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# AN EVALUATION OF ASSIGNING CREDIT/DEBIT TO THE ENERGY FACTOR OF CLOTHES WASHERS BASED ON WATER EXTRACTION PERFORMANCE

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**U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige,** ***Secretary***

**NATIONAL BUREAU OF STANDARDS, Ernest Ambler,** ***Director***

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## Abstract

To reduce the moisture retention of a clothes load from 65% to 40%, a clothes dryer uses about 200 times more energy than a clothes washer. Therefore, improving the clothes washer's water extraction performance can significantly reduce energy-use of a dryer. For example, a clothes dryer uses about 40% less energy, when the clothes washer extracts 38% more water from the clothes load. Based on clothes washer extraction performance, NBS has developed, for the Department of Energy (DOE), a procedure for assigning credit/debit to the energy factor of a clothes washer. The purpose of this procedure is to provide an incentative for clothes washer manufacturers to improve the water extraction performance of washers. Using this procedure, the energy factors for two clothes washers improves by 44% and 28% respectively. This energy factor improvement corresponds to improved water extraction which reduces the moisture retention of the clothes load from 65% to 40%. One case study shows that dryer energy savings, resulting from reduced moisture content, justifies a $50 incremental cost for improved water extraction performance for clothes washers.

# I. Introduction

## A. Objective

An integrated approach to appliance energy consumption involves determining what effect the energy consumption and the performance attributes of one appliance has on the energy consumption and performance of another appliance. Of particular interest in this case is the performance of a clothes washer during water extraction (i.e., spin cycle) and the effect on the clothes dryer energy consumption. The more water that remains in the clothes load after the spin cycle, the more energy that must be expended in the drying process. The major emphasis of this study is to devise a plan for assigning credits/debits to the clothes washer for the energy effect on the clothes dryer. This study will examine the energy cost trade-offs of extracting practical amounts of water during the spin cycle versus removing excess water by means of thermal energy in the clothes dryer. In addition, other performance related attributes that may be adversely affected by increased water extraction using the spin method are identified.

## B. Background

The cost for water extraction by mechanical energy in the clothes washer is small in comparision with the cost of supplying thermal energy to the clothes load during the drying cycle in a dryer. Figure 1 shows the moisture transfer between a washer, a dryer, and the environment, and the corresponding amounts of energy required for extracting water in the clothes washer and the clothes dryer. For example, an average value for the machine electrical energy during a full wash cycle including the spin cycle is about 0.25 kilowatt-hour. If one assumes that 20% of the total machine's electrical energy is used during the spin cycle, this would amount to only 50 watt-hours.

Limited test data indicates that the amount of water removed from a standard 7 lb test load [1]* during the spin cycle from the "drip wet" conditions to the "spin dry" condition is 9.5 pounds of water. Therefore, the water extraction during the spin cycle is 190 lbs of water/kWh (= 9.5 lb/.050 kWh). This value compares with an average water removal by clothes dryers of 2.07 lbs of water/kWh. This ratio is the average of the incremental dryer ratio corresponding to moisture retention values between 70% and 40% (see Figure 2 and Table 1). Therefore, the ratio of water removal during the clothes washer spin cycle to clothes dryer thermal cycle is about 90. Although within certain ranges of moisture removals, it is 90 times more efficient to extract water during the clothes washer spin cycle than during clothes dryer thermal cycle, there are practical limitations to the amount of water that can be extracted by means of mechanical energy.

The amount of water removed from a test load varies from clothes washer to clothes washer. The test data shown in Table 2 and plotted in Figure 3

*Numbers in brackets refer to the references at the end of this report.

indicates that the clothes load moisture retention for different machines varies from 74% to 50% depending on the temperature of rinse and the weight of clothes load. For a 7 lb test load this variation in moisture retention amounts to 1.05 pounds of water (= 0.70 x 7 lbs – 0.55 x 7 lbs).

If a 7 lb test load spun in a clothes washer resulted in a 70% water retention rather than a 55% moisture retention, the clothes dryer would have to expend an additional 0.5 kWh (= 1.05 lbs/2.07 lb/kWh). Therefore, a clothes washer resulting in 55% moisture retention for a 7 lb test load would contribute significantly in reducing energy required to dry this load. These results are presented to indicate the significant variation in the amount of energy required to dry a load when various clothes washers are used to prepare a load for the same clothes dryer.

## C. Energy Savings

To compare the effect of clothes washer spin performance on the energy consumption of clothes dryers, it is logical to select 70% moisture retention as the baseline case since starting moisture retention for the 7 lb test load specified in the clothes dryer test procedure is 70 ± 3.5%. Clothes washers which spin the load to below 70% moisture retention may be considered to achieve energy savings for the clothes dryer. Conversely, clothes washers which spin the load to a moisture retention value above 70% may be considered to be wasting energy in the clothes dryer. Table 3 shows the relationship between moisture retention and the corresponding computed levels of energy savings for the clothes dryer. These data indicate, for example, that for a 40% moisture retention, the possible energy savings in a clothes dryer is 1.0 kWh.

## D. National Significance of Reducing Moisture Retention

To establish a base case, assume that all clothes loads have a starting moisture retention of 65% (weighted average). If the extraction performance of clothes washers can be improved such that the weighted average moisture retention of all clothes loads are 40%, the starting moisture weight of the clothes load would be reduced by 1.75 lbs (for a 7 lb test load). A reduction in wet load weight by 1.75 lbs corresponds to an energy saving for the clothes dryer of about 0.85 kWh. On a per cycle basis, this 0.85 kWh savings represents about a 38% savings. It should be noted that this estimated energy savings is based on an average dryer efficiency of 2.07 lbs of water per kilowatt-hour.

The variation in clothes dryer efficiency over certain ranges of moisture retention is shown in Figure 2. Figure 4 shows the test data relating energy consumption and efficiency of dryer A when the test load is spun to 70% moisture retention by washer I and compared to 40% moisture retention when spun in washer G. On an annual basis, the 0.85 kWh savings per cycle corresponds to an energy savings of 354 kWh or a dollar savings of about $20 per year based on 8 cycles per week and an energy cost of 5.64 ¢/kWh. From a national viewpoint, the savings of 354 kWh per dryer would represent a national energy saving of $13.9 \times 10^9$ kWh per year (354 kWh/unit x 39 x $10^6$ units) or about 8 million barrels of oil equivalent per year.

The mechanical energy required to obtain higher water extraction during the spin cycle is negligible (about 1%) in comparison with the potential thermal energy savings in the clothes dryer.

## II. Parameters Affecting Moisture Retention

The clothes load water retention is affected by:

1. the characteristic of the particular clothes load,
2. the machine operating characteristics, and
3. the rinse water temperature.

The primary characteristics that affect clothes load water retaining ability are the weight and composition of the fabric (cotton, synthetic etc.). For example, a load composed of all cotton fabric tends to retain about twice as much water as a blend of 50% cotton and 50% polyester. In general, the percent water retention decreases with increasing load weight, Figure 3.

The machine parameters which affects moisture retention of the clothes load are spin speed, spin time, and basket diameter. Only spin speed and spin time are practical design options for increasing moisture extraction. Increasing spin speed offers the greatest potential for improving water extraction. Increasing spin time is the easiest design option to implement, however, it offers only a modest potential for improving extraction efficiency.

The temperature of the rinse water that preceeds the final extraction cycle has a modest (about 5%) effect on the water-retention of the clothes load. Tests have shown the temperature of the rinse water affects the amount of water extracted. See Table II. One possibility to explain this is that cold water rinse causes a more viscous water to remain in the clothes load. since cold water has a higher surface tension, higher centrifugal forces are required. To quantify these effects the following test data are presented:

### A. Effects of Spin Time

Test results (See Figure 5) shows that when the spin time of four minutes is increased by a factor of three. the moisture retention of a standard test load is reduced by five to ten percentage points. Figure 5 shows the variation in moisture retention of three clothes washers, A, I, and G. The moisture retention of the clothes load spun in machine G approach 40% after about 12 minutes of spin.

### B. The Effect of Spin Speed and Load Type

Moisture extraction tests were performed by using a standard size household clothes washer which was modified to accept a variable speed drive motor. This clothes washer had a six minute spin cycle, therefore all spin test were conducted for six minutes. Two types of test loads were selected to examine the effects of load composition. One load was a seven-pound standard test load which consisted of a blend fabric of 50% cotton/50% polyester and the other load was a seven pound load which consisted of 100% cotton fabric.

Figure 6 shows the variation in the mosture retention for each test load as the spin speed was increased from 400 rpm to 900 rpm. Each load was subsequently dried in the same dryer to about 3% moisture level. Figure 7 shows the variation in energy use to dry each load for various values of initial moisture retention which corresponds to spin speeds between 400 rpm and 900 rpm. Figure 7 indicates that for a standard test load the energy used by the dryer was reduced from 2.42 kWh to 1.28 kWh when the initial moisture retention was reduced from 77% respectively to 40%. This is a 47% reduction in the energy used by the dryer.

Figure 6 shows that for the 100% cotton test load, the 400 rpm spin speed resulted in a 93% moisture retention and the 900 rpm spin speed resulted in a 63% moisture retention. These corresponding retention values can be compared with 77% and 40% for the standard test load (with a 50% cotton/50% polyesters). Figure 7, shows that the clothes dryer used 2.96 kWh to dry a 100% cotton load from a 93% moisture retention to a 3% final moisture retention. These results represent an energy saving of about 28% if the initial moisture retention of a 100% cotton load is 63% instead of 93%.

Figure 8 is the derivative of the moisture retention versus spin speed variation shown in Figure 6. These data show that the water moisture retention per change in rpm was about 2.5 times greater at 425 rpm than at 875 rpm. At 425 rpm the moisture retention per unit change in rpm was 0.12 percent per rpm. Whereas at 875 rpm the moisture retention rate was 0.046 percent per rpm. These results suggest, as might be expected, that more water is removed at higher spin speeds and that the more that has been removed, the more difficult it is to remove the remaining water.

C. Cold Water Rinse

The effect that cold water rinse has on water extraction was determined from previous work done at NBS. These test results were presented in a milestone report titled "The Effect of Water Temperature on Washing Performance" [2]. Some of these test results are presented in Table 2 and show that the difference in water retention is typically about five percentage points higher for cold water rinsing. These data suggest that due to slightly higher initial moisture retention, an additional small amount of energy is used in the dryer to remove this additional amount of water (0.35 lbs of water for a standard test load) corresponding to 5% higher initial moisture retention. However the energy saving due to using cold water rinsing as compared with warm water is about 20 times greater than the incremental thermal energy required by the dryer to remove this additional amount of moisture.

## III. Limitations

In addition to diminishing returns in terms of the amount of water extracted for corresponding spin speeds above a certain limit, there are additional factors that will limit the spin speed to a specified value. These factors include:

1. Higher spin speeds may require more critical balancing system to avoid excessive vibration.

2. Higher spin speeds produce larger centrifugal forces which may cause more wrinkles to remain in the clothes after drying, and

3. Higher spin speeds may result in increased cost for drive component design changes.

## A. Vibrations

During the water extraction test in which the spin speeds were varied from 400 to 900 rpm, excessive vibration occurred in this clothes washer at 900 rpm. Although the vibration which occurred at 900 rpm was objectionable, the moderate to slight vibrations that occurred at speeds between 500 rpm to 850 rpm were acceptable. This qualitative evaluation of machine vibration was based on a test of the one clothes washer which was modified to accept a variable speed drive and was conducted on a hard concrete floor. Resonant vibrations for this clothes washer with a test load are not necessarily typical of other clothes washers and mixed clothes loads. Vibration characteristics are dependent on the design parameters such as bearing location, weight distribution, and support stiffness of the particular clothes washer.

## B. Wrinkle Performance

Some concern has been expressed that increased spin speeds would cause more wrinkles to remain in the clothes. Therefore, tests were conducted to determine if higher spin speed would cause more wrinkles to remain in the test cloth after drying.

Two identical permanent press cloth test loads having a composition of 65% polyester and 35% cotton were selected. One test load was spun at 400 rpm and the other test load was spun at 900 rpm. Each test load was dried sequentially in the same clothes dryer. One group of 12 test cloths was obtained for evaluation by randomly selecting six test cloths from each of the dried load. Six participants visually evaluated each of the twelve test cloths to form two groups - one being more wrinkled and the other being less wrinkled.

As shown in Figure 9, sixty percent of the sorted test cloths confirmed the hypothesis that higher spin speeds caused more wrinkles and forty percent negated this hypothesis. Three of the test cloths received identical grouping by all six participants and these identical groups were congruent with the hypothesis. Each participant expressed difficulty in sorting the twelve test cloths into two groups of one being more wrinkled than the other. The conclusion from this test is that, with exception of three test cloths, the influence of higher spin speeds on wrinkle performance was only slightly detectable by the six participants. The effects of repeated washings and/or higher spin speeds were not investigated, nor were actual clothes.

The clothes dryer tends to remove some of the wrinkles that are set in the clothes during high spin speed water extraction process. Therefore, high spin speeds are expected to cause some more wrinkles to remain in the line-dried clothes as compared with clothes dried in a clothes dryer.

C. Cost Analysis

Higher water extraction, if done by spinning, may require a different drive motor capable of spinning the basket to approximately 800 rpm. Because of concern for wrinkle performance, some manufacturers may chose to replace current drive motors with two speed motors. A high speed setting for efficient water extraction and a lower speed setting recommended for use when wrinkle performance is of concern. NBS does not have reliable cost estimates for the various water extraction design options which manufacturers may choose to implement; however, the incremental unit costs that are economically justified by the energy savings achievable in the clothes dryer can be computed. The economic feasibility for higher extraction efficiency will be based on the present value of the energy savings for various holding periods (3, 5, 10, 15 years).

Two base cases are presented:

Case 1 is for a change in water retention from 65% to 40%

Case 1: Retention changes by 25%

| | |
|---|---|
| Energy savings | $20 |
| Discount rate | 10% |
| Holding periods | 3,5,10,15 yrs. |
| Uniform series present value factors | 2.48, 3.79, 6.14, 7.60 |
| Average drying efficiency | 2.07 lbs of water/kWh |

Case 2: is the same as Case 1 except moisture retention is considered to change from 65% to 50%. Thus, retention changes by 15% and the annual energy savings is $11.60, all other parameters remaining the same.

These data, shown in Table 4, indicate that if the increase in purchase cost for improved extraction performance (65% to 40%) is about $50 the annual energy savings in the clothes dryer will repay (at 10% discount rate) this incremental cost of $50 in about 3 years. However, in Case 2 where the extraction performance is improved to yield a 15% reduction in water retention (65% to 50%) it will require about 6 years to repay the increase in purchase cost of $50. If improved extraction performance can be achieved for about $75, it will require about 5 years to repay this increase in purchase cost for Case 1 and 10 years for Case 2. It is questionable whether a payback period as long as 10 years would be generally acceptable. However, since the expected economic life of a clothes washer is about 12 years, it is expected that a 3 to 5 year payback period would be acceptable.

These two cases give a reasonable indication of the economic feasibility of increased cost for drive component design changes for a range of achievable moisture retention and acceptable payback periods.

## IV. Energy Factor Credit/Debit Analysis

### A. Need for Credit/Debit

The intent of the National Energy Policy and Conservation Act is to result in a program designed to require manufacturers to produce and encourage consumers to purchase more energy efficient appliances. Assigning credits to clothes washers with superior water extraction performance may provide one method for manufacturers to improve the efficiency of clothes washers in order to meet minimum energy efficiency standards. If the credit incentive provided to the manufacturer is large enough, they may develop innovative ways of increasing water extraction.

### B. First Approach to Credit/Debit

The first approach considered for assigning credits or debits was to utilize a continuous linear relationship of energy savings with respect to the percent of moisture retention as summarized in Table 3. A plot of this energy credit or debit is shown in Figure 10. The effect of any credits or debits is to change the energy factor by increasing or decreasing the denominator of the energy factor. The energy factor specified in the current test procedure is defined as useful volume (basket volume) which the clothes can occupy divided by the total per cycle energy consumption.

As shown in Table 2, the range of moisture retention for most current clothes washers is between 74% and 50%. Therefore, this approach which prescribes credit or debit according to a continuous linear relationship as shown in Figure 10 would award credit for most existing levels of water extraction performance without having manufacturers make any design changes to improve water extraction performance. If no design changes are made to enhance spin performance, the credits assigned to the energy factor will not be indicative of any actual dryer energy savings due to a reduced initial moisture retention. This approach has the following distinct disadvantages:

(1) credits are awarded for existing levels of extraction performance,

(2) such credits would not reflect any additional energy saved in the clothes dryer,

(3) awarding credits for existing level of moisture retention, would stifle manufacturers incentive to make design changes to further improve extraction performance, and

(4) a linear relationship does not impose a very severe penalty for exceeding the base moisture content (70%).

C. Second Approach to Credit/Debit

To overcome the disadvantages of the first approach discussed above, it is proposed that the moisture retention be divided into three ranges. The moisture values selected for dividing the spectrum into 3 ranges are 50% and 70% moisture retention.

1. No credit nor debit is assigned within the range of 50% to 70% moisture retention.
2. Credit is increased linearly with reduction in moisture retention below 50%.
3. A constant debit is assigned for moisture retention values that exceed 70%.

The three ranges for assigning credit and debit are shown in Figure 11.

A review of available moisture retention data for current clothes washers show that a few compact clothes washers have moisture retention slightly below 50% which will qualify for a credit. However, some standard clothes washers have moisture retention just above this value. Being close to this 50% value or slightly greater than 70% value provides an attainable goal which will give manufacturers the incentive to improve the water extraction efficiency of the spin cycle. The amount of energy credit or debit is based on the difference in the pounds of water remaining in the clothes after the spin cycle and the amount of water corresponding to a 70% moisture retention (see Table 3). Figure 11 shows a plot of the amount of energy credit or debit corresponding to various moisture retention levels. The assumption used in determining these credit/debit values is that each pound of water remaining in the clothes load at the end of the spin cycle requires about 0.48 kWh of energy consumption in the clothes dryer to remove the excess water. If a clothes washer spins the clothes load to 90% moisture retention, an excess of 1.4 pounds of water remains in the clothes load as compared with 70% moisture retention. To remove this 1.4 pounds of water in the clothes dryer would require about 0.68 kWh. Therefore, a debit of 0.68 kWh would be given to clothes washers in the form of addition to the total per cycle energy consumption, thus reducing the clothes washer energy factor.

D. Energy Factor as Affected by Credit/Debit

The proposed credit/debit system will only affect the energy factor and not the annual operating cost. To debit or credit the annual operating cost based on water extraction performance would mislead the consumer with respect to the actual operating cost for a representative consumer use cycle. However, if minimum efficiency standards are set according to the energy factor, the proposed credit or debit to the energy factor would provide sufficient incentive to manufacturers to improve the water extraction performance.

To apply a credit/debit to the energy factor, the total per cycle energy consumption would be adjusted by the kilowatt-hour of credit/debit shown in Figure 11. To illustrate, let:

$K_1$ = useful capacity, $ft^3$

$E_T$ = total per cycle energy consumption, kWh

R = moisture retention, %

From Figure 11 the energy credit, kWh:

$$C = 0 \quad \text{for} \quad 50 < R < 70$$

$$C = 0.68 + \frac{50-R}{30} \quad \text{for} \quad R < 50$$

$$C = -0.68 \quad \text{for} \quad R > 70$$

The current energy factor, EF, is:

$$EF = \frac{K_1}{E_T} \quad \text{and} \qquad (1)$$

the adjusted energy factor would be,

$$EF' = \frac{K_1}{E_{ATE}} \qquad (2)$$

where the adjusted total per cycle energy consumption, $E_{ATE}$, is:

$$E_{ATE} = E_T - C \qquad (3)$$

Therefore, the adjusted energy factor would be

$$EF = \frac{K_1}{E_T - C} \qquad (4)$$

The following examples for clothes washers A and B are devised to illustrate the effect that credit and debit would have on the energy factor. The data shown in Table 5 for washers A and B and the debit and credit values shown in Table 6, are substituted into equations 3 and 4 to obtain a comparison of energy factors and percentage change (see Table 7) as affected by credit and debit corresponding to various moisture retention.

Figure 12 shows how the energy factor for washers A and B are affected by various moisture retentions. An energy credit or debit for a given moisture retention has a greater effect on the energy factor for washer A than for washer B. For example, if the moisture retention for clothes washer A is reduced to 40%, a corresponding one kWh credit would increase the energy factor from 0.83 $ft^3$/kWh to 1.19 $ft^3$/kWh which is a 44% improvement in the energy factor.

However, if the moisture retention of clothes washer B is reduced to 40%, a corresponding one kWh credit would increase the energy factor from 0.70 $ft^3$/kWh to 0.90 $ft^3$/kWh which is a 28% improvement in the energy factor. The significance of this example is that the higher the original base energy factor the greater the impact of the debit/credit plan.

## V. Conclusions

For most clothes washers the water retention in a standard 7 lb test load range between 50% to 70% of dry test load weight. Water extraction during a spin cycle can be improved by increasing spin speed and/or spin time. However, increasing spin speed has the greatest effect on reducing moisture retention.

A credit/debit plan has been proposed for providing an incentive for manufacturers to improve water extraction performance (by increasing spin speed, spin time etc.). Using this plan, a reduction in the water retention to 40% by two representative clothes washers has shown to improve the energy factor by 44% and 28%.

Annual energy savings of about $20 per year can be achieved if the water extraction performance is improved to reduce the moisture retention by 25 percentage points (65% to 40%). For a 10% discount rate and a 3 year payback period, a $20 annual saving will justify an increase in purchase cost up to $50. However, for 5 year payback period the economic justifiable purchase price increase should not exceed $75.

## References

1. Test Procedure for Clothes Washers, Federal Register, Vol. 42, No. 188. September 28, 1977.

2. Toner, S., "The Effects of Water Temperature on Washing Performance," Milestone Report, National Bureau of Standards, Washington, D.C., 1977.

## A DIAGRAMMATIC ILLUSTRATION OF MOISTURE TRANSFER BETWEEN CLOTHES WASHER AND CLOTHES DRYER

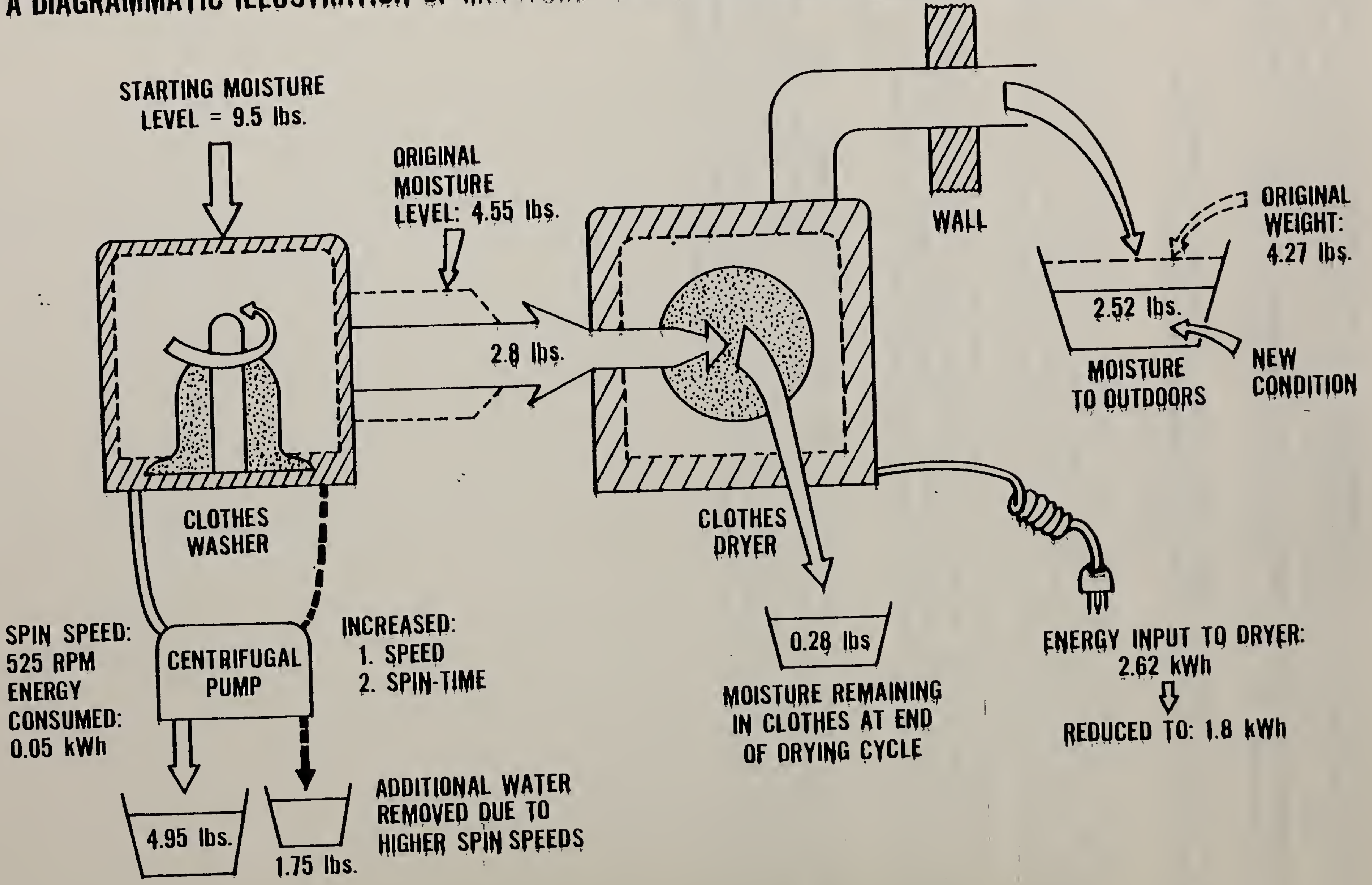



FIGURE 1

## INCREMENTAL DRYER EFFICIENCY VERSUS MOISTURE RETENTION

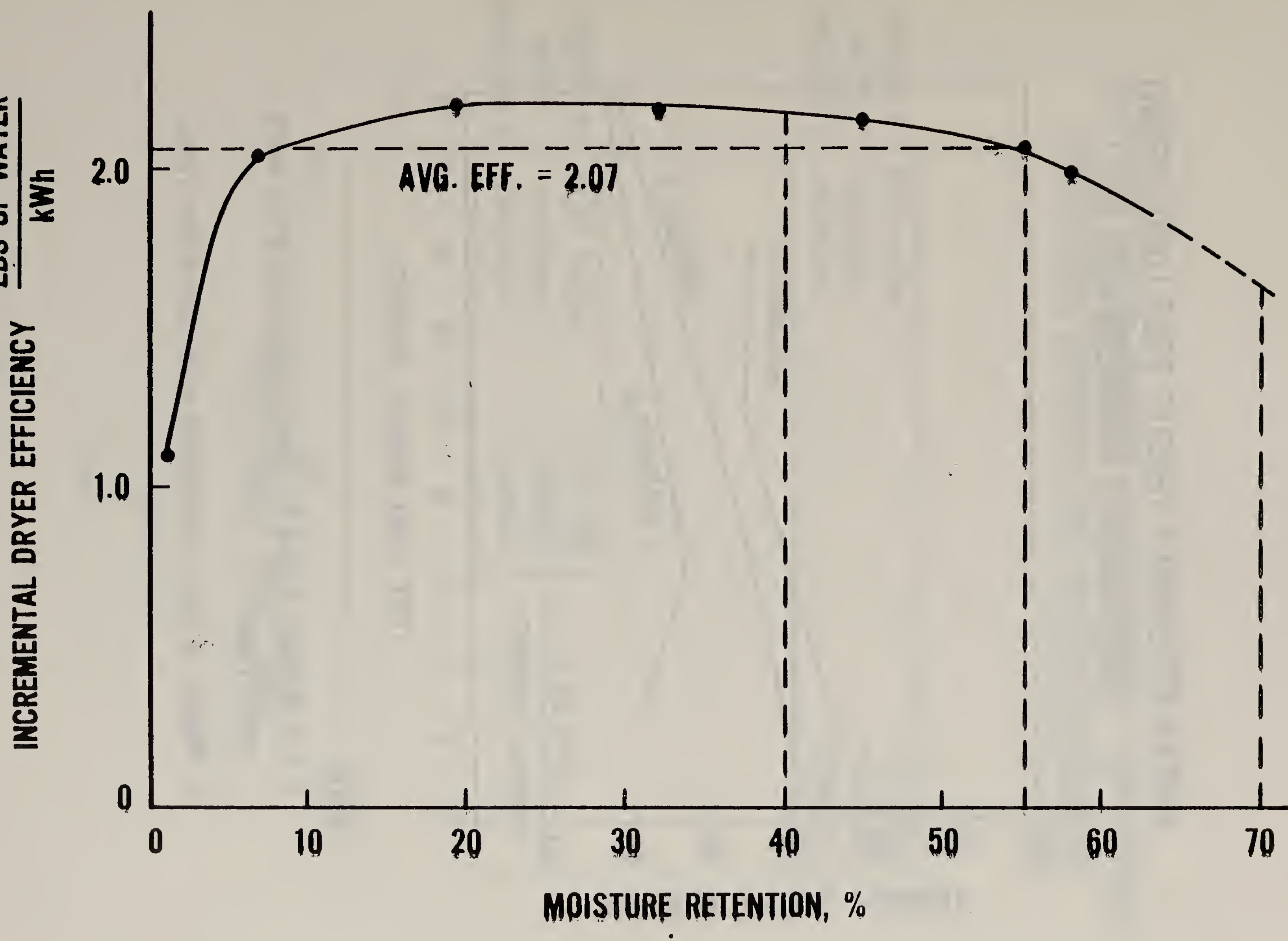
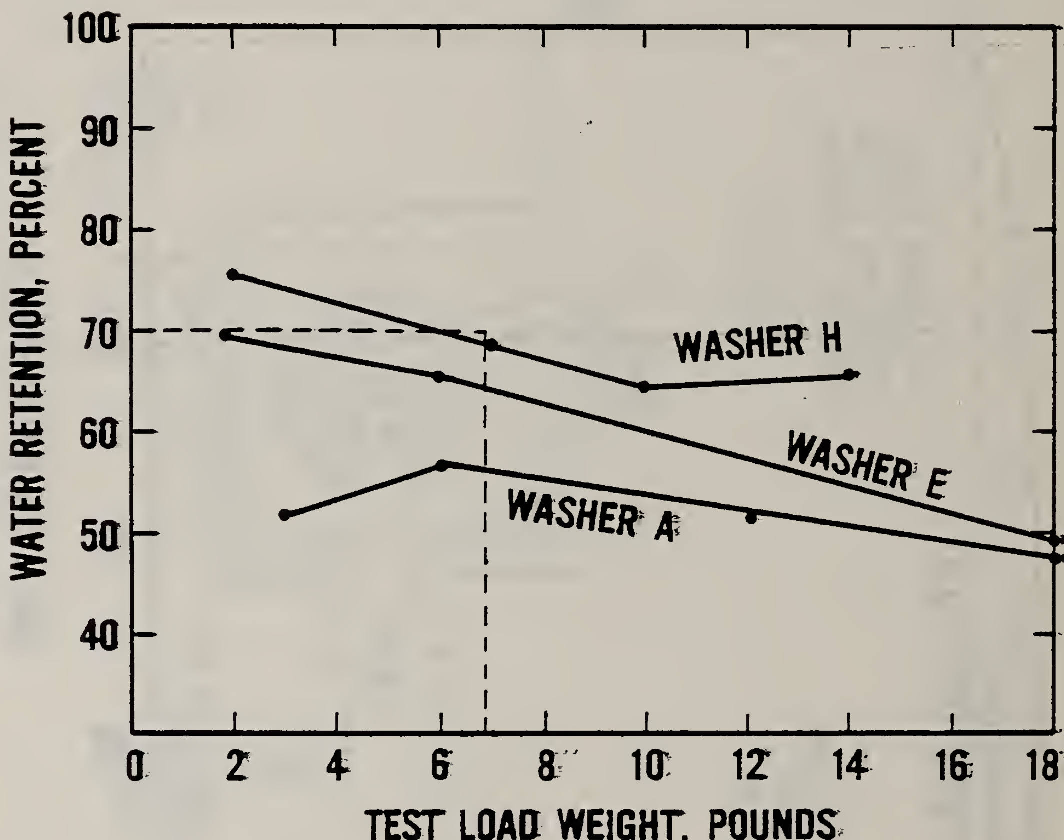



FIGURE 2

## WATER RETENTION VERSUS TEST LOAD WEIGHT FOR CLOTHES WASHERS A, E, H




**Note:**

1. For Washer A and E , test conducted with warm water rinse
2. Washer H test conducted with cold water rinse

FIGURE 3

CLOTHES DRYER ENERGY CONSUMPTION FOR DRYING TEST LOADS SPUN IN TWO CLOTHES WASHERS

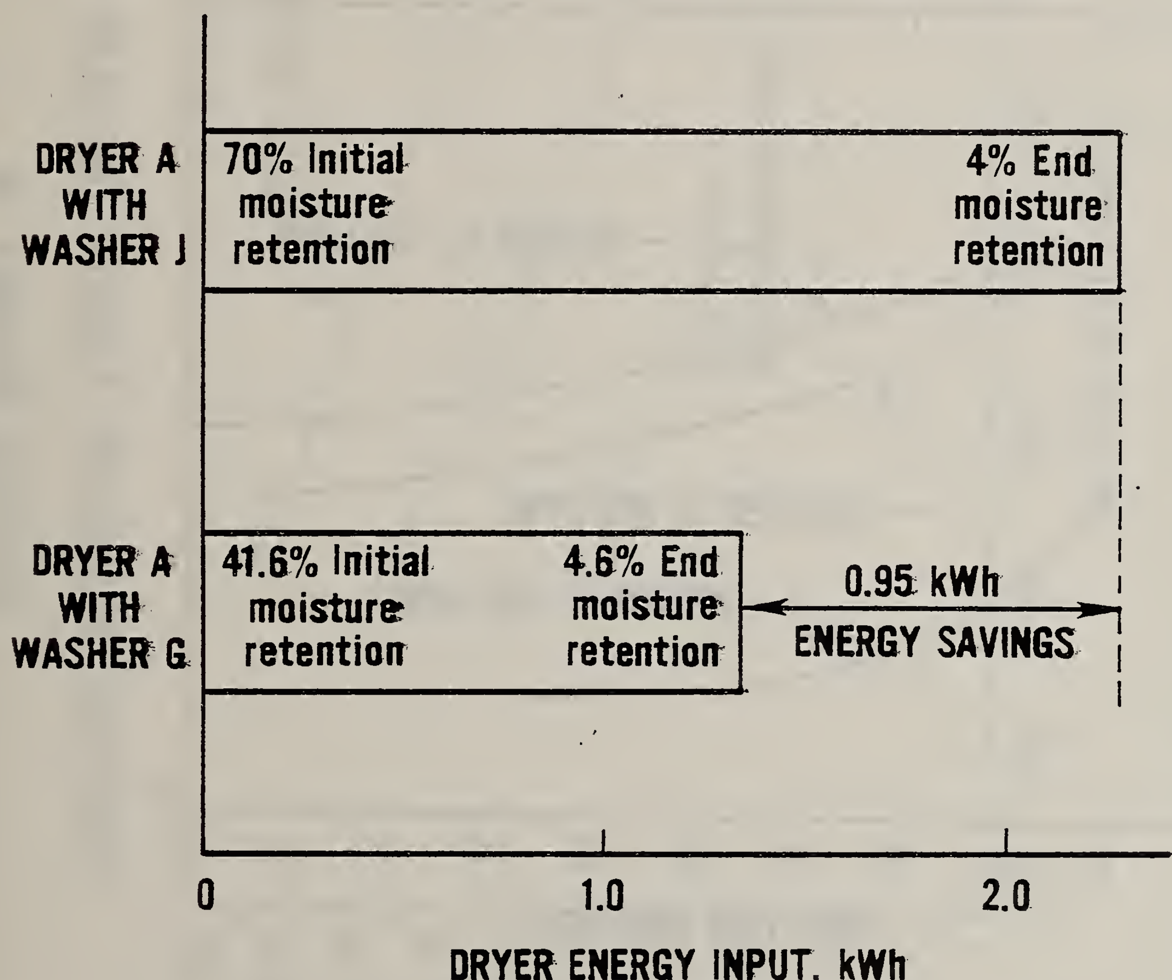
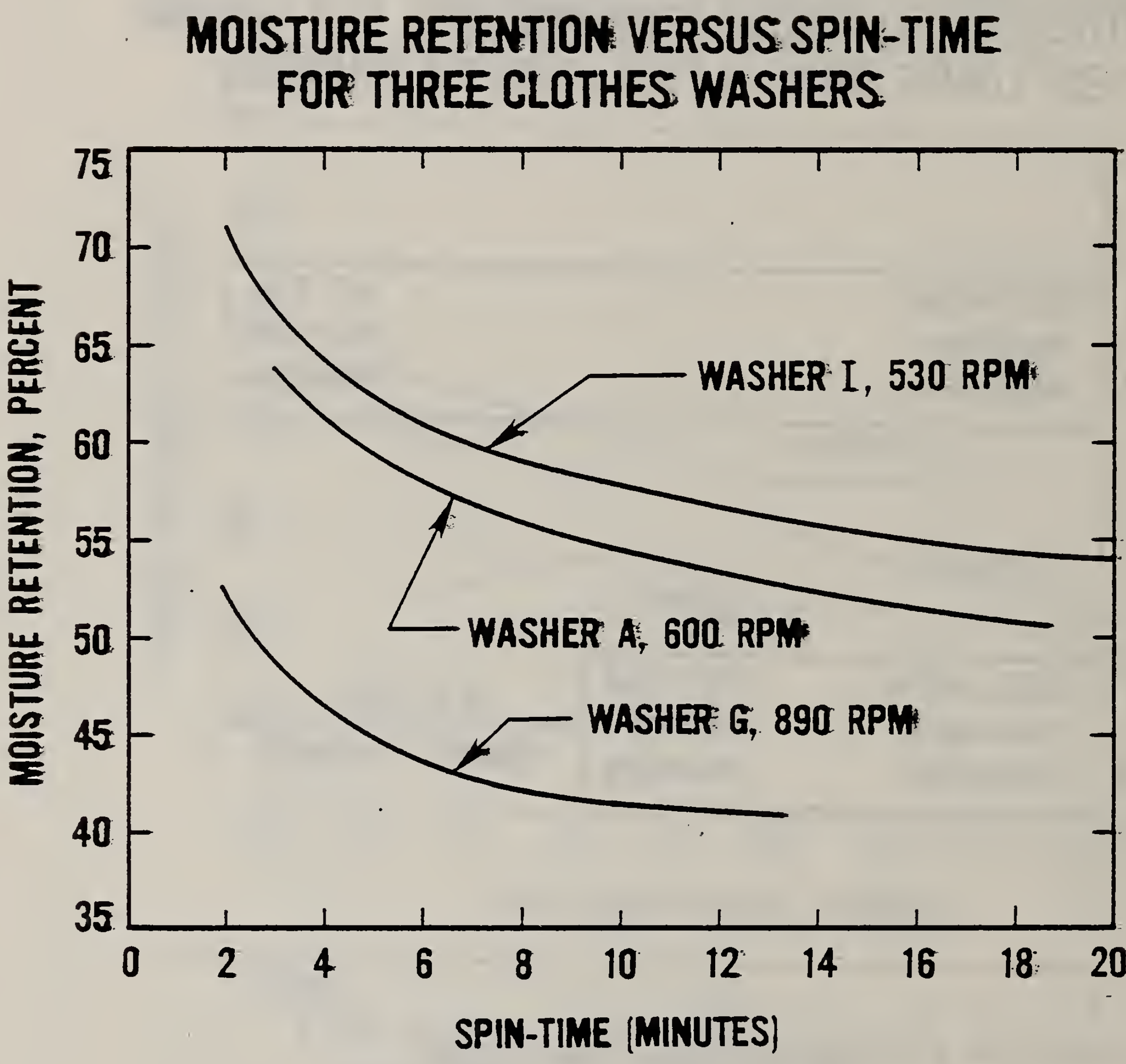



FIGURE 4




Note: Spin-cycle automatically terminates after
6 minutes for Washer I
5 minutes for washer A
3½ minutes for washer G

FIGURE 5

CLOTHES WASHER H

MOISTURE RETENTION VERSUS TUB SPIN SPEED

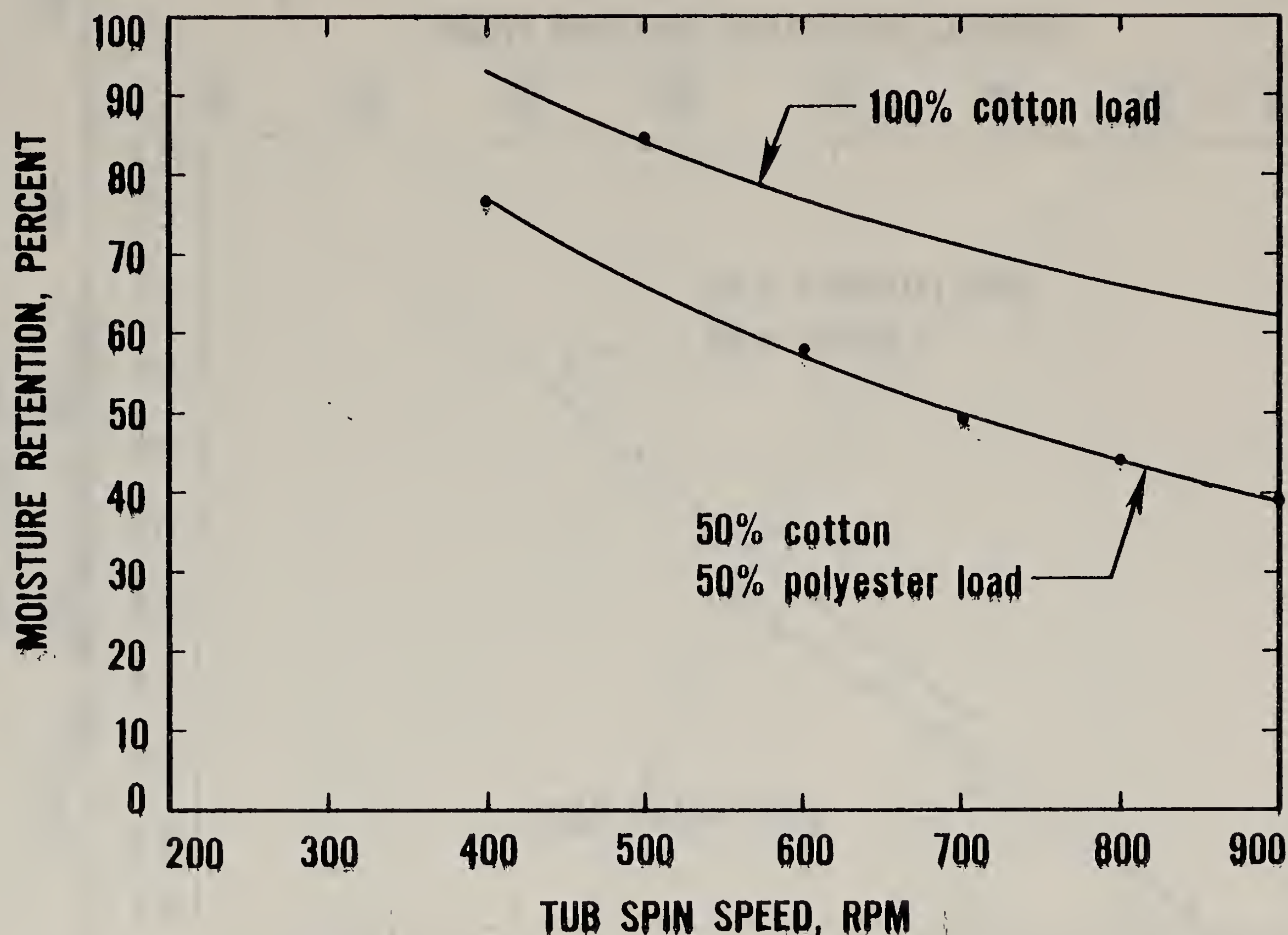



FIGURE 6

## CLOTHES DRYER

## ENERGY CONSUMPTION VERSUS INITIAL MOISTURE RETENTION

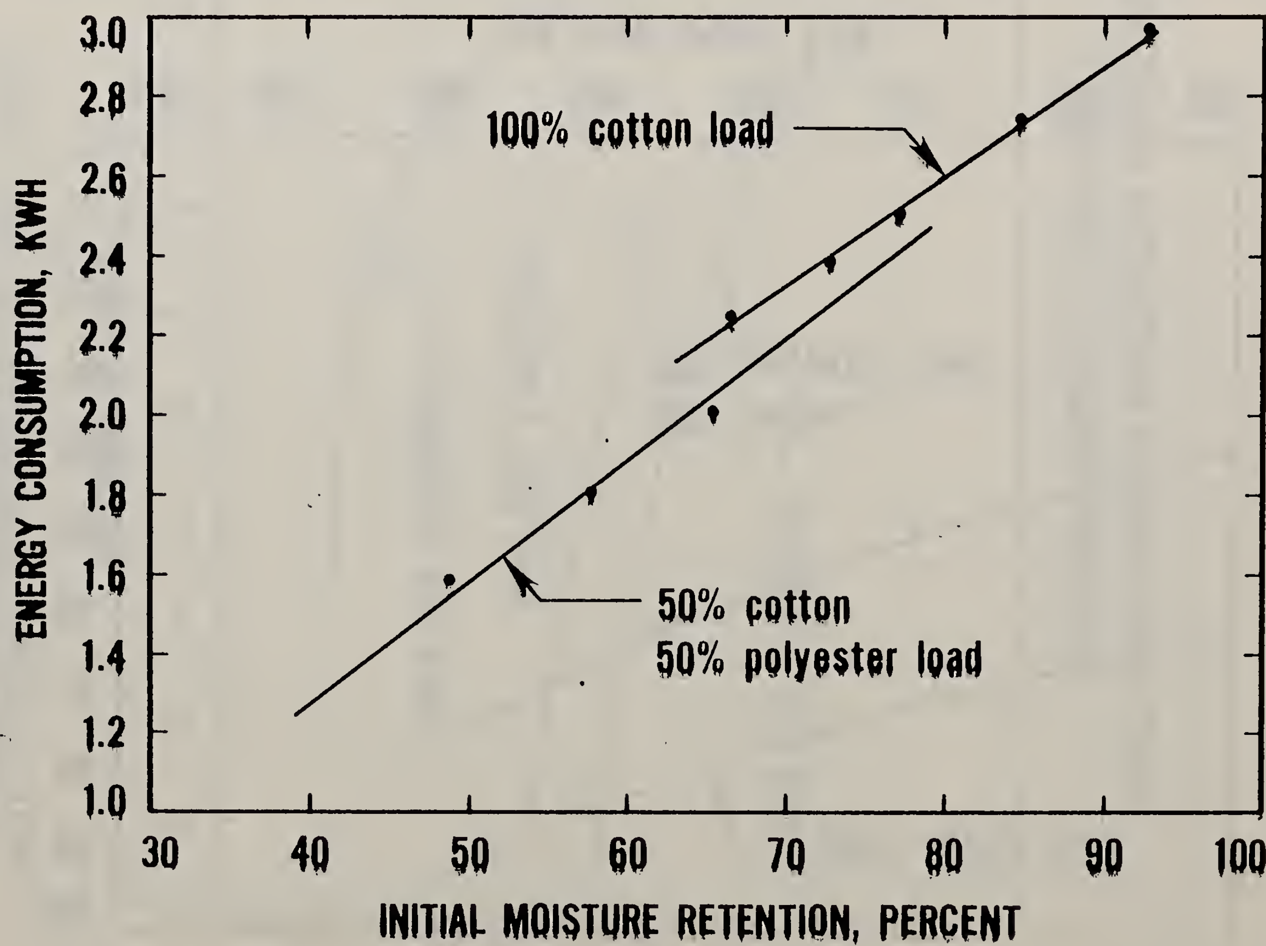



FIGURE 7

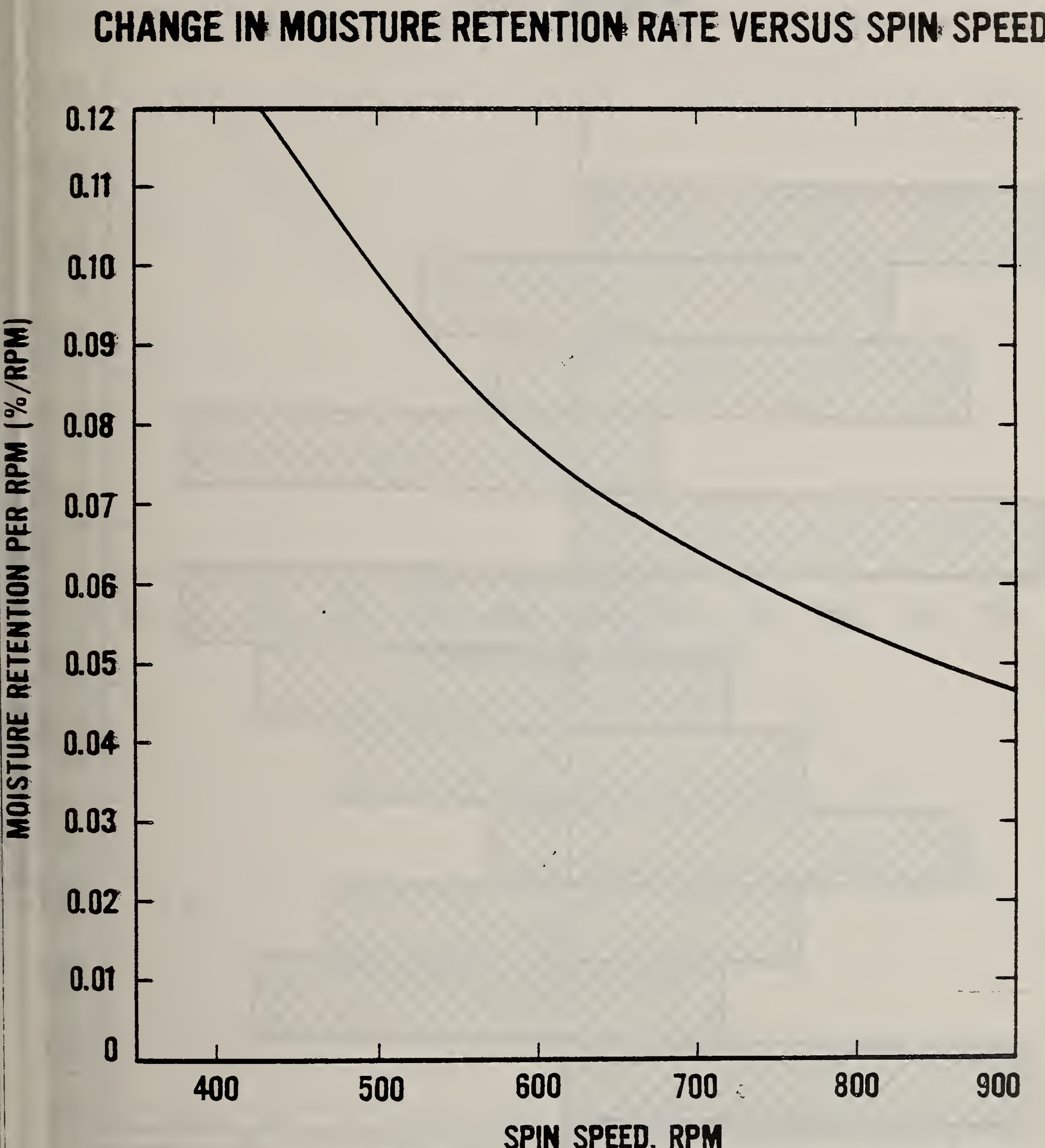
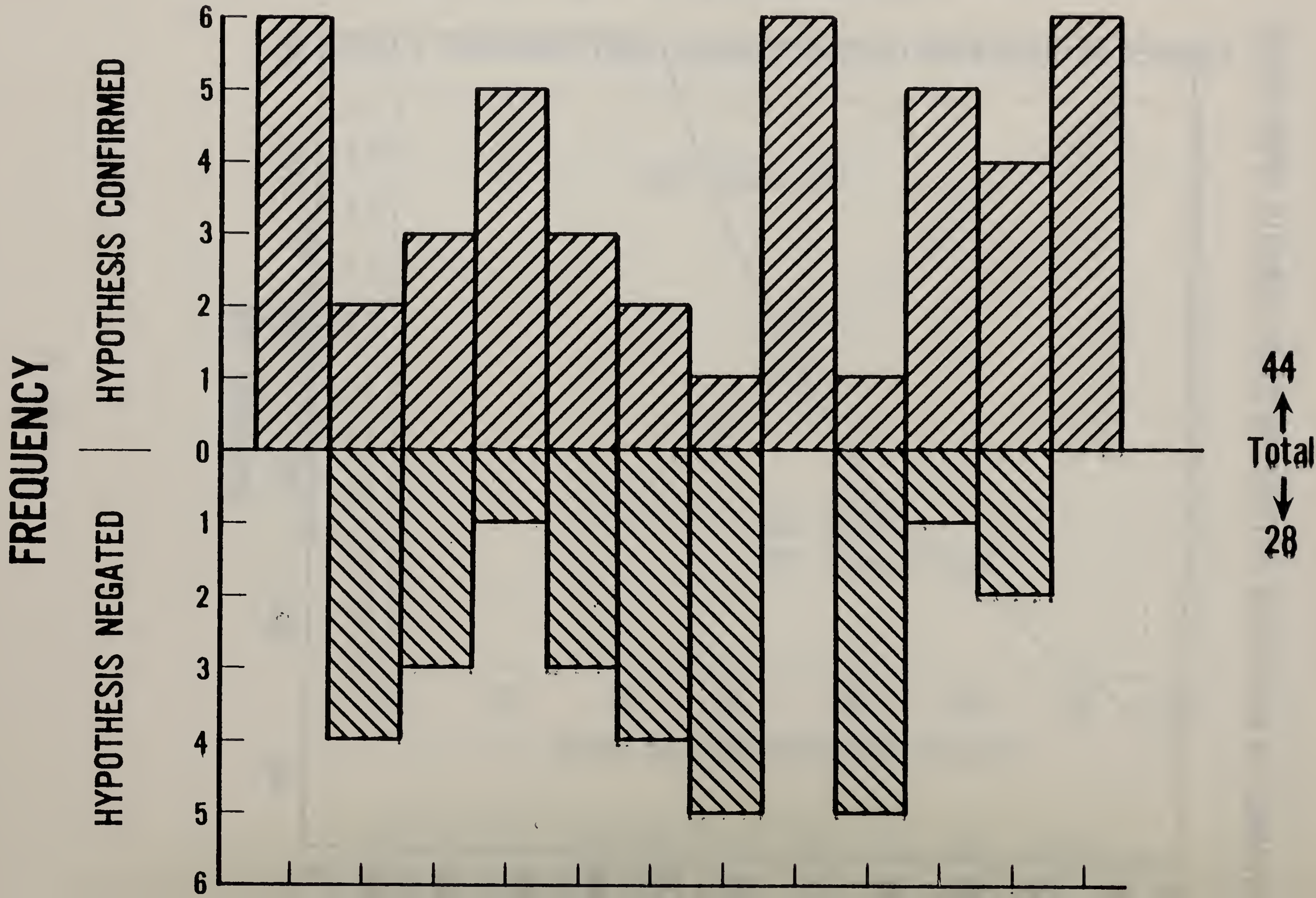

CHANGE IN MOISTURE RETENTION RATE VERSUS SPIN SPEED
MOISTURE RETENTION PER RPM (%/RPM)
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
400
500
600
700
800
900
SPIN SPEED, RPM

FIGURE 8

## EVALUATION OF WRINKLE HYPOTHESIS BY SIX JUDGES

HYPOTHESIS: More wrinkles when spun at 900 RPM than at 400 RPM



# CREDITS / DEBITS TO INFLUENCE THE ENERGY EFFICIENCY FACTORS OF CLOTHES WASHERS

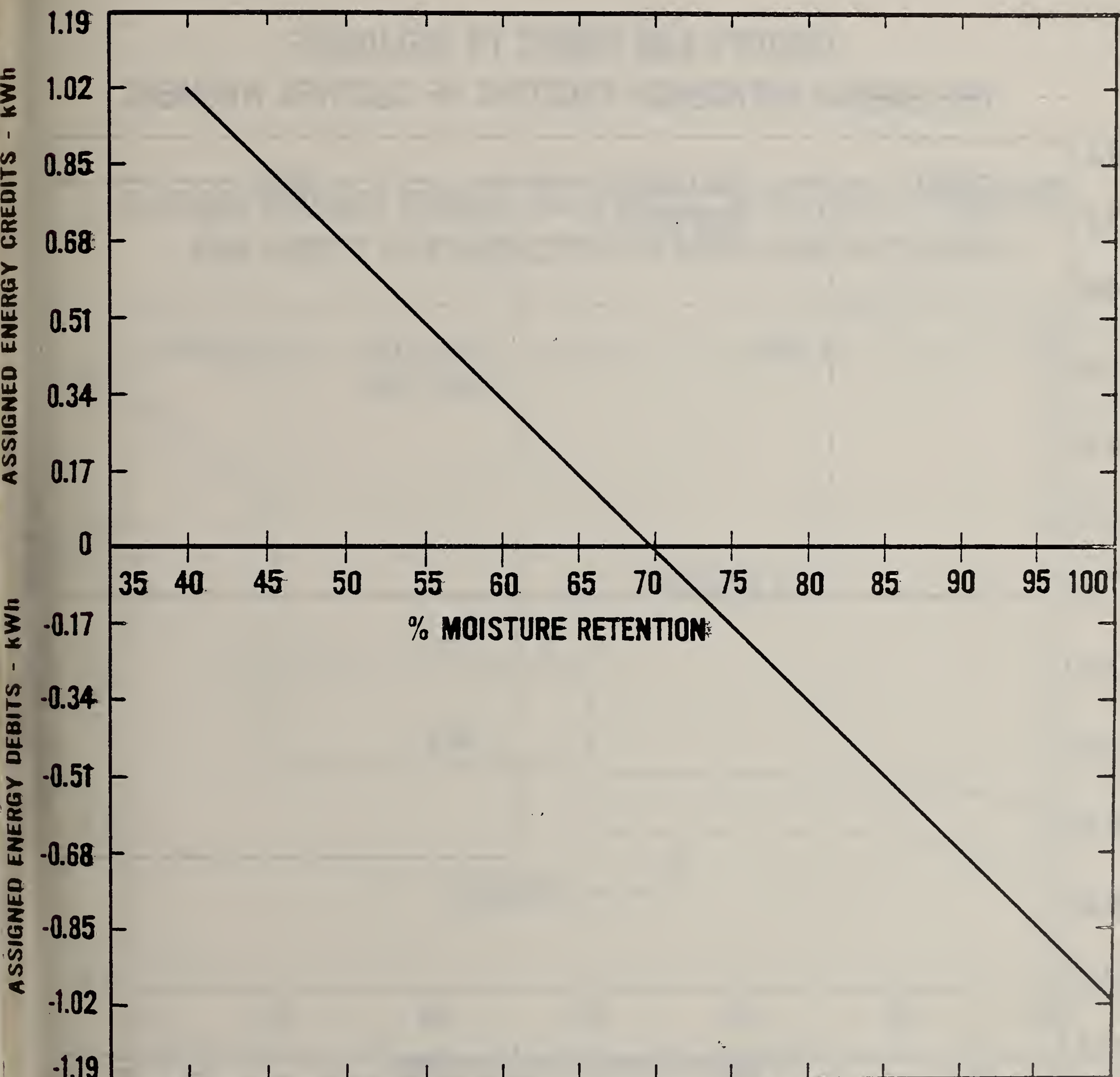



FIGURE 10

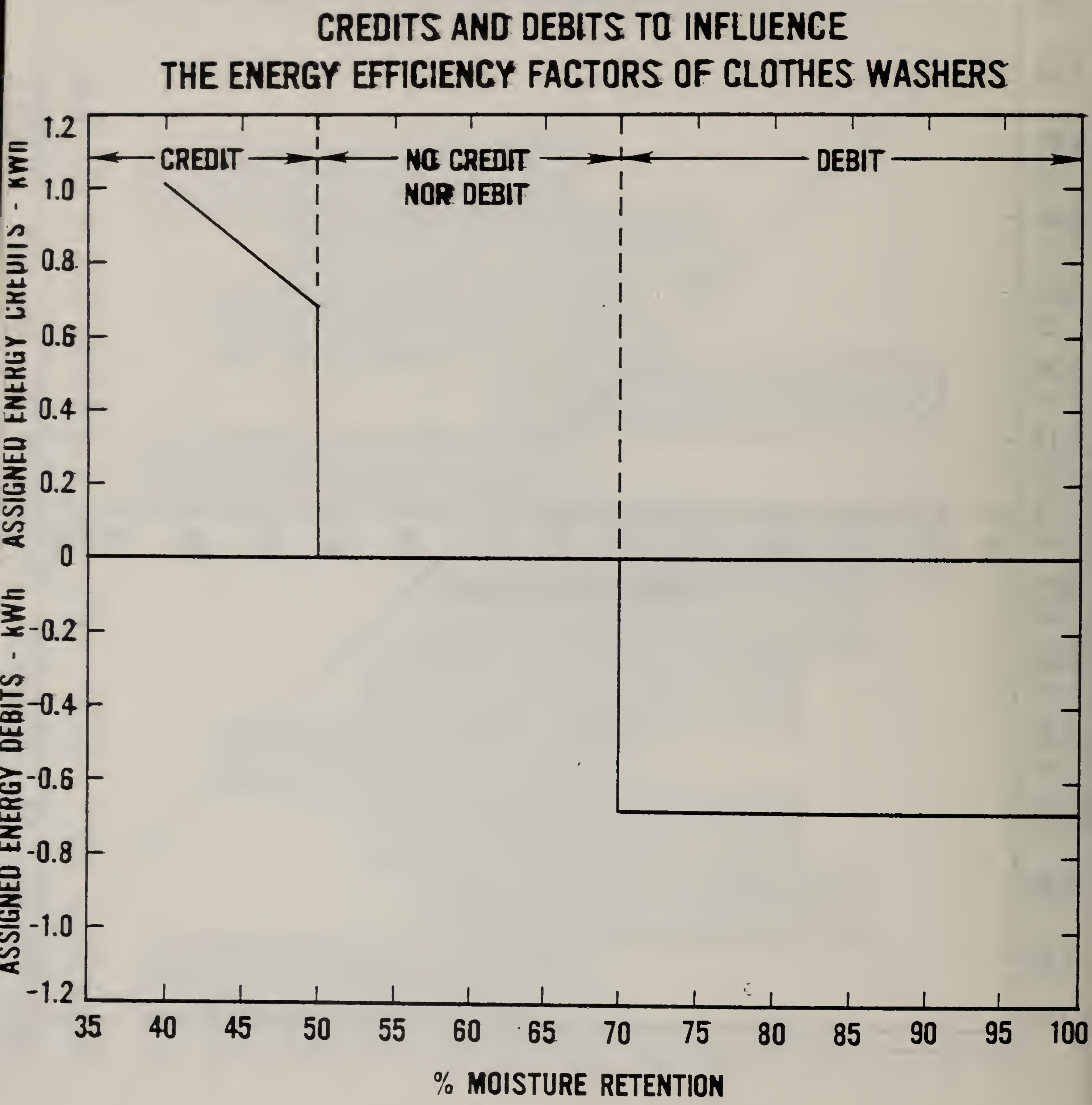

CREDITS AND DEBITS TO INFLUENCE
THE ENERGY EFFICIENCY FACTORS OF CLOTHES WASHERS
CREDIT
NO CREDIT
NOR DEBIT
DEBIT
ASSIGNED ENERGY DEBITS - kWh
ASSIGNED ENERGY CREDITS - kWh
1.2
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
35
40
45
50
55
60
65
70
75
80
85
90
95
100
% MOISTURE RETENTION

FIGURE 11

## CLOTHES WASHER ENERGY FACTOR, AS EFFECTED BY CREDITS AND DEBITS FOR REDUCTION IN MOISTURE RETENTION

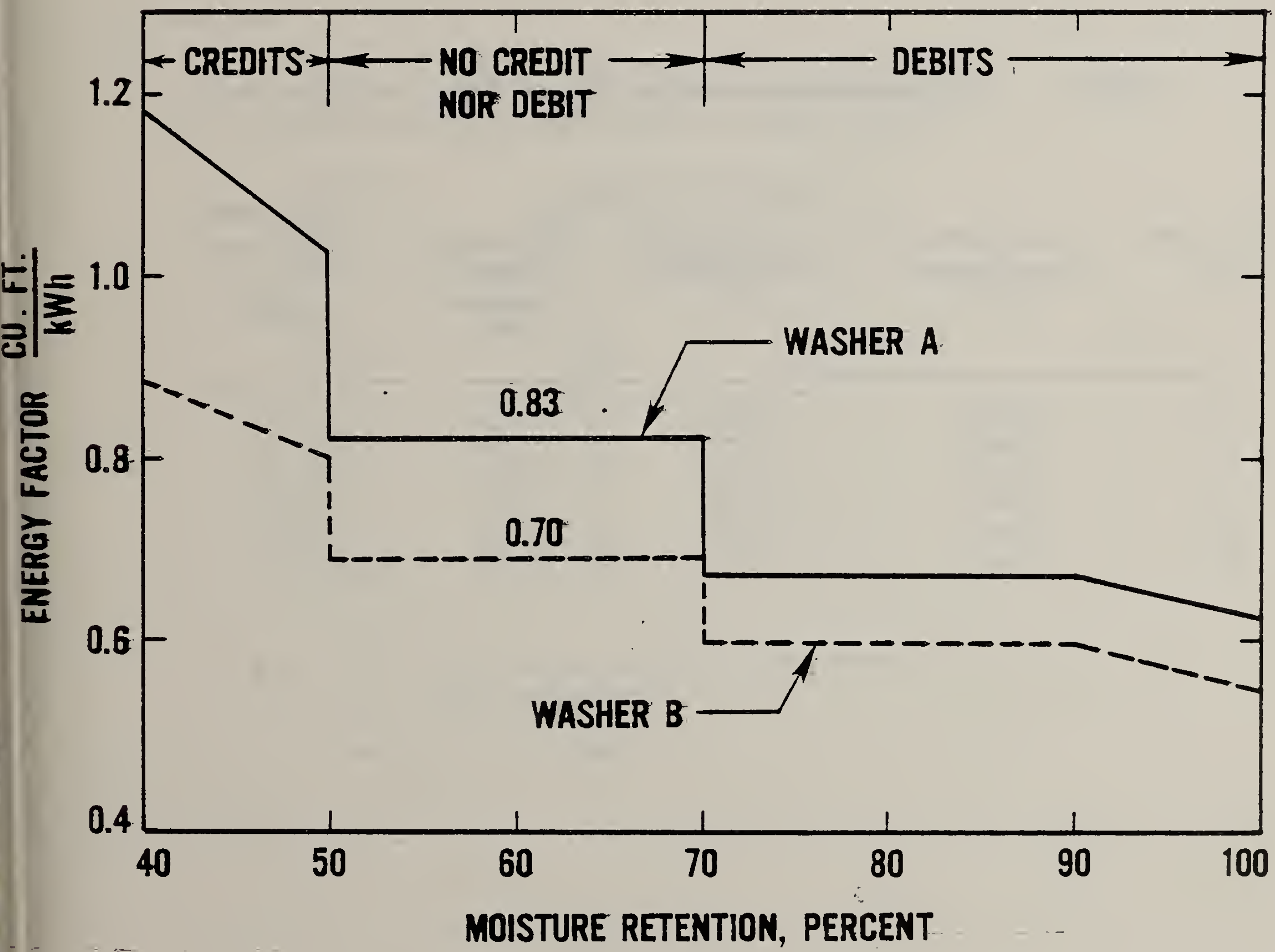



FIGURE 12

TABLE 1. Clothes Dryer Incremental Energy Efficiency and Amount of Water Removed During Each 5 Minute Interval

| Run Time (min) | Incremental Water Removed (lbs) | Cumulative Water Removed (lbs) | Incremental Energy Consumed (kWh) | Incremental Efficiency $\frac{\text{lbs } H_2O}{\text{kWh}}$ |
|---|---|---|---|---|
| 5 | 0.828 | 0.828 | 0.424 | 1.95 |
| 10 | 0.905 | 1.733 | 0.421 | 2.15 |
| 15 | 0.927 | 2.660 | 0.424 | 2.18 |
| 20 | 0.916 | 3.576 | 0.415 | 2.20 |
| 25 | 0.871 | 4.447 | 0.423 | 2.06 |
| 30 | 0.464 | 4.911 | 0.418 | 1.11 |

TABLE 2. Water Retention for Various Clothes Washers with 6 Pound Test Load

| Machine | Water Retention (%) | |
|---|---|---|
| | Warm Rinse | Cold Rinse |
| A | 54 | 58 |
| B | 53 | — |
| C | 50 | — |
| D | 57 | 61 |
| E | 66 | 67 |
| E* | 69 | 74 |
| F | 61 | 63 |
| G | 46 | — |
| H** | 62 | 68 |

*E — 8.2 pound test load 50% cotton, 50% polyester

**H — front loader

TABLE 3. Potential Dryer Energy Savings for Various Moisture Retentions in a Seven Pound Test Load

| % Moisture Retention | Pounds of Water Remaining in Clothes | Differential Water Removable Below 70% Level | Energy Saving* (kWh) |
|---|---|---|---|
| 100 | 7.00 | -2.10 | -1.01 |
| 95 | 6.65 | -1.75 | -0.85 |
| 90 | 6.30 | -1.40 | -0.68 |
| 85 | 5.95 | -1.05 | -0.50 |
| 80 | 5.60 | -0.70 | -0.34 |
| 75 | 5.25 | -0.35 | -0.17 |
| 70* | 4.90 | 0 | 0 |
| 65 | 4.55 | 0.35 | 0.17 |
| 60 | 4.20 | 0.70 | 0.34 |
| 55 | 3.85 | 1.05 | 0.50 |
| 50 | 3.50 | 1.40 | 0.68 |
| 45 | 3.15 | 1.75 | 0.85 |
| 40 | 2.80 | 2.10 | 1.01 |

*All differential moisture removal and energy savings are measured relative to the 70% moisture retention level and 2.07 lb/kWh.

TABLE 4. Potential Dollar Energy Savings for Various Holding Periods

| Periods Years | Annual Savings $ | Uniform Series Present Worth Factors | Present Value of Annual Energy Savings ($) Case 1 | Case 2 |
|---|---|---|---|---|
| 3 | 20 | 2.48 | 49.60 | 28.76 |
| 5 | 20 | 3.79 | 75.80 | 43.96 |
| 10 | 20 | 6.14 | 122.80 | 71.22 |
| 15 | 20 | 7.60 | 152.00 | 88.16 |

Note: For case 2 the present worth energy savings is about 58% the present worth of the annual energy saving.

TABLE 5. Machine Capacity and Energy Consumption Data

| | | Washer A | Washer B |
|---|---|---|---|
| 1. | Useful Capacity, $K_1$, $ft^3$ | 2.71 | 3.12 |
| 2. | Energy Consumption, $E_T$, kWh | 3.27 | 4.48 |
| 3. | Base Energy Factor, EF, $\frac{ft^3}{kWh}$ | 0.83 | 0.70 |

TABLE 6. Debit/Credit from Figure 11

| Water Retention, R (%) | Credit, C kWh | Debit, C kWh |
|---|---|---|
| 90 | 0 | -0.68 |
| 71 | 0 | 0.68 |
| 50-70 | 0 | 0 |
| 49.9 | 0.68 | 0 |
| 40 | 1.01 | 0 |

TABLE 7. Energy Factor and Energy Factor Change as a Function of Water Retention for Two Washers, Using Proposed Credit/Debit Plan. (See Figure 11.)

| Water Retention, R % | Energy Factor, EF, and Energy Factor Change, EF, % | | | |
|---|---|---|---|---|
| | WASHER A | | WASHER B | |
| | EF, $\frac{ft^3}{kWh}$ | EF, % | EF, $\frac{ft^3}{kWh}$ | EF, % |
| 40 | 1.19 | 44 | 0.90 | 28 |
| 49.9 | 1.05 | 27 | 0.82 | 17 |
| 50–70 Base | 0.83 | 0 | 0.70 | 0 |
| 80 | 0.69 | -17 | 0.60 | -14 |

# APPENDIX A

Test Procedures for Clothes Washers.
Federal Register, Vol. 42, No. 188,
Wednesday, September 28, 1977.

Chapter II, Federal Energy
Administration Part 430--Energy
Conservation Program for Appliances.

Test Procedure Changes

Modify section 2.8.1 to read as follows:

2.8.1 Top-loader clothes washers. The top loader clothes washer shall be tested with a clothes load as described in 2.7.1.

3.2.1.2 Moisture retention. Remove and weigh the wet clothes load at the completion of the normal cycle. Determine percent of moisture retention as follows:

$$R,\ \text{moisture retention},\ = \frac{W_w - W_b}{W_b} \times 100,\ \%$$

$W_w$ = weight of wet load upon completion of spin cycle as determined according to 2.5.1.1, lbs.

$W_b$ = bone dry weight of the test load as determined according to 2.7.1., lbs.

4.7 Adjusted total per cycle energy consumption when electrically heated water is used. Calculate the adjusted total per cycle energy consumption $E_{ATE}$ using $E_{TE}$ for electrically heated water, as defined in 4.6, expressed in kilowatt-hours per cycle.

$$E_{ATE} = E_{TE} - C$$

where:

$$C = 0.68 + (\frac{50 - R}{30}) \text{ for } R < 50$$

$$C = 0 \text{ for } 50 < R \leq 70$$

$$C = -0.68 \text{ for } R > 70$$

Change section 430.22, column 3, first paragraph (2) to read as follows:

(2) The energy factor for automatic and semi-automatic clothes washers shall be the quotient of the cubic foot capacity of the clothes container as determined in 3.1 of Appenxix J to this subpart divided by the clothes washers adjusted total energy consumption per cycle, as determined in 4.7 and the result being rounded off to the nearest 0.01 cubic foot per kilowatt-hour.

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4. TITLE AND SUBTITLE

An Evaluation of Assigning Credit/Debit to the Energy Factor of Clothes Washers Based on Water Extraction Performance

5. AUTHOR(S)

C. Denver Lovett

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

To reduce the moisture retention of a clothes load from 65% to 40%, a clothes dryer uses about 200 times more energy than a clothes washer. Therefore, improving the clothes washer's water extraction performance can significantly reduce energy-use of a dryer. For example, a clothes dryer uses about 40% less energy, when the clothes washer extracts 38% more water from the clothes load. Based on clothes washer extraction performance, NBS has developed, for the Department of Energy (DOE), a procedure for assigning credit/debit to the energy factor of a clothes washer. The purpose of this procedure is to provide an incentative for clothes washer manufacturers to improve the water extraction performance of washers. Using this procedure, the energy factors for two clothes washers improves by 44% and 28% respectively. This energy factor improvement corresponds to improved water extraction which reduces the moisture retention of the clothes load from 65% to 40%. One case study shows that dryer energy savings, resulting from reduced moisture content, justifies a $50 incremental cost for improved water extraction performance for clothes washers.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Clothes washers; clothes dryer; extraction performance; energy savings; credits/debits; wrinkle performance

13. AVAILABILITY

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