Instrumental Method for Evaluating Static Control in Laundry[1]

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The most difficult performance attribute to measure when evaluating a fabric softener has been static control. Several instrumental methods have been used in the past, all with limited success. The most frequently used method has been a subjective evaluation by an experienced operator, but this also has obvious shortcomings. The topic method is based on a Faraday Cage. Test swatches are removed from the dryer and placed in an insulated stainless steel tank. As each swatch is removed, a corresponding charge is induced on the tank, which is measured by a high impedence volt meter.

Results indicate that this method: (i) Exhibits very good reproducibility; (ii) differentiates well between types or levels of fabric care products; (iii) demonstrates effects of different static control agents on various fabric types; (iv) correlates well with real-world experience, and (v) is an objective method, minimizing operator bias. In addition, time involved to record and evaluate the data has been minimized with automated data acquisition and tabulation by means of a computer interface.

When evaluating a fabric softener for performance, there are a number of parameters that should be considered. Among these are softness, absorbency (or rewet), whiteness retention, and the topic of this discussion, static control. There are well established methods to evaluate the first three of these characteristics, but quantitative evaluation of static control has been difficult at best.

A number of methods have been used in attempting to measure static electricity on fabric. Perhaps the most common instrumental method has been with the electrostatic meter. This is a device that measures the electric field around a charged object rather than measuring the charge itself.

This method requires multiple measurements on the object (fabric) that must be mounted in a standard fashion and be of a standard shape and size. In a situation such as this, the task of mounting the fabric has inherent discharging possibilities, and the time required for multiple measurements and mounting each fabric separately allows significant charge dissipation and alters the charge profile of the total load. These and other factors make it difficult to obtain reproducible results with this method.

Another method, based on fabric cling, estimates the static charge by measuring the ability of the electrostatic cling to overcome the pull of gravity. This method has the drawbacks of the previous method. In addition, it introduces the weight and flexibility of the fabric as variables in determining the amount of static charge.

Because of the lack of reproducibility and other problems with these instrumental methods, many laboratories have relied on subjective evaluation by an experienced operator as the most reliable method for measuring static charge on fabric. Using this method, the operator removes the fabric from the dryer one swatch at a time and gives each piece a subjective rating on, for example, a 1 to 5 scale, where 1 = no static or cling, and 5 = large amounts of static, crackle and cling. Although this method has been used with relative success and is fairly reproducible, it has the inherent shortcomings of a subjective evaluation, including operator error and limited sensitivity.

The subject of this discussion is a method based on the Faraday Cage. This method allows measurement of the static charge directly under normal use conditions.

The basis for our work was initiated by a Chemical Specialties Manufacturers' Association (CSMA) task force on fabric softener evaluation methods. The method apparently has had limited use in the past. We have adapted the method to meet our testing requirements

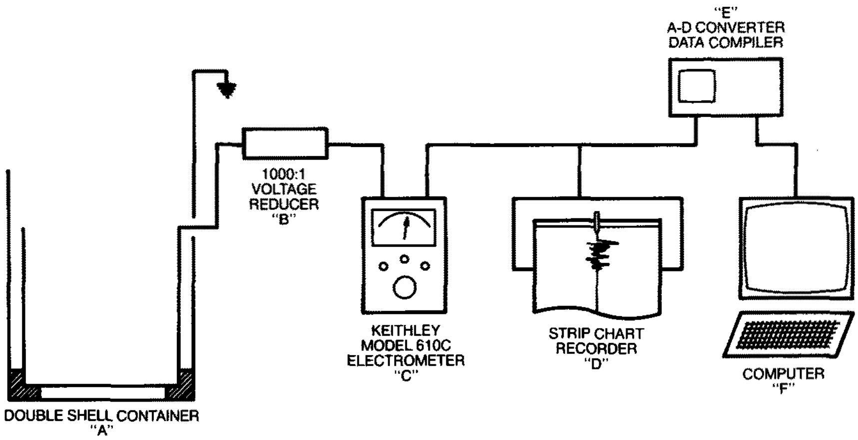

FIG. 1. Faraday Cage static evaluation system.

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[1] Presented at the AOCS meeting in Honolulu, HI in May 1986.

and have added automation and modifications to improve its usefulness significantly. These changes allow us to evaluate multiple formulations in a single test series.

EXPERIMENTAL

Schematically, the equipment for evaluating static charge on a load of fabric is assembled as in Figure 1. The heart of the equipment is the double shell container (A) into which the load of fabric is placed directly after the drying cycle. This container consists of two stainless steel tanks separated by an air space. The inner tank is 21 3/4" in diameter by 12 1/2" high. The outer tank is 23 5/8" in diameter by 24 1/2" high. The spacing at the sides and a one-inch air space at the bottom are maintained by four plastic insulating support blocks. The outer tank is grounded, and a shielded cable passes through a rubber grommet in the outer shell to connect the inner tank to the electronic equipment.

The load of fabric is transferred from the dryer to the inner tank immediately after the drying cycle. During this transfer, some variation in total charge on the load is inevitably introduced. This variable is minimized by (i) removing the load from the dryer as a single bundle as much as possible (i.e., do not separate the fabric pieces before they are placed in the tank), and (ii) transferring the load into a plastic basket with as little operator contact as possible and transferring from the basket to the tank as quickly as possible. The inner tank is then grounded so that the test begins with an electrically neutral load. By taking these steps, we have found that differences introduced in the transfer process are usually negligible.

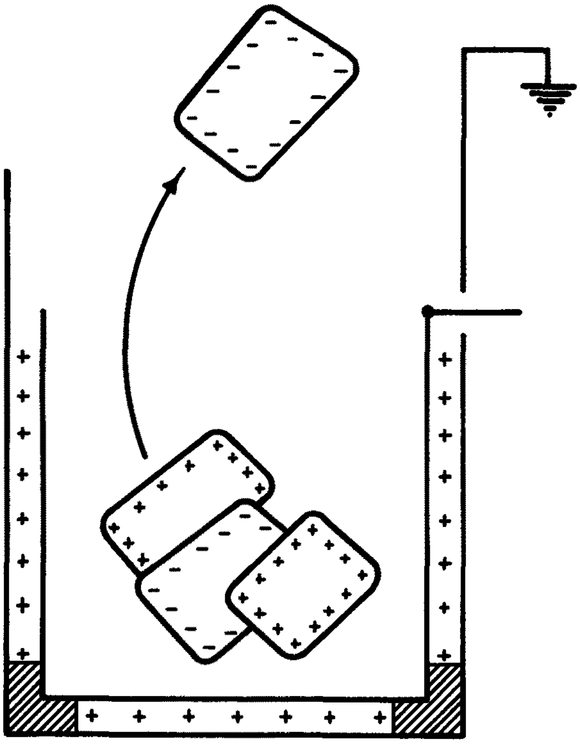

FIG. 2. Charge transfer to the Faraday Cage.

Figure 2 illustrates how the cage works. Wearing latex gloves, the operator removes the fabrics from the tank, one at a time. As a charged fabric is removed from the inner tank, the tank acquires a charge equal and opposite to the charge on the fabric. This charge is measured directly by the instrumentation. The tank is then grounded to drain the charge from the tank, and another swatch is removed. The absolute values of the charges (i.e., disregarding the sign) are added together to give the total charge on the load.

Referring again to Figure 1, the other critical component of the system is the voltmeter (C). The unit we are using is a Keithly Model 610C Electrometer with a 1,000:1 voltage reducer, available from Keithly Instruments, Cleveland, Ohio. The important factor is that this must be a high impedance voltmeter. Although the voltage encountered in static electricity can be very high, there is not sufficient current flow to drive a standard voltmeter. A standard meter would drain the charge off of the tank before it would be able to measure it. A high impedance meter, such as the Keithly 610C, measures the voltage with minimal current flow.

Between the tank and the voltmeter is a 1,000:1 voltage reducer (B). The range of adjustment on the voltmeter allows measurement from .001 to 100 volts. In a high-static situation, a single fabric may be charged with as much as 2,000 volts. The voltage reducer converts this into a voltage range measurable by the meter.

Connected to the voltmeter are a strip chart recorder (D) which traces the voltage peaks from the voltmeter, and an analog to digital converter (E) which we constructed as a custom piece of equipment. This unit converts the analog output from the voltmeter to digital data bits and stores the data along with a code to identify the sample. At the end of a test, these data are transferred to a computer (F) for processing.

Standardized loads are washed and dried under conditions typical for the test products. Each standard load typically contains four 18-inch square pieces of cotton, polyester/cotton, polyester, nylon, and acetate, along with bulk fabric consisting of terrycloth towels and polyester/cotton sheeting. The total load weighs 6-8 lb. The loads are washed and dried in matched sets of typical domestic washers and driers. Usually a warm wash/cold rinse is used with drying for 60 min on a permanent press cycle. The load content and/or washing conditions may vary depending on the objective of the particular test.

When drying is complete, the load is transferred immediately into the Faraday Cage. The static evaluation equipment is contained in an environmentally controlled room so temperature and humidity effects are eliminated as much as possible.

As each swatch is removed from the inner tank, a charge equal and opposite to the charge on the fabric is induced on the tank. This charge is read by the voltmeter and registered on the chart recorder. Immediately after the peak registers on the meter and recorder, the operator keys a code number into the A-D converter. This automatically stores the data in digital form along with the fabric code, and grounds the tank in preparation for removal of the next swatch. The A-D converter/data compiler is a custom built Z8 single board computer which includes a static-proof keyboard and other safety features to prevent damage to its circuitry by a high static build-up in its immediate environment, or on the operator. The unit is programmed to collect the data, categorize it by dryer number and fabric, and communicate the information to another computer for data processing and output in a desirable format.

The A-D converter and computer interface are optional for operation of the Faraday Cage. If anyone desires details on its construction, the author may be contacted at Amway Corp. Eliminating this portion of the equipment would simply require hand tabulation of the height of the peaks generated on the strip chart recorder.

RESULTS

Three basic questions that must be answered with the development of any test method are:

- Are the results reproducible?
- Do the results differentiate between systems where differences would be expected?
- Do the results correlate with real-life experience?

REPRODUCIBILITY

As an indication of reproducibility. Figure 3 illustrates an evaluation of three replicates of dihydrogenated-tallow dimethyl ammonium chloride used at 2.5 g active material/rinse for three successive cycles. The vertical axis is the sum of the absolute values of the voltages recorded for the various fabrics in the load. The three bars represent the static charge contained in each of the three replicates, washed and dried in three separate washers and dryers. Each group of bars is an additional cycle in the test. As well as exhibiting the reproducibility of the test, these results depict the trend of decreasing static charge with each successive application of a rinse-added fabric softener.

DIFFERENTIATION

Figure 4 shows the results from four currently available rinse-added softeners used at manufacturers' recommended use levels over three cycles. These results indicate that product C has the lowest initial static charge, but product B has a more effective build-up of static control agent over three cycles. Product D is the least effective. The first three products here are well known, brand name products, the fourth is a private label softener with a lower use concentration. Considering the type and level of active material, and the recommended use level, these results correlate well with the comparative static control we would expect from past history using these types of products.

Figure 5 compares two liquid and two powder commercially available detergent-softener products. It is evident from these results that a much broader range of performance is seen in this product category. Also note that this type of product does not give the increase static control with each successive cycle as is characteristic of the liquid rinse-added softeners.

Dryer softener sheets are significantly more effective for static control than the other product types (Fig. 6).

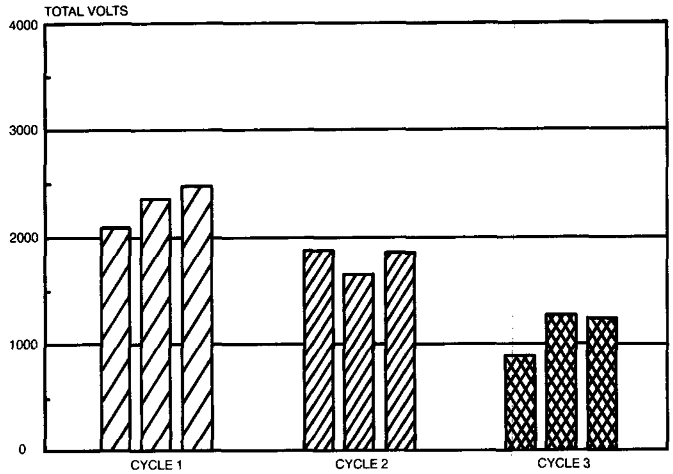

FIG. 3. Reproducibility, three replicates of dihydrogenated-tallow dimethyl ammonium chloride (DHTDMAC).

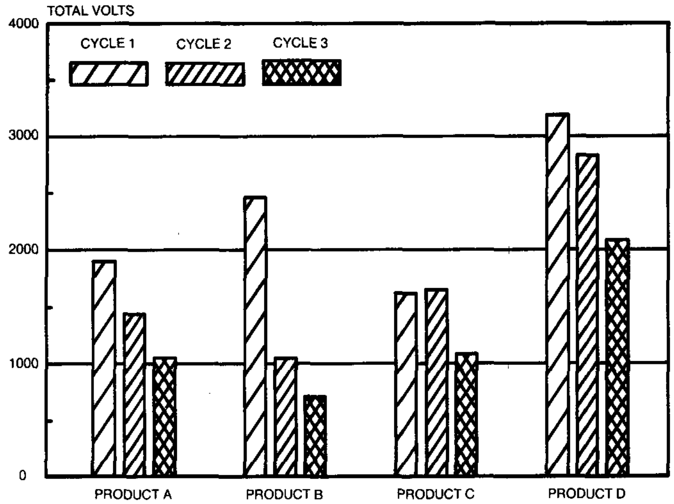

FIG. 4. Liquid rinse-added softeners.

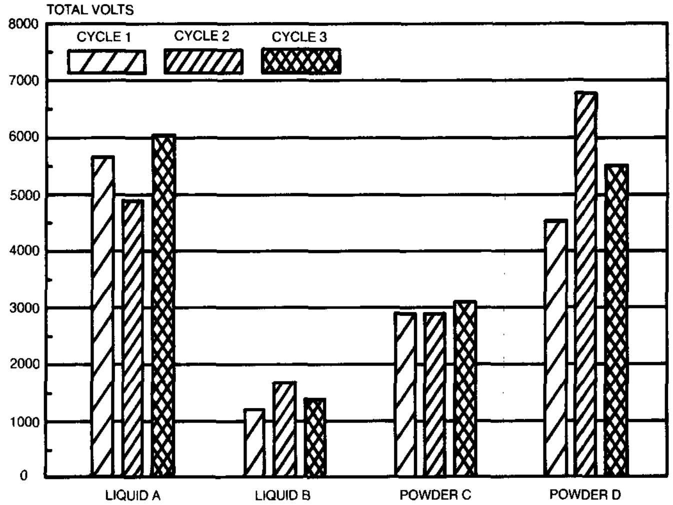

FIG. 5. Combination detergent-softeners.

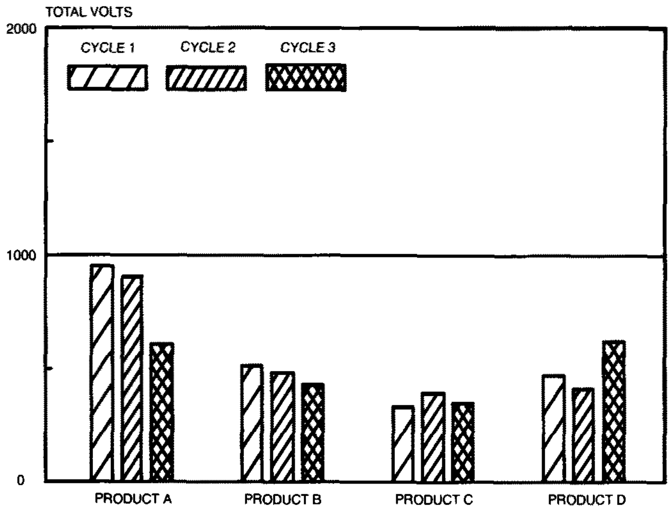

FIG. 6. Dryer softeners.

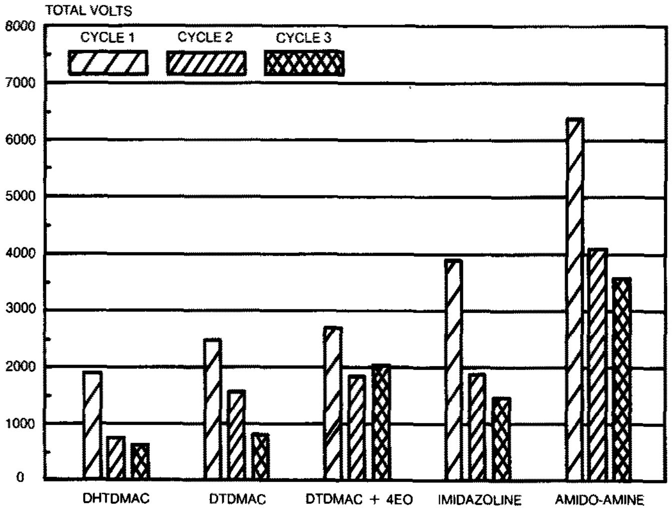

FIG. 7. Various softener actives.

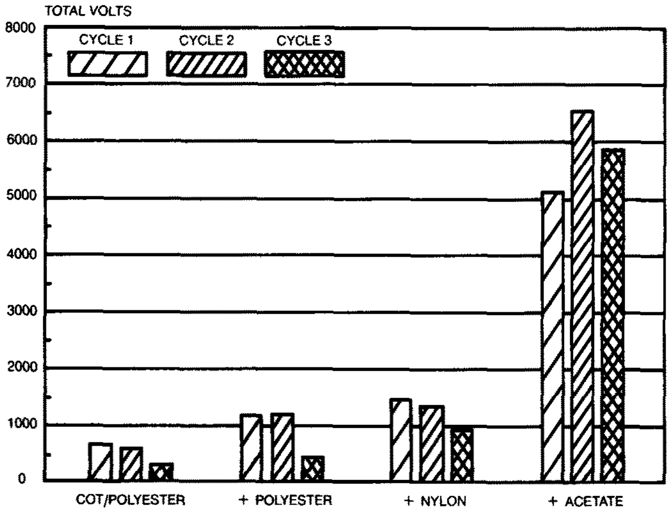

FIG. 8. Fabric effects.

Note that none of these products exceeds 1,000 volts for the load total.

This exceptionally good static control is indicative that (i) the softener is concentrated on the surface of the fabric rather than penetrating into the central fibers; (ii) it is applied during the time that static would be generated, and (iii) it is not dependent on chemical exhaustion from a water solution. Note that static control build-up with each cycle is also not as apparent with dryer softeners as with rinse-added softeners.

Figure 7 depicts the performance of rinse-added fabric softeners based on various types of cationic softener actives. The products tested were dihydrogenated-tallow dimethyl ammonium chloride (DHTDMAC), ditallow dimethyl ammonium chloride (DTDMAC), ditallow dimethyl ammonium chloride with four moles of ethylene oxide substituted at the methyl positions (DTDMAC+4EO), a ditallow imidazoline quaternary, and a ditallow amido-amine quaternary. These materials were all tested at 2.5 g active/rinse for three successive cycles. The results indicate that the DHTDMAC provides the best static control. Some theories would predict that unsaturation (i.e., introduction of double bonds in the alkyl group as in the DTDMAC), or the addition of ethylene oxide (DTDMAC+4EO) should improve static control, but these results would indicate otherwise. The imidazoline and amido-amine softeners are characteristically poorer in static control, as we would have expected from previous experience.

Also of particular interest were the results with the introduction of various fabrics to the wash load using a rinse added softener. Figure 8 shows the effect on static charge due to the addition of various synthetic fabrics to the load. The first three bars represent three cycles using DHTDMAC in a load that contains only cotton and cotton-polyester blends. The next set shows somewhat increased static with the addition of 100% polyester to the load. The next set adds nylon along with the polyester, and the last set adds acetate as well as the other two synthetics. It is obvious that acetate adds significantly to the static build-up in the load. This is, perhaps, because the acetate fiber is essentially nonionic in character, and therefore has little affinity for the charged softener molecule out of water solution.

In comparison, a similar test with dryer-added softeners showed very little difference when acetate was added to the load. This is evidence of the difference between application by chemical affinity in the rinse cycle and the "melting process" application in the dryer.

CORRELATION WITH "REAL-WORLD" EXPERIENCE

In order to demonstrate correlation between the Faraday Cage method and what the consumer might see, we evaluated several commercially available formulations both subjectively and instrumentally. The bars in Figure 9 represent the range of results seen over several cycles with multiple products in each category. The first bar in each pair represents the instrumental values using the Faraday Cage, and the second bar represents the subjective values generated by two experienced operators for the same products. For example, for the detergent/softeners that were evaluated in these tests values ranged from 3,700 volts to 9,300 volts, while by sub-

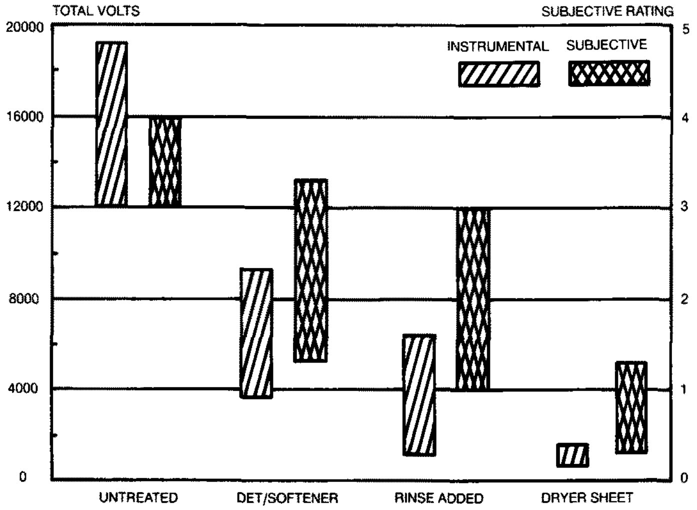

FIG. 9. Subjective vs instrumental comparison of methods.

jective evaluation these formulations gave results ranging from 1.3 to 3.3 on a 0 to 5 rating scale.

Obviously, the placement of the voltage scale (left side) and subjective scale (right side) in relationship to each other is a judgment call. Although there is not a one-to-one relationship of subjective to instrumental ratings, it is still apparent that similar patterns of performance are achieved with both methods.

The Faraday Cage has allowed us to substitute an objective, instrumental method of evaluating static control for an operator dependent, subjective method. This has improved accuracy, reproducibility and method sensitivity. As with most evaluations, it is preferable to attach an objective value to a result rather than a "good-fair-poor" description. The Faraday Cage has provided this capability for measuring static control in laundry applications.

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