A Quantitive Estimation of Detergency

By O. M. MORGAN

Development of Method

IN THE estimation of the detergent properties of soaps and alkalis, two methods have been chiefly resorted to. The one which has received the greatest attention has been the correlation of the physical properties of these products in solution with the washing efficiency. Surface and interfacial tensions, viscosities, lathering powers, etc., have been investigated as well as the emulsifying and suspending properties of these solutions with respect to some finely divided material, such as carbon black, lamp black, etc. The other mode of attack has been a direct method involving the washing of standardly soiled or stained pieces of cloth followed by measurements of brightness or color of the washed articles, either by instrument or by eye.

In the present work it was decided to use the latter method—as it was desired to obtain results which would be of most value to the laundry industry.

Considerable time was spent upon the preparation of standardly soiled cloth which would have a sufficiently sensitive reaction to both the chemical and mechanical treatments as met with in the laundry wash wheel. The development of this method has been reported in detail in the Canadian Journal of Research, 6:292-305, 1932. At present it will only be dealt with briefly.

Standardly soiled cloth was prepared using a mixture of lamp black, Nujol, Russian tallow with a carbon tetrachloride vehicle. This mixture was applied to the cloth by passing it through rubber covered rollers under pressure, this being maintained the same from one batch to the other. A laboratory wash wheel illustrated in Fig. No. 1 was built and in this small machine our preliminary

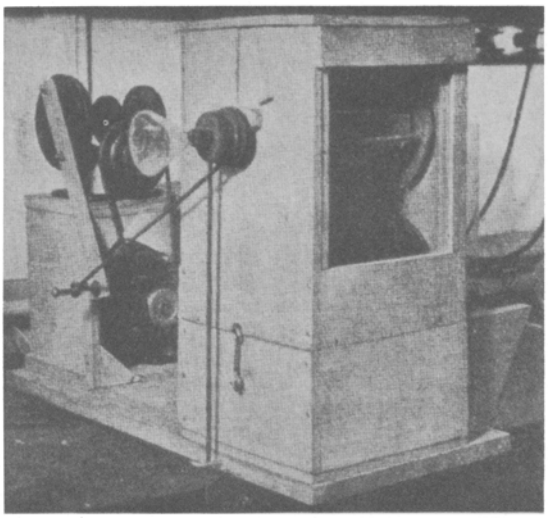


Fig. 1

tests were carried out. The soiled cloth was sewed up into bags 10x10 cm. and weighted with 100 gms. of glass beads to give the fabric a drop-back. Five hundred cc. of washing solution was used for each wash. Under these conditions the fabric-liquid ratio is not the same as in power laundry practice, but the quantities were maintained constant throughout our entire series of experiments. Since we were only interested in relative measurements at this time, this procedure is quite legitimate.

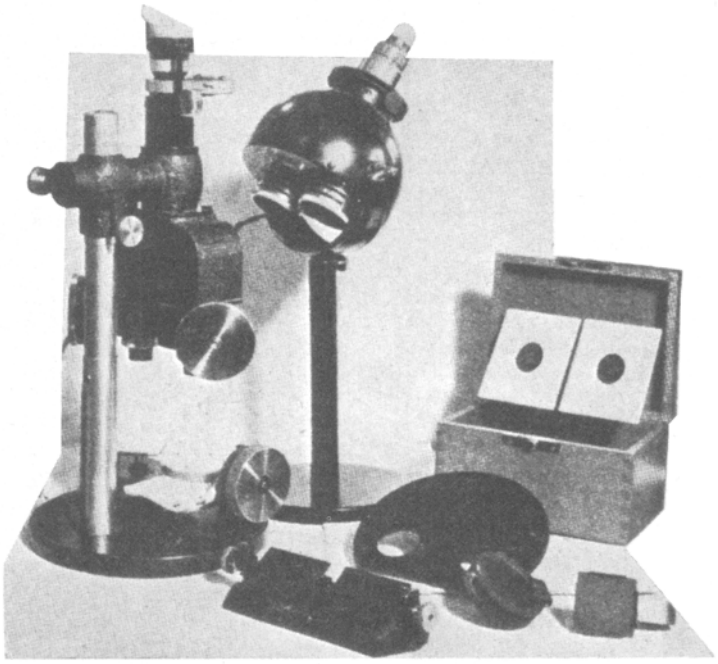


Fig. 2.

Fig. No. 2 shows the Zeiss Pulfrich Photometer which was used for brightness measurements which were made after each wash. In calibrating this soil, the time of washing, temperature, soap concentration and rates of agitation were varied over a wide range.

Fig. No. 3 gives a picture of the time-period effect at three different temperatures. It will be noted that in each case little is to be gained by exceeding a ten minute washing period.

Fig. No. 4 illustrates the effect of temperature experiments having been conducted at five temperatures between 25° and 75° C. It will be noted that at 50° C.

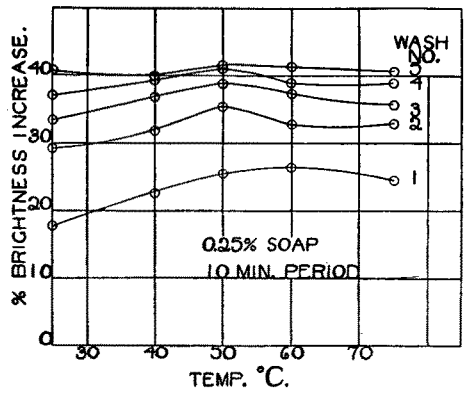
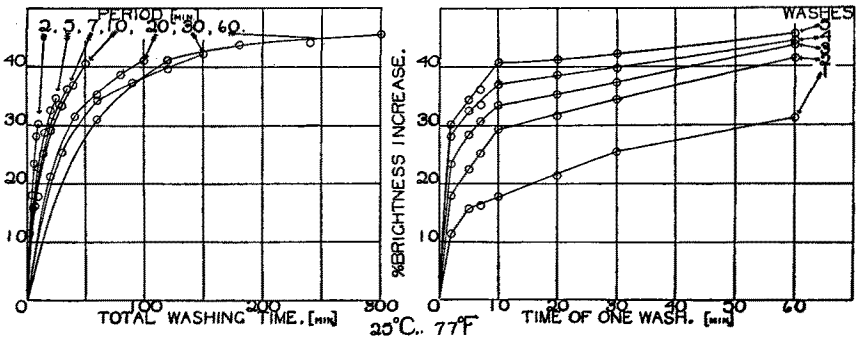


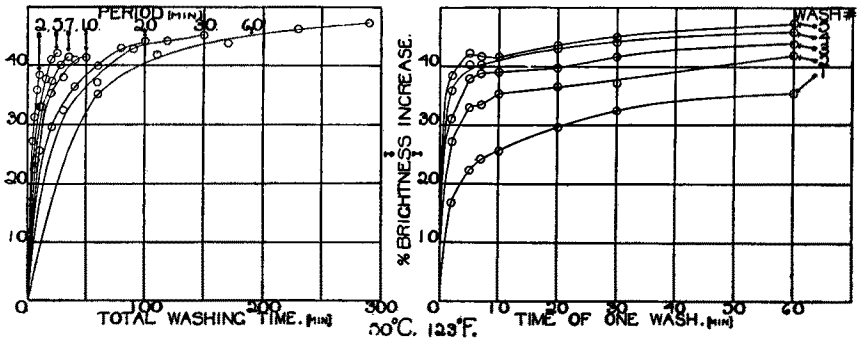
FIG. *Effect of temperature; 25°, 40°, 50°, 60°, 75°C.*

Fig. 4

there is quite a decided maximum, where the increase in brightness is plotted against temperature. This does not necessarily mean that 50° C. is the optimum temperature for plant practice, but merely shows that the soiled fabric is sensitive to temperature.



Time period effect, 25°C.



Time period effect, 50°C.

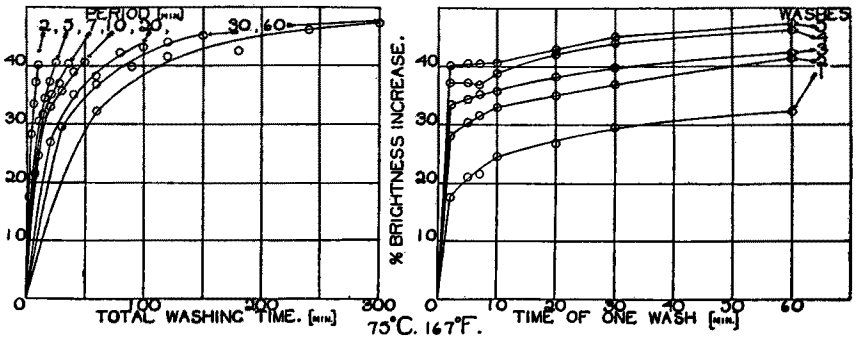


Fig. 3

Fig. No. 5 shows brightness increase plotted against total washing time in minutes for several soap concentrations. It will be noted that above 0.2% concentration of soap there is very little increase in the detergent efficiency. The greatest increase in efficiency is expressed up to 0.10% concentration.

Fig. No. 6 shows that the soil is sensitive to mechanical agitation. The dotted curves represent washing results in which the wash wheel was not reversed. The complete curves which lie considerably higher than the dotted curves are for experiments in which the wash wheel was reversed. The washing on the average was

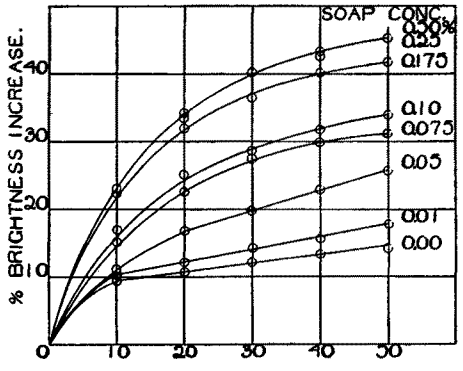


Fig. 5

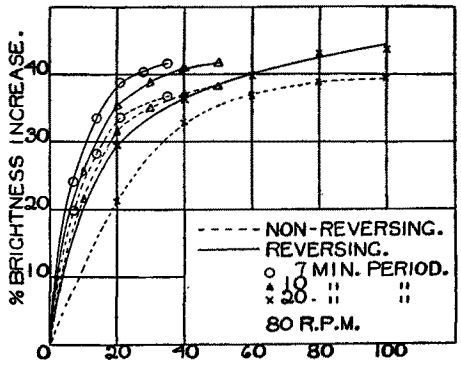


Fig. 6—Total Washing Time

12.5% more efficient when the machine was reversed every 2.75 revolutions.

By the foregoing it was shown that the standardly soiled cloth was sufficiently sensitive to show up differences in washing procedure.

A Laboratory Comparison of Laundry Soap Builders

To continue this work, a comparison of the detergent efficiencies of several common laundry soap builders was made on laboratory scale, utilizing in the main the same technique as previously described. In this work the soap concentration was maintained constant at 0.10%, which is nearly comparable with that found in plant practice. The concentration of builders used was varied over a wide range involving a spread of pH values of from 10.2 to in some cases 12.2. The time of washing was 10 minutes, followed by two one-minute rinses and the temperature was maintained constant at 50° C. Photometric readings were taken after each wash and differences in detergent efficiency were found to exist. These are illustrated in Fig. No. 7, where concentration is plotted against increasing efficiency. The efficiency was calculated according to the method previously used by Rhodes and Bascom.

$$E = \frac{100(B-S)}{S}$$ where B—

the increase of brightness of the soiled cloth after five washes with 0.10% soap solution to which builders have been added. S equals the increase in brightness of the soiled cloth after five washes with 0.1% neutral soap. This mode of calculation gives neutral soap an E value of zero.

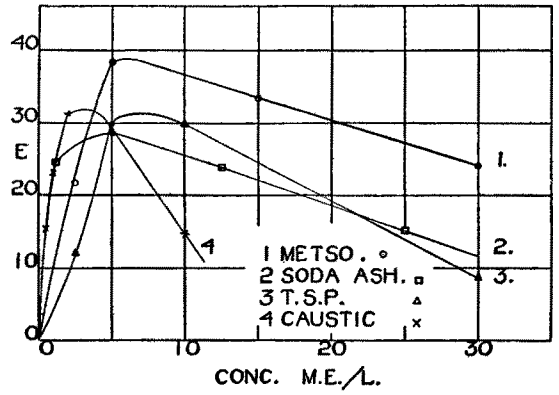


Fig. 7

It will be noted from Fig. No. 7 that sodium metasilicate was the most efficient detergent in this work. This was followed in order by caustic soda, trisodium phosphate and soda ash. It will be noted also that for soda ash the peak at which the maximum detergent efficiency exists is not as clearly defined as for the other three alkalis. This will be referred to again.

In each case, except that of caustic soda, it will be noted that maximum detergent efficiency was attained at a concentration of approximately 5 milli-equivalents per liter. For caustic soda the peak was attained at about 2.5 milli-equivalents per liter, due to its high available alkalinity. It might also be stated here that the pH values for maximum efficiency were not constant as previously stated by other investigators.

A Power Laundry Comparison of Soap Builders

Having found that on laboratory scale, differences in detergent efficiencey did exist from one builder to another, it was decided to extend the work to plant scale experiments. Test bundles were made up with pieces of our standardly soiled cloth sewed onto a piece of towel, the latter being to check tensile strength losses and loading, if any, of the fabrics. The test towelling had a thread count of 60x42 and the tensile strength in the filling of 81 lbs. per inch.

Two wash wheels were used with Monel metal cylinders and shells and wooden ends. The dimensions of these wash wheels were 42x84 ins., with four longitudinal ribs 7 inches in height. The washing formula used was the recognized multiple suds formula with four suds and six rinses. The maximum sudsing temperature being 170° F.

CONCENTRATION OF BUILDER IN WEIGHT %

Conc. No.	Soda Ash	Trisodium Phosphate	Modified Soda	Sodium Meta-silicate	Caustic Soda
1	0.013	0.03	0.01	0.026	0.004
2	0.026	0.06	0.05	0.052	0.008
3	0.053	0.12	0.10	0.104	0.020
4	0.106	0.24	0.20	0.208	0.040

Note.—At Concentration No. 2 the most efficient washing was effected in each case.

A 5% neutral soap stock was prepared from a high quality 97% commercial soap and was added to the wheel in measured quantities. The amount of alkali necessary was calculated as a percentage of the weight of water in the wheel. This was weighed into bottles and added dry, except in the case of caustic soda, which was added

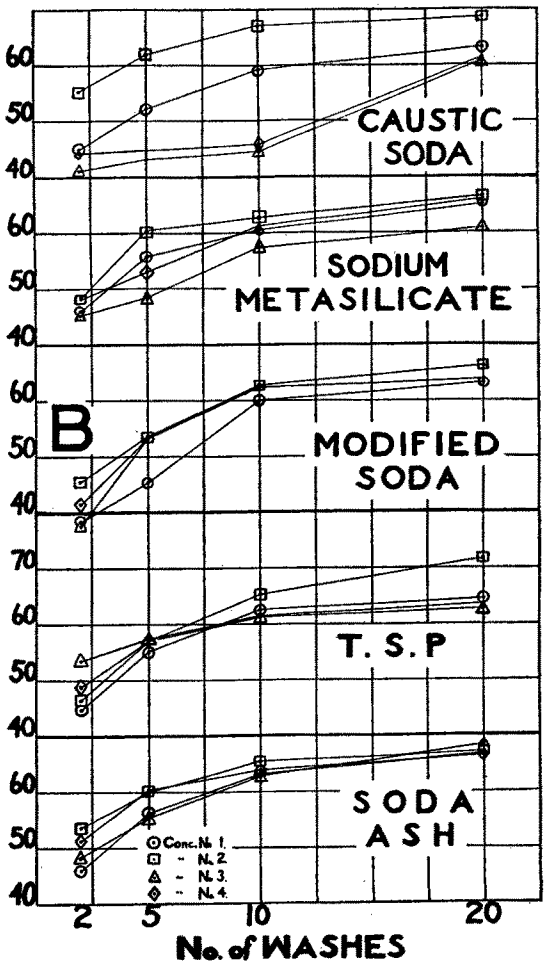


Fig. 8

in liquid form. Two quarts of sodium hypochlorite bleach carrying 1% available chlorine per 100 lbs. clothes was added in the fourth operation.

The off wash liquors from each operation in five consecutive washes were titrated against 0.1 N nitric acid using both methyl orange and phenolphthalein as indicators. pH determinations were also made using a Taylor long range slide comparator. This instrument was previously checked against electrometric pH measurements on buffer solutions covering the laundry pH range. In this way a careful check was kept on the uniformity of the washing. Data were also obtained on the free rinsing qualities of the various builders and were further substantiated by subsequent ash determinations on the test pieces. This will be discussed in a later section.

After 2, 5, 10 and 20 washes photometric measurements were conducted on the standardly soiled strips using a Zeiss Pulfrich photometer. The increase in brightness of the fabrics is considered as the criterion of washing efficiency.

After the completion of 20 washes tensile strength measurements were made using an Alfred Suter tensile strength machine having breaking ranges of 0-150 and 0-300 lb. Tensile strength losses are given in a later section.

In Fig. No. 8 the increase in brightness of the standardly soiled fabric is plotted against the number of washes for the five alkalies investigated. It will be noted that in each case alkali concentration No. 2 is definitely more efficient than the other concentrations used. In the case of trisodium phosphate concentration No. 2 leads the field after 10 and 20 washes which is quite definite proof of its superiority. In the case of soda ash the differences in efficiency are not so pronounced from one concentration to another. Repeated experiments gave similar results. However, at the end of 2, 5 and 10 washes concentration No. 2 showed a slight superiority. While showing Fig. No. 7 it was mentioned that the efficiency peak for soda ash was not as clearly pronounced as for the other builders used. This is borne out again here. It will also be noted that caustic soda, which showed the sharpest peak in Slide No. 7 here shows the most definite efficiency differences from one concentration to another. It is for this reason that when washing with caustic soda very careful chemical control must be exerted in the washroom.

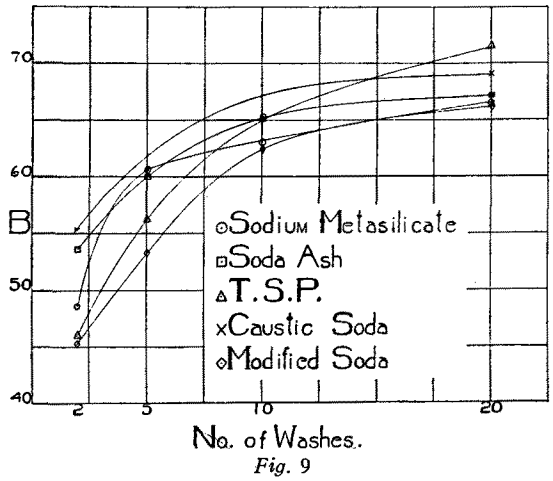


Fig. 9

In Fig. No. 9 increasing brightness is again plotted against number of washes and the curves of concentration No. 2 for each of the five alkalies are compared for relative efficiency. It will be noted that smooth and nearly parallel curves exist for caustic soda, soda ash and modified soda, falling in the foregoing order of decreasing efficiency. The curves for trisodium phophate and sodium metasilicate intersect at certain points. This makes exact comparison uncertain on some aspects of the case. The broad conclusions regarding these builders are however unaffected.

At this point the following question may be raised: "After how many washes is it practical to make efficiency comparisons when the comparisons are based on test bundle results?" From the experience gained in this work it has been found that after 2 or 5 washes the results are based to too great an extent on the idiosyncrasies of the individual washes. After 5 washes individual factors begin to disappear and more definite conclusions may be drawn from the 10- and 20-wash data.

After visiting approximately 100 laundries both in Canada and the United States the writer has been impressed by the fact that equally good grades of finished laundered fabrics are being turned out with various combinations of supplies, provided that certain important features of technique are observed. These may be summarized as follows:

(a) The maintenance of a high suds on the "break" operation.

(b) The maintenance of a good running suds on the succeeding sudsing operations. Poor quality work is often the result of allowing a suds to fall before the operation is complete.

(c) The maintenance and proper use of a stock soap solution that is properly blended with respect to soap and alkali.

(d) Careful temperature control and adequate rinsing facilitated by an ample hot water supply is very important. Water of zero hardness should be used.

In Fig. No. 9 where optimum conditions of the five alkalies are compared it will be noted that after 10 and 20 washes the difference in efficiencies is not very pronounced, nor did the quality of the actual washing in the plant itself vary to any marked extent. Hence comparisons of the efficiencies of these builders cannot be logically made from a quality standpoint. The proper concentrations of builder to be used must be stressed. A comparison of these concentrations combined with the amount of soap necessary to produce effective washing gives the clearest picture of the situation.

Considering for the moment only actual washing efficiency with a given fixed concentration of soap and optimum conditions as regards concentration of builder, an equal efficiency figure will be ascribed to each builder. Let it be the average brightness figure for 10 washes, which approximates 65.

The most simple method of comparing the efficiency data for these five alkalis is by means of Fig. 10. In the first column the five builders, namely, caustic soda, soda ash, sodium metasilicate, trisodium phosphate and modified soda are listed. In the next column the builder concentrations in percent at which maximum efficiency was obtained are given. Following that are the weights of alkali used in the break and suds operation. These are calculated on the weight of water in the wheel and since a 5 inch level was used on the break and a 4 inch level on the suds, the additions to the suds baths are smaller. We have been criticized for adding the same amount of alkali to all our suds baths. However, our point in doing so was to be able to make comparisons more readily. These comparisons would be made more difficult if varying amounts of builders were added to each of the 4 baths, i.e., it would be harded to make concentration comparisons. The fifth column gives the

COMPARISON OF SEVERAL SOAP BUILDERS

Size of Washer.....42 x 84 inches
Water Level .....Break 5 inches
Suds 4 inches
Weight of Load.....225 pounds

Builder	Builder Conc. (%)	Weight of Builder Break, Lbs.	Weight of Builder Suds	Soap Used, Lbs.	Alkali Efficiency Index	Pound Efficiency Index
Caustic Soda	0.008	0.10	0.09	2.6	8125	1.0
Soda Ash	0.026	0.30	0.25	4.0	2500	3.2
Sodium Metasilicate	0.052	0.62	0.55	3.4	1250	6.5
Trisodium Phosphate	0.06	0.72	0.60	4.0	1083	7.5
Modified Soda	0.05	0.60	0.55	4.2	1300	6.2

amount of soap used in pounds to wash 225 lbs. clothes. It will be noted that soap consumption is considerably reduced by the use of sodium metasilicate or caustic soda. The alkali efficiency index is given in column No. 7 and is obtained by dividing the arbitrary efficiency value of 65 by the alkali concentration. It will be noted that in order of decreasing efficiency the alkalis fall as follows: caustic soda, soda ash, modified soda, sodium metasilicate, trisodium phosphate.

In Column No. 7 this is expressed in a different manner where pound efficiency indices are given. The number of pounds for other builders that will do the same work as one pound of caustic soda are listed.

Discussion of Results

The pH values at which maximum detergent effects were noted varied considerably. For soda ash, trisodium phosphate and modified soda the maximum pH values obtained during the sudsing operations were 10.1-10.2. Sodium metasilicate gave optimum results at a pH value of 10.8 and caustic soda at 10.6. These values are all lower than those obtained in the laboratory and are at variance with the laboratory results of Rhodes and Bascom. The lowering of the pH values may be attributed to the residual acidity in the soiled fabrics as well as a slight hardness in the water used.

It is sufficient to say that no trouble was experienced in rinsing out any of the alkalis used in this work. Titration data combined with ash determinations on the fabrics after 20 washes conclusively proved this point. When a multiple rinse formula is used and an adequate supply of hot water is available no fears in this direction need be entertained.

The test fabrics used in these experiments showed quite normal tensile strength losses after 20 washes in the majority of cases. The results are given in the following table:

The loss of 12.2% incurred with the use of sodium metasilicate is questionable. Other laundries using sodium metasilicate report tensile strength losses in the region of 10.5%. So many other factors blend to give the tensile strength loss that the builder alone cannot be held responsible.

The efficiency indices of the alkalies presented in Fig. No. 10 agree remarkably well with those obtained in previous laboratory tests. The same order of efficiency was obtained. In the laboratory tests modified soda was not included. This product is third in the order of decreasing efficiency.

It is quite well realized that this work has its limitations and may be criticized from many angles. The work has been carried out in a single laundry under one set of conditions as regards temperature, soil on the clothes, water, etc. Only one type of standardly soiled cloth has been used. One is dependent to a certain extent upon reliable co-operation with the washman but in this respect we were rather fortunate in having dependable men to assist us. Another difficulty arises in the fact that the test bundle may occasionally come in contact with stains. Wherever this was noted the test bundles were rejected. Since the work is of a comparative nature many of the annoying factors mentioned above will cancel out, giving more weight to the general nature of the results. It is not claimed that the results obtained are the last words in this connection. It is felt, however, that a decided step forward has been made in the study of the actual laundry performance of the many soap builders.

TENSILE STRENGTH LOSSES

Alkali	Soda Ash	Trisodium Phosphate	Modified Soda	Sodium Metasilicate	Caustic Soda
Tensile strength loss, %	10.7	8.0	8.5	12.2	11.4

Discussion of Paper

Dr. Barbour inquired how closely it had been possible to duplicate brightness determinations.

Mr. Morgan replied that after three months' experimenting, he was able to standardize his procedure so that after 5 washings he could check his brightness determinations to 1% or better on the photometer.

Dr. Barbour inquired if the soil could be duplicated on different kinds of cloth.

Mr. Morgan stated a cloth of 65/84 thread count was used. If a cloth of different thread count were used, he expressed doubt as to the possibility of duplicating the soil exactly.

Mr. Long inquired if by "alkali" he meant "total alkali."

Mr. Morgan replied in the affirmative.

Mr. Richardson asked if he attributed much significance to the differences of soda and metasilicate on his efficiency curve.

Mr. Morgan commented that his efficiency curve extended from 38 to 28. In laboratory experiments metasilicate appeared most efficient of the builders and soda least efficient, but in plant practice the reverse was true.

Mr. Richardson inquired if this could be due to experimental error in the laboratory trials.

Mr. Morgan replied that the laboratory experiments had been repeated and checked.

Mr. Hoyt asked if the soil was aged.

Mr. Morgan replied that it was aged for a month. At first ordinary tallow and lubricating oil had been used, but later he changed to Russian tallow and Nujol, as these latter did not become rancid.