APPENDIX C.
DEVELOPMENT OF A STANDARDIZED ENERGY TEST CLOTH

Report: **Development of a Standardized Energy Test Cloth Report for Masuring Remaining Moisture Content in a Residential Clothes Washer**

Appendix A: Test Data

Appendix B: Summary of Extractor Based Test Data

Appendix C: Procedure for Using RMC Correction Factors in Clothes Washer Efficiency Tests

Development of a Standardized Energy Test Cloth for Measuring Remaining Moisture Content in a Residential Clothes Washer

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Buildings, Research and Standards

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1 Introduction

This report summarizes the result to-date of the investigation, “remaining moisture content” (RMC) testing, fabric characterization, and correction procedure undertaken to define a standardized energy test cloth.

1.1 Background

Under the National Appliance Energy Conservation Act (NAECA), energy efficiency standards and energy test procedures have been established for a wide range of consumer appliances, including clothes washers and clothes dryers. The energy test procedures for these two laundry appliances originally were established in 1977 (clothes washers) and 1981 (clothes dryers) (10 Code of Federal Regulations (CFR) 430, Subpart B, Appendices J and D, respectively). Both specify a 50/50 cotton/polyester blend “energy test cloth” that is used as a simulated wash load for testing clothes washers and for testing clothes dryers.

The energy test procedure that is currently in effect for clothes washers measures the electric energy input to the washer and the energy content of the hot water consumed by the clothes washer. A clothes washer energy factor is defined in terms of the basket volume and the total electric and hot water energy use. The current efficiency standard is set in terms of this measurement of the energy factor. The effectiveness of the final spin cycle in removing moisture from the wash load (and thereby reducing the energy consumption of the clothes dryer) is not measured or considered.

For a number of years, a rulemaking has been ongoing to revise both the test procedure and the efficiency standard for clothes washers to take moisture removal effectiveness into account. A revised test procedure was adopted in a Final Rule dated August 27, 1997 (10 CFR 430 Subpart B, Appendix J and J1). Revisions to Appendix J are currently in effect, however, Appendix J1 will not go into effect until proposed efficiency standards into effect. A modified energy factor (MEF) is defined in Appendix J1, based on the electric energy input, the hot water energy, and the dryer energy. Dryer energy is based on the remaining moisture content of a test wash load. The process to establish the new efficiency standard in terms of the MEF is ongoing.

In the Appendix J1 test procedure, “remaining moisture content” (RMC) in a test load of the aforementioned energy test cloths is the measure of water removal effectiveness. Over the approximately 20 year period that the original clothes washer and clothes dryer test procedures have been used, no variations or inconsistency of washer or dryer test results had been attributed to variations in the test cloths. A significant inconsistency in RMC test results under the new Appendix J1 procedure was noted by Alliance Laundry Systems LLC and was brought to the Department of Energy’s (DOE’s or Department’s) attention in a letter dated June 7, 1999. In the tests referred to in this letter, which were run at Intertek Testing Services (ITS), the RMC values that were obtained in one machine with two different lots of energy test cloths differed by over 11 percentage points (67.9 percent versus 56.0 percent). When these two lots of energy test cloth were run through a second machine, a similar difference in RMC occurred.

The effect of RMC on MEF can be substantial, particularly for washers which are more efficient with respect to electrical consumption and use of hot water. The following scenario illustrates: For a high efficiency horizontal axis washer, an 18% increase in RMC (54.5%-64.5%) will result in a 13% decrease in MEF (1.52-1.33). For a lower efficiency washer, a 17% increase in RMC (57.7%-67.7%) will result in only a 6% decrease in MEF (.82-.77).

1.2 Energy Test Cloth

A wide variety of articles and fabrics are machine washed by consumers, including:

- Cotton knit goods, denim, towels
- Cotton/polyester blends in shirts, sheets, tablecloths
- Various synthetics in a wide variety of articles

It is clear that all of the above could not be evaluated in the revised procedures that include moisture content. As mentioned above, to simplify RMC testing, the standardized cloth used successfully in previous energy tests was specified. A number of qualified vendors have been providing these test cloths to manufacturers and other test labs on an ongoing basis for many years. The specifications stated in the energy test procedure are:

- A 50/50 cotton/polyester to represent a rough average of the typical mix of cotton, cotton/polyester blend, and synthetics. The cloth has a momie or granite weave and a pure bleached finish.
- The thread count shall be 61 x 54 (warp x fill) per inch
- The fabric weight shall be 5.75 oz. per sq. yd. (195.0 gm. per sq. m.)

Aside from the historical success with respect to previous procedures, there is no justification for these specifications.

The energy cloths are 24 in. by 36 in. (61.0 cm by 91.4 cm.) and are hemmed to 22 in. by 34 in. (55.9 cm. by 86.4 cm.) before washing. Energy stuffer cloths (smaller cloths used to even-out load size) are 12 in. by 12 in. (30.5 cm. by 30.5 cm.) and are hemmed to 10 in. by 10 in. (25.4 cm. by 25.4 cm.) before washing. Both energy test cloths and stuffers cloths should shrink no more than 4% on the length and width after five washes.

Cloth manufacturers typically produce yarn from fiber and subsequently weave and finish the cloth material. Two suppliers, Textile Innovators Corp. (TI) and Cotton Goods Mfg. Co. Inc. (CG) purchase cloth material, prepare the energy cloth by sewing and hemming and provide it to washer manufacturers and testing laboratories. They have supplied energy test cloth that, over the years, has varied somewhat from the above standards.

There are additional cloth specifications that influence the moisture content. The yarn size is a parameter that is related to the yarn diameter. This, together with thread count, blend (fiber content) and weight define the porosity of the cloth. Finish, referred to by descriptors such as "pure bleached" must be clearly identified. Any finish, particularly a water repellant finish (frequently specified for cloth used in other applications), must be avoided.

1.3 Moisture Absorption and Retention in an Energy Test Cloth

The amount of water absorbed and retained in an energy test cloth can be attributed to several factors:

- Surface wetting, which is a function of relative humidity
- Water retained between the warp and fill
- Water retained between the fibers
- Water retained in the lumen, or center of the cotton fiber
- Water ionically bonded in the cotton fiber

Polyester is hydrophobic, and essentially has no attraction for water. All of the factors listed, except ionic bonding, are effected by the mechanical removal process. Water that is ionically bonded can only be removed chemically or by heating. Since RMC tests are only mechanical, there is a limit to the moisture that is removed.

1.4 Summary and Approach

It is apparent that a standardized test cloth is required in order to provide consistent RMC test results. The work summarized herein is aimed at:

- Identifying the variables in the construction of 50/50 polyester cloth and its constituent fiber and yarn that affect the moisture absorption and moisture retention characteristics of the cloth
- Developing a process for obtaining and validating standard test cloth
- Generating data that indicates the sensitivity of RMC values to different operating variables and reporting them in a publicly available document

This report summarizes our efforts to date in addressing these issues. Our approach includes the following tasks:

- In-house laboratory testing using an extractor to obtain effects of operating variables on RMC for cloth from different suppliers and different lots from the same supplier
- Analyze cloth samples using external testing laboratories
- Use information from above to:
  - Document the effect of variables on RMC
  - Propose a procedure to obtain and verify consistent test cloth
  - Propose a revised definition of test cloth for regulations

Details on progress are found in the following report.

2. Extractor based RMC Testing

To understand the effects of operating variables and cloth specifications, it is necessary to conduct laboratory tests to determine RMC. To insure that test results would not be influenced or biased by any manufacturer's product (clothes washer), we used an extractor to remove moisture content. An extractor is a centrifuge – basically a rotating basket that has a controllable speed to produce a variety of centrifugal forces. The speed was varied to impose different centripetal accelerations on the test load. These accelerations are reported in terms of gravitational acceleration (g). We also chose to soak the cloth in a tub at controlled temperature rather than use the agitated soak cycle provided by a typical washer. Otherwise, our RMC tests closely resembled those specified in the energy test procedure.

2.1 Purpose of Test Program

The extractor-based RMC tests have two basic purposes:

1. To evaluate the differences in spin g vs. RMC for available test cloths from different suppliers and different lots from the same supplier. Ultimately, relate these variations (or lack of variation) to differences in cloth specification that can be ascertained by laboratory tests (as explained in Section 4.). Determine whether differences in RMC vs. g in the extractor test correlate with differences in RMC in a particular clothes washer as obtained by Intertek Testing Services (ITS).

2. To evaluate the impact of several basic variables on RMC results and the consistency/ repeatability of RMC results when identical cloth is run under identical conditions using an extractor. Variables to be studied are:

- Effect of spin time on RMC
- Effect of soak water temperature prior to spinning on RMC
- Effect of length of soak time prior to spinning on RMC
- Effect of load weight/basket volume on RMC
- Effect of test fabric life (cumulative wet – dry cycles) on RMC and shrinkage

Quantitative data addressing each of these variables and repeatability under identical test conditions will be indicative of which variables need to be closely controlled in future testing and/or where bounds need to be established to ensure consistent results.

2.2 Laboratory and Procedure

This section discusses our extractor-based RMC testing laboratory and procedures. Also included is a description of shakedown tests used to verify testing procedures and establish initial test parameters.

2.2.1 Laboratory Equipment

Table 2.1 details major equipment used in our extractor-based RMC studies. As noted, our preferred extractor had a long delivery time, so a smaller unit with immediate availability was initially utilized.

Table 2.1 Equipment used in Extractor Based RMC Tests

ITEM	SPECIFICATION	SUPPLIER	PURPOSE
Washing Machines (2)	Typical , 3 speed, 14 cycle, 2.9 ft^3 (Maytag Model # LAT9706AAE)	Local supplier	For initially preparing cloth for extractor. Two machines of identical construction.
Clothes Dryer	90000 BTU/hr, gas fired	Local Supplier	A commercial size dryer to insure "bone dry" cloth.
Extractor	35 lb. capacity, 20 in. diameter, 11.5 in. depth, with variable speed drive	Bock Engineered Products	This extractor is sized to satisfy all test requirements.
Extractor	20 lb. capacity, 17 in. diameter, 10.5 in. depth	Smart-Sox, Inc.	This is a smaller extractor, purchased because of its immediate availability. It was used for initial testing.
Power Inverter	MagneTek, 3 hp, 3 phase, 220 volts	Blanchard Electric, Inc.	Required to operate the smaller extractor at variable speed.
Water Heater	40 gallon capacity	In-house	Required for 135F wash water.
Scales	26 lb. +/- .00022 lb.480 lb. +/- .01 lb.	In-house	Required for weighing cloth.

2.2.2 Procedure

Our procedure closely resembles those in the existing energy test procedure. We have a pretest procedure to both precondition the cloth and the clothes washers. Test loads are preconditioned once unless otherwise noted. A series of extractor-based RMC tests is then performed on the test load at specified conditions.

Pretest Procedure

1. Test lots of cloth (energy test cloth and stuffer(s)) from different sources are divided into test loads. Each cloth is marked with the test load number in indelible ink.

2. Clothes washers are preconditioned per Appendix J1: Section 2.9 (J1:2.9)

3. Inlet hot and cold water temperatures are recorded. Hot water is maintained at 135F +/- 5F.

4. Each load is prewashed:

    - 2 complete cycles: warm prewash/ warm wash w/AHAM detergent and 2 warm rinses and drying

    - 3 complete cycles: warm normal wash and warm rinse and drying

5. Each load is made bone-dry per J1:1.3.

RMC Test Procedure

Each extractor-based RMC test is conducted using the following procedure:

1. Record the bone-dry weight.

2. Soak in a cylindrical vessel 16" in diameter containing approximately 10 gallons of water. Soak temperature is either cold (60F ± 5F) or warm (100F ±5F) and time is variable.

3. Remove the load and place carefully in the extractor without wringing the cloth.

4. Run the extractor at the prescribed g and time.

5. Remove the load and record the weight.

6. Compute %RMC as follows: % RMC= [(Weight after extraction – bone-dry weight) / bone-dry weight] *100

7. Bone-dry the load and repeat steps 1-7 as prescribed in test plan.

2.2.3 Shakedown Tests

We conducted shakedown tests to verify the above procedures and to establish parameters for our initial tests. The load size was 4.5 lbs., which represented a mid-sized load for a washer with the dimensions of our initial extractor. Other parameters included soak time and spin time. A soak time of 20 minutes and spin time of 10 minutes was selected for the initial tests.

2.3 Test Cloth Sources

Our test cloth is obtained primarily from Textile Innovators Corporation. (TI) and Cotton Goods Manufacturing Company, Inc. (CG). To date, five lots (orders) have been received from TI and two lots from CG. In addition, cloth was distributed as follows:

- A portion was sent to Intertek Testing Services Inc. (ITS) for washer-based RMC tests.(see Section 3)

- Samples from each lot were sent to independent laboratories for determination of cloth characteristics (see Section 4).

- A small portion of TI lot 3, and a larger portion of TI lot 5 was sent to each washer manufacturer for in-house laboratory testing.

In addition, we performed extractor-based RMC tests on cloth received from Alliance Laundry Systems LLC. It was suspected that a fluorochemical finish was present on this material. Consequently, as detailed below, we tested this cloth both as received and also after a finish removal process was conducted.

Table 2.2 summarizes the status of test lots.

Table 2.2 Summary of Test Lot Status

Lot and Load Identification	Test Loads per Lot	RMC Tests	ITS Testing	Characteristics Tests at Labs	Manufacturers Tests
TI Lot 1, (ADL 1)	2	C	C	C	N
TI Lot 2, (ADL 2)	1	C	C	C	N
TI Lot 3, (ADL 3)	1	C	C	C	C
TI Lot 4, (ADL 4)	1	C	N	C	N
TI Lot 5, (ADL 5)	1	C	P	C	C
CG Lot 1	2	C	C	C	N
CG Lot 2	1	C	N	N	N
Alliance Initial	1	C	C	C	N
Alliance Treated	1	C	C	N	N

KEY TO TABLE: C = Complete, P = planned, N = not planned

2.4 Test Matrix

A test program was designed to carry out the objectives outlined in Section 2.1. As indicated in Table 2.3, the program was divided into a series of tests. The first two series of tests were intended to evaluate the differences in RMC vs. spin g with respect to test lots. We also tested the Alliance load with and without a fluorochemical finish. In the remaining tests, we evaluated the effect of variables (in addition to g) on RMC results. These variables included:

- Spin time
- Load size
- Soak water temperature prior to spin
- Soak time prior to spin
- Cloth life (cumulative wash cycles, shrinkage)

The Appendices include a list of all test results included in this report.

Table 2.3 Extractor Based RMC Test Program

Cloth I.D.	Spin g	Spin Time, min	Soak Temp.	Soak Time, min.	Load size, lb.	Purpose of Test
TI1, CG1, CG2	100 300 500	10	Warm	20	4.7	Evaluate RMC vs. g for Lots from different Suppliers
TI1, TI2, TI3	50 100 200 300 500 800	15	Warm	20	8.4	Evaluate RMC vs. g for Lots from the same Supplier
Alliance Initial and Treated	100 300 500	10	Warm	20	4.7	Effect of Finish Removal on RMC
TI1, TI2	100, 300	2 4 6 10 15 20 25	Warm	20	8.4	Effect of Spin time on RMC
TI2	100, 300	15	“Wash”*	“Wash”*	3 4.7 8.4	Effect of Load Size on RMC
TI2, TI3	50 100 200 300 500 800	15	Warm, Cold	20	8.4	Effect of Soak Temperature on RMC
TI1	115	10	Warm, Cold	10 20 60 120 16 hr.	4.7	Effect of Soak Time on RMC
TI2, TI4, TI5	100	15	“Wash”*	“Wash”*	8.4	Effect of Cloth Life on RMC (50 “washes” with RMC determined after every fifth “wash”)
TI3, TI4, TI5	50 200 350	4 15	Warm, Cold	20	8.4	Obtain data for generation of correction curves

* A “wash” consists of an agitation, spinning lightly and a second agitation with no detergent and warm water in a washer

2.5 Test Results: RMC vs. g for Different Test Lots

This section discusses the differences in RMC vs. spin g with respect to different cloth suppliers. We report results for cloth from the two suppliers, TI and CG, as well as evaluation of the Alliance cloth that was suspected to have a fluorochemical finish. Below, we first compare the TI and CG lots, discuss differences between lots, and finally address the Alliance lot.

2.5.1 Comparison of Cloth Lots

Comparison of TI and CG lots is shown on Figure 2.1. These data (taken in the smaller, Smart-Sox extractor) are with a spin time of 10 min., warm soak temperature, 20-min. soak time and a 4.7 lb. load. As expected, there is a clear decrease of moisture content with higher g. Typical vertical axis washing machines produce spin g's in the range of 120 g's. The asymptotic value at high g represents the maximum amount of moisture that can be mechanically removed from cloth. (see Section 1.3) The CG cloth clearly has higher RMC with decreasing differences at higher g values. At 100 g's, the lot-to-lot variation of the TI loads was 2% RMC, while the CG to TI difference is 11%. The two cloths had a different "feel", the CG cloth feeling much smoother than the TI cloth. In Section 4, we present laboratory results indicating that TI and CG cloth had some differences in characteristics. However, there is no clear connection between these differences and RMC. Further investigation indicated that the CG cloth and TI cloth came from different manufacturers. The TI cloth was purchased from Riegel Mills, which produces finished product (cloth) from raw material. The mill that produced the CG cloth is unknown. CG obtained their cloth from Artex, a distributor that purchases cloth from mills and resells it to users. Our conclusion is that, in this case, differences in RMC could not be easily explained by examining cloth specifications. Water absorption and retention may change with manufacturers who are supplying material with similar characteristics. Identifying the mill of origin may help determine these differences. This may suggest that a single manufacturer of energy cloth may be desirable.

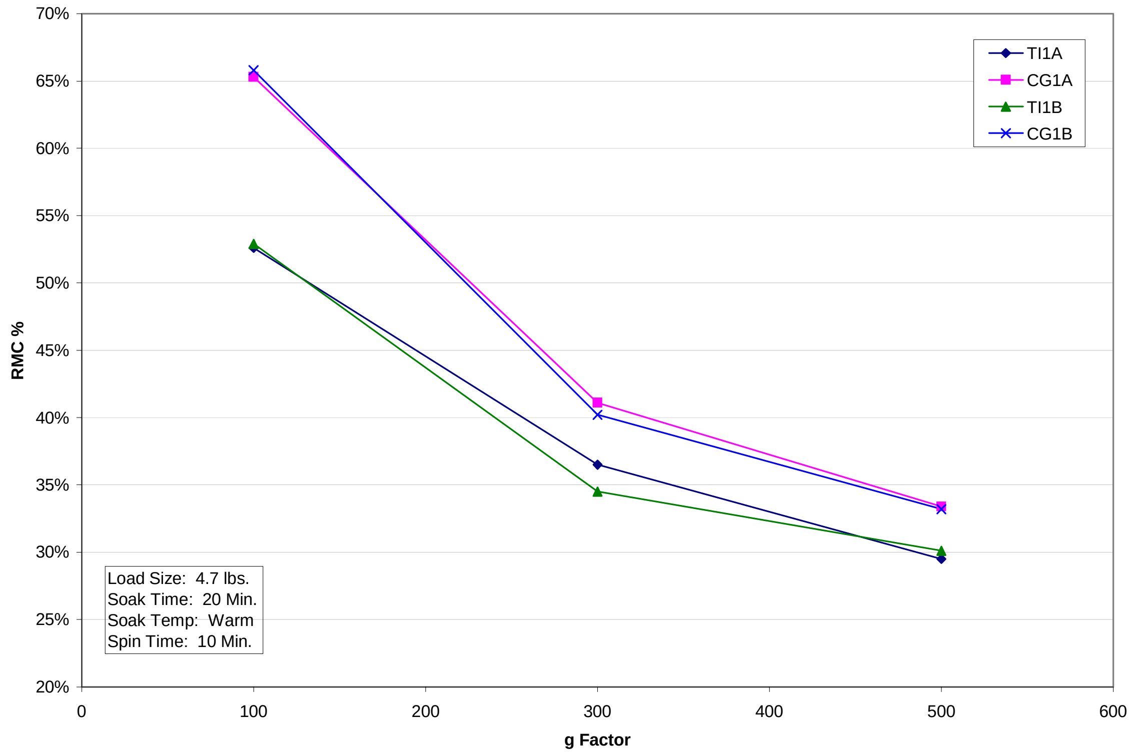

Figure 2.1 RMC vs. g for TI and CG Cloth

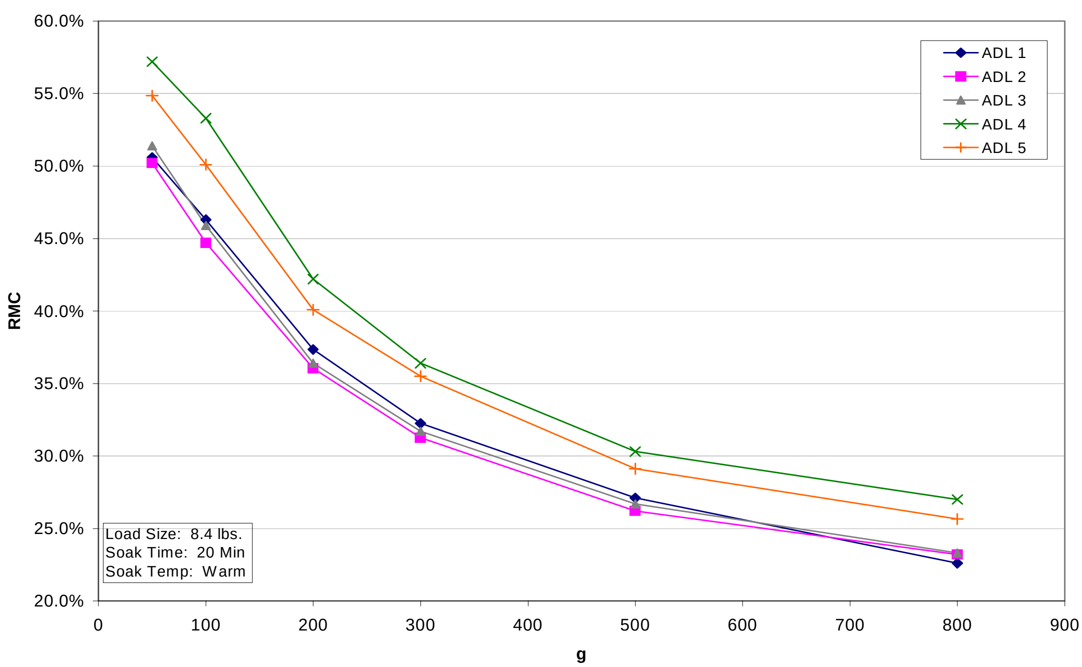

Figure 2.2 RMC vs. g for all TI loads

Also of interest is the difference between lots supplied by the same manufacturer. Figure 2.2 shows data for five TI lots (ADL1-5). These data (taken in the Bock extractor) are all with a spin time of 15 minutes, warm soak temperature, 20-minute soak time and an 8.4 lb. load. For the first three lots tested ADL1, ADL2, ADL3, there is a maximum data spread of about 2 percent. Subsequent lots 4 and 5 varied significantly as shown.

2.5.2 Evaluation of Alliance Cloth

As part of our test program, we were asked to perform RMC tests on cloth supplied by Alliance Laundry Systems LLC. They had purchased this cloth from TI and obtained inconsistent results in their in-house tests, i.e., RMC was lower than expected. It was suspected that a fluorochemical finish that would repel moisture was present on this material. This was verified by laboratory tests performed by Minnesota Mining and Manufacturing Company (3M). We tested this cloth as received and also after a finish removal process.

A procedure recommended by the United States Department of Agriculture (USDA) Laboratory (Southern Regional Research Center) for removal of finish was performed. The procedure called for a mixture of Triton X-100, Trisodium pyrophosphate, and Tide^{O} to be mixed at a concentration of 1 gram/Liter, each. The test load was then soaked for one hour at 200 to 212 °F. The results are shown in Figure 2.3. These data are with a spin time of 10 minutes, warm soak temperature, 20 minute soak time, and a 4.7 lb. load (taken in the smaller, Smart-Sox extractor). The results show that the RMC values were higher in the treated cloth, but not to the extent expected with finish removal. The conclusion is that the fluorochemical finish was not removed by the process or that the fluorochemical finish was not responsible for the differences in RMC. Since the removal process is used routinely by USDA, we suspect the latter conclusion is correct.

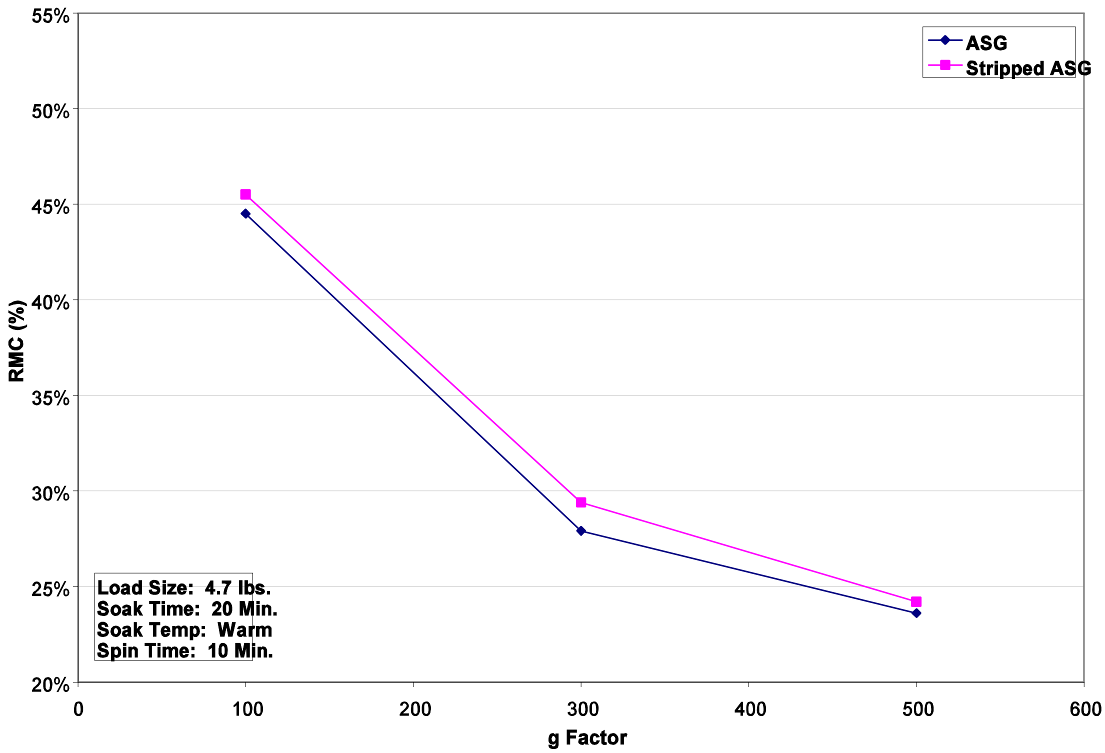

Figure 2.3 RMC for Alliance Cloth before (ASG) and after Treatment for Removal of Stain-Resistance Fluorochemical Surface Finish (ASG Stripped)

2.6 Test Results: Influence of other Test Variables on RMC

The data in the previous section shows that the RMC is strongly influenced by spin g level. Several other operating variables also influence the RMC level reached after a spin cycle:

- Spin time
- Load size
- Soak water temperature prior to spin
- Soak time prior to spin
- Cloth life (cumulative wash cycles, shrinkage)

The primary focus of the work reported herein has been to develop a test cloth specification, so that consistent RMC values are obtained with different lots of test cloth. In pursuit of this objective, it is of interest to understand the quantitative magnitude of the effect of these variables on RMC levels; it is further of general interest to have this information publicly available.

2.6.1 Effect of Spin Time on RMC

For a fabric and load size, at a given spin g level, there appears to be an equilibrium RMC level that is reached after a comparatively long spin time. This is the limit of the mechanical removal process for that g force. Figure 2.4 plots RMC vs. spin time for two different lots at 100 and 300 g. These data represent TI1 and TI2 loads with warm soak temperature, 20-minute soak time, and an 8.4 lb. load. The figure shows evidence of dependence of spin time on RMC. The equilibrium time at 300g (about 20 minutes) appears to be somewhat longer than at 100 g (about 15 minutes). There is, of course, more moisture removed at higher g. The process (see Section 1.3) involves several mechanisms with effectiveness that varies with g, apparently resulting in somewhat longer equilibrium times as more moisture is removed.

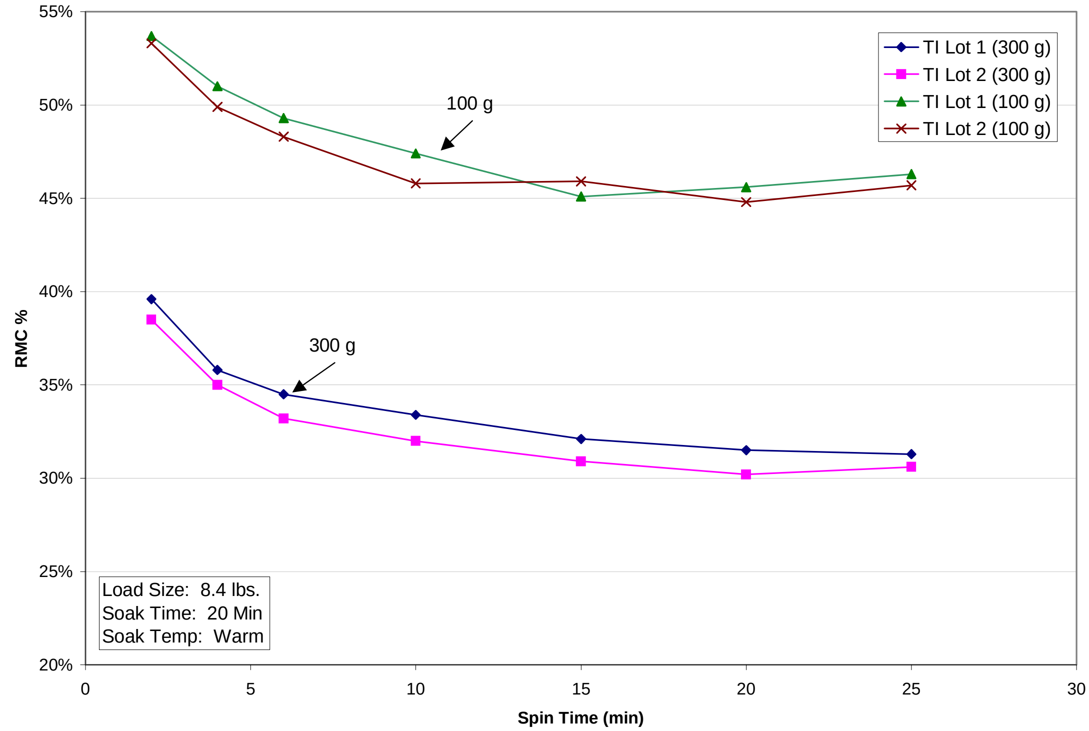

Figure 2.4 RMC vs. Spin Time for 100 and 300g.

2.6.2 Effect of Load Size on RMC

RMC vs. load size is plotted in Figure 2.5 at 100 and 300 g's respectively. These data were taken in conjunction with our tests on cloth life (see Section 2.6.5). The three load sizes represent the minimum, average, and maximum load size recommended for the extractor drum volume. The normal soak process was replaced by a "wash" that consisted of an agitation, light spin and a second agitation. No detergent and warm water was used. This was followed by the extractor-based spin. For these tests, the spin time was 15 minutes and the spin g was 100 and 300. Figure 2.5 shows the RMC decreases by several percentage points with increasing load at an amount that is independent of g force. This is possibly due to the increased pressure on the outer cloths in the basket caused by the increased radial depth of the load. It suggests that the load size and extractor dimensions (diameter, depth and perhaps basket porosity) be specified for RMC tests.

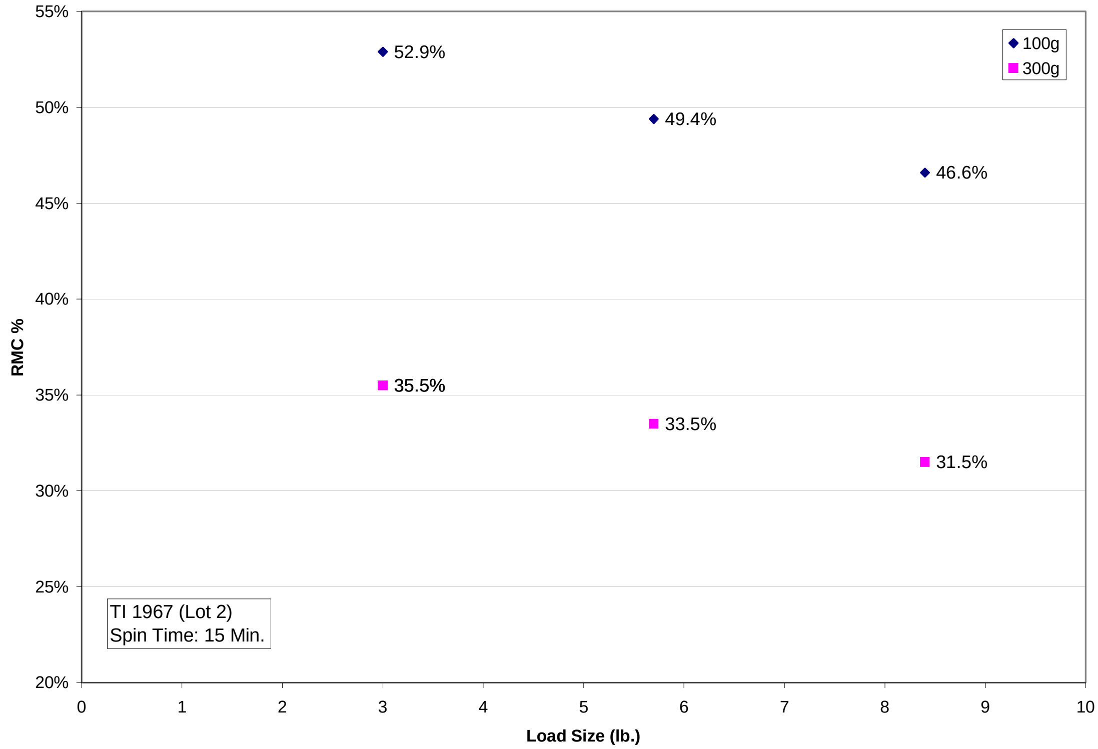

Figure 2.5 RMC vs. Load Size at 100 and 300 g's

2.6.3 Effect of Soak Water Temperature on RMC

The RMC is generally higher when the rinse water temperature is lower. Figures 2.6 and 2.7 show RMC vs. g for TI2 and TI3 loads respectively at warm (100°F) and cold (60°F) soak temperatures. The spin time was 20 minutes, soak time was 20 minutes and the load was 8.4 lb. Two figures are provided since the effect of temperature is difficult to discern when compounded with the data spread with load. Similar results were obtained with future lots 4 and 5. The cold water RMC values are as much as 8%, but generally 2-3% higher than the warm water RMC values. This is perhaps attributable to the temperature dependence of the surface tension and the absorptivity of water in cotton (both decrease with increasing temperature).

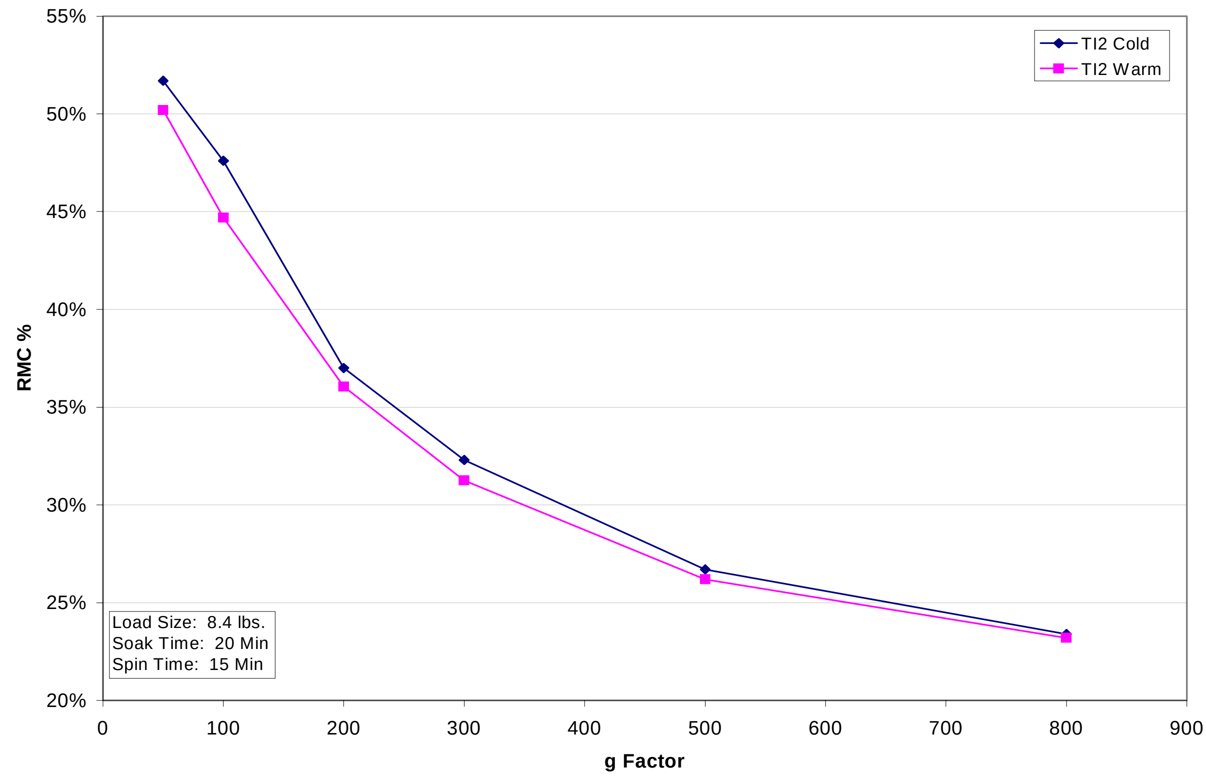

Figure 2.6 RMC vs. g for Warm and Cold Soak for Load TI2

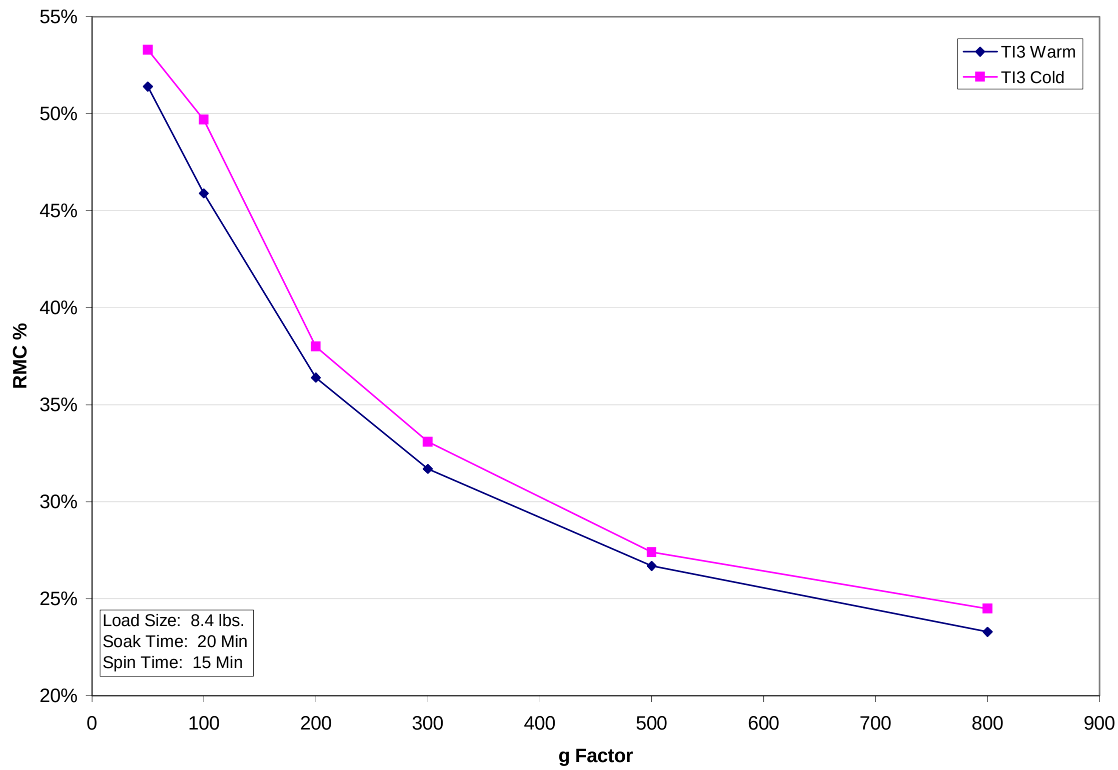

Figure 2.7 RMC vs. g for Warm and Cold Soak for Load TI3

2.6.4 Effect of Soak Time on RMC

In actual RMC tests, a washer is used and the soak time also includes agitation. As explained earlier, for our extractor based RMC tests, we soak the cloth in a cylindrical tub containing 10 gallons of water. During our shakedown tests, we determined the effect of soak time on RMC. Figure 2.8 shows results for warm and cold soaks. The data are for TI cloth, 115 g, 10-min. spin time and a 4.7 lb. load. The data show no discernable trends in RMC vs. soak times for cold soaks. There appears to be an increase in RMC with soak times of warm soaks for time greater than 1 hour. In order to resemble, to some extent, actual washer soak time and to maintain reasonable test times, we selected 20 minutes as soak time for our tests.

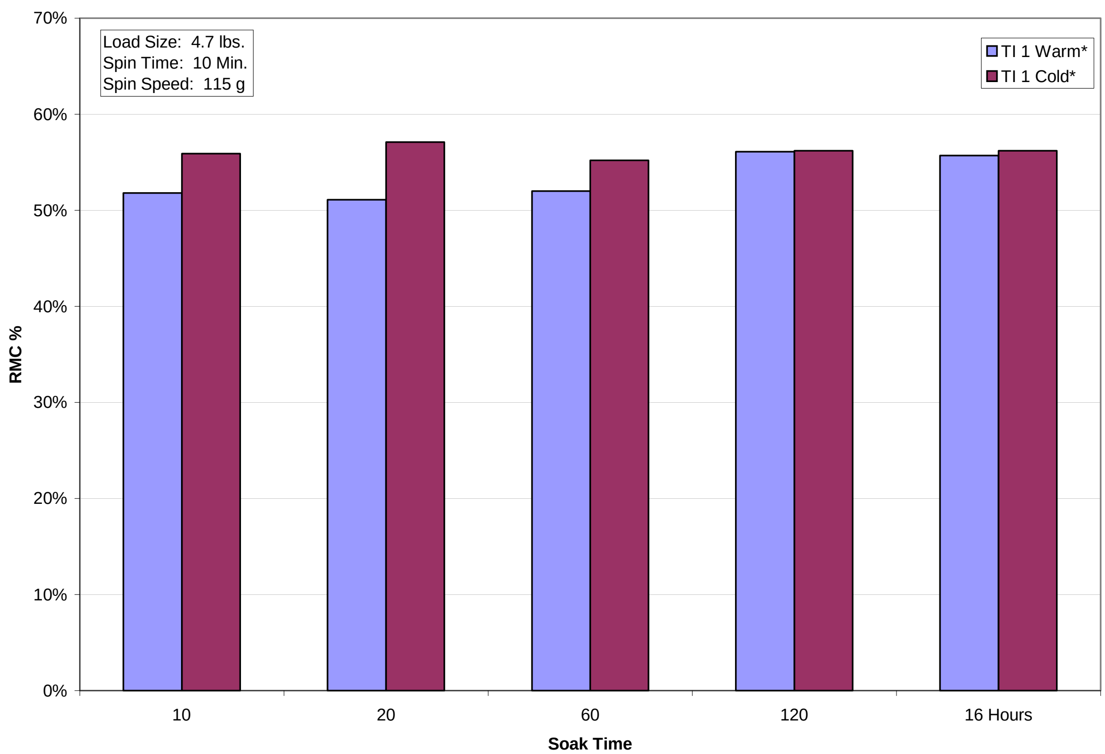

Figure 2.8 RMC vs. Soak Time in Minutes for Warm and Cold Soak at 115 g.

2.6.5 Effect of Cloth Life on RMC

To determine the effect of cloth life or cloth durability on RMC, we repeatedly “washed” a load of cloth and periodically performed RMC tests (omitting soak time). Our “wash” cycle includes agitation, spinning lightly and a second agitation with warm water, all with no detergent. Other portions of a normal wash cycle are presoak and spin/rinse. The presoak is optional and we considered the spin/rinse taken care of in the RMC test. We “washed” the load 5 times, then performed an RMC test and repeated this process 10 times, ultimately completing 50 “washes”. Results for RMC change with “washes” and the change in bone dry cloth weight with “washes” are shown in Figures 2.9 and 2.10, respectively. The data are for TI cloth, at 100 g, with 15-min. spin time, and an 8.4 lb. load. The cloth weight is reduced approximately 2% in 50 "washes" because of the continual removal of material in the washing process. The RMC increases on the order of 1% in 50 "washes". The rate of weight loss from the fabric and the rate of RMC increase were linear over the entire 50 wash cycles. Neither showed any sign of increasing toward the end of the 50 wash cycles. The conclusion is that the cloth appears to hold slightly more moisture as it ages. This is possibly due to greater voids created in the cloth with age. Note that the DOE test procedure allows test cloths to be used for up to 25 wash cycles.

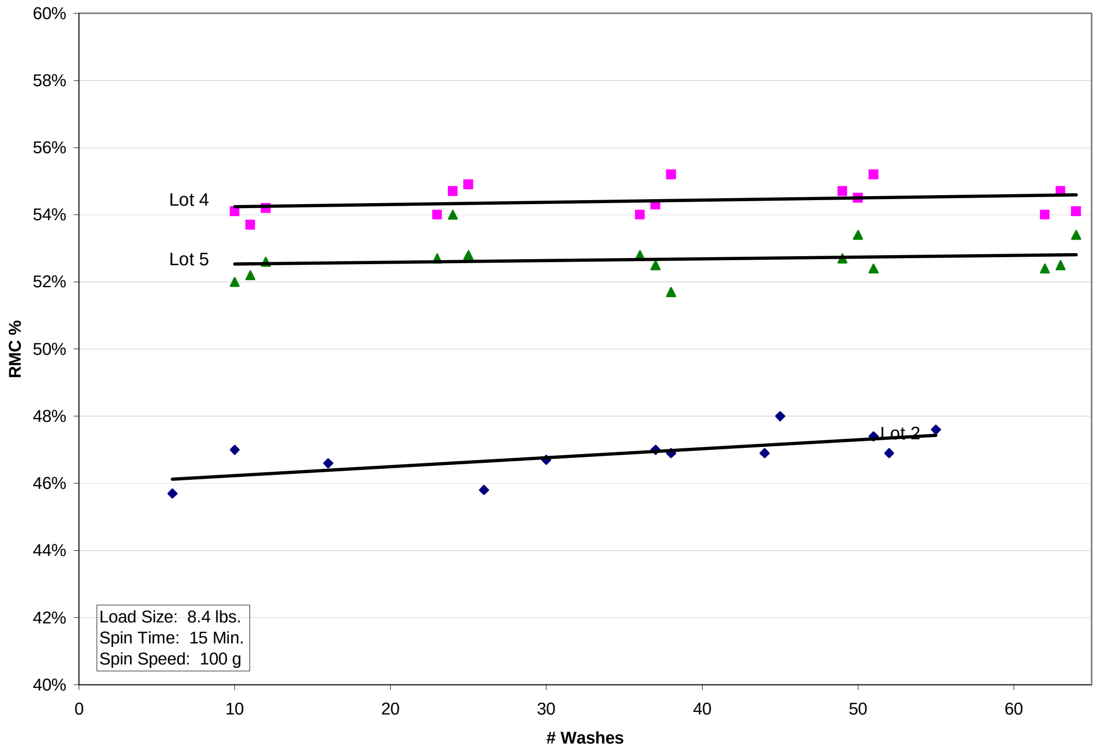

Figure 2.9 RMC vs. Number of Wash/dry cycles

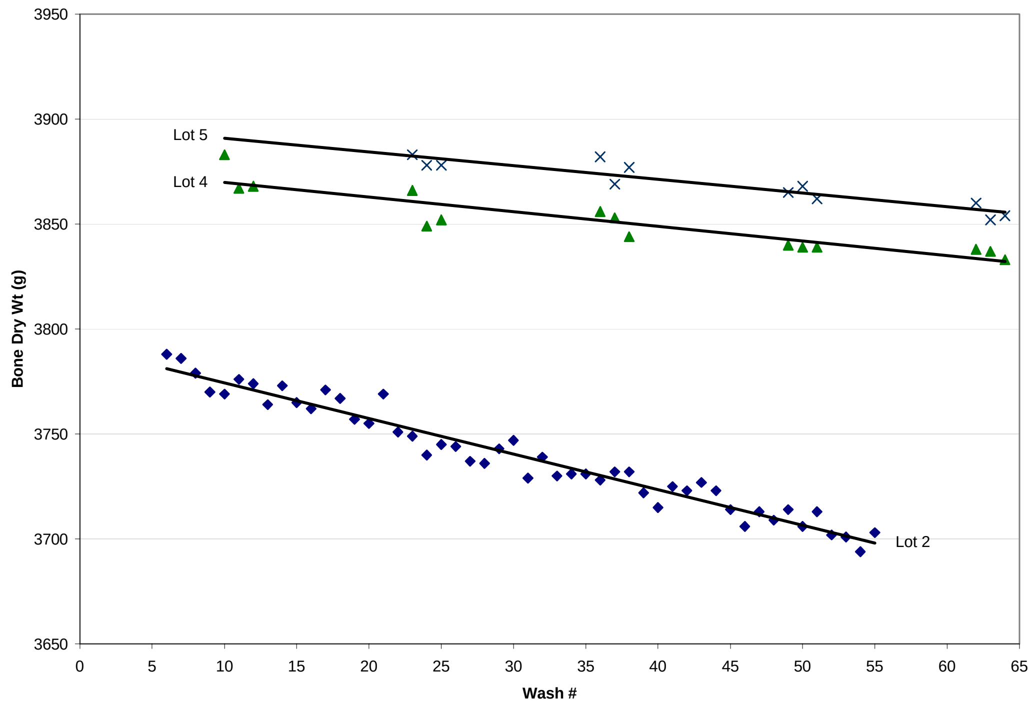

Figure 2.10 Bone Dry Weight vs. Number of "Washes"

As part of the fabric life testing the test cloth shrinkage was monitored. Linear dimensions were taken in three locations on both the horizontal and vertical axis of the test cloth. The unwashed test cloth dimensions established the baseline. Measurements were recorded after each of the five pre-conditioning washes and then after every ten wash cycles. The results are shown in Figure 2.11. The percent shrinkage increased steadily during the pre-conditioning process, reaching a plateau after ten wash cycles. The variation in percent shrinkage between lot 4 and lot 5 was nearly consistent at 1%. There is no compelling evidence that the percent shrinkage has an impact on the moisture retention of the test cloth. With the improved test cloth specification and more robust pre-conditioning procedure, it is suggested that the shrinkage requirement be removed from the test procedure.

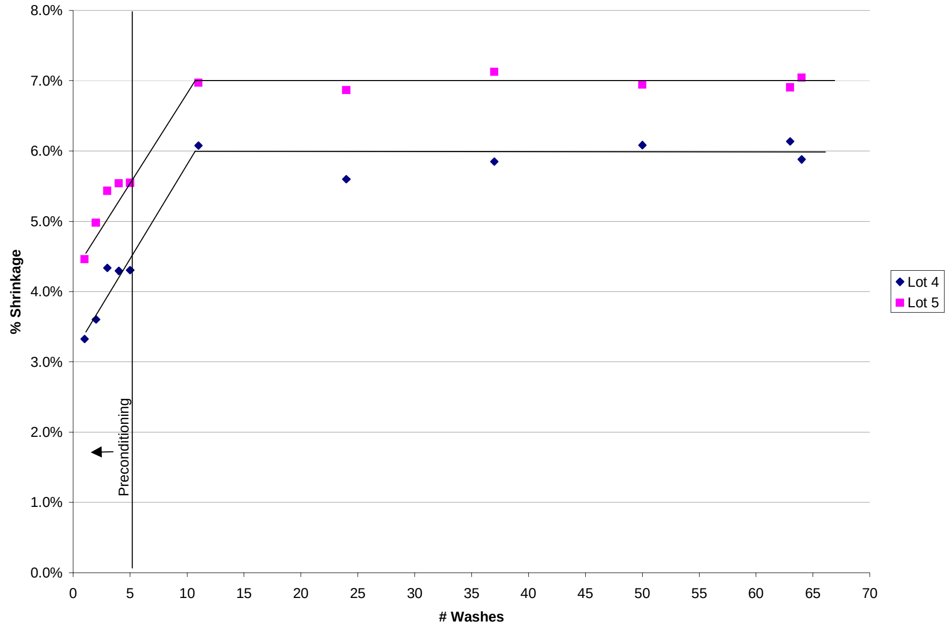

Figure 2.11 Shrinkage of Energy Cloth Used in Cloth Life Tests

2.6.6 Effect of Pre-Conditioning on RMC

The pre-conditioning procedure was verified using both a vertical and horizontal axis washing machine to determine if the machine type used in pre-conditioning impacts the RMC results. TI Lot 4 and Lot 5 were each pre-conditioned following the procedure described in section 6.3, subsection 2.6.3. Each load was then run in the extractor to compare RMC values. The extractor tests were performed, as previously, with a 20 minute warm soak, 15 minute spin, at 100 g. The results, shown in Table 2-4, show nearly identical RMC results regardless of the pre-conditioning machine type used. Based on these results, specification of a pre-conditioning machine type is not necessary.

Table 2-4: RMC Values for Different Pre-Conditioning Machine Type

Machine Type	Lot 4	Lot 5
Vertical	53.3%	50.1%
	52.1%	51.0%
Horizontal	53.1%	50.9%
	52.3%	50.3%
	53.0%	50.5%

3. Results of Washer Based RMC Tests Conducted by Intertek Testing (ITS)

Since ITS is an independent laboratory that routinely does washer based RMC testing for the industry, it was decided to send cloth to them from the same lots we used in our extractor-based RMC tests for evaluation. This would allow a comparison of washer-based RMC to extractor-based RMC. The results of ITS washer based RMC tests are given in Table 3.1. The ITS tests are done on two washers, listed as Amana and Whirlpool. The loads that originated the study are listed as Alliance (origin TI) and ITS (origin CG). Our (ADL) cloth came from lots used in our RMC tests discussed above. The lots were purchased at different times from the supplier listed. The dramatic difference between the Alliance and ITS loads is also evident in the ADL data, suggesting that the discrepancies in RMC between TI and CG cloth is independent of lot. There is about 5% maximum difference in the TI lots per machine and up to a 7 % difference between machines. A comparison of values between those in the table and Figure 2.1, extractor-based results, indicates a similarity in trend. Numerical values cannot be compared because of the differences in test methods, i.e., washer-based vs. extractor-based.

Table 3.1 ITS Washer-Based RMC Results

	Alliance	ADL TI1	ADL TI2	ADL TI3	ITS	ADL CG1
Amana	56.0%	55.21%	52.28%	53.09%	67.9%	66.09%
Whirlpool	53.7%	54.65%	51.56%	49.58%	64.9%	63.84%

3.1 Cloth Characteristics and Relation to RMC

The construction of a textile fabric and its constituent yarns is characterized by a number of basic variables. For a particular fabric, cloth specifications could define the nominal value of these variables and the acceptable tolerance range. The material that follows is a discussion of these variables and the likely relationship of these variables to the moisture absorption and retention of the cloth.

Following the discussion of the variables, the test results are summarized from several labs to characterize the test cloths that have been examined in this project.

3.2 Discussion of Cloth Characterization Variables

A listing of cloth characterization variables, their descriptions, suspected relation to RMC, specification in current (proposed) regulation and appropriate test for evaluation is given in Table 4.1. Note that only fabric construction, thread count, fiber content, fabric weight and finish are currently specified in the proposed regulation.

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4.1 Discussion of Cloth Characterization Variables

A listing of cloth characterization variables, their descriptions, suspected relation to RMC, specification in current (proposed) regulation and appropriate test for evaluation is given in Table 4.1. Note that only fabric construction, thread count, fiber content, fabric weight and finish are currently specified in the proposed regulation.

Table 4.1 Cloth Characterization Variables

Property	Description	Relation Suspected to RMC	Current Specification	Test for Evaluation
Fabric Construction	Weave of cloth. Either momie (granite)- irregularly woven with rough surface or plain weave-regularly woven.	Unknown	Momie (granite) weave	Identified visually
Yarn Type	Either open-end or ring spun (open end common today)	Unknown	Unspecified	Identified visually
Thread Count	Number of yarns that run lengthwise (warp or ends)/number of yarns that interlace(fill or picks)	Higher thread count implies more cotton, higher RMC	65/57	ASTM D 3775: Thread Counts per Inch
Fiber Content	% blend by weight of fiber type in yarn	More cotton fiber implies higher RMC	50/50 cotton / polyester	AATCC 20A-with moisture: Fiber Composition
Yarn Number	Linear density of yarn, mass/length	Thicker thread implies more cotton , higher RMC	Not specified	ASTM D 1059: Standard Test Method for Yarn Number
Fabric Weight	Dry weight per unit area (oz. per sq. yd. or gms. per sq. m.)	Heavier weight implies more cotton, more RMC	5.75 oz. Per sq. yd.	ASTM D 3776: Weight
Finish	Could cover a variety of finishes applied to the cloth (related to final uses or facilitating manufacturing process)	Any finish would lower RMC	Pure finished bleached	AATCC TM 94: Finishes in Textiles: Identification
Water Retention	Amount of water retained in a centrifuge test	Water retention increases RMC	Not specified	ASTM D 2402: Water Retention by Imbibition
Absorbency	Amount of time for a drop of water to absorb	Absorbency increases RMC	Not specified	AATCC TM 79: Absorbency of Bleached Textiles
Vertical Wicking Rate	Time for water to travel a fixed distance up the cloth. Tested in the warp and fill directions	Faster wicking implies higher RMC	Not specified	Vertical Wicking Rate
Repellency to Oil and Water	If a surface is wetted by oil or water. Identifies fluorochemical and other finishes	Repellency lowers RMC	Not specified	AATCC TM 118: Oil Repellency

4.2 Results of Cloth Characterization Tests

Tables 4.2 and 4.3 present results from the independent laboratories for the cloth characterization tests. As shown, there is an absence of data in some cases. Either the data was not requested or the laboratory was unable to perform the required tests. Also there are some discrepancies in the reporting and/or method of analysis (see results for water retention). Information on fabric construction and yarn type is particularly sparse. Vartest reported the weave on both CG and TI samples to be “crepe weave” (not momie), CG to be “ring-spun” yarn, and TI to be “open-end” spun yarn.

Table 4.2 Cloth Characterization: Fabric Weight, Thread Count, Yarn Number and Fiber Content

Fabric Source	Sample ID	Test Lab	Fabric Weight,oz. Per sq. yd.	Thread Count		Yarn Number		Fiber Content	
				Warp	Fill	Warp	Fill	Cotton %	Poly%
Textile Innovators	"Alliance"	ACTS	5.86	65.0	60.0	-	-	49.58	50.2
		Intertek	5.90	67.20	61.00	-	-	49.8	49.5
			6.2	67.00	62.00	-		50.2	49.8
		USDA	5.81	61.00	67.00	16.90	16.20	51.9	48.1
			5.84	-	-	-	-	-	-
		Vartest	5.90	66.20	61.00	-	-	50.53	49.47
			5.98	66.70	61.00	-	-	50.24	49.76
	ADL Lot1 (TI1)	Vartest	5.60	64.80	55.00	16.20	15.5	51.21	48.79
			5.64	64.00	55.30	16.40	16.10	50.7	49.3
	ADL Lot2 (TI2)	Intertek	5.3	60	54	16.0	16.0	52.6	47.4
		Vartest	5.23	60.5	53.5	16.3	15.8	48.5	51.5
	ADL Lot 3 (TI3)	ACTS	5.3	62	53	16.3	15.8	48.5	51.5
		Intertek	5.3	61	53	15.9	15.9	51.5	48.5
		Vartest	5.33	61.7	54.0	15.8	15.5	50.09	49.91
	ADL Lot 4 (TI4)	ACTS	5.87	63	53	14.6	14.7	50.5	49.5
		Intertek	5.9	65.6	53.6	15.1	14.3	51.6	48.4
		Vartest	5.62	64.3	53.0	16.7	15.1	51.76	48.24
	ADL Lot5 (TI5)	ACTS	5.5	63	52	15.4	14.5	50.7	49.3
		Intertek	5.89	66.0	54.0	15.2	15.2	52.0	48.0
		Vartest	5.44	63.3	53.0	15.3	15.0	51.76	48.24
Cotton Goods	ITS	ACTS	5.73	70.00	61.00	-	-	45.1	54.9
		Intertek	5.90	70.60	64.00	-	-	47.2	52.8
			5.80	70.40	62.40	-	-	48	52.0
		USDA	5.67	63.00	71.00	18.10	17.50	47.8	52.2
			5.75	-	-	-	-	-	-
		Vartest	5.88	69.70	63.00	-	-	48.32	51.68
			5.88	71.00	64.30	-	-	48.32	51.68
	CG1	Vartest	5.20	67.30	56.00	18.00	18.10	54.27	45.73
			5.24	67.00	55.50	17.30	17.50	54.02	45.98

Table 4.3 Cloth Characterization: Water retention, Drop Absorbency, Finish, Repellency and Vertical Wicking Rate

Fabric Source	Sample ID	Test Lab	Water Retention %	Drop Absorbency, sec.	Finish	Repellency, D=absorb, A=repel		Vertical Wicking, sec. for 2 cm	
						Water	Oil	Warp	Fill
Textile Innovators	"Alliance"	USDA	15.5	388				68	399
			15.2	153					
		Vartest				D	D		
						A	D		
	ADL Lot 1 (TI1)	Vartest	191	0.8	Possible lubricant or surfactant	D	D		
			185	0.8	Possible lubricant or surfactant	D	D		
	ADL Lot 2 (TI2)	Intertek		8.0					
		Vartest	196.6	5.9	Polyvinyl Acetate	D	D	30	30
	ADL Lot 3 (TI3)	ACTS	13.75	7.1		D	D		
		Intertek		6.4					
		Vartest	226.68	6.6	None	D	D	30	30
	ADL Lot 4 (TI4)	ACTS		<1		D	D		
		Intertek		2.6					
		Vartest		1.9		D	D		
	ADL Lot 5 (TI5)	ACTS		<1					
		Intertek		1.2		D	D		
		Vartest		1.4		D	D		
Cotton Goods	ITS								
		USDA	18.4	<1				15	12
			17.2	<1					
		Vartest				D	D		
						D	D		
	CG1	Vartest	292	0.4	Wax, Silicone/polyester oligomer, Possible lubricant or surfactant	D	D		
			287	0.5	Possible lubricant or surfactant	D	D		

Table 4.4 summarizes the differences found in the laboratory results and provides comments on conclusions and effect on RMC. Here we discuss only the lots tested in our extractor-based RMC tests, not the "Alliance" and ITS data.

Table 4.4 Summary of Results from Independent Laboratories

Property	Differences between laboratories	Differences between lots, same supplier (TI only)	Differences between CG and TI	Conclusion and relation to RMC
Fabric Construction	Vartest reported TI and CG cloth to be crepe weave (not momie)			More data needed
Yarn Type	Vartest reported CG to be ring-spun and TI to be open-end yarn			More data needed
Thread Count	2%	4%	4% -11% between TI and CG, but not overlapping TI lot difference	Significant difference between CG and TI. may be connected to RMC
Fiber Content	4%	4%	6-12%	No discernable differences between lots and laboratories. Differences between CG and TI may be connected to RMC
Yarn Number	2%	2%	12%	No discernable differences between lots and laboratories. Differences between CG and TI may be connected to RMC
Fabric Weight	Small	5%	2%	5% between lots may be significant
Finish	Not enough data	Some reported	Same finish on both	Finishes reported, but no connection to RMC
Water Retention	Data here difficult to analyze because of differences in test methods/results			More information needed
Absorbency	Large	Large	Not reported	More information needed
Vertical Wicking Rate	Not enough data	Not enough data	Not reported	More information needed
Repellency	Data indicates all samples studied absorb oil and water			No differences noted

4.3 Comparison of Cloth Characterization Test Results with RMC Test Results

Table 4.3 indicates some differences in cloth characteristics that may be linked to RMC results. However, there are no clear connections. There is reasonable uniformity in characteristics between TI lots reported here and these differences are within the same bounds as the differences in RMC results. This suggests that a "standard" cloth should originate one manufacturer to limit the variability of characteristics. The tests available for finish can be extensive. However, two simple droplet tests for absorbency of water and oil can be used to detect the type of stain of water repellent finish that could be inadvertently applied during production of this fabric.

5. RMC Correction Factor

As discussed in the preceding sections, the relationship that can be discerned between measurable, specifiable properties of the cloth and the resulting moisture absorption/retention characteristics as measured by a standard RMC test is tenuous at best. The difficulty of relating specifiable characteristics – fiber content, weight, etc. to RMC characteristics is compounded by the wide tolerances that apply to the nominal specifications of textile products. The textile industry requires wide tolerances to allow for the variability of cotton and synthetic fibers, as well as process control variability. Based on discussions with textile industry marketing and manufacturing managers, special manufacture to tighter specifications is probably not available; based on the laboratory testing to date, tight specifications alone will not necessarily lead to a comparably consistent RMC characteristic.

Based on the highly consistent extractor based RMC-g curves for TI lots 1, 2, and 3, it appeared that a viable approach to minimize the effects of cloth variation on RMC would be to consistently specify a single type of fabric that is produced frequently by one mill to a consistent set of specifications. Riegel Permalux 50/50 Momie Weave (the cloth used for TI lots 1, 2, and 3) appears to be a suitable choice, because this cloth is produced in high volume, has been produced to a consistent specification for many years and is likely to continue to be produced on this basis for the foreseeable future. Riegel produces the yarns from purchased fiber and weaves and finishes the cloth material, so they have complete control over the process.

However, as discussed in the preceding sections, the extractor based RMC-g curves of subsequent lots of the Riegel cloth (TI lots 4 and 5) were 5 to 8 percentage points higher than the corresponding RMC-g curves for TI lots 1, 2, and 3. To account for lot-to-lot variation, Robert Van Buskirk of Lawrence Berkeley Laboratory (LBL) proposed a linear least squares fit based RMC correction (Appendix C). The basic approach is to define standard RMC vs. g values for cold and warm (60°F and 100°F) water and 4 minute and 15 minute spin times. The RMC values of TI lot 3 have been adopted as this standard. For other lots of test cloth, RMC-g values are absorbed in the standard extractor. A linear least squares fit between the new cloth RMC and the “standard” cloth RMC yields a linear relation between the RMC obtained with the new cloth and the RMC that would have been expected with standard cloth. Figure 5-1 illustrates the basic concept.

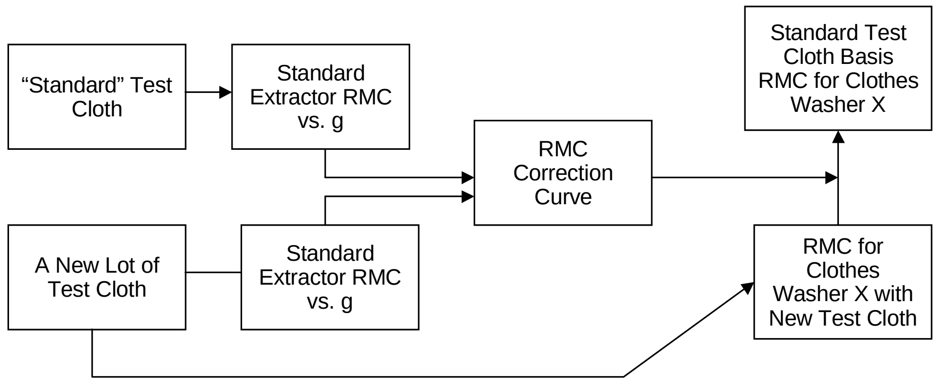

Figure 5-1 RMC Correction to Determine the RMC that would have been Measured with "Standard" Test Cloth

As described below, test results to date indicate that this procedure produces results that are highly consistent.

The material below summarizes the proposed method to determine the correction factor curve for a new lot of test cloth and the test data, to date, that shows that this procedure will yield consistent RMC results for clothes washers.

5.1 Procedure to Calculate Correction Factor

The typical linear correction curve that is generated is shown in Figure 5-2. The simple algebraic equation is

$$RMC_{corrected} = A + B*RMC_{measured}$$

Where:

- $RMC_{corrected}$ is the average RMC that would have been expected at each test condition for clothes washer X if "standard" test cloth had been used for the J1 RMC test
- $RMC_{measured}$ is the RMC measured by the J1 test procedure for clothes washer X with a lot of non-standard test cloth for which a linear correction curve has been created.

- A and B are the coefficients (intercept and slope) that result in the least squares linear fit relating the RMC values measured in the standard extractor for a particular lot of non-standard test cloth and those that were measured with standard test cloth, at each water temperature, spin time, and g test point

The procedure has four basic steps.

1. Establish the standard RMC vs. g values for cold and warm water and 4 minute and 15 minute spin time.

2. For a new lot of test cloth, measure the RMC vs. g values for cold and warm water and 4 minute and 15 minute spin time.

3. Linear least squares fit and root mean square (RMS) error check to generate the linear correction curve.

4. Apply correction to J1 measurements of RMC with clothes washer.

5.1.1 Standard RMC vs. g Curve

The standard RMC vs. g values are summarized in the "standard cloth" column of Table 5-1. They are the average of three measured RMC values at each spin time – water temperature – spin g test point with test cloths from TI lot 3. They were measured in a Bock Model 215 extractor. For this test procedure it was decided that the Bock Model 215 extractor would be the "standard".

5.1.2 Establish RMC vs. g Values for New Test Cloth

Using the standard Bock Model 215 extractor measure the RMC at the specified combinations of spin time, water temperature and spin g in Table 5-1. Each of the RMC measurements should be done three times, with the average used to determine the correction curve.

5.1.3 Least Squares Fit and RMS Error Verification

Using a spreadsheet or statistical calculator, calculate the linear least squares fit relating the pairs of "standard" and "new cloth" RMC values at each of the spin time – water temperature – spin g test points.

To quantify the uncertainty of the linear least squares fit a root mean square error analysis is performed. The root mean square value of:

$$\left(\sum_{i=1}^{12} \frac{\left(RMC_{standard\_i} - RMC_{corr\_i}\right)^2}{10}\right)^{1/2}$$

Should be less than 2-percent.

The Root Mean Square (RMS) is a standard statistical quantity generated in least-squares regression analysis. It is typically used to construct confidence interval estimates and to test hypotheses about the derived model. The RMS quantifies the amount of variation (or uncertainty) associated with estimating the standard RMC % from any corresponding RMC % value observed with new cloth. Underlying theory and computational details are given in most applied statistics texts.

Table 5-1: Standard RMC vs. g Values and Corresponding New Cloth RMC Values for Linear Least Squares Fit

Spin Time	**Water Temperature**	**Spin g's**	**RMC Measured in the Standard Extractor**	
			Standard Cloth	**New Cloth**
4 min.	Cold	50	59.0%	
		200	43.1%	
		350	35.8%	
	Warm	50	55.7%	
		200	40.4%	
		350	33.1%	
15 min.	Cold	50	52.8%	
		200	37.9%	
		350	30.6%	
	Warm	50	50.4%	
		200	35.6%	
		350	29.6%	

5.1.4 Apply to Clothes Washer Test Results

Once the linear correction curve has been generated for a new lot of test cloth, energy test cloths and stuffers may be used to perform the J1 RMC test on any clothes washer to which the J1 test procedure is applicable. The RMC measured with the new test cloth is corrected to the standard test cloth RMC, either graphically using a plot of the linear correction curve, or arithmetically, using the linear equation with the coefficients A and B that define the linear correction curve.

5.2 Test Data Confirming Correction Procedure

To evaluate the effectiveness of the correction procedure, results from extractor RMC-g tests for TI lots 4 and 5 were used to generate the linear correction curves to TI lot 3. The resulting coefficients for the linear correction equation $RMC_{std} = A + B*RMC_{measured}$ are summarized in Table 5-2.

Table 5-2: Correction Coefficients

Test Cloth Lot	A	B
TI 4	-0.038	0.967
TI 5	-0.0319	0.9975

The linear correction curve and the individual extractor RMC data points for lots 4 and 5 are plotted in Figures 5-2 and 5-3, respectively. The individual data points are the average of the 3 RMC values measured for each combination of water temperature, spin time, and spin g. The detailed data is shown in tabular form in Appendix D.

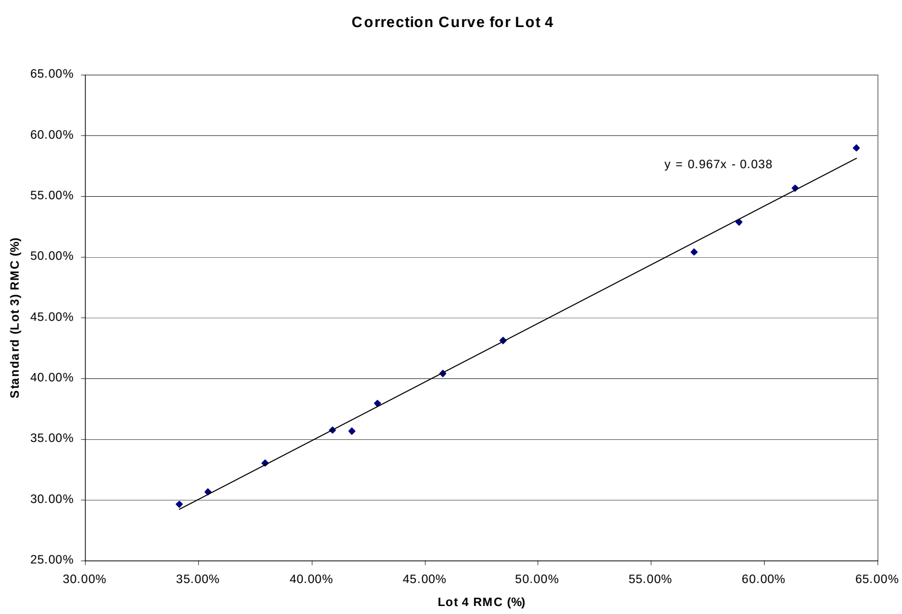

Figure 5-2: Linear Correction Curve for TI Lot 4

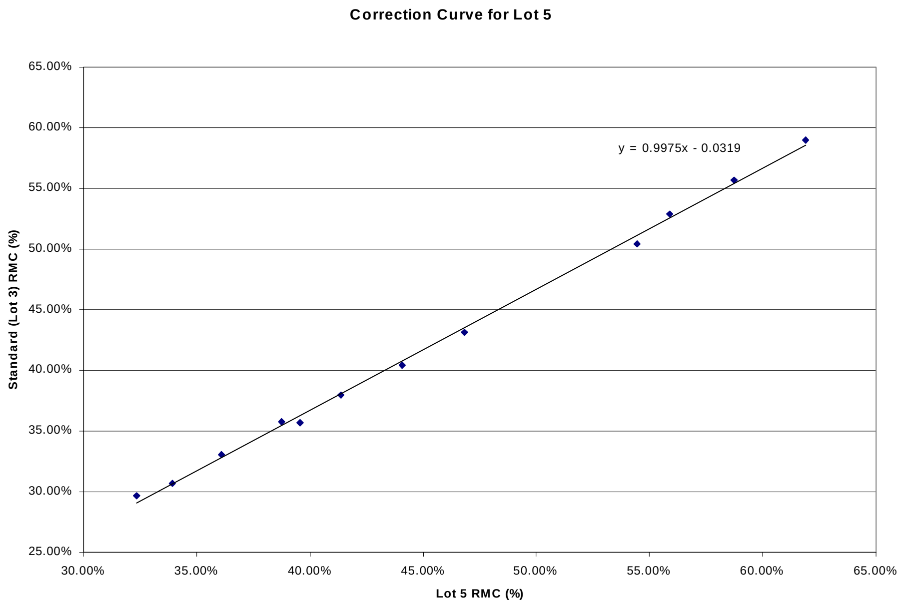

Figure 5-3: Linear Correction Curve for TI Lot 5

The results of the extractor-based correction curve tests are shown in table 5-3 and 5-4. The tables show the standard (Lot 3) measured value, the Lot 4 (or 5) measured value, and the corrected value. All measured values are shown, however, the average of the three test values at each condition are used for the least squares curve fit.

Table 5-3: Lot 4 Verification of Correction Factor in Clothes Washer

Test Point (Soak Temp., Time, g)	Lot 3 RMC (Standard)	Lot 4 RMC	Corrected RMC
Warm, 15, 50	*51.4%*	*56.2%*	*50.5%*
	49.6%	*57.2%*	*51.5%*
	50.2%	*57.2%*	*51.5%*
Warm, 15, 200	*36.4%*	*42.2%*	*37.0%*
	35.7%	*42.6%*	*37.4%*
	34.9%	*40.5%*	*35.4%*
Warm, 15, 350	*29.1%*	*34.2%*	*29.3%*
	29.9%	*34.2%*	*29.3%*
	29.9%	*34.1%*	*29.2%*
Warm, 4, 50	*55.8%*	*61.5%*	*55.6%*
	55.8%	*61.5%*	*55.6%*
	55.5%	*61.1%*	*55.3%*
Warm, 4, 200	*41.1%*	*46.3%*	*41.0%*
	40.6%	*45.6%*	*40.3%*
	39.6%	*45.5%*	*40.2%*
Warm, 4, 350	*32.1%*	*37.5%*	*32.5%*
	33.6%	*37.8%*	*32.8%*
	33.5%	*38.5%*	*33.5%*
Cold, 15, 50	*52.2%*	*58.8%*	*53.0%*
	53.3%	*58.0%*	*52.3%*
	53.1%	*59.8%*	*54.0%*
Cold, 15, 200	*38.0%*	*43.1%*	*37.9%*
	37.9%	*42.2%*	*37.0%*
	37.9%	*43.4%*	*38.2%*
Cold, 15, 350	*30.2%*	*35.5%*	*30.6%*
	30.7%	*35.4%*	*30.5%*
	31.1%	*35.4%*	*30.5%*
Cold, 4, 50	*59.1%*	*64.6%*	*58.6%*
	58.9%	*64.4%*	*58.4%*
	58.9%	*63.2%*	*57.3%*
Cold, 4, 200	*43.5%*	*47.9%*	*42.5%*
	43.0%	*49.0%*	*43.6%*
	42.8%	*48.5%*	*43.1%*
Cold, 4, 350	*35.3%*	*41.5%*	*36.3%*
	36.0%	*40.3%*	*35.2%*
	36.1%	*41.0%*	*35.9%*

Table 5-4: Lot 5 Verification of Correction Factor in Clothes Washer

Test Point (Soak Temp., Time, g)	*Lot 3 RMC (Standard)*	*Lot 5 RMC*	*Corrected RMC*
Warm, 15, 50	*51.4%*	*54.8%*	*51.4%*
	49.6%	*55.4%*	*52.0%*
	50.2%	*53.1%*	*49.7%*
Warm, 15, 200	*36.4%*	*40.1%*	*36.8%*
	35.7%	*39.5%*	*36.2%*
	34.9%	*39.1%*	*35.8%*
Warm, 15, 350	*29.1%*	*32.8%*	*29.6%*
	29.9%	*32.2%*	*29.0%*
	29.9%	*32.1%*	*28.9%*
Warm, 4, 50	*55.8%*	*58.1%*	*54.7%*
	55.8%	*59.4%*	*56.0%*
	55.5%	*58.7%*	*55.3%*
Warm, 4, 200	*41.1%*	*44.6%*	*41.3%*
	40.6%	*44.4%*	*41.1%*
	39.6%	*43.2%*	*39.9%*
Warm, 4, 350	*32.1%*	*36.6%*	*33.4%*
	33.6%	*36.4%*	*33.2%*
	33.5%	*35.2%*	*32.0%*
Cold, 15, 50	*52.2%*	*56.4%*	*53.0%*
	53.3%	*55.4%*	*52.0%*
	53.1%	*55.8%*	*52.4%*
Cold, 15, 200	*38.0%*	*41.7%*	*38.4%*
	37.9%	*40.0%*	*36.7%*
	37.9%	*42.4%*	*39.1%*
Cold, 15, 350	*30.2%*	*35.1%*	*31.9%*
	30.7%	*33.0%*	*29.8%*
	31.1%	*33.7%*	*30.5%*
Cold, 4, 50	*59.1%*	*61.4%*	*58.0%*
	58.9%	*61.9%*	*58.5%*
	58.9%	*62.4%*	*59.0%*
Cold, 4, 200	*43.5%*	*46.6%*	*43.3%*
	43.0%	*47.6%*	*44.3%*
	42.8%	*46.3%*	*43.0%*
Cold, 4, 350	*35.3%*	*38.6%*	*35.3%*
	36.0%	*38.7%*	*35.4%*
	36.1%	*39.0%*	*35.7%*

RMC values were determined for a horizontal axis washer and a vertical axis washer, following the J1 RMC test procedure, with each of TI lots 3 (the standard), 4 and 5. The RMC tests were run three times for each clothes washer/test cloth lot combination. Tables 5-5 and 5-6 summarize the RMC measured in each of the machines using test cloth from TI lots 4 and 5, respectively. In each table, these values are corrected to the TI lot 3 standard and compared to the RMC values measured with test cloths from TI lot 3. With one exception, the corrected RMC is less than 1% of the RMC measured with the standard (TI lot 3) test cloth.

Table 5-5: Verification of Lot 4 Correction Curve in Clothes Washer

Machine Type	Lot 3 RMC	Lot 4 RMC	Corrected Lot 4 RMC
Vertical-Axis Machine	55.4%	62.0%	56.1%
	56.0%	61.5%	55.7%
	56.1%	61.2%	55.3%
Horizontal-Axis Machine	47.1%	53.6%	48.1%
	49.3%	54.3%	48.7%
	48.6%	54.5%	48.8%

Table 5-6: Verification of Lot 5 Correction Curve in Clothes Washer

Machine Type	Lot 3 RMC	Lot 5 RMC	Corrected Lot 5 RMC
Vertical-Axis Machine	55.4%	59.4%	56.0%
	56.0%	59.6%	56.2%
	56.1%	60.0%	56.6%
Horizontal-Axis Machine	47.1%	50.3%	47.0%
	49.3%	49.8%	46.5%
	48.6%	51.9%	48.5%

6 Approach to obtaining and verifying consistent test cloth

An approach to minimize the effects of cloth variation on RMC is to consistently specify a single type of fabric that is produced frequently by one mill to a consistent set of specifications. Riegel Permalux 50/50 Momie Weave appears to be a suitable choice, because this cloth is produced in high volume, has been produced to a consistent specification for many years and is likely to continue to be produced on this basis for the foreseeable future. Riegel produces the yarns from purchased fiber and weaves and finishes the cloth material, so they have complete control over the process. With the modest inconsistencies between lots that have been observed to date, a correction factor needs to be applied to obtain consistent clothes washer RMC test results.

The previous section presented a linear least squares fit method to correct actual cloth to “standard” cloth.

The material below summarizes the cloth specifications, the approach to consistency verification and the translation of these into draft language that could be inserted into the test standard (Appendix J1).

6.1 Outline of Proposed Specification

1 Specify one standard grade of cloth from one mill: e.g., **Riegel Permalux 50/50 Momie Weave** with pure bleached finish

2 Change the energy test cloth specification in 10 CFR 430 Subpart B Appendix J1 to:

- Duplicate the Riegel Mills specifications for the Permalux 50/50

  -50/50 cotton/polyester ± 4%
  -5.60 oz/sq. yd. ± 5%
  -Warp and filling yarns 15/1 ± 5% cotton count, open end spun yarn
  -Thread counts of 61 x 54 (warp x fill) ± 2%

- Require AATCC-118 with “D” across the board result

- Require AATCC-79 with drop absorbing time on the order of 1 second

- Require standard extractor based RMC vs. g standardization curves and RMC correction curve for each new lot of test cloth

6.2 Verification

1. AATCC-118 Oil Repellency Test (DuPont or 3M version) of each new lot of test cloth (when purchased from Riegel) to confirm absence of Scotchguard or other water repellent finish (required scores of "D" across the board)

2. AATCC-79 Drop Absorbency Test of each new lot of test cloth (when purchased from Riegel) for further confirmation of the absence of Scotchguard or other water repellent finish (time to absorb one drop should be on the order of 1 second)

3. Run 4 minute and 15 minute standard RMC vs. g curves with 60°F and 100°F water temperature for each new lot of test cloth as the basis for calculating an RMC correction curve to correct RMC test results to "standard" test cloth (average of TI lot 3)

6.3 Standard Language

DOE Draft Language for Changes to J1 Test Procedure to Specify The Energy Test Cloth and The RMC Correction to "Standard" Test Cloth RMC

Appendix J and J1 to Subpart B of Part 430 of the clothes washer test procedure is amended to read as follows:

§430.23 Test procedures for measures of energy consumption
*** * * * ***

Appendix J to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-Automatic Clothes Washers
*** * * * ***

2.3 <u>Supply water</u>.

2.3.1 <u>Supply water requirements for water and energy consumption testing</u>. For nonwater-heating clothes washers not equipped with thermostatically controlled water valves, the temperature of the hot and cold water supply shall be maintained at 100E+10EF (37.8EC+5.5EC). For nonwater-heating clothes washers equipped with thermostatically controlled water valves, the temperature of the hot water supply shall be maintained at 140EF+5EF (60.0EC+2.8EC) and the cold water supply shall be maintained at 60EF+5FE(15.6EC+2.8EC). For water-heating clothes washers, the temperature of the hot water supply shall be maintained at 140EF+5EF(60.0EC+2.8EC) and the cold water supply shall not exceed 60EF (15.6EC). Water meters shall be installed in both the hot and cold water lines to measure water consumption.

2.3.2 Supply water requirements for remaining moisture content testing. For nonwater-heating clothes washers not equipped with thermostatically controlled water valves, the temperature of the hot water supply shall be maintained at 140F + 5F and the cold water supply shall be maintained at 60F + 5F. All other clothes washers shall be connected to water supply temperatures as stated in Section 2.3.1.

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2.10 Wash time (period of agitation or tumble) setting. If the maximum available wash time in the normal cycle is greater than 9.75 minutes, the wash time shall be not less than 9.75 minutes. If the maximum available wash time in the normal cycle is less than 9.75 minutes, the wash time shall be the maximum available wash time.

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2.11 Agitation speed and spin speed settings. Where controls are provided for agitation speed and spin speed selections, set them as follows:

2.11.1 For energy and water consumption tests, set at the normal cycle settings. If settings at the normal cycle are not offered, set the control settings to the maximum speed permitted on the clothes washer.

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3.3.1 The wash temperature shall be the same as the rinse temperature for all testing. Cold rinse is the coldest rinse temperature available on the machine. Warm rinse is the hottest rinse temperature available on the machine.

*** * * * ***

Appendix J1 to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-Automatic Clothes Washers

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1.22 Cold rinse means the coldest rinse temperature available on the machine (and should be the same rinse temperature selection tested in section 3.7).

1.23 Warm rinse means the hottest rinse temperature available on the machine (and should be the same rinse temperature selection tested in section 3.7).

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2.6 Test Cloths.

2.6.1 Energy Test Cloth. The energy test cloth shall be made from energy test cloth material, as specified in 2.6.4, that is 24 inches by 36 inches (61.0 cm by 91.4 cm) and has been hemmed to 22 inches by 34 inches (55.9 cm by 86.4 cm) before washing. The energy test cloth shall be clean and shall not be used for more than 60 test runs (after preconditioning as specified in section 2.6.3). Mixed lots of material shall not be used for testing the clothes washers.

2.6.2 Energy Stuffer Cloth. The energy stuffer cloth shall be made from energy test cloth material, as specified in 2.6.4, and shall consist of pieces of material that are 12 inches by 12 inches (30.5 cm by 30.5 cm) and have been hemmed to 10 inches by 10 inches (25.4 cm by 25.4 cm) before washing. The energy stuffer cloth shall be clean and shall not be used for more than 60 test runs (after preconditioning as specified in section 2.6.3). Mixed lots of material shall not be used for testing the clothes washers.

2.6.3 Preconditioning of Test Cloths. The new test cloths, including energy test cloths and energy stuffer cloths, shall be pre-conditioned in a clothes washer in the following manner:

2.6.3.1 Perform 5 complete normal wash-rinse-spin cycles, the first two with AHAM Standard detergent 2A and the last three without detergent. Place the test cloth in a clothes washer set at the maximum water level. Wash the load for ten minutes in soft water (17 ppm hardness or less) using 6.0 grams per gallon of water of AHAM Standard detergent 2A. The wash temperature is to be controlled to 135º + 5ºF (57.2º + 2.8ºC) and the rinse temperature is to be controlled to 60º + 5ºF (15.6º + 2.8ºC). Repeat the cycle with detergent and then repeat the cycle three additional times without detergent, bone drying the load between cycles (total of five wash and rinse cycles).

2.6.4 Energy test cloth material. The energy test cloths and energy stuffer cloths shall be made from fabric meeting the following specifications. The material should come from a roll of material with a width of approximately 63 inches and approximately 500 yards per roll, however, other sizes maybe used if they fall within the specifications.

2.6.4.1 Nominal fabric type. Pure finished bleached cloth, made with a momie or granite weave, which is nominally 50 percent cotton and 50 percent polyester.

2.6.4.2 The fabric weight shall be 5.60 ounces per square yard (190.0 g/m^2), +5 percent.

2.6.4.3 The thread count shall be 61 x 54 per inch (warp x fill), +2 percent.

2.6.4.4 The warp yarn and filling yarn shall each have fiber content of 50 percent +4 percent cotton, with the balance being polyester, and be open end spun, 15/1 +5 percent cotton count blended yarn.

2.6.4.5 Water repellent finishes, such as fluoropolymer stain resistant finishes shall not be applied to the test cloth. The absence of such finishes shall be verified by:

2.6.4.5.1 AATCC-118 Oil Repellency Test (DuPont or 3M version) of each new lot of test cloth (when purchased from the mill) to confirm the absence of Scotchguard or other water repellent finish (required scores of “D” across the board).

2.6.4.5.2 AATCC-79 Drop Absorbency Test of each new lot of test cloth (when purchased from the mill) to confirm the absence of Scotchguard© or other water repellent finish (time to absorb one drop should be on the order of 1 second).

2.6.4.6 The moisture absorption and retention shall be evaluated for each new lot of test cloth by the Standard Extractor Remaining Moisture Content (RMC) Test specified in section 2.6.5.

2.6.4.6.1 Repeat the Standard Extractor RMC Test in section 2.6.5 three times.

2.6.4.6.2 An RMC correction curve shall be calculated as specified in section 2.6.6.

2.6.5 Standard Extractor RMC Test Procedure. The following procedure is used to evaluate the moisture absorption and retention characteristics of a lot of test cloth by measuring the RMC in a standard extractor at a specified set of conditions. Table 2.6.5 is the matrix of test conditions. The 500g requirement will only be used if a clothes washer design can achieve spin speeds in the 500g range. When this matrix is repeated 3 times, a total of 48 extractor RMC test runs are required. For the purpose of the extractor RMC test, the test cloths may be used for up to 60 test runs (after preconditioning as specified in section 2.6.3).

Table 2.6.5 Matrix of Extractor RMC Test Conditions

“g” Force	**Warm Soak**		**Cold Soak**	
	15 min. spin	**4 min. spin**	**15 min. spin**	**4 min. spin**
50				
200				
350				
500				

2.6.5.1 The standard extractor RMC tests shall be run in a Bock Model 215 extractor (having a basket diameter of 19.5 inches, length of 12 inches, and volume of 2.1 ft^3), with a variable speed drive [Bock Engineered Products, P.O. Box 5127, Toledo, OH 43611] or an equivalent extractor with same basket design (i.e. diameter, length, volume, and hole configuration) and variable speed drive.

2.6.5.2 Test Load. Test cloths shall be preconditioned in accordance with 2.6.3. The load size shall be 8.4 lbs., consistent with section 3.8.1.

2.6.5.3 Procedure.

2.6.5.3.1 Record the "bone-dry" weight of the test load (WI).

2.6.5.3.2 Soak the test load for 20 minutes in 10 gallons of soft (< 17 ppm) water. The entire test load shall be submerged. The water temperature shall be 100EF ±5EF.

2.6.5.3.3 Remove the test load and allow water to gravity drain off of the test cloths. Then manually place the test cloths in the basket of the extractor, distributing them evenly by eye. Spin the load at a fixed speed corresponding to the intended centripetal acceleration level (measured in units of the acceleration of gravity, g) ±1 g for the intended time period ±5 seconds.

2.6.5.3.4 Record the weight of the test load immediately after the completion of the extractor spin cycle (WC).

2.6.5.3.5 Calculate the RMC as (WC-WI)/WI.

2.6.5.3.6 The RMC of the test load shall be measured at three (3) g levels: 50g; 200g; and 350g, using two different spin times at each g level: 4 minutes; and 15 minutes. If a clothes washer design can achieve spin speeds in the 500g range than the RMC of the test load shall be measured at four (4) g levels: 50g; 200g; 350g; and 500g, using two different spin times at each g level: 4 minutes; and 15 minutes.

2.6.5.4 Repeat 2.6.5.3 using soft (<17 ppm) water at 60EF ±5EF.

2.6.6 Calculation of RMC correction curve.

2.6.6.1 Average the values of 3 test runs and fill in Table 2.6.5. Perform a linear least-squares fit to relate the standard RMC ($RMC_{standard}$) values (shown in table 2.6.6.1) to the values measured in 2.6.5 (RMC_{cloth}): $RMC_{standard} \sim A * RMC_{cloth} + B$

Where A and B are coefficients of the linear least squares fit.

Table 2.6.6.1 Standard RMC values ($RMC_{standard}$)

G	RMC percent			
	Warm Soak		Cold Soak	
	15 min. spin	4 min. spin	15 min. spin	4 min. spin
50	50.4%	55.7%	52.8%	59.0%
200	35.6%	40.4%	37.9%	43.1%
350	29.6%	33.1%	30.6%	35.8%
500	24.2%	28.7%	25.5%	30.0%

2.6.6.2 Check accuracy of linear least squares fit using the following method:

The root mean square value of:

$$\left| \sum_{i=1}^{12} \frac{\left(RMC_{standard\_i} - RMC_{corr\_i} \right)^2}{10} \right|^{1/2}$$

shall be less than 2 percent, where a sum is taken over all of the different tests, where $\underline{RMC}_{standard\_i}$ is the RMC standard value measured for the I-th test, and $\underline{RMC}_{corr\_i}$ is the corrected RMC value for the I-th cloth test. This equation is valid only for the use with three (3) g force values therefore when using the 500g requirement; replace the 500g value instead of the 350g value.

2.6.7 Application of RMC correction curve.

2.6.7.1 Using the coefficients, A and B calculated in section 2.6.6.1:

RMC_{corr} = A * RMC + B

2.6.7.2 Substitute RMC_{corr} values in calculations in section 3.8.

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4.1.5 * * * * * ER_x, ER_a, ER_n, are reported electrical energy consumption values, in kilowatt-hours per cycle, at maximum, average, and minimum test loads, respectively, for the warm rinse cycle per definitions in section 3.7.2.

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