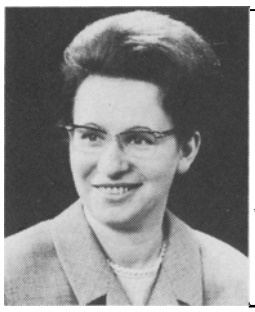

The Evaluation of Washing Machines[1]

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ABSTRACT

The evolution of washing machines on the German market during the past decade will be discussed, with emphasis on differences between machines. Technical data and different washing programs and techniques will be stressed. Of particular importance in the future will be comparative product testing for the consumer, energy conservation, and product information. Specific examples will be discussed.

INTRODUCTION

Domestic washing machines represent an important factor in the economy. In 1960 about 3.1 million electric washing machines were manufactured in Western Europe, corresponding to a 23% saturation of the market. In 1972 the production more than doubled, and 7.9 million machines were manufactured, and the median market saturation amounted to about 56%. The Netherlands, the German Federal Republic, Belgium/Luxemburg, Italy, Great Britain, and Austria were the countries with the highest market saturation (1). In the German Federal Republic in 1976 ca. 1.77 million washing machines were manufactured (2), of which ca. 40% were exported. About a half million machines were imported. These figures represent 33% of the German domestic market. At present the market in the Federal Republic is about 85% saturated, as compared with the dryer market which has attained only a 4-5% saturation. The washers currently produced are almost entirely of the drum type, and about 90% of the washers are fully automatic, i.e., they spin-dry automatically after the wash and rinse cycles.

The sales price of washers in Germany varies over a wide range, depending upon design and features, and is generally between 500 to 1,800 DM.

ESSENTIAL CHARACTERISTICS OF A WASHING MACHINE

For the above-mentioned reasons, we shall be concerned here only with drum type machines with spinning action which are called fully automatic machines according to the German nomenclature. The following four aspects cover the essential characteristics of the machines: design of the machines, washing characteristics, ease of handing, and safety features.

The design is characterized by the type of programming, use of energy, water and time for the various programs, nature of the surfaces (i.e., quality of the lacquer or enamel), pressure safety of the hoses and stability of the hose connections, durability test behavior, ease of servicing, and unbalance behavior. A multitude of individual characteristics are integrated into the programming aspect, such as the speed of the drum during the wash and spin cycles, the setup for various reversing rhythms, various treatment solutions, etc.

The laundering characteristics are especially relevant for the three most important washing programs, namely the high temperature washing program, the wash-and-wear program at 60 C, and the wool wash program. Essential aspects of these programs are cleaning efficiency, bleaching efficiency, kindness to fabrics, rinsing efficacy, spinning efficiency, wrinkle formation (in the wash-and-wear program), and felting shrinkage (in the wool program).

Important criteria for the concept of handling or ease of handling are, for example, manipulation and clarity of marking of controls, possibility for control of action within a program and choice of program, addition of detergents and softeners, the loading and unloading of the machine, as well as the nature of the use directions with respect to intelligibility and required hints.

In the German Federal Republic, the safety features must comply with the Law on Mechanical Appliances.

In the following section, a survey is given of commercial machines with respect to individual aspects on the basis of voluminous test results of the Bundesanstalt für Materialprüfung (BAM). The data relate to the number of machine types available without consideration of their share of the market.

CHARACTERISTICS OF COMMERCIAL WASHING MACHINES

During the past 10 years more than 200 machines of the German market have been examined on a continuous basis. Naturally these are not only models of German production but also imported ones from Italy, France, etc. These investigations cover primarily the laundering characteristics and determination of data for the different programs. On the basis of these results we can make statements with respect to the range of such characteristics and the major changes that have taken place during the past 10 years.

Technical Data

Capacity: In general the manufacturers give values of 4 to 5 kg wash per load as a maximum for the appliances. The capacity of the drum was determined as between 40 and 54 liters, and usually as 45 liters. The drum diameter was 44 to 48 cm, occasionally 50 cm, and sometimes 42 cm for compact machines. From the various drum volumes and the manufacturer's statements concerning the recommended load of average soiled laundry, we calculated the load ratio, i.e., the ratio of laundry load in kg over the drum volume in liters, which varied from 1:9 to 1:12. The most common range was between 1:10 and 1:11.

Water level: Almost all machines feature two water levels. The high level is used for the rinse, and with some programs, also for the wash cycle. Appliances with only one level used to be available but have practically disappeared from the marketplace. However, there is an increasing trend toward the production of models with a third water level, which is provided especially for light washloads. The following values were determined for the two and occasionally three water levels of current commercial machines:

[1]Translated by W.M. Linfield.

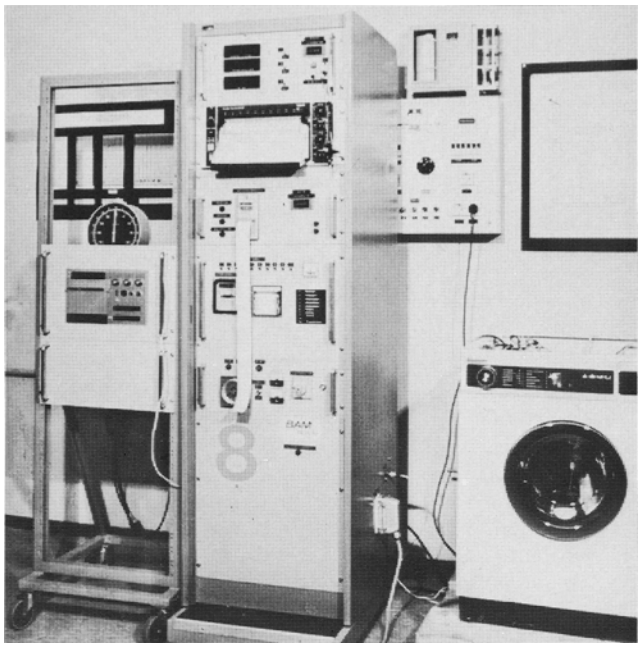

FIG. 1. BAM test equipment.

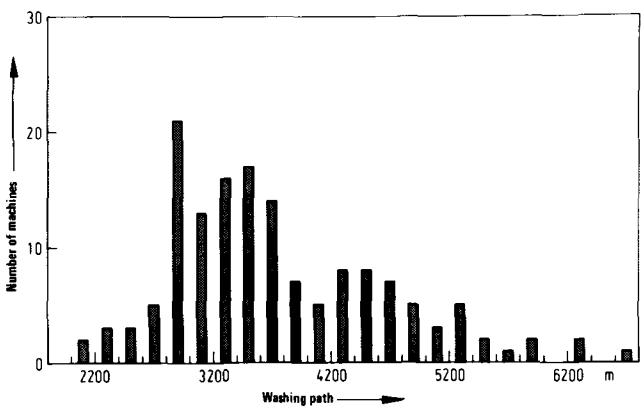

FIG. 2. Washing paths of about 150 washing machines (1971-1976).

Water level 1 (low)	ca. 9-16 liters
Water level 2 (high)	ca. 20-27 liters
Water level 3 (very low for small loads)	ca. 8-10 liters

There was a trend toward lower water values in recent years. Machines from 1971-1972 showed volumes of 11-20 liters for level 1 and 20-27 liters for level 2. This trend is certainly due to efforts to save energy and water. The data given above as well as all subsequent technical data were obtained with the aid of a test stand developed at BAM (3) which has now been further improved (Fig. 1). The measurements of the water levels were made without any laundry load and while the drums were not rotating.

The load ratio calculated from water volume and load weight, as used in the heavy wash cycle of the high temperature wash program for recent machines, lies in the range of 1:4.5 (occasionally 1:4 to 1:6.5); hence, 4.5-6 liters of wash liquor are used per kg of washload of average composition. Since the dosage of detergent used is based upon the washload, different machines will thus give different detergent concentrations both in tests and in practical usage.

Drum movement: The perforated stainless steel drum, which usually has three ribs on the inside, rotates in the wash liquor in a fixed rate around a horizontal axle. The machines made during the past 5 years rotate in the range

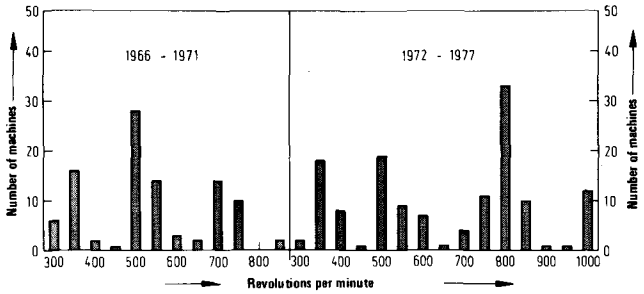

FIG. 3. Spin revolutions of 235 commercial German washing machines (1966-1977).

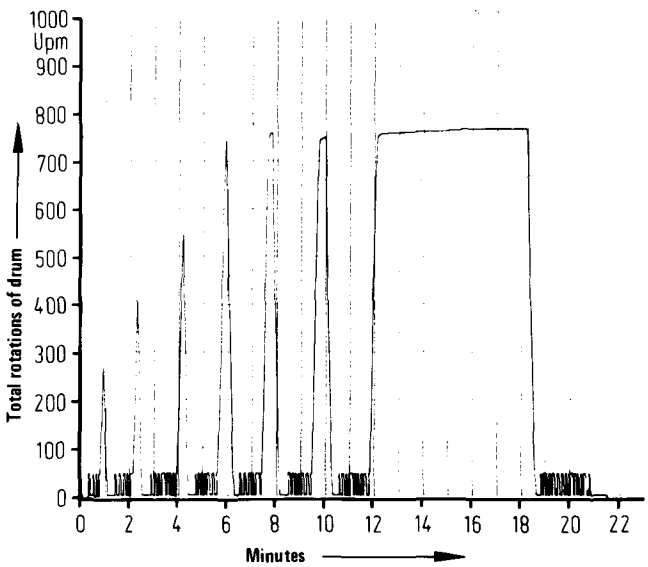

FIG. 4. Time schedule for intermittent operation.

of 48-60 rpm, which corresponds to circumferential speeds of 1.1-1.4 msec. After a fixed time interval, the drum reverses the direction of rotation in order to avoid tangling of the wash. Most machines have two reversing systems, the so-called normal one and the delicate fabric one. Sometimes three systems are used. Some appliances in the lowest price range (ca. 4%) have only one rhythm. The different reversing cycles result in periods of running and standing still of different duration.

The following examples characterize the structures of such reversing rhythms. The numbers refer to seconds, L designates running time, and St standing time:

	Normal mode	Delicate mode
Machine 1	16 L, 4 St	5 L, 15 St
Machine 2	15 L, 5 St	5 L, 17 St
Machine 3	12 L, 3 St	3 L, 12 St
Machine 4	12 L, 3 St	8 L, 7 St 5 x (3 L, 12 St)
Machine 5	10 L, 10 St, 15 L, 10 St, 10L, 5 St	4 L, 10 St, 10 L, 35 St

These reversing rhythms are frequently set in a relatively simple fashion. In many cases the running and standing still phases in the normal mode are simply reversed in the delicate mode, as is shown for machine 3. However, the cycles are often quite complicated, especially in the delicate setting, and some machines feature combinations of the normal and delicate modes. The programs for the high temperature wash or for colored fabric wash are usually in the normal mode, however, the heating cycle is often run in the delicate mode. Naturally only the delicate mode is used in the wool washing program, and long periods of standing are frequently employed during the heating cycle.

TABLE I

Results of High Temperature Wash Tests

	1969-1974					1975-1977				
	Frequency of ratings (in %)									
Rating symbol[a]	++	+	0	−	−−	++	+	0	−	−−
Cleaning effectiveness	35	54	10	1	0	53	33	12	2	0
Bleaching effectiveness	40	29	22	8	1	54	31	10	3	2
Lack of fabric damage	6	41	37	11	5	3	57	35	5	0
Rinsing effectiveness	68	24	6	1	1	45	43	10	0	2

[a](++) Very good, (+) good, (0) satisfactory, (−) less than satisfactory, (−−) unsatisfactory.

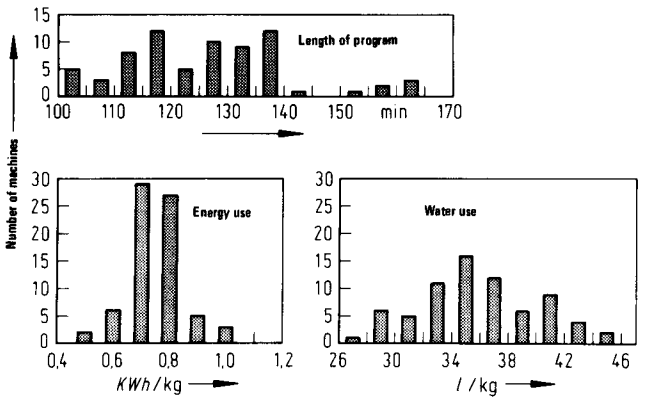

FIG. 5. Consumption data for about 70 washing machines operated in the high temperature washing mode (1975-1977).

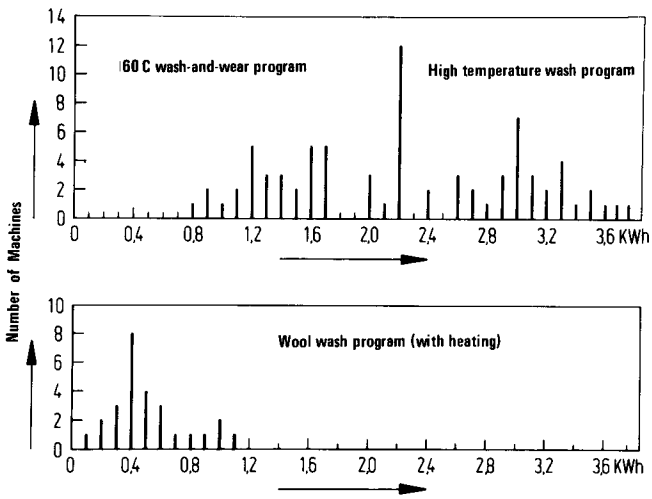

FIG. 6. Energy consumption during the three major washing programs of 30 washing machines (1975-1977).

The rotation speed of the drum or the circumferential speed, combined with the setting and distribution of the reversing rhythms over the entire laundering program, together with the total duration of the wash, thus determine the effective running time of the drum and the so-called washing path of a program. The washing path is that distance which a given point on the surface of the drum will travel in the course of a given washing program. The washing path, in turn, together with the washing bath volume, laundry load, and a few other factors, represent a measure of an effective mechanical setup.

Figure 2 shows the large span of distribution of washing paths for about 150 fully automatic machines run in the high temperature wash program. The values vary from 2,200 m to 6,000 m, and only a few have longer paths. Most machines operate in the range from 3,000 to 4,500 m. Recently there has been a noticeable trend toward longer washing paths.

Spin cycle: The speed of the spin cycles of a fully automatic machine is an essential factor in the cost since higher speeds demand more complex construction. The differences between spin speeds of commercial appliances are very large. Apparently low-cost machines with a spin speed of only 350 rpm are still being sold, naturally their centrifuging efficiency is quite low. During the past 5 years a trend toward higher rpm's is clearly evident. Figure 3 shows the distribution of spin speeds for 98 machines during the period of 1966-1971 and for 137 appliances during the period 1972-1977. Both groups contain machines in different price brackets as well as some space-saving compact models. It is evident that up to 1971 the top speeds were at about 750 rpm. Of the less than 100 machines tested, the largest percentage of automatic machines were those with rpm values in the range of 500-550. Among the almost 140 machines of the past 5 years, the maximum speed is 1,000 rpm. Values of 800 rpm were encountered most frequently. The rpm values for the almost 140 machines of 300-1,000 rpm correlate with the determinations of residual moisture of 140-60% for a washload consisting of 50% terry cloth fabric and 50% smooth cotton fabric. By comparison, manual wringing out of the same washload results in a 150-160% moisture content. The trend toward higher spin speeds in recent years can be ascribed most probably to the increased market for laundry dryers. If a cotton laundry load is to be dried uniformly and economically from an energy point of view, a maximum residual moisture content of 75% after spinning is required. This means that tumble drying has to be preceded by a fully automatic machine with a spin speed of 800-1,000 rpm, otherwise the laundry has to be de-watered in a separate centrifuge.

Since 1971 an increasing number of machines is available, in which instead of an increasing rpm speed or a constant speed for 5 to 6 min, there is introduced a stepwise spin with intermittent operation for loosening up the laundry load. Such interval spin systems (Fig. 4), also called stepwise spin, intermittent spin, or Variomatic spin, have the high temperature or colored wash program followed by an intermittent spin. The spin takes place, for example, in six steps of 5 to 30 sec each, and the final speed is attained in the last intervals. The drum stops briefly between the individual spin phases, the drum then rotates for about 1 min at the washing speed, and the same takes place for 6 min, for example, after the final spin. The advantage of this spin system is that it provides a more uniform spinning effect over the entire laundry load, and it facilitates the unloading of the washload from the machine.

For the wash-and-wear program these machines frequently come with a short spin system which, for example, may consist of three brief spins of increasing speed, with intermittent stops for loosening the load. The advantage of this is that, in addition to the ease of handling, the drying time is greatly reduced as compared with the drip-dry state. The textiles hardly wrinkle more under these conditions than when they are removed in the drip-dry state.

Another variant of the machine design is a spin speed without intervals which can be set anywhere from 120-800 rpm.

Programming

A modern washing machine should have programming that permits the choice of the appropriate wash process with respect to temperature and mechanical action for the great variety of commercially available textiles. The variety of textiles does not only refer to the fiber but also to the finish, dye, and fabrication. Due to these requirements, about seven to eight basic programs have emerged which are offered for the great majority of commercial machines. For machines with multiple control knob automation (about 90% of the appliances of the past 5 years are in this category), additional possibilities are possible for combining temperature control with various mechanical factors. For advertising reasons more than ten washing programs are frequently offered. Ideally each temperature step—95 C, 60 C, 40 C, and/or 30 C—should be provided with a program for high mechanical action for cotton, linen, etc., a program with reduced mechanical action for wash-and-wear articles made from mixed fibers or pure synthetics. In addition, there should be a program at perhaps 30 C with greatly reduced mechanical action for wool. Reduction of mechanical action is made possible through reduction in load weight, use of a high wash liquor level, drum movement in the wash-and-wear mode, etc. The resulting laundering treatments correspond to a great extent to those proposed for the international symbol for wash-and-wear laundering. The symbol for milder mechanical treatment, for example, is a washtub with a bar beneath it.

High temperature laundering program: The high temperature wash program is still the most important one, and most studies were carried out on it. The high temperature wash programs of the machines currently available in Germany have maximum temperatures of 88-96 C with an average active wash period (length of wash period at maximum temperature) of 10 to 20 min. Occasionally the active wash period is up to 25 min, and for about 20% of the machines the active period is only a few minutes long. Since 1975, machines with high temperature automation are no longer manufactured, and maximum temperatures of above 95 C are generally avoided. Subsequent to the active wash period, the wash liquor is diluted by filling from the low wash level to the high rinse level and is also cooled somewhat. The rinse cycle may start as the so-called pendulum rinsing or rinse-through followed by perhaps four normal rinses. For machines with discontinuous rinse cycles, the number of rinses has been reduced recently to three or four.

In view of temperature limitations of some plastic drain pipes, the maximum temperature of the initial wash water discharge is of interest:

Maximum temperature of pumped-off wash liquor in high temp. wash program	Percentage of machines tested	
	1970-75	1975-77
70 C	65	75
70-80 C	28	21
80 C	7	4

The trend toward lower temperatures is evident.

For machines with a 3 KW power requirement, the length of the program in the high temperature wash setting amounts to 110-140 min. The prewash cycle requires about 15-35 min, and the main wash cycle 55-89 min.

Since about 1968 more machines with so-called BIO programs have appeared on the market in response to an increasing spread of enzyme-containing prewash and main wash detergents. Since machines with a 3 KW power rating run rather quickly through the temperature range at which proteases are effective, both in the prewash and main wash cycles, some manufacturers increased their programs in this temperature range by switching off one of the heating steps or switching off the heater after the proper temperature has been attained. In some machines the prewash step was lengthened in this manner, and in a few machines the main wash cycle was also lengthened. Investigation of such BIO programs showed that only 12 among 36 programs designated as BIO prewash and 8 among 9 programs designated as BIO main wash had a residence time of at least 40 min in the range of 30-60 C. In recent years the excitement about BIO programs has abated.

TABLE II

Weighting of Washing Characteristics

High temperature laundering which comprises	60 points
Cleaning efficiency	20 points
Bleaching efficiency	5 points
Lack of fabric damage	10 points
Rinsing efficiency	10 points
Spinning efficiency	15 points
Wash-and-wear laundering at 60 C which comprises	20 points
Cleaning efficiency	10 points
Wrinkle formation	10 points
Wool laundering program which comprises	20 points
Cleaning efficiency	10 points
Felting shrinkage	10 points

Wash-and-wear 60 C programs: This program has been increasing in importance during the past 10 years because of the corresponding increase of wash-and-wear textiles. It can be carried out with or without a prewash cycle. The manufacturers' recommendations for load weight are between 1 and 2 kg. Before rinsing, the wash liquor is cooled off in steps in order to prevent excessive wrinkling. Whereas in previous years the program was usually run at high water levels in the wash cycle, during the past 2 years or so a low level is being used in some programs.

Wool wash program: The development of wool wash programs in domestic washing machines was advanced especially through the efforts of the International Wool Secretariat, which recommended machines that pass specifications with respect to felting shrinkage, cleaning efficiency, and rinsing for washable nonfelting wool. The washload is usually 1 to 1.5 kg, the main wash and three to four rinse cycles are run only at the high water level, the drum rotation is always set in the delicate mode, and occasionally there are more periods of standing still. The wash temperature is usually that of cold water but more recently as high as 40 C. The washing path in the cold temperature program (20 C) of 75 machines was from 100-650 m (for 80% of the machines from 150-450 m) and in a warm program (25-35 C) 100 to 900 m (65% of the machines from 200 to 500 m). The felting shrinkage of wool increases noticeably with an increase in washing path, and even more so at higher temperatures. Systematic investigations (4) on the various factors affecting wool washing have shown that in the interest of satisfactory cleaning and minimal felting shrinkage, it is best to set up a program at 35-40 C and a washing path of about 200 m rather than one at 20 C and a 400 m washing path. In the above statement it is assumed that the usual washloads and water levels are used. Besides machines with the usual drum speeds of 48-60 rpm, there are a few running at 25 rpm, which has a favorable effect on felting shrinkage of the wool.

Washing Effectiveness

Figure 1 shows the broad spectrum of washing paths as a measure of mechanical action in the high temperature washing program for 150 commercial washing machines. In order to achieve optimum washing efficiency, various manufacturers combine the temperature programming with those factors that govern mechanical action in different ways.

In the course of about 10 years, we tested more than 200 washing machines, and we would like to report here the results of a few important washing characteristics in order to show the "state of the art." For the sake of simplicity the results are given in judgmental terms rather than in measured values. In essence the evaluations are based upon methodology we developed. In these studies, particularly in recent years, the textile testing washing machine according to DIN 53 920 was used as the reference machine (5).

A total of 210 washing machines was evaluated in the high temperature wash mode, 150 of these were tested in the period of 1969-1974. Distribution of evaluation ratings spread over five steps as shown in Table I.

The cleaning effectiveness of the great majority of the machines tested during the two time periods is at a high level, and almost 90% of them were rated as good or very good. According to the table, during the past 2 years the percentage of machines with very good cleaning ability even increased. A similarly favorable situation could be determined for the majority of the machines with respect to bleaching effectiveness. On the other hand, barely 50% (1969-1974) and 60% (1975-1977) were rated good or very good with respect to lack of fabric damage. The majority of machines do well on rinsing.

Since 1975 machines have been tested also in the wash-and-wear program mode at 60 C for their cleaning ability. Results with 70 machines were: 7% ++, 76% +, 16% 0, and 1% -.

Whereas these two wash programs gave, for the most part, favorable results for the major laundering characteristics, the wool wash program frequently gave unfavorable results with regard to felting shrinkage. The manufacturers should weigh the various factors influencing washing more carefully, and especially try to reduce the very long washing paths.

ENERGY SAVING

In west European countries energy saving has assumed major importance. Therefore, efforts are being made within the framework of the Common Market to find ways of saving energy with household appliances.

Figure 5 shows the usage of electricity and water per kg washload for about 70 machines from 1975-1977 run at the high temperature washing program. Data for the program duration are also given. Programs of long duration are frequently found in machines with only a 2 KW power requirement. Most programs run for 110-140 min. The most frequently encountered values for energy consumption lie between 0.7 and 0.8 KWh per kg of dry laundry load, with a water usage that ran usually between 28 and 42 liters, and for the most part at 35 liters per kg of washload.

The total energy consumption of the three major wash programs is shown in Figure 6 for about 30 machines. In the high temperature wash mode the total energy requirement lies between 2.4 and 3.8 KWh, usually at 3.0 KWh. Considerable differences in energy demand are evident in the 60 C wash-and-wear programs. This is partly due to the fact that some machines wash at a high water level and others at a low level. Values between 0.8 and 2.1 KWh were observed, most frequently between 1.2 and 1.7 KWh. In the wool wash programs (with heating) the values for power consumption lie usually between 0.3 and 0.6 KWh.

Efforts toward saving of power (and water) will start with the program with the highest energy requirement, the high temperature program. The reader should be reminded here of the above-mentioned measures such as lowering the water level and shortening the rinse cycles. Some manufacturers achieve energy savings by offering a 60 C maximum wash temperature with an increased active wash period, in place of the high temperature wash program, for lightly soiled laundry. About 30% energy saving can thus be achieved. Another relatively simple solution for energy saving consists of omitting the prewash cycle for slightly soiled laundry.

A third fairly widespread concept of an energy saving program, for example, features a smaller load setting for the high temperature wash program for a 2 kg load, especially for small households. In the prewash and main wash cycles the water saving level (3rd level) is used, and rinsing is carried out at the normal (i.e., low) level. If the use data per kg for such savings programs are compared with those obtained in a normal wash cycle for a corresponding load, it can be shown that both power and water can be saved in this fashion. If we compare the per kg usage of energy and water with those for a full load, then the "savings" are negative. Thus the lowest consumption values are always obtained when the drum is fully loaded. Nevertheless such savings programs can be of help in those households where only small washloads are used in a given wash program.

The practical utility of a savings program depends greatly on clear, informative use directions for such programs.

CONSUMER INFORMATION

In recent years consumerism in the Federal Republic has increased greatly. In connection with this, two activities are worthy of note. Starting about 12 years ago comparative consumer goods tests were carried out on a large scale by the Stiftung Warentest (consumer goods test foundation) and published by them in an independent magazine *Test* which currently has a circulation of 800,000. In such tests of washing machines, various characteristics were weighted by different factors, and overall evaluations were obtained. The four major characteristics contribute the following percentages to the overall ratings: (a) functional test (washing results), 50%; (b) technical tests, 20%; (c) safety tests, 20%; and (d) ease of handling, 10%.

Within the category of functional tests the individual wash programs or their characteristics were weighted as shown in Table II.

More recently the Federal Republic is pushing for product information on household electrical appliances. The purpose of this is to permit the consumer to recognize in advertising material and at the time of purchase the most important features of the appliance. The form in which the information is given is being worked out by a committee which has proportional representation from industry and from consumers. In addition there is one voting representative each from the German Standards Institute (DIN) and from the Federal Institute for Materials Testing (BAM). The product information is supposed to assure that the user has information about the product even if the last product test was carried out years ago or if the product was not tested altogether.

It is important for the manufacturer to know the requirements of a test since there is an undeniable effect of the test results upon the sale of the products. The manufacturer can also use the product information simultaneously for factual informative advertising purposes. In contrast to the product test, it is still questionable at this time whether a large number of consumers is able to or wants to use the product information to the desired extent.

ACKNOWLEDGMENTS

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