel jacket. Variation in cooling rate for other machines was slight. In no case was the cooling rate high enough to be of significance in the selection of a washing machine.

No machines studied met all reasonable requirements for convenience in constructional features. There is room for improvement, especially in attachment of lids and height and placement of controls, regulation of tension between wringer rolls, and shape and control of drainboards on wringers.

A Study of Washing Machines

By EDNA B. SNYDER, *Department of Home Economics*, and MORTON P. BRUNIG, *Department of Agricultural Engineering* [1]

Manufacturers have made available washing machines of various types, materials, and finishes, which provide many features designed to promote comfort and ease in the laundering of clothing. There is a fairly wide price range to meet various incomes. Changes in washing machines have recently been rather rapid, leaving the purchaser in doubt as to the resulting increase in efficiency or rapidity of the washing process. The purpose of this investigation was to study the performance of various types of washing machines and the constructional features which are factors in adapting them to family needs.

Washing machines, to be of maximum service, should fulfill several quite definite requirements. Such requirements are listed as follows: (1) thorough and rapid removal of dirt from fabric; (2) minimum wear on fabric; (3) constructional features which afford convenience, safety, ease in handling and cleaning, durability, and good heat-retention qualities; and (4) capacity sufficient to accommodate the clothing of an average family and at the same time require only a minimum of space.

Results of this investigation are reported under the following headings:

1. Cleansing action of various types of washing machines and relation of cleanness of fabric to length of washing period, temperature of water, and size of load.
2. Wear upon fabric from various types of machines.
3. Retention of heat by different machines.
4. Constructional features of machines which add to convenience in operation.

TYPES OF MACHINES STUDIED

In general, washing machines are of four types, which may be classified upon the basis of the mechanical construction of the washer. The original intent was to choose for this study a certain number of machines of each type and to include a fairly wide range in price. Upon investigation, it was learned that the trend of manufacturers was toward one particular type, and that it was difficult to purchase locally some of the others desired. There arose the question of underlying reas-

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[1] The writers wish to acknowledge suggestions and constructive criticism on this project from Miss Mary Mason of the Division of Household Equipment and Miss Gladys Winegar of the Division of Clothing and Textiles, Department of Home Economics, Mr. R. C. Abbott, Department of Chemistry, and Mr. E. B. Lewis, Department of Agricultural Engineering, University of Nebraska.

ons for the popularity of the predominent type, and the justification for discontinuing others. Instead of adhering to the original plan, it seemed more feasible to select several machines of the type most in evidence. There appeared to be more minor differences among the various makes of this type than in others. Eight machines were selected and purchased. Two were of the dolly type, four of the gyrator type, one of the cylinder type, and one of the vacuum type.

Table 1 lists the machines studied, giving type and description. The machines are designated by letter, as shown in the table.

TABLE 1.—*Type and description of machines used in the study*

Machine	Type of washer unit	Shape of tub[1]	Capacity		No. of speeds	O. P. M.[2]	Type of drive	Motor horse-power
			Water	Clothes				
			Gals.	*Lbs.–dry*				
A	Gyrator 4 vanes	Round	12	8	2	60 forward 60 backward	Belt	1/4
B	Gyrator 4 vanes	Square	17	8	1	50 forward 50 backward	Belt	1/4
C	Gyrator 6 vanes	Square	17	8	Variable[3]	50 forward 50 backward	Belt	1/4
D[4]	Cylinder	......	17	10	1	6 forward 6 backward R. P. M.	Shaft	1/6
E[5]	Vacuum, 3 cups	Round	17	10	1	....	Shaft	1/4
F	Dolly supported in bottom of tub—3 vanes	Round	12	6	1	63 forward 63 backward	Belt	1/6
G	Dolly attached to lid—4 vanes	Round	14.5	8	1	53 forward 53 backward	Belt	1/6
H	Gyrator—1 large, 1 small vane	Round	17	8	1	60 forward 60 backward	Belt	1/4

[1]Shape of tub denotes shape of horizontal cross section.

[2]O. P. M. denotes oscillations per minute.

[3]Variable speed is a difference in *length* of stroke rather than the number of oscillations per minute.

[4]The tub of this machine is a cylinder with horizontal axis.

[5]The vacuum cups of Machine E are supported on horizontal arms projecting from a vertical axis. They move up and down and at the same time revolve around the axis, making seven revolutions and 68 up and down motions per minute.

NOTE: Machines A, B, C, D, and E retail at between $160 and $175. Machines F, G, and H retail at less than $100.

FUNDAMENTAL PRINCIPLES OF WASHER IN DIFFERENT TYPES OF MACHINES

A washing machine is constructed so that dirt is removed from clothing by one of three methods: (1) moving clothes through the water, (2) moving water through the clothes, (3) a combination of the two methods. The mechanical action of the machine is combined with the chemical action of a soap solution in the cleansing process.

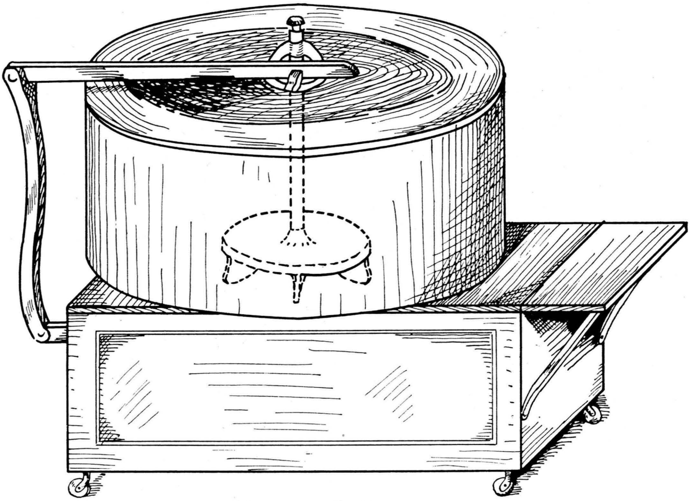

FIG. 1.—Dolly type.

The dolly type of machine (Figure 1) is perhaps the most familiar, since many of the older hand-power machines were of this type. The "dolly," which is made of wood, metal, or rubber prongs projecting downward from a solid, circular piece supported by a central vertical shaft, is usually attached to the lid of the machine. The clothes are washed by being moved through the water, first in one direction and then in the other. Often the tub is grooved to provide greater friction.

The gyrator type (Figure 2) somewhat resembles the dolly, and is frequently spoken of as a modified dolly. The gyrator is supported in the bottom of the tub and may have two or more blades or vanes, which differ considerably in shape, position, and material in different makes of machines. The gyrator oscillates in a horizontal plane about a vertical axis through an arc (usually about 180°), the driving force being directed against the water.

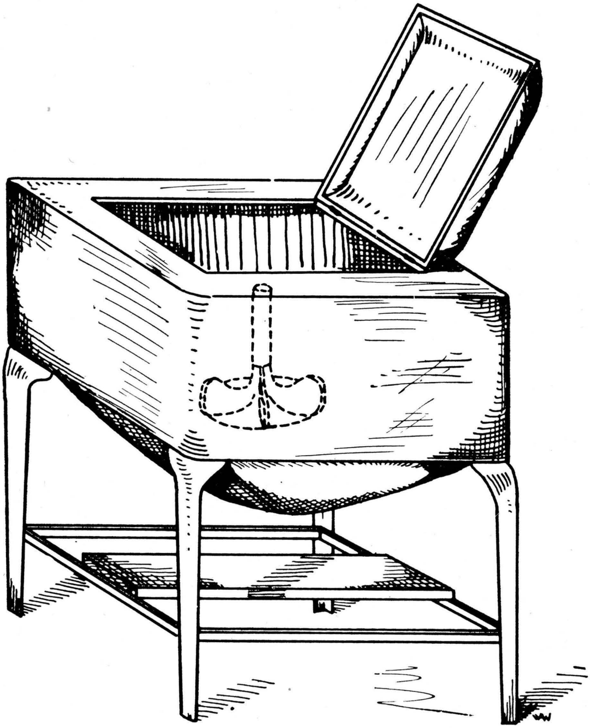

FIG. 2.—Gyrator type.

In the cylinder type of machine is a perforated metal or wood cylinder, which is made to revolve several times, first in one direction and then in the reverse, carrying the clothes through the water. (See Figure 3.) There are two to three inches of space between the cylinder and the tub. The clothes are carried from the water and dropped back into it by means of shelves or baffles on the inside of the cylinder. This process produces both agitation and friction.

The vacuum type (Figure 4), which has evolved from the old hand "stomper," consists of several inverted semi-spherical cups, mounted on a central shaft. The cups move up and down and around in the machine, moving both water and clothes and drawing the water through the clothes. The action consists of a combination of suction and pressure.

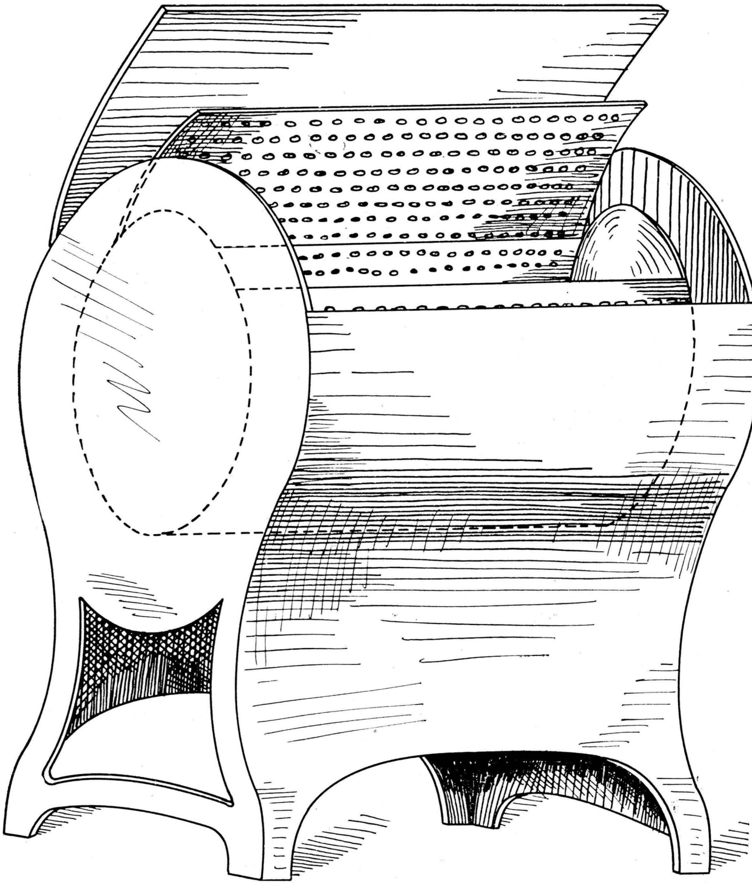

FIG. 3.—Cylinder type.

RELATION OF CLEANNESS OF FABRIC TO LENGTH OF WASHING PERIOD, TEMPERATURE OF WATER, AND SIZE OF LOAD

There has been considerable investigation to determine satisfactory methods for comparing the performance of washing machines. Such a procedure involves uniformity of materials and manipulation and should be of such a nature that the process may be duplicated. Variable factors must, insofar as possible, be eliminated. The soiling mixture must be uniform in content and application; fabric of one brand and construction must be used for test work; and the temperature and hardness of water, the quantity of soap, the load, and the length of washing period must be kept constant

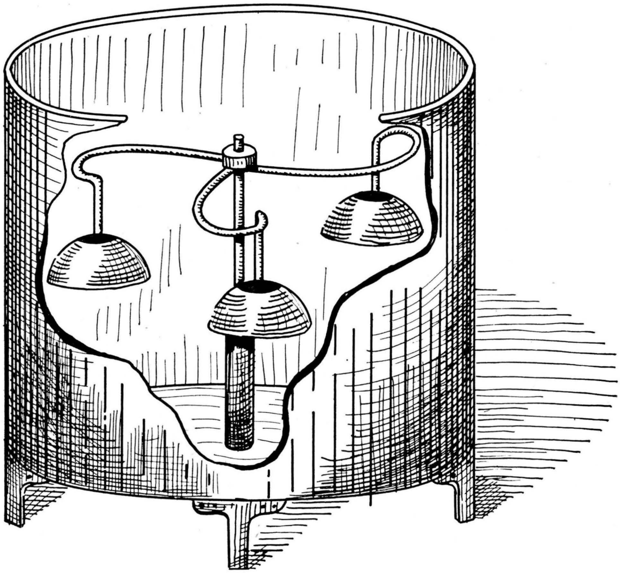

FIG. 4.—Vacuum type.

so that variations in results may reasonably be attributed to differences in the mechanical action of the machines. In order to obtain results of practical value the soiling mixture should, as nearly as possible, approximate actual "dirt" on clothing and household linens. Such "dirt" is complex in character, consisting in general of soot, earth, fats, oils, starchy substances, and proteins. Ordinary dirt comes from body secretions, from foods, and from outside sources, depending upon the occupation of the wearer of the clothing. The various forms of dirt react differently to heat, and, as a result, methods of laundering are complicated.

Different "standard" soiling mixtures which have been developed generally include lampblack, which is nearly insoluble in water, as the dark constituent, with fats and oils dissolved in some volatile liquid. The solvent, by dissolving fats and oils, makes even soiling possible, leaving only the solid material in the soiled cloth.

DIRT MIXTURES USED AND METHOD OF SOILING

Preliminary to this study, experiments with dirt mixtures were carried on in the Agricultural Engineering Department, University of Nebraska. The problem was to devise a soiling mixture which could be applied uniformly to a very large number of test samples. Any volatile liquid having the necessary characteristics was prohibitive in cost, because of the quantity required. It was found that boneblack, which forms a more stable suspension in water, gave better results than lampblack. To make the study comprehensive, and therefore of practical value, two "dirts" differing in composition were used, designated herein as Dirt No. 1 and Dirt No. 2.

The following constituents and method of soiling were adopted for Dirt No. 1. One hundred fifty grams of bone black and two hundred grams of flour were mixed dry. Enough water to form a thin paste was then slowly added. The mixture was poured into five gallons of water in a gyrator-type washer, and agitated by operation of the machine for three or four minutes. To this soiling mixture were added 64 test specimens which had been separately crushed, after which they were bunched and pushed under the solution. The specimens consisted of 11-inch squares of white Indian Head muslin, woven with 52 warp threads and 46 filling threads per inch, and of a brand easily duplicated.[2] They were "washed" in the dirt solution for 20 minutes, put through the wringer flat, and hung in a dark room for 24 hours to "set," the dark room reducing the possibility of bleaching.

The following constituents and method of soiling were adopted for Dirt No. 2. A mixture consisting of 1,000 grams of black loam, 150 grams of water, two grams of lampblack, and five cubic centimeters of heavy lubricating oil of a popular brand was selected as being satisfactory after various combinations of these substances had been tried. Since the dirt in Solution No. 1 was pretty well "set" in the cloth, Dirt No. 2 was devised to represent a "mild" dirt. Enough moisture and oil were present to give the dirt the desired property of spreading over and adhering to the surface of the cloth, without the penetration between fibres as with Dirt No. 1. To provide even distribution of the dirt on the cloth, the mixture was rotated for 30 minutes in a mixing box with 50 specimens, like those used with Dirt No. 1, together with several small wooden blocks. The mixing box, Figure 5, was patterned after a Wheat Seed Treatment Device (No. 10.40122-1 Agricultural Engineering Blue Print). One side of the box was hinged to form a lid. A wooden grooved pulley wheel about nine inches in diameter was attached flat against one end of the box. Sections of three-quarter-inch pipe, attached to the center of each end of the box by means of plates, formed the axle of the mixer. A small motor belted to a reducing gear and from this to the grooved pulley on the end of the box gave a uniform rotation of 30 R.P.M. to the box, making a total of 900 revolutions for the soiling period.

[2] With sizing.

The interior dimensions of the box were 15″ x 15″ x 30″. It was fitted with four baffle boards $\frac{7}{8}$″ x $1\frac{1}{2}$″, running full length of the box. These boards, together with flat sides and square corners, provided greater agitation and better mixing of the material than would a uniform cylinder. There was no evidence of bunching or twisting of specimens. The blocks of wood and dirt were always found well distributed throughout the box after rotation. Following soiling, the specimens were dried in the dark for 24 hours.

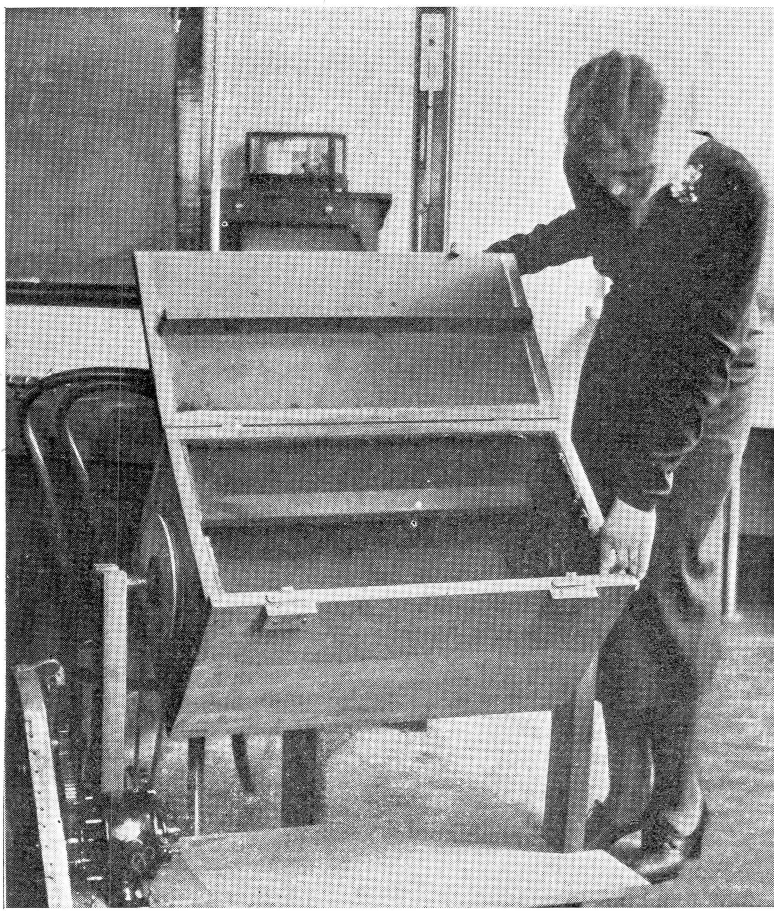

FIG. 5.—Mixing box used to apply Dirt No. 2 to test specimens.

CONDITIONS AND METHOD OF WASHING SOILED SPECIMENS

Water of 16 degrees hardness was used for the washing. The water was softened by ordinary washing soda of a widely used brand. The washing soda was purchased in small sealed packages to prevent changes from evaporation. A popular soap was used. It was ground in a food chopper and made into solution. The machines were loaded with sheets and strips of sheeting. The sheets were new, of standard size, nine-quarter double sheets, weighing two pounds each. The strips, used for the purpose of providing articles of uneven size in the load, were of sheeting of the same width and brand, torn through the middle, and two and one-half yards in length. The soiled samples were distributed throughout the load before washing.

The machines were operated, first, with 100 per cent load and amount of water as specified by the manufacturer; second, with less than the specified load, or 75 per cent load; and third, with more than the specified load, or 125 per cent load. Machines having variable speeds were operated at maximum speed. With each machine the samples were passed through a wringer except for Washer E, which was provided with a centrifugal dryer. Each wash or suds was followed by a three-minute rinse in the machine. The temperature was varied for both suds and rinse, and the washing periods were varied for the suds. For Dirt No. 1, the washing periods were 5, 10, 15, and 20 minutes. For Dirt No. 2, they were 3, 5, 7, and 10 minutes. Temperatures with Dirt No. 1 were: suds 120° F. with rinse 65° F.; suds 120°F. with rinse 160° F.; and suds 140°F. with rinse 65° F. Temperatures with Dirt No. 2 were: suds 120° F. with rinse 65° F. and suds 120° F. with rinse 160° F. Time was checked by a stop watch. The proportion of soap and softener used was uniform throughout the study. With Dirt No. 1 no attempt was made to wash the test samples clean. The washed specimens were smoothed with a warm iron to prevent wrinkling, after which they were dried for 24 hours, and kept in a dark room.

DETERMINATION OF CLEANNESS

The determination of cleanness of a piece of cloth is a difficult process. The cloth might be weighed and a known amount of dirt added, after which it could be washed and weighed again. This method has been tried by other investigators, but the disadvantage lies in the fact that there is no assurance that the apparent loss of dirt is not also accompanied by loss of weight caused by wear on material. The method which is now most commonly used, and which seems to be most accurate, consists of the measurement of brightness or "whiteness" of a sample of white material which has been soiled and washed, as compared with a standard.

The most simple process of determining whiteness is by visual comparison of the washed fabric with the original clean material. More accurate but also more complicated measurements involve the directing of a light of known intensity upon a sample and measuring the intensity of the reflected light. The latter, or photometric method, involves difficulties, with ordinary electric lights as a source, because of the wide voltage variation. These difficulties led to the design and construction of the apparatus shown in Figure 6.

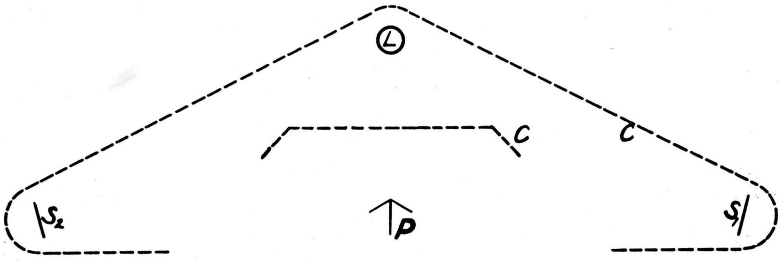

FIG. 6.—Diagram of apparatus used for measuring relative brightness of washed specimens.

In the diagram, S_1 and S_2 are screens upon which specimens to be compared are mounted. L is a light of any desired intensity. P is a simple Bunsen Photometer. A curtain, allowing light to pass freely from L to the screens, was suspended between P and L. The apparatus was used in a dark room, but it was found necessary to enclose all except a space in front with a dark curtain to eliminate wall reflection. The distance between the centers of the screens was 200 centimeters. The screens were 11 inches square, black, and were covered with a facing of black wall board which had circular openings 10 inches in diameter. The specimens were mounted on the screen, the wall board serving as a frame and allowing the same area of each specimen to be exposed to the light. The light L was in a position which permitted its adjustment to throw equal amounts of light to the two screens. Before the apparatus was used, two pieces of new material (white Indian Head muslin) were placed on the screens, and the lamp was adjusted until the photometer balanced at a point half way between the screens. One new specimen was removed and replaced by a washed specimen. The washed specimen received the same light as the new specimen, but reflected less, because of the darker surface. It was possible to move the photometer toward the washed specimen until a point was reached where it received as much light from the latter as from the new specimen. At this point the photometer was said to be balanced.

A set of tables was made so that scale readings could be converted into percentage readings. For example, if the photometer was balanced at a point 75 centimeters from one screen and 125 from the other, the percentage reading was 36, since 75 squared is 36 per cent of 125 squared. If the washed specimen reflected the same amount of light as the new, it was considered 100 per cent clean. The new specimen was used as a standard of comparison because of the ease of duplication. In the opinion of the investigators, errors due to possible variation in whiteness of the new material were no greater than other errors.

Readings were taken by two observers to insure accuracy. After some practice, the observers were able to read the specimens independently and obtain readings with a difference of less than one centimeter of variation. This gave a maximum error of less than three per cent for the part of the scale used. When readings failed to agree within this limit, they were checked and new readings obtained. The same observer was able to repeat readings on different days on the same sample with results within this limit. The method used does not come within the accuracy possible by the use of higher-grade instruments, but does come within that for other phases of the study.

COMPARISON OF CLEANSING ACTION OF INDIVIDUAL MACHINES UNDER DIFFERENT WASHING SCHEDULES

In Table 2 are shown data on the performance of Washer A, a gyrator type. The gyrator, which is made of cast aluminum, has four vanes, which curve outward gradually from near the top of the central shaft of the gyrator, toward the bottom of the machine. The base of the gyrator is square with rounded corners. The tub of the machine is round. For Washer A, Dirt No. 1, Schedule 1, the brightness of the washed specimens was at its peak for the 10-minute period, after which there was a decrease. For Schedule 2, the temperature of the rinse was changed to 160° F., other conditions remaining as in Schedule 1. With this schedule, the peak in brightness was reached with the 15-minute period. As a whole, results from Schedule 2, with the hot rinse, were lower than those from Schedule 1 with the cold rinse. For Schedule 3, the temperature of the suds was changed to

TABLE 2.—*Relative brightness of test specimens from Machine A, a gyrator type, in relation to washing period, temperature of water, and size of load*

Dirt No.	Schedule No.	Temperature		Load[1]	Specimens	Relative brightness at different washing periods					
		Suds	Rinse			3 min.	5 min.	7 min.	10 min.	15 min.	20 min.
		Deg. F.	*Deg. F.*	*Pounds*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	120	65	10	12	35.97	40.95	.....	43.69	41.67	40.10
1	2	120	160	8	12	.....	33.22	.....	35.37	37.99	33.51
1	3	140	65	8	12	.....	33.88	.....	33.02	35.63	39.20
1	4	120	65	6	12	.....	31.66	.....	30.18	.....	.....
1	5	120	65	10	12	.....	.....	.....	.....	32.33	33.56
2	6	120	65	8	8	86.22	85.86	86.79	85.72	.....	.....
2	7	120	160	8	8	85.40	85.78	86.02	86.34	.....	.....

[1]Normal load for this machine is 8 pounds.

140° F., and the cold or 65° F. rinse was used, other conditions as in Schedule 1. This schedule gave results quite similar to those of Schedule 2, and lower than those of Schedule 1. The peak in brightness was reached at 20 minutes. For Schedules 4 and 5, 120° F. was used for suds and 65° F. for rinse, but the load was decreased for the 5- and 10-minute periods, and increased for the 15- and 20-minute. The difference between results from a 70 per cent load washed a short time and a 125 per cent load washed a longer time was not significant. The latter gave slightly higher results. A comparison of results from underloads and overloads with results from the normal load shows that those from the latter were higher than from either of the other two.[3]

Schedules 6 and 7, with Dirt No. 2, were used with normal loads, with suds at 120° F. and with the rinse varied from cold (65° F.) to hot (160° F.). For the different washing periods used, the difference in brightness was slight, less than that between periods with Dirt No. 1. There was very little difference between results from the cold rinse and the hot rinse. The peak in brightness was reached at 7 minutes in both schedules.

In Table 3 are shown data on performance of Washer B, a gyrator type. The gyrator on this machine has four radial vanes, embedded in a circular base, which project directly at right angles to the bottom of the central shaft of the gyrator and curve upward at the outer end. The vanes are made of aluminum. The tub is square with rounded corners. Results from Schedule 1, with Dirt No. 1, suds at 120° F., rinse at 65° F., and normal load, were highest, but the maximum brightness came at the 15-minute period. Results from Schedule 2 were better than from Schedule 1 for the 5- and 10-minute periods, but lower for the longer periods. Results from Schedules 2 and 3 indicate that this machine reaches its maximum somewhat more quickly than is indicated by Schedule 1. There was little difference between results from underloading with short washing periods and overloading with longer periods, and there seemed to be no advantage for either as compared with the normal load.

With Dirt No. 2 the peak in brightness was reached at 7 minutes with Schedule 6, and in 5 minutes with Schedule 7. However, the difference in brightness was slight between the schedules with a cold and a hot rinse.

In Table 4 are data on performance of Washer C, a gyrator type. The gyrator in this machine has six vanes which are made of bakelite, projecting outward at right angles from

[3] Normal load is that designated by the manufacturer, or a 100 per cent load.

TABLE 3.—*Relative brightness of test specimens from Machine B, a gyrator type, in relation to washing period, temperature of water, and size of load*

Dirt No.	Schedule No.	Temperature		Load[1]	Specimens	Relative brightness at different washing periods					
		Suds	Rinse			3 min.	5 min.	7 min.	10 min.	15 min.	20 min.
		Deg. F.	*Deg. F.*	*Pounds*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	120	65	8	12	.....	28.53	.....	31.46	42.30	41.78
1	2	120	160	8	12	.....	34.38	.....	36.16	37.18	38.33
1	3	140	65	8	12	.....	26.38	.....	26.07	25.98	23.88
1	4	120	65	6	12	.....	30.18	.....	30.01	.....	.....
1	5	120	65	10	12	.....	.....	.....	.....	31.93	31.23
2	6	120	65	8	8	86.19	85.56	87.44	82.62	.....	.....
2	7	120	160	8	8	84.44	86.33	85.55	86.85	.....	.....

[1]Normal load for this machine is 8 pounds.

TABLE 4.—*Relative brightness of test specimens from Machine C, a gyrator type, in relation to washing period, temperature of water, and size of load*

Dirt No.	Schedule No.	Temperature		Load[1]	Specimens	Relative brightness at different washing periods					
		Suds	Rinse			3 min.	5 min.	7 min.	10 min.	15 min.	20 min.
		Deg. F.	*Deg. F.*	*Pounds*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	120	65	8	12	.....	39.28	.....	41.11	40.13	39.37
1	2	120	160	8	12	.....	33.10	.....	33.74	34.68	34.39
1	3	140	65	8	12	.....	26.24	.....	24.72	23.20	24.23
1	4	120	65	6	12	.....	27.11	.....	30.27	.....	.....
1	5	120	65	10	12	.....	.....	.....	.....	32.23	29.43
2	6	120	65	8	8	85.06	85.57	86.47	80.47	.....	.....
2	7	120	160	8	8	87.27	87.45	89.01	83.87	.....	.....

[1]Normal load for this machine is 8 pounds.

the base of the central shaft. The vanes are embedded in a circular base. The tub is square with rounded corners. Results were higher from Schedule 1, with Dirt No. 1, suds at 120° F., and a cold rinse, than from Schedules 2 and 3. The maximum brightness of washed specimens was reached in a 10-minute period. Results from Schedule 2, with 120° F. and the hot rinse were higher than from Schedule 3, with 140° F. suds and a cold rinse. There was no significant difference in results from the underload washed 5 and 10 minutes and the overload washed 15 and 20 minutes. However, neither Schedule 4 nor 5 gave as good results as Schedule 1, with the normal load.

Results with Schedules 6 and 7, Dirt No. 2, showed no significant differences for the cold or hot rinse. Those from Schedule 7 were slightly higher. The maximum brightness was reached, in both Schedules 6 and 7, at the 7-minute period.

In Table 5 are data on the performance of Washer D, a cylinder type. The cylinder is made of aluminum and is provided with baffles to catch the clothing as the cylinder revolves. Results from Schedule 1 were highest. This machine required slightly longer to reach its maximum than the gyrator types. Results from Schedule 2 were higher than from Schedule 3. The normal load for Washer D is 10 pounds, while 8 pounds is normal for most of the machines. The table shows results with loads of 6 and 8 pounds washed for periods of 5 and 10 minutes, and loads of 8, 10, and 12 pounds washed 15 and 20 minutes. Results were uniformly higher with the 8-pound load (Schedule 1), which seemed the optimum load for this machine. There was little difference in results between the 10- and 12-pound load when washed 15 and 20 minutes, or between the overload and the underload washed a shorter time.

With Dirt No. 2, there were no significant differences in results for either time or temperature variations. In both schedules the maximum brightness of specimens was reached at the end of a 7-minute period.

In Table 6 are data on the performance of Washer E, a vacuum type. The tub of this machine is round and double walled, with an air space between the walls. Instead of a wringer the machine is provided with a centrifugal dryer. With Dirt No. 1 results were better with Schedule 1. The peak in brightness of washed specimens was reached at 20 minutes. Results from Schedule 2 with a hot rinse were slightly better than from Schedule 3 with suds at 140° F. and a cold rinse. The normal load for Washer E is 10 pounds (see Table 1). Results with an 8-pound load, under con-

TABLE 5.—*Relative brightness of test specimens from Machine D, a cylinder type, in relation to washing period, temperature of water, and size of load*

Dirt No.	Schedule No.	Temperature		Load[1]	Speci-mens	Relative brightness at different washing periods						
		Suds	Rinse			3 min.	5 min.	7 min.	10 min.	15 min.	20 min.	25 min.
		Deg. F.	*Deg. F.*	*Pounds*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	120	65	8	12	.....	38.54	.....	39.67	41.64	44.02	36.99
1	2	120	160	8	12	.....	33.09	.....	34.09	34.86	34.53	.....
1	3	140	65	8	12	.....	27.34	.....	27.53	26.83	27.27	.....
1	4	120	65	6	12	.....	29.93	.....	30.45	.....	.....	.....
1	5	120	65	10	12	.....	.....	.....	.....	28.20	29.35	.....
1	5	120	65	12	12	.....	.....	.....	.....	27.75	30.65	.....
2	6	120	65	8	8	85.91	89.62	90.68	85.99	.....	.....	.....
2	7	120	160	8	8	86.13	86.62	87.83	87.61	.....	.....	.....

[1]Normal load for this machine is 10 pounds.

TABLE 6.—*Relative brightness of test specimens from Machine E, a vacuum type, in relation to washing period, temperature of water, and size of load*

Dirt No.	Schedule No.	Temperature		Load[1]	Specimens	Relative brightness at different washing periods						
		Suds	Rinse			3 min.	5 min.	7 min.	10 min.	15 min.	20 min.	25 min.
		Deg. F.	*Deg. F.*	*Pounds*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	120	65	8	12	.....	39.02	.....	40.36	42.32	44.49	41.62
1	2	120	160	8	12	.....	30.39	.....	32.64	34.22	36.74	.....
1	3	140	65	8	12	.....	34.41	.....	30.77	31.69	33.37	.....
1	4	120	65	6	12	.....	31.37	.....	27.41	.....	.....	.....
1	5	120	65	10	12	.....	.....	.....	.....	33.32	36.53	.....
1	5	120	65	12	12	.....	.....	.....	.....	32.31	32.61	.....
2	6	120	65	8	8	85.94	87.18	89.15	85.91	.....	.....	.....
2	7	120	160	8	8	86.11	85.33	86.77	85.53	.....	.....	.....

[1]Normal load for this machine is 10 pounds.

ditions as in Schedule 1, were uniformly higher than those from either Schedule 4 or 5 under the same conditions. Apparently the optimum load for this machine is 8 pounds. Results obtained with the 10-pound load washed 15 and 20 minutes were higher than from the 12-pound load. There was little difference between results with 6 pounds, an underload, washed a shorter time, and results with the overloads washed longer. With Dirt No. 2 results were slightly higher with Schedule 6 than with Schedule 7. The peak in brightness with both schedules was reached in 7 minutes.

In Table 7 are data on performance of washer F, a dolly type. The dolly in this machine is supported in the bottom of the tub. The vanes are made of rubber and point downward. The tube is round and is corrugated on the sides. Results from Schedule 1 were best with this machine, although 6 pounds (see Table 1) is its normal load. However, the strain on the motor seemed too great with the 8-pound load.[4] Results from Schedule 3 were higher than from Schedule 2, and only slightly lower than from Schedule 1. The maximum brightness of washed specimens came at a 15-minute period for Dirt No. 1. Results from Schedule 4, the normal load for this machine, were not quite as high as for Schedule 1. Results from Dirt No. 2 show little variation in brightness due to changes in washing period or temperature. The peak in brightness was reached with both schedules in 7 minutes.

In Table 8 are data on the performance of Washer G, a dolly type. The tub is round in shape with corrugated sides. The vanes on the dolly are made of aluminum. Results were highest from Schedule 1. The maximum brightness of washed specimens was reached at the end of a 5-minute period. With Schedule 2, results were higher than with Schedule 3. There was little variation in brightness of specimens from either underloading or overloading, and in neither case were results as high as for the normal load.

For Dirt No. 2, variations in results from both change in length of washing period and rinse temperature were slight. The maximum brightness of specimens was reached at 7 minutes, and was higher for Schedule 6 than for Schedule 7.

In Table 9 are data on the performance of Washer H, a gyrator type. The tub is round in shape. The gyrator is made of aluminum and has two vanes, one large and one small, which project out and upward from the center. The vanes rest in a solid circular base. Results from Schedule 1, Dirt

[4] It is probable that this machine would carry an 8-pound load satisfactorily if the load were made up of small pieces.

TABLE 7.—*Relative brightness of test specimens from Machine F, a dolly type, in relation to washing period, temperature of water, and size of load*

Dirt No.	Schedule No.	Temperature		Load[1]	Specimens	Relative brightness at different washing periods					
		Suds	Rinse			3 min.	5 min.	7 min.	10 min.	15 min.	20 min.
		Deg. F.	*Deg. F.*	*Pounds*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	120	65	8	12	.....	30.04	.....	31.09	33.17	32.36
1	2	120	160	8	12	.....	20.88	.....	21.28	25.71	26.06
1	3	140	65	8	12	.....	26.96	.....	28.63	26.84	28.76
1	4	120	65	6	12	.....	27.29	.....	28.63	.....	.....
1	5	120	65	10	12	.....	.....	.....	.....	28.81	.....
2	6	120	65	8	8	79.22	82.72	85.93	77.33	.....	.....
2	7	120	160	8	8	79.69	82.74	83.67	82.68	.....	.....

[1]Normal load for this machine is 6 pounds.

TABLE 8.—*Relative brightness of test specimens from Machine G, a dolly type, in relation to washing period, temperature of water, and size of load*

Dirt No.	Schedule No.	Temperature		Load[1]	Specimens	Relative brightness at different washing periods					
		Suds	Rinse			3 min.	5 min.	7 min.	10 min.	15 min.	20 min.
		Deg. F.	*Deg. F.*	*Pounds*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	120	65	8	12	.....	35.73	.....	34.17	31.96	30.36
1	2	120	160	8	12	.....	30.55	.....	32.34	30.32	30.38
1	3	140	65	8	12	.....	26.33	.....	25.42	26.75	25.54
1	4	120	65	6	12	.....	28.10	.....	25.65	.....	.....
1	5	120	65	10	12	.....	.....	.....	.....	27.68	27.81
2	6	120	65	8	8	77.36	81.50	83.17	77.90	.....	.....
2	7	120	160	8	8	75.71	77.27	78.67	84.55	.....	.....

[1]Normal load for this machine is 8 pounds.

TABLE 9.—*Relative brightness of test specimens from Machine H, a gyrator type, in relation to washing period, temperature of water, and size of load*

Dirt No.	Schedule No.	Temperature		Load[1]	Specimens	Relative brightness at different washing periods					
		Suds	Rinse			3 min.	5 min.	7 min.	10 min.	15 min.	20 min.
		Deg. F.	*Deg. F.*	*Pounds*	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	1	120	65	8	12	.....	37.05	.....	39.40	36.89	37.93
1	2	120	160	8	12	.....	22.93	.....	24.46	24.07	24.61
1	3	140	65	8	12	.....	24.13	.....	24.24	27.27	33.22
1	4	120	65	6	12	.....	25.37	.....	27.07	.....	.....
1	5	120	65	10	12	.....	.....	.....	.....	27.79	31.88
2	6	120	65	8	8	83.93	83.68	87.97	82.26	.....	.....
2	7	120	160	8	8	83.28	86.21	88.50	85.63	.....	.....

[1]Normal load for this machine is 8 pounds.

No. 1, were highest. The maximum brightness of washed specimens was reached at 10 minutes. Results from Schedule 3 were slightly higher than from Schedule 2. Differences between results from underloading and overloading were slight, and were not as high as with the normal load.

With Dirt No. 2 differences in results were very slight, due either to washing period or to temperature change. The maximum brightness was reached at 7 minutes under both sets of conditions.

COMPARISON OF CLEANSING ACTION OF DIFFERENT TYPES OF MACHINES USED UNDER THE SAME CONDITIONS

In Figure 7 is shown a comparison of cleansing action of different types of machines when operated under the same conditions—Dirt No. 1, Schedule 1, load 100 per cent, tem-

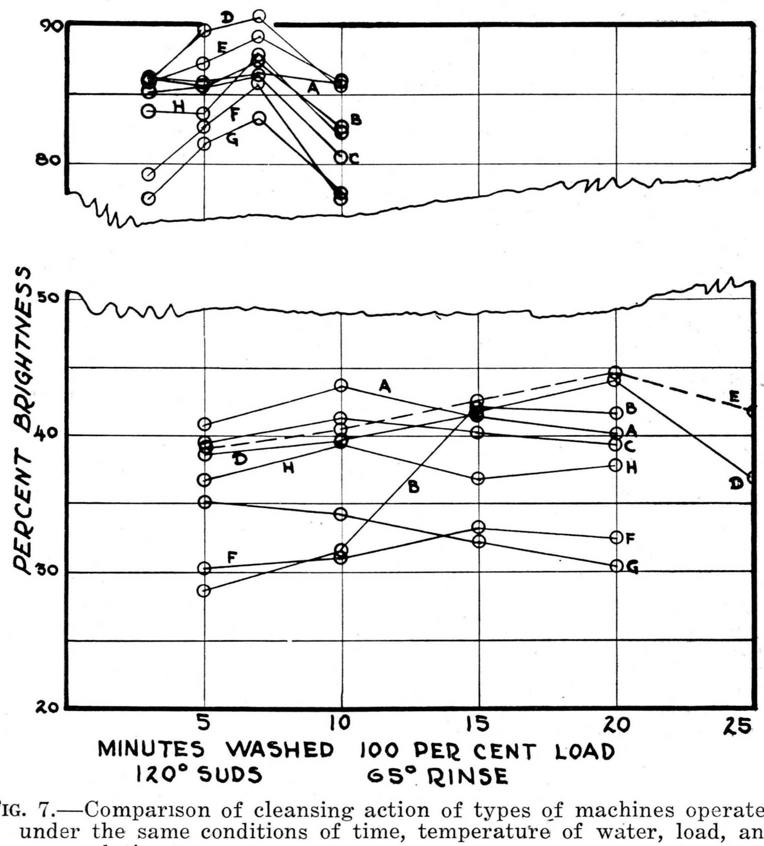

FIG. 7.—Comparison of cleansing action of types of machines operated under the same conditions of time, temperature of water, load, and soap solution.

perature of suds 120° F., rinse 65° F. The conditions for Schedule 1 were chosen because results show a uniformly high relative brightness for washed specimens, as compared with other conditions, and should therefore offer a fair comparison of the performance of the different machines. Of the gyrator machines, results show that for three machines the maximum brightness of the washed samples was reached at a 10-minute period (B at 15 minutes), after which there was a decline. It will be recalled that other washing schedules indicated somewhat more rapid action for Washer B. (See Table 3.) The brightness at the maximum did not vary appreciably for the different machines. That for Washer A was highest and that for Washer H lowest. The vanes on the gyrators of Washers A, B, and C are of uniform size, while Washer H has one large and one small vane.

For Washer E, a vacuum type, the maximum brightness of washed samples was reached at a 20-minute period. While the time required for this machine to reach maximum was longer than for the gyrator types, the brightness at the maximum was slightly higher.

For Washer F, a dolly type, with dolly supported in the bottom of the tub, the maximum brightness was reached at a 15-minute period, but it was lower than that for the gyrator machines at their maximum washing period. For Washer G, with a dolly attached to the lid, the maximum was reached at 5 minutes, a period less than for other machines, but the brightness at this maximum was lower than for any machine except F.

With Dirt No. 2 and temperature and load as in Schedule 1, the maximum brightness for washed specimens was reached at 7 minutes with each machine. The brightness at the maximum for the gyrator machines was very nearly the same for all the machines. For Washer E, a vacuum type, it was slightly higher. For the dolly types F and G, the brightness at the maximum washing period was slightly lower than for other types. For Washer D it was highest of any of the machines.

In considering a comparison of the relative brightness of washed specimens, with Dirt No. 1 and Dirt No. 2, it will be observed that those for Dirt No. 2 showed less variation for different washing periods on the same machine than was shown for Dirt No. 1. Dirt No. 2 was much more easily removed, as will be shown by a comparison of brightness for 3 minutes and 7 minutes. Probably with dirt of this nature, any machine would remove it in a short time. It would seem that, even though the test specimens were not washed clean, results with Dirt No. 1 provide a better comparison of the mechanical action of the machines than do those with Dirt No. 2.

DISCUSSION OF RESULTS

An analysis of results from this study with reference to the comparative performance of the various machines shows some variation for different types as regards thoroughness and rapidity of dirt removal. There are shown, also, for each machine, certain fairly definite relationships between such factors as length of washing period, load, temperature of water, and cleanness of fabric. These are of sufficient significance to offer suggestions of practical value.

RELATION OF LENGTH OF WASHING PERIOD TO CLEANSING ACTION

A consideration of results with regard to the relation of length of washing period to cleanness of fabric shows that for each machine there appears to be an optimum washing period for any one set of conditions. This optimum may or may not be the same for different machines of the same type. Operating a machine beyond the optimum period results in a decline in brightness for the test samples. Apparently clothes washed longer than a certain period actually become dirtier. In general, the optimum washing period for gyrator machines is less than for other types. However, one dolly-type machine was more rapid than the gyrator types, but the brightness of the washed specimens at the optimum period was lower than for other machines. The optimum period for the cylinder- and vacuum-type machines was the same, and longer than for other machines. The brightness at their optimum was slightly higher than for either gyrator or dolly machines, but the differences were not great enough to be of significance. The optimum washing period for any machine seems to depend upon the character of the soiling mixture. The findings in this study in regard to relation of length of washing period to cleanness are in accordance with those of several other investigators. Rhodes and Brainard, at Cornell University, in a study of the detergent action of soap, found the optimum results with their soiling mixture at a washing period of 7½ minutes, after which there was a decline.[5] A probable explanation (after elimination of several others possible), according to them, is that with washing periods longer than

[5] Rhodes and Brainard measured the detergent action of distilled water and compared it with that of a soap solution. With a comparatively short washing period (30 minutes) distilled water showed about one-half the detergent action of soap, but when length of washing period was increased to five hours the cleansing action of the distilled water was increased, and that of the soap solution markedly decreased. They therefore concluded that the decline in brightness for short periods was not due to deterioration of the soap solution. *Industrial and Engineering Chemistry,* Vol. 21, No. 1, Jan., 1929.

the optimum period, equilibrium between soap solution and dirty cloth is reached, and that this is followed by some condition which displaces the apparent equilibrium, rendering the cleaning of the cloth more difficult. Such a condition is, they believe, brought about by continued agitation, the dirt becoming increasingly finely divided, so that it is adsorbed more firmly by the cloth and coats it more effectively.

Lennox and Gilmore, Department of Research, American Institute of Laundering, found little increase in dirt suspension after a washing period of 5 minutes, but state that extra time may be justified by considering that additional dirt is being prepared for suspension in a following suds.[6]

If the theory of Rhodes and Brainard is correct, the practice of putting a whole family wash through the same water and soap solution, as is frequently done, is open to considerable objection. Clothing should be washed for two or more short washing periods with change of soap and water. The method used by the better laundries, known as the "multiple suds" process, consists of several washing periods with change of soap and water. In general, single washing periods should not be longer than ten minutes. The purchaser is justified in expecting sufficient agitation of suds and clothing within this period to obtain maximum value from the suds.

RELATION OF WATER TEMPERATURE TO CLEANNESS OF FABRIC

A consideration of results with regard to the relation of water temperature to cleanness of fabric must take into account the character of the dirt used. Results in this study show that with Dirt No. 1 the relative brightness was uniformly higher with Schedule 1 (suds 120° F., rinse 65° F.) than for the remaining sets of conditions. While Dirt No. 2, Schedule 1, gave generally higher results, it will be observed that there were exceptions, and the differences between the hot (160° F.) and cold (65° F.) rinse were very slight. Dirt No. 1 contained flour, and therefore starch and protein, both of which react unfavorably to the higher temperature. Dirt No. 2 contained oil, which is easily removed by the higher temperature. It should be kept in mind that there was no attempt to wash thoroughly the test samples which had been soiled with Dirt No. 1 and it is possible that the extremely hot rinse "cooked" or "set" the dirt remaining in the meshes of the cloth. Results in general for Schedule 2 (suds 120° F., rinse 160° F.) were higher than for Schedule 3 (suds 140° F., rinse 65° F.) Probably because of the higher suds tempera-

[6] Laundryowners' National Association and American Institute of Laundering. *Special* Bulletin, March, 1929, *A Practical Study of Sudsing and Rinsing Time.*

ture (Schedule 3), more dirt was "set" in the fabric than with the medium suds (Schedule 2) and final hot rinse.

It is generally believed that an extremely cold rinse, or one more than 20° F. below the suds, will cause the fabric of the cloth to contract, and hold the soap and dirt. With the Dirt No. 1 used in this study the extremely hot rinse probably produced more undesirable results than the extremely cold, and the hot suds (140° F.) applied to the dry fabric more undesirable results than either. Because of the complex character of dirt found on clothing, a suds temperature around 120° F., followed by a medium-hot rinse, or one below 140° F., is probably a safer combination, eliminating undesirable effects from extremes of temperature. Much more detailed study would be necessary to establish absolutely correct washing temperatures for different varieties of dirt. However, these results do indicate that high temperatures may be very detrimental. It is probable that, in general, washing temperatures used in common practice are too high. Some manufacturers recommend that they be not above 125° F. Good Housekeeping Institute and the Delineator Institute recommend temperatures around 120° F. unless the clothing has been previously soaked. Higher temperatures (160° F. to boiling) are recommended following soaking.[7] Soaking clothing previous to washing requires labor, which many feel might as well be performed by the machine, and prefer to omit it. Probably less labor is involved by washing clothing through a suds of medium temperature for a short period in the machine, and following this with another suds at a higher temperature.

Current modes and customs determine to some extent the methods of laundering which are best adapted to clothing and linens used. With present fashions there is much less pure white clothing or linen used than formerly. Color and tint of fabric limit ranges of temperature. Frequently excessively high temperatures are used for hygienic reasons, which fall outside the field of this study. When such procedure is necessary, the hot rinse could be a final rinse, since at this stage of the washing process there is no problem of dirt removal. The reason for a cold final rinse is largely to prevent streaking the clothing with bluing. With tinted or colored fabrics, there is no need for bluing.

SIZE OF LOAD IN RELATION TO CLEANNESS OF FABRIC

Results showing relation of cleanness of fabric to size of load indicate that there is one best load for every machine.

[7] Any conclusions drawn from this study in regard to method could not be applied to woolen or silk fabrics.

There was no advantage in underloading with short washing periods (5 and 10 minutes) as compared with overloading with longer washing periods (15 and 20 minutes), and neither gave generally as good results as the normal load, washed for the same periods.[8] A possible explanation is that underloading provides too little friction between clothes, and between water and clothes, and that overloading prevents adequate agitation of clothes and decreases the proportional amount of water. There was little justification for washing an overload longer than 15 minutes, or the underload longer than 5 minutes.

WEAR UPON FABRIC BY DIFFERENT MACHINES STUDIED

Popular opinion appears to differ in regard to wear upon fabric by different types of washing machines. Statements are frequently made in advertisement literature concerning the merits of different types of machines in this respect. A consideration of advantages and disadvantages of types leads to the question of a possible relationship of thoroughness and rapidity of washing to the wear on the fabrics.

To determine the relative merits of the different machines used in this study, with respect to wear, they were tested as follows. Strips of Indian Head muslin, 10″ x 36″, torn across the material, were washed in each machine, under uniform conditions, for a period of 19.15 hours. The washed strips were cut into ten two-inch specimens, of 90 threads each, of both warp and filling. Control specimens (ten in number) were prepared in the same way from warp and filling of the new, unwashed material. The specimens were heated in an Emerson conditioning oven to remove moisture. They were

TABLE 10.—*Breaking strength of washed fabric as compared with new unwashed fabric. Specimens 90 threads for both warp and filling*

Type of machine		Average breaking strength		Decrease in breaking strength	
		Warp	Filling	Warp	Filling
		Pounds	*Pounds*	*Per cent*	*Per cent*
UNWASHED FABRIC		101.6	94.2	.....	.....
WASHED FABRIC		......	.....	.....	.....
Machine A	Gyrator	82.8	93.1	18.5	1.17
Machine B	Gyrator	86.1	93.8	15.3	.42
Machine C	Gyrator	84.4	90.7	16.9	3.7
Machine D	Cylinder	81.2	89.1	20.1	5.4
Machine E	Vacuum	78.7	86.6	22.5	8.1
Machine F	Dolly	69.2	70.9	31.9	24.7
Machine G	Dolly	82.0	81.9	19.3	13.1
Machine H	Gyrator	80.0	89.3	21.3	5.2

NOTE: Figures for breaking strength are averages of 10 specimens washed 19.15 hours.

[8] Results from this study indicate that for two machines the normal load is less than that designated by the manufacturer. (See Tables 1, 5, and 6.)

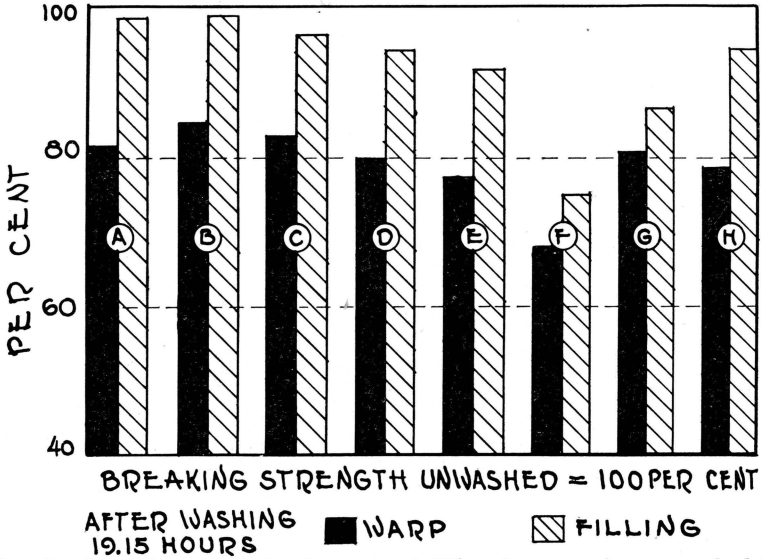

FIG. 8.—Breaking strength of warp and filling from specimens washed in different machines compared with the breaking strength of new unwashed fabric.

then tested for breaking strength by a Scott tester, which measures breaking strength in pounds.[9] Care was taken to break the specimens immediately after removal from the oven, to prevent any regain in moisture.

Table 10 and Figure 8 show the breaking strength of both warp and filling as compared with the breaking strength of the new, unwashed fabric. These figures are averages of the results obtained from the ten specimens. There was considerable variation in breaking strength in both warp and filling from specimens cut from any one strip. This is to be expected; the friction would vary on different areas of the material washed, and agitation would vary with the position in the machine. It will be observed that the filling, in each case but one, was stronger after washing than was the warp, and in some instances was very little below that of the new sample. In the unwashed material the warp was considerably stronger than the filling. The shrinkage from washing seemed insufficient to explain the differences in resulting strength. The relative strength of warp and filling may have been affected by differences in sizing of yarns previous to weaving.

A comparison of results showing wear by the different

[9] The speed of the Scott Tester is regulated according to specifications by Committee D—on Textile Testing.

machines as measured by breaking strength of the test specimens fails to disclose conspicuous differences, except for Washer F, a dolly type. For the latter, the wear was significantly greater. The relative wear upon warp and filling was in general fairly consistent for the different machines. Results for three of the gyrator machines were quite similar; those from Washer B showed the least wear and those from Washer H the most. The manufacturer of Washer C claims that the smooth vanes on the gyrator (bakelite) prevent wear on the clothing. The gyrator on H is made with two uneven vanes; the speed of the gyrator is higher than that of B and C, and the same as that of A. Results from Washer D, a cylinder machine, showed somewhat greater wear upon the fabric than did three of the gyrator machines. These results are contrary to prevalent opinion, which appears to favor the cylinder type of machine as regards its wear upon clothing. Results from Washer E, a vacuum type, showed greater wear on the warp than from any machine except F, but less than some others on the filling. Results from G, a dolly machine, compare favorably with the others in regard to wear on the warp, but less favorably on the filling.

In Table 11 and Figure 9 is shown a comparison of wear upon test specimens by the different machines as measured by breaking strength, in relation to cleansing action and length of washing period.

An analysis of Table 11 and Figure 9 shows that in general the gyrator machines, in comparison with other types, caused relatively little wear upon fabric, washed relatively clean,

TABLE 11.—*Wear upon fabric as related to cleansing action and time required to reach maximum brightness*

Washer		Decrease in breaking strength after washing		Relative brightness	Time required to reach maximum brightness
		Warp	Filling		
	Type	*Per cent*	*Per cent*	*Per cent*	*Minutes*
A	Gyrator	18.5	1.17	43.69	10
B	Gyrator	15.3	.42	42.30	15
C	Gyrator	16.9	3.7	41.11	10
H	Gyrator	21.2	5.2	39.40	10
D	Cylinder	20.1	5.4	44.02	20
E	Vacuum	22.5	8.1	44.49	20
F	Dolly	31.9	24.7	33.17	15
G	Dolly	19.3	13.1	35.13	5

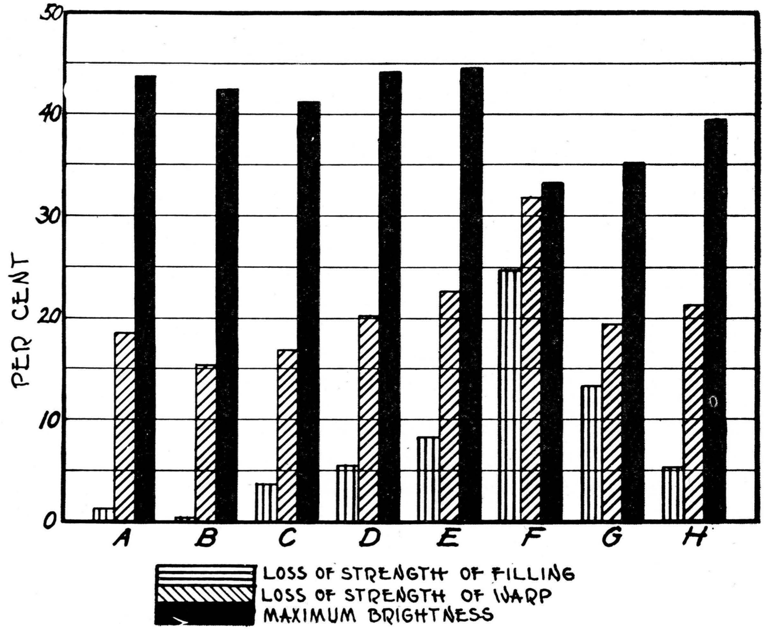

FIG. 9.—Comparison of wear on test specimens, in relation to cleansing action of machines.

and required a relatively short time for washing. Specimens from Washer H showed a greater decrease in breaking strength than those from other machines in the gyrator group, and were washed less clean. The gyrator in Washer H has one large and one small vane. Since this machine was purchased the manufacturer has discontinued the present gyrator and has replaced it with a tri-vane gyrator having vanes of equal size. While the brightness of specimens washed in the vacuum and cylinder machines was slightly higher than from the gyrators, the wear upon the fabric was also rather high. It is possible that the longer washing period required by these machines would result in considerable wear upon the clothing. Results show a relatively greater amount of wear by the dolly machines (F showing most of all machines tested), and the maximum brightness of test specimens was not as high as for the other machines. Washer F, which required a longer time than the gyrators to reach maximum, might wear clothing excessively. It is interesting to note that this machine (See Table 1) is the most rapidly moving machine of all those studied; that is, the dolly has the greatest number of oscillations per minute. Washer G appeared to wash more rapidly than F, with less wear.

Findings from this study fail to show any essential relation between the thoroughness and rapidity of washing clothing and the wear of the machine upon the fabric. A washing machine which will wash clothing clean and rapidly without undue wear seems to be an engineering achievement entirely possible, and the purchaser is justified in expecting such performance.

COMPARATIVE HEAT RETENTION OF DIFFERENT MACHINES

Washing machines are usually constructed of metals. In some machines are combined several metals, either plated or pressed together. A few machines have double walls with an air space between, for the purpose of preventing loss of heat. The loss of heat from any machine would be expected to vary according to the kind of material, the shape and the surface area, and the finish.

To learn the comparative heat retention of the various machines, the following tests were made. The machines were filled with water at 160° F. and covered. During the tests they were opened only sufficiently to insert a thermometer for temperature readings. The temperature was taken at 10-minute intervals for a period of one hour. Openings to the room were kept closed to reduce air currents. Room temperature during the test was 58° F. Table 12 and Figure 10 show the cooling rate for each machine. The material and finish, as well as the volume of water in the machines, are included in the table.

Results show that the cooling rate in the various machines is gradual. Except for Washers A and D, the total temperature drop did not vary significantly. A is built with a double wall to provide air insulation, and is finished both inside and out with white porcelain enamel. The volume of water in the machine is less than for most of the others. The material used in Washer D is plated copper. The openings, both in the tub and in the cylinder, are relatively large and it was necessary to release both in order to insert the thermometer for temperature readings. As a result, larger quantities of steam were allowed to escape. With other machines it was possible to insert the thermometer with less exposure. While Washer A, with a double wall, showed the lowest cooling rate, that for Washer E, also with a double wall, was relatively high. However, the outside wall of E is corrugated, a factor probably tending to increase radiation from this machine.

TABLE 12.—*Comparative cooling rate for different machines*

Washer	Material	Shape[1]	Finish		Temperature							Total drop	Volume of water
			Inside	Outside	At start	10 min.	20 min.	30 min.	40 min.	50 min.	60 min.		
					Deg.F.	*Deg.F.*	*Deg.F.*	*Deg.F.*	*Deg.F.*	*Deg.F.*	*Deg.F.*	*Deg.F.*	*Gallons*
A	Nickel-plated copper lid. Steel double—walled tub.	Round	Porcelain enamel	Porcelain enamel	160	157.3	155.5	154	152.6	151.3	149.3	10.7	12
B	Cast aluminum.	Square	Polished nickel chromium	Enameled	160	155.6	153.6	150.3	147.3	145.3	142.3	17.7	17
C	Nickel chromium plate on copper steel armor.	Square	Polished stainless	Enameled	160	158	154.3	151.6	148.6	146.3	144.6	15.4	17
D	Nickel-plated copper . .	Rectangular[2]	Polished	Duco	160	152.3	147	142.3	139	136	132	28	17
E	Nickeled copper lid. Double walled, steel jacket—nickel-plated copper.	Round	Polished nickel	Enameled corrugated	160	155.6	152.6	150.6	147.3	145	141.6	18.4	17
F	Spun-aluminum lid. Nickel-plated copper tub.	Round	Polished nickel corrugated	Lacquer enameled finish corrugated	160	156.3	152.6	151	149.6	147.3	144.3	16	12
G	Nickel-plated copper tub.	Round	Polished nickel corrugated	Enameled corrugated	160	156.3	152.6	151	149.6	147.3	144.3	15.7	14.5
H	Nickel plated copper	Round	Polished nickel copper	Polished natural copper	160	157	154	152	149	147.6	146.3	13.7	17

[1]Shape of body denotes shape of horizontal cross section.

[2]Cylinder with horizontal axis.

NOTE: These figures are averages of three tests. Room temperature was 58° F.

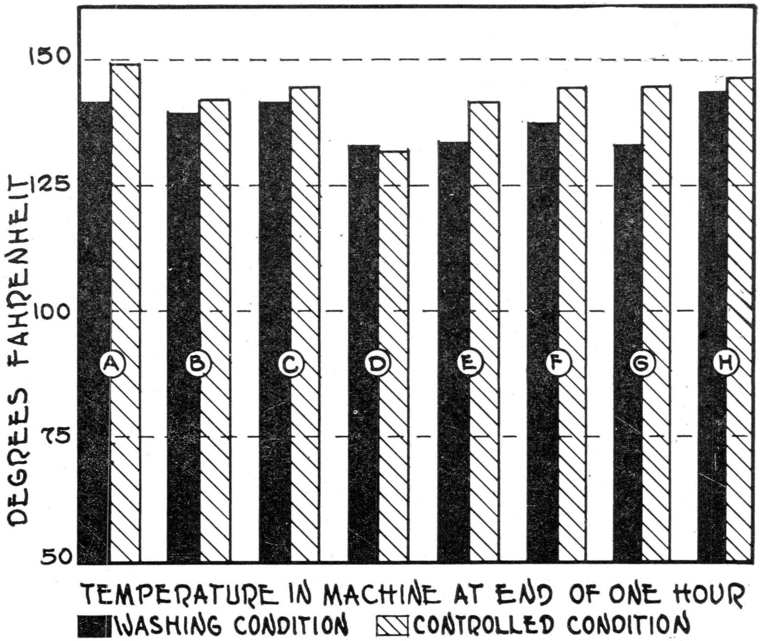

FIG. 10.—Cooling rate of machines.

It does not follow necessarily that a machine which retains heat well, under conditions as described above, would be superior in heat retention under actual washing conditions. The size of the lid and the nature of its contact with the machine are factors affecting loss of heat when the lid must be frequently removed. To compare the heat loss under practical conditions the machines were filled with a normal load of clothes and water at a uniform temperature and were operated as in ordinary washing. Three loads were washed for 10-minute periods in each machine, the machines being opened to pass the clothes through the wringer. The temperature was taken at the beginning and end of each washing period. Results are shown in Table 13 and Figure 10.

In Table 13 is included the approximate surface area of the water in each machine, and that of the lid. The relative cooling rates for different machines are fairly consistent with those shown in Table 12 and Figure 10. Results from Washer H show a slighly lower rate than those from Washer A, the latter having the lowest rate in the preceding tests. The covers on Washers B and C have the least area in proportion to surface area of water, and therefore the least area of exposure. Of these two machines, the rate for C is relatively

TABLE 13.—*Comparative cooling rate of washing machines when operated under practical washing conditions*

Washer	Room temperature	Temperature at end of first washing	Temperature when reloaded	Temperature at end of 2nd washing	Temperature when reloaded	Temperature at end of 3rd washing	Total drop in temperature	Approx. surface area of top of water	Approx. size of opening for lid
	Deg. F.	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Deg. F.*	*Sq. in.*	*Sq. in.*
A	82	155.3	154	148	146.3	141.3	18.7	363	314
B	80	154.6	153	148	146.6	139	21	462	225
C	74	156.3	155	151.3	149.3	141.3	18.7	506	225
D	72	147.6	146.6	139.6	138.6	132.6	27.4	600	540
E	81	151	148	142.6	141	133.6	26.4	434	434
F	77	154.6	153	147.3	146	137.6	22.4	346	314
G	72	155.6	154.6	150	148.3	140	20	353	307
H	72	155.3	153.6	150	148.6	143.3	16.7	346	314

[1]Temperature in all cases was 160° F. at the beginning of the test.

NOTE: These figures are averages of three tests. Washing periods were 10 minutes.

low, while that for B is higher. B is made of aluminum, and C of nickel chromium plate on copper with a steel jacket. Results show highest cooling rates for Washers D and E. As was mentioned above, lids in both the cylinder and tub on Washer D provide large surface exposure. The cover on Washer E is as large as the surface area of the water. Washer F, with a relatively high cooling rate, also has a large cover in proportion to surface area of water.

As a whole, the comparative loss of heat from the different machines, as shown in Tables 12 and 13, is of no consequence. These results are only of significance in that they show the kind of material and finish with relation to heat retention are not important factors in the selection of a washing machine from those now available. Moreover, during an hour's time, the water would be saturated with dirt and should, in any case, be changed.

CONSTRUCTIONAL FEATURES WHICH ADD CONVENIENCE AND SAFETY

While operating the different machines, observations were made of the advantages and disadvantges of the various constructional features of the eight machines studied. Table 14 shows a summary as recorded by different operators.

As was previously mentioned in this bulletin, the trend of manufacturers appears to be toward one particular type of machine. While this study does indicate somewhat superior performance of the gyrator type, its popularity is manifestly due, at least partially, to other factors than performance. It is probable that the gyrator supported in the bottom of the machine provides for greater rigidity and therefore fewer mechanical troubles. Appearance, including design, finish, and size or compactness, and constructional features are all of considerable importance in selection. While appearance of a washing machine should perhaps be given only minor consideration, the modern purchaser is undoubtedly attracted toward a shiny metal or a porcelain enamel finish. He is more interested than formerly in good design. Many of the earlier power machines were bulky, clumsy, and difficult to move and operate. The gyrator types now so popular suggest lightness, and therefore ease of handling. While the material of which the machine is made and the nature of the castors determine its weight and the ease with which it is moved, the purchaser is likely to react unfavorably toward a machine which appears bulky even though it may actually weigh less than the more compact machine. Frequently storage space as well as space for operating are factors in favor of the less bulky machine.

Materials which are used in washing machines have their respective advantages and disadvantages. The relation of material to heat retention has been discussed. A machine made of aluminum is light in weight and reasonably durable. The disadvantage is that it does discolor from alkali and soap. The action of the alkali may affect its durability. If it is necessary to use hard water and therefore a water softener, probably a machine made of material other than aluminum would be preferable. Copper, nickel, steel, and cast iron are all heavier than aluminum. Nickel plated copper makes a finish which is fairly easy to keep bright. The "stainless steel" or chromium nickel finish remains bright and unaffected by alkalis. Porcelain enamel on cast iron is ideal in so far as appearance and ease of cleaning are concerned. The finish may chip if handled carelessly. To prevent such damage metal rims are provided by some manufacturers to protect the finish at points where exposure is greatest.

Of the eight machines used in this study none appeared to be ideal in so far as constructional features were concerned. It may be that to provide certain convenient features others must frequently be sacrificed, but there could be found no good reasons for some of the undesirable features found. The machine with attached lid has several advantages. There is no danger of misplacing or damaging the lid; an attached lid when open provides additional space for placing clothing when operating the wringer; and because the machine is more likely to be kept closed with the lid attached, there is less loss of heat. The location of the gear control and wringer controls is very important. Persons may differ in their preferences as to position with reference to the machine when using the wringer. However, there is probably one most efficient procedure. In the opinion of persons operating the machines used in this study, there was least bodily strain when in a position facing the machines in a direction at right angles to the wringer. The discomfort from operating the wringer varies with the distance across the tub and the height and size of the operator. It should be possible to reach the gear control and all wringer controls, as well as a switch, without moving around the machine. On some of the machines studied the controls are so placed that the operator must stand facing the wringer, reach across the tub, or move around the machine, to manipulate them. The controls should be placed high enough so that a woman of average height can reach them without stooping. Machines should be built so that height may be adjusted to the height of the operator. Only two of the eight machines studied were provided with this adjustment. Switches on machines are a great convenience, but again were provided on only two of the machines used in this study. Repairs in case of a leak might possibly be complicated by the double walls used on some machines. This may not be an important consideration, as a machine is not likely to need repairs for leakage before it is otherwise worn out.

TABLE 14

Advantages	Disadvantages
1. Little noise	1. No switch to motor
2. Comfortable height	2. Lid detachable
3. Easy to move	3. Controls inconveniently placed
4. Easy to clean	4. Drainboard on wringer catches clothing
5. Gyrator control lever convenient to reach	5. Height not adjustable
6. Automatic tension control on wringer	6. Gear lever difficult to turn
7. Safety release on wringer easy to manipulate	7. Aluminum discolors with alkali
8. Attached hose to drain	8. Clothing of operator catches on gyrator control lever
9. Pump to drain lessens time necessary to empty machine	9. Switch too low and inconveniently placed
10. Moving parts enclosed	10. Wringer stalls easily—corners of drainboard catch clothing—drainboard rusts
11. Attractive in appearance	11. Lid inconveniently placed with relation to wringer
12. Height adjustable	12. Wringer shaft projecting in front of machine, preventing rinsing tub from fitting closely
13. Lid attached	13. Noisy
14. Controls placed so that operator may reach them when standing at right angles to wringer	14. Too much machinery
15. Rounded drain on wringer—does not catch clothing	15. Too many detachable parts (lid, vacuum cups)
16. Soft roll on wringer	16. Machine too high to lift clothes into dryer comfortably
17. Stainless steel finish	17. Vacuum cups must be removed to fill machine with clothing
18. Starting lever easy to manipulate	18. Unpleasant vibration from dryer
19. A switch to motor which automatically protects from overloading.	19. No provision for stopping dolly without removing it or disconnecting motor
20. Easy to get clothes out and in	20. Danger from catching finger in lever which controls dolly
21. Handles bulky loads well	21. Wringer support not rigid
22. Dryer provides extra space for clothing	22. Cotton covered lamp cord
23. Dryer has some advantages when laundering heavy bedding	23. Inadequate provision for control of water from wringer
24. Gyrator takes little space in the machine	
25. Adequate control of water from wringer to tub	
26. Rubber-covered cord	

Wringers differ considerably on different machines. They differ in the size and hardness of the rolls, in tension control, in ease of manipulating safety release, and in type of drainboard. Wringers which automatically control the tension are less likely to stall. The large soft rolls seem to provide more even pressure and are a protection to buttons. The drainboards on the wringer should be reversible and rounded sufficiently to prevent any possibility of catching and tearing clothing, but in this respect only two of the wringers used are satisfactory. While all are slightly rounded, they extend too far out from the wringer and interfere with the passage of the clothes. The safety releases provided on the various wringers are in general quite satisfactory. In all cases the releases were instantaneous and easily manipulated.

There is at the present time considerable effort to popularize the centrifugal dryer in preference to the wringer. Some manufacturers build their machines so that the purchaser may have a choice of either process of removing water from clothes. Only one of the machines used in this study was provided with a centrifugal dryer. There are some advantages of a dryer as compared with a wringer and there are likewise some disadvantages. By increasing the time the clothes are rotated in a dryer, it is possible to remove a greater amount of water. A dryer furnishes additional space for clothing, frequently taking the place of a rinsing tub, and with some machines it is possible to rinse in the dryer. There is little chance for removing buttons from clothing, and no danger of catching fingers as with a wringer. On the other hand, the entire weight of the clothing must be lifted by the operator when transferring the clothes from the machine to the dryer, while with a wringer, a part of the weight of the clothing is supported. If the water is extremely hot there is likely to be danger of burning the fingers, because of handling a large bulk. With a heavy load it may be necessary to fill the dryer twice. The vibration is often unpleasant, especially if clothing is not properly packed, and may cause considerable wear on the machine. More floor space is required for a machine with a dryer. However, manufacturers are improving the mechanics of the dryer and reducing the vibration.

The time required to remove water from clothing with a dryer depends upon the ability of the operator to lift all of the clothing into the dryer at once, a qualification which few women are able to meet. If this is taken into consideration, the relative advanage compared with a wringer as regards use of time is of little significance.

In this study the one dryer was used for extracting water from heavy blankets. While it was difficult to lift the wet blankets into the dryer, they were left in a light and fluffy condition, which seemed preferable to results from the wringer. With cotton-filled comforts there is less danger of wadding the cotton.

Only six of the machines studied provided complete protection for the motor and moving parts. On two machines there was partial protection. The obvious danger to children from exposed mvoing parts on a washing machine needs no comment. There is danger from such construction to those operating the machines. The driving mechanism on one machine used in this study is through a toothed bar placed in mesh with a gear-toothed wheel above the top of the lid. These parts are not fully covered and protected. Such construction endangers the hands of the operator. One such accident occurred in the laboratory during these studies.

[5M]