THE STABILITY TO LAUNDERING OF DURABLE WATER REPELLENTS

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THE STABILITY TO LAUNDERING

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THE STABILITY TO LAUNDERING OF DURABLE WATER REPELLENTS

INTRODUCTION

The problem of the stability to laundering of durable water repellents was suggested by Dr. J.Fred Oesterling of the United States Army Philadelphia Quartermaster Depot. The Army Quartermasters Corps purchases large quantities of cloth treated with durable water repellents, such as Zelan, Norane and Permel. However, reports from the field indicated that after laundering, the garments made from these fabrics require re-treating with a non-durable water repellent to restore adequate water repellency. The non-durability of the so-called "durable" water repellents therefore creates a number of problems. The Army is interested in finding out what effect the various factors in laundering, such as water hardness, type of detergent, use of alkali, adquacy or inadequacy of rinsing, have on the water repellency of these fabrics.

The terms "waterproof" and "water repellent" have recently been redefined to refer to definite finishes and fabrics. The term "waterproof" in regard to fabric means that the cloth is impermeable to both air and water. This is accomplished by closing the interstices of the fabric with a substance such as rubber or oil. The term "water repellent" denotes a fabric which has been so treated that it will repel water but allow air to pass through the interstices of the cloth. The Army is interested in knowing more about the washing characteristics of the latter, or water repellent type.

It is the purpose of this paper to determine the effect of various detergents, hardness, alkali, mechanical action, and number of washings on the stability of durable water repellent finishes.

Method of Attack.— In this study, fabrics treated with two representative durable water repellents, Permel and Zelan, were submitted to all tests. The Permel finish is an aqueous resin dispersion; the Zelan finish is a quaternary ammonium compound of high molecular weight. Army oxford cloth treated with Permel was obtained from the Pepperell Manufacturing Company of Pepperell, Alabama, and the same cloth treated with Zelan was obtained from the Lanett Bleachery and Dye Works of Lanett, Alabama.

Cloth samples treated with both types of water repellents were washed throughout the experiments in an automatic washing machine and a Smith-Drum hosiery dyeing machine. These two machines were used to determine the effect of mechanical action on the water repellents. The Smith-Drum hosiery dyeing machine washed with a very gentle motion and little mechanical action; the automatic washed gave the cloth much mechanical action.

In order to determine the effect of various types of detergents, two anionic detergents and a nonionic detergent were used. The anionic types were soap and Igepon T (sodium sulfonate salt of oleyl methyl tauride), a synthetic detergent. The nonionic type was Triton X-100 (alkylarypolyether alcohol). A procedure of first washing with the detergent alone, and then the detergent with various degrees of hardness was used to determine the effect of hardness on the water repellents. The effect of changes in the pH of the detergents solutions on both water repellents was also investigated.

Washings were repeated in each machine until a definite breakdown (American Association of Textile Chemists and Colourists spray rating of 50) of the water repellent occurred. Tests for water repellency were made after washings by the A.A.T.C.C. spray, immersion and penetration tests. (1) (2)

Review of the Literature. — There are very few references in the literature concerning the effect of washing on the durable water repellents. However, much material is available describing various methods of testing the water repellency of cloth.

When Zelan A was first introduced in 1939, Slowinske (3) ran a series of washing tests to show the durable characteristic of Zelan A as opposed to the non-durable wax aluminum type. Spray, immersion, hydrostatic and spot tests were used. Mandikos (4) in 1940 studied the importance of having standard conditions when testing water repellent fabrics by the spray, immersion and penetration tests. He concluded that standard conditions were necessary only for the immersion test. He further concluded that mechanical action alone was probably sufficient to lower spray test ratings after laundering.

EQUIPMENT

Washing

Smith-Drum Rotary Hosiery Dyeing Machine, Model 12-RD, 15 pound capacity.

American Merchandise Corporation Automatic Washing Machine, 9 pound capacity, model A149EP.

Testing

Impact penetration tester.

A. A. T. C. C. spray tester.

Laboratory padder.

Immersion tank.

General Electric Automatic Iron, 4½ pounds, model 119F32.

Beckmann pH Meter.

MATERIALS

Cloth

1. Wind-resistant, oxford cotton cloth, military specification MIL-C-484A (5), type I —6.5 ounce (treated with Zelan water repellent).
2. Wind-resistant, oxford cotton cloth, military specification MIL-C-484A (5), type I —6.5 ounce (treated with Permel water repellent).
3. White cotton muslin sheeting (ballast cloth).

Detergents

1. Arctic Crystal Soap Flakes, 88% real soap, 42^{0} titer (chipped soap, federal specification P-S-566b) (6).
2. Igepon T Gel, 16% Igepon T (sodium sulfonate salt of oleyl methyl tauride).
3. Triton X-100, 100% Triton NE (alkylarylpolyether alcohol).

White A. A. T. C. C. Textile Blotting Paper.

Erusto Special Salts (sodium acid and silico flouride salts).

Calcium Chloride.

Trisodium Phosphate.

Sodium Carbonate.

Adjusted Calgon Flakes (sodium hexametaphosphate).

Calcium Oxalate.

EXPERIMENTAL PROCEDURE

Washing

Mechanical Action.— Oxford cloth samples treated with Permel and Zelan water repellents were washed in both an automatic home laundry machine and a hosiery dyeing machine. The automatic machine washed with great mechanical action, and the hosiery dyeing machine washed with little mechanical action.

Automatic Washing.— The AMC automatic washing machine used was of the center agitator type. During operation the agitator, consisting of three fins located 120° apart, reversed its direction every 1/3 revolution, with 64 reversals per minute. The bowl of the machine revolved in a horizontal plane. The water was extracted at the top of the bowl instead of through the sides as in other automatic machines. The filling of the machine was not part of the automatic cycle.

Cloth samples treated with Zelan and Permel were sewed between ballast cloth and entered into the machine. Ballast cloth was added to make up a normal load of 6½ pounds for the machine. The machine was next filled with 11 gallons of water at 130° F., then the dissolved detergent was added. The following laundering procedure was employed:

24 minutes - wash with detergent (agitator in motion).
3 minutes - extraction.
30 seconds - hot spray rinse (while extracting).
4 minutes - filling and overflow cold rinse.

2½ minutes - agitator in motion with entering water.

30 seconds - agitator in motion without entering water.

5 minutes - final extraction.

Smith-Drum Washing.— The Smith-Drum hosiery dyeing machine used was the small laboratory model. It consisted of a perforated steel cyclinder which revolved in a vertical plane in a stainless steel tank. The cyclinder was divided into four compartments separated by perforated stainless steel partitions. Its speed was 8 revolutions per minute with a reversal every 2½ revolutions. In all the washings 23 gallons of solution was employed.

Cloth samples treated with Permel and Zelan and enough ballast cloth to make up a load of 6½ pounds were put in the machine. The detergent was dissolved and added to the water. The cyclinder was then set in motion for a 24 minutes wash (12 minutes at 100° F.), (12 mimutes at 140° F.). At the end of the wash, the tank was drained and the samples submitted to four 5 minute rinses. The first rinse was at 140° F., the second at 120° F., and the last two at 100° F. At the first 100° F. rinse, 5 grams of Special Erusto Salts (laundry sour) were added. At the end of each rinse, the machine was stopped, drained and refilled with water. The temperature of the water was adjusted before starting the cyclinder. This procedure, except for times involved, is the same as the Army Mobile Wash Test. (7)

Drying.—After washing, the samples were dried and cured with a household

iron the temperature of which was maintained at a temperature of approximately 490 F.

Rinsing.— To determine if there was adequate rinsing in the Smith-Drum machine, a special rinse was given fabrics after their breakdown. This rinse consisted of putting the fabrics through the complete automatic machine cycle with water alone.

Detergents and Hardness. — Cloth samples treated with both types of water repellents were washed with anionic detergents (soap and synthetic) and nonionic detergents to determine their effect on the finished. Various degrees of hardness were added along with the detergents to determine if hardness would have a detrimental effect upon the stability of the water repellents. When hardness decreased the effectiveness of soap by forming isoluble calcium soap, additional soap was added to maintain the original soap concentration. The amount of excess soap necessary was determined by the method described in Whittaker and Wilcock. (8) Washes were made with Calgon and hardness, and with calcium oxalate (precipitated hardness) to determine the effect of hardness in these forms on the water repellents. A wash with water alone was also made. The procedure and formulas used were as follows:

1. Water alone.
2. 1½% Arctic Crystal Soap.
3. 1½% Arctic Crystal Soap, .1% hardness as $CaCl_2$.
4. 1½% Arctic Crystal Soap, .3% hardness as $CaCl_2$.

5. 1½% Arctic Crystal Soap, .1% hardness as $CaCl_2$ with enough Calgon to react with Ca^{+2} and prevent formation of an insoluble soap.
6. 1½% Arctic Crystal Soap, .1% hardness as CaC_2O_4.
7. 1/3% Igepon T.
8. 1/3% Igepon T, .1% hardness as $CaCl_2$.
9. 1/3% Igepon T, .3% hardness as $CaCl_2$.
10. ½% Triton X-100.
11. ½% Triton X-100, .1% hardness as $CaCl_2$.
12. ½% Triton X-100, .3% hardness as $CaCl_2$.

All percentages are based on the total weight of the samples and ballast in each machine. The total hardness as $CaCO_3$ in the automatic machine was 83.5 ppm for the .1% as $CaCl_2$ and 265.0 ppm for the $CaCl_2$; in the Smith-Drum it was 50.3 ppm for the .1% as $CaCl_2$ and 111.0 ppm for the .3% as $CaCl_2$. Both Zelan-treated and Permel-treated samples were washed in both machines with all combinations of detergents and hardness listed above. Washings were stopped when there was an average spray rating of 50.

In order to determine the effect of alkali on the Zelan and Permel finishes the following procedures were used:

1. 1½% Arctic Crystal Soap, ½% $NaCO_3$ (automatic machine only)
2. 1½% Arctic Crystal Soap, 1/3% Na_3PO_4 (automatic machine only)

All percentages are based on the total weight of the samples and ballast in each machine.

Testing

Spray Test. — All samples were submitted to the A.A.T.C.C. Spray Test (Standard Test Method -22-41). (1) The spray tester consisted of a six-inch metal embroidery hoop, a six-inch laboratory funnel, a household spray nozzle, and a stand to hold the funnel and the embroidery hoop. The funnel was held six inches above the center of the hoop. The hoop was held at a 45° angle on the stand. Although the A.A.T.C.C. procedure called for the conditioning of the samples before testing, this step was eliminated because Mandikos (4) showed that conditioning, or the lack of it, did not affect the spray test. The cut samples, seven inches wide from selvage to selvage, were placed in the embroidery hoop in seven-inch sections with the warp vertical. The embroidery hoop was placed on the stand so that the center of the cloth was directly under the spray nozzle. 250 cubic centimeters of water at 80° - 2° F. was poured into the funnel and sprayed onto the samples. After the spray, the hoop was removed from the stand, held at one edge, and tapped against a solid object. The hoop was then held at the opposite side and tapped again. The surface of the tested cloth was then compared to a rating chart (1) and rated as follows:

100 - No sticking or wetting of upper surface.
90 - Slight random sticking or wetting of upper surface.
80 - Wetting of upper surface at spray points.
70 - Partial wetting of whole upper surface.
50 - Complete wetting of whole upper surface.
0 - Complete wetting of whole upper and lower surface.

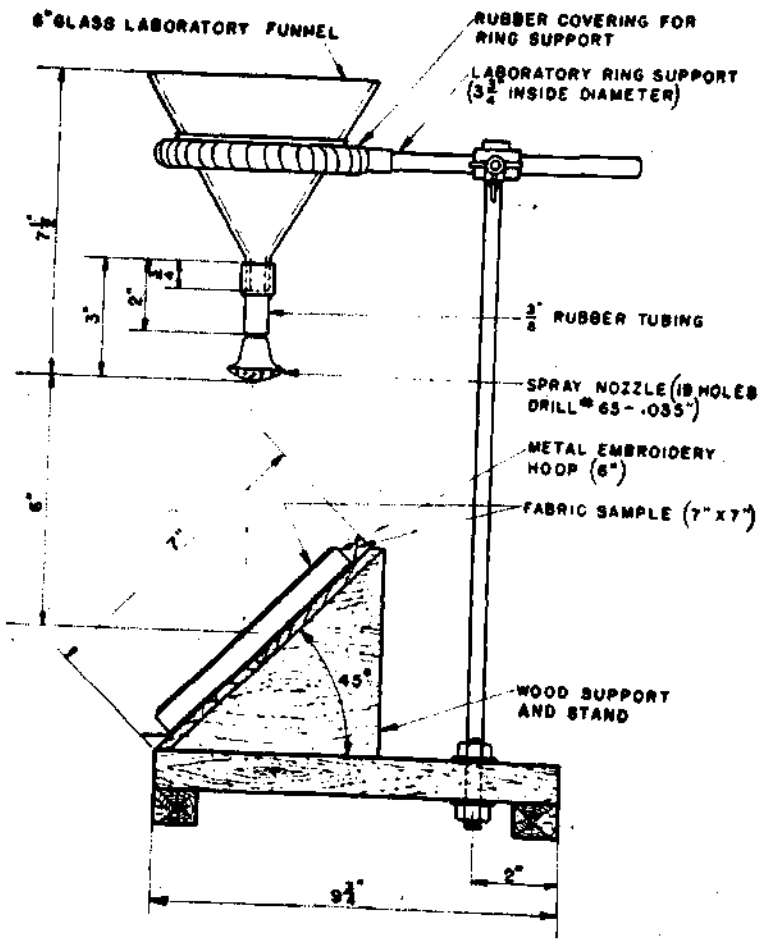

Figure 1 Spray Test Apparatus

(Reprinted from the 1951 Technical Manual and Year Book of the American Association of Textile Chemists and Colorists)

Ten spray tests were made on each sample after every wash and averages of these tests were recorded.

Immersion Test. — Samples were submitted to the A.A.T.C.C. Immersion Absorption Test (Tentative Test Method - 21-41) (1) after every other wash. Two specimens, each 3 x 3 inches, were taken from each sample, conditioned for 4 hours at 70° F. and 65% relative humidity, and weighed to the nearest 5 milligrams. One edge of a specimen was then attached to a weight, and the specimen and weight dropped into an immersion tank filled with water at 80° - 2° F., remaining for 20 minutes. The depth of the water in the tank was adjusted so that the average hydrostatic head above the specimen was 3.5 inches. The specimen was then removed from the tank, the weight taken off, and quickly placed between two pieces of dry A.A.T.C.C. white blotting paper. This sandwich was passed through the laboratory padder with 60 pounds pressure on the top roll. The specimen was then removed from the blotters and reweighed. The per cent water absorbed was calculated by dividing the increase in weight by the original weight of the specimen. The average of two specimens was recorded for each sample tested.

Penetration Test. — A certain number of the samples were submitted to the A.A.T.C.C. Impact Penetration Test (Tentative Test Method - 42-45). (1) The impact penetration tester consisted of a six-inch funnel, a special head, a clip board, and a six-inch clip weighted to one pound. The spray head was suspended 24 inches over the center of the clipboard; the clipboard was attached at a 45° angle to a stand. The samples to be

tested were cut 7 x 13 inches with the warp in the long direction. The samples were not conditioned (4) before testing. For testing, the sample was attached at the top by the clip on the clipboard, and at the bottom by the clip-weight. The cloth was held taut by the attached weight hanging over the edge of the clipboard. A standard A.A.T.C.C. white blotter, 6 x 9 inches, was weighed and placed under the sample, then 500 cubic centimeters of water at 80° - 2° F. was sprayed onto the sample. The blotter was removed and reweighed to the nearest 0.1 gram. Two specimens from each sample were tested and the average increase in blotter weight was recorded.

pH Determination. — All wash solutions were tested for pH with a Beckmann pH meter.

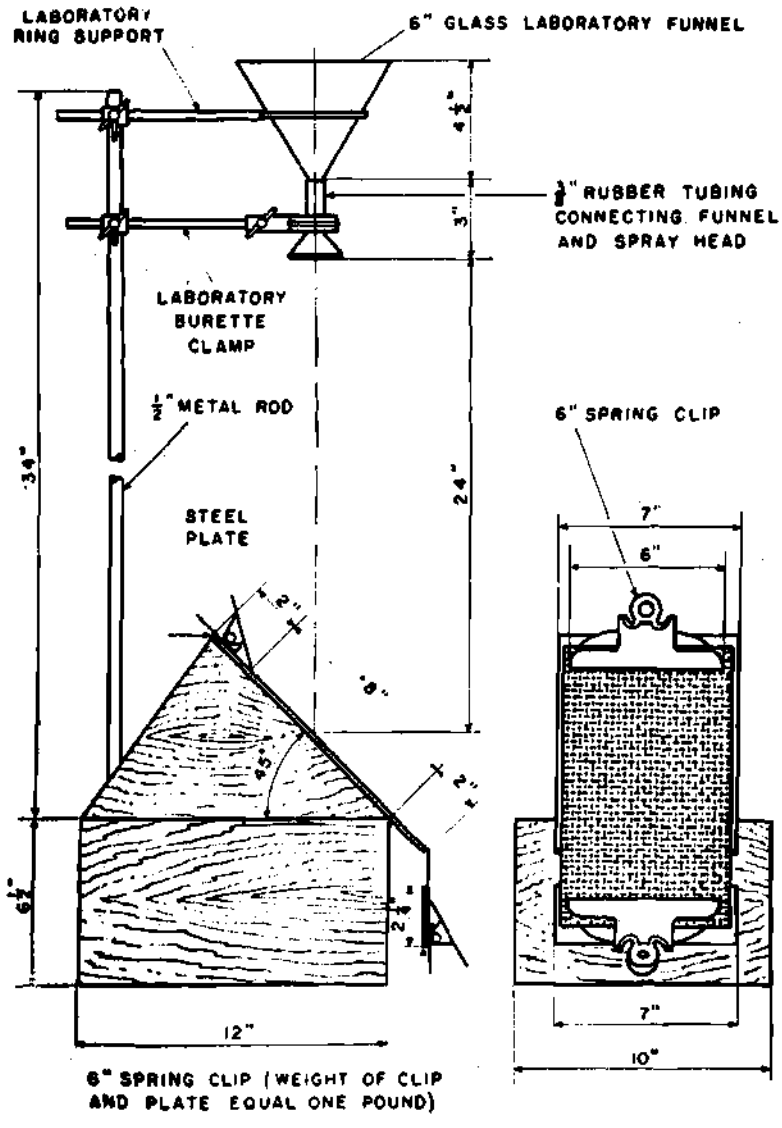

Figure 2 Impact Penetration Test Apparatus

(Reprinted from the 1951 Technical Manual and Year Book of the American Association of Textile Chemists and Colorists)

RESULTS AND DISCUSSION OF RESULTS

The penetration test did not give significant results (see table 1). This was probably due to the fact that washings were stopped at a spray rating of 50, and up to that point there is little differential water penetration. Spray and immersion tests did give significant ratings and the results and conclusions of this work were based on them.

Spray Test. — In general, the Permel finish had higher spray ratings and took more washes to break down than did the Zelan finish (see figure 3). This was most pronounced in the cases of soap and Triton. When only water was used in washing with the automatic machine the opposite was true, i.e., the Permel treated fabric showed a more rapid decrease in spray ratings than the Zelan (see figure 4). In the case of washing with water alone in the Smith-Drum machine, both fabrics maintained spray ratings of 100 for 10 washes. Therefore, the greater mechanical action given the fabrics in the automatic machine appeared to be more detrimental to the Permel finish than to the Zelan finish.

In all cases the decrease in water repellency was slower with the Smith-Drum machine than the automatic machine (see figure 5). Initial breakdown of water repellents in the automatic machine always occurred at the creases in the fabrics. In the Smith-Drum machine there was an even breakdown of the finish.

In every case except the wash with Triton in the Smith-Drum machine, increased hardness caused faster breakdown of the finish; this was most

pronounced with soap (see figures 5, 6, 7, 8, 9, 10 and 11; and tables 2, 3, 4, 5 and 6).

When alkali was added as Na_2CO_3 and Na_3PO_4 to soap, the spray ratings for a given number of washes for both Zelan and Permel were less than those ratings when soap alone was used (see figure 12).

The only Smith-Drum washing in which higher ratings were obtained after the final special rinse was the one which contained soap, hardness and Calgon. This occurred because of the failure of the Smith-Drum machine to rinse the samples adequately.

The breakdown in repellency due to differences in mechanical action (i.e., two different machines) when soap is used, is greater for Zelan than for Permel. (see figure 1) For Igepon and Triton the breakdowns were almost equivalent for the two fabrics; however, they were much greater than when soap alone is used.

Immersion Test. — In general, the immersion test substantiated the results of the spray tests. The immersion ratings of the fabrics at breakdown were lower for washings with soap than were the ratings when Triton and Igepon were used. (see tables 7, 8 and 9) The immersion test did not show any differentiation between different degrees of hardness, but it did show the differences in breakdown in the different machines.

pH Determination. — Both the Igepon and Triton solutions had lower pH values than the soap solutions (see table 10). The Na_2CO_3-soap solution had about the same pH as the soap solution alone. No definite conclusions can be drawn as to the effect of pH or the breakdown in water repellency of the two fabrics.

CONCLUSIONS

The most significant conclusion is that the Permel finish is more stable to washing than the Zelan finish; however, the difference in stability of the finishes is not great. When evaluating the same fabrics treated with these finishes, other properties in addition to water repellency such as hand, stiffness, crease resistance and abrasion resistance must also be considered.

The faster breakdown of the finishes in the automatic machine as compared to the Smith-Drum machine is due to the greater mechanical action given the fabrics by the automatic machine, and also to the higher concentration of detergents employed in this machine. In washing the fabrics in the automatic machine, creasing of the fabrics and mechanical action applied at these creases seem to be the most significant factor in the breakdown of water repellency. In the Smith-Drum machine, no such creasing was observed and the differences observed for the two water repellent finishes when different detergents are used, are really functions of these detergents.

Since the Permel finish broke down faster than the Zelan finish in plain water in the automatic machine and at no other time, it can be concluded that lubrication of the fabrics by the detergents is an important factor in water repellent breakdown by mechanical action.

The presence of hardness in washing durable water repellents increases the rate of breakdown of these finishes.

When Calgon was used to counteract the hardness, a more thorough

rinse was necessary to obtain complete water repellency.

The presence of alkali in washing durable water repellents definitely reduced the stability of both finishes.

With heavy mechanical action, soap was the best detergent to wash fabrics possessing durable water repellent finishes; with little mechanical action, a nonionic detergent such as Triton X-100 would be preferred.

RECOMMENDATIONS

This problem offers a very wide field for further investigation. This work has examined the stability of durable water repellents to detergents, hardness, mechanical action and alkali. An investigation along the same lines should be made on non-durable water repellents and durable water repellents (at various stages of breakdown) re-treated with non-durable types.

Mechanical action during laundering seems to be more important than any other factor in the breakdown of the durable water repellents. A study should be made in which mechanical action can be varied and measured during the washing of water-repellent fabrics. The lubricating value of various detergents should also be investigated as to their effect in reducing the adverse effect of severe mechanical action on water-repellent finishes.

Many other variables such as type of weave, weight of cloth, and type of durable water repellents offer excellent opportunities for research.

BIBLIOGRAPHY

BIBLIOGRAPHY

Literature Cited

1. American Association of Textile Chemists and Colorists, Technical Manual and Year Book, 27:133-139, 1951.

2. "Supplement to Federal Specification for Textiles; General Specifications, Test Methods, CCC-T-191a, October 8, 1945", U.S.Government Printing Office.

3. Slowinske, G.A., "A New Type Water Repellent", American Dyestuff Reporter, 28:647, October 30, 1939.

4. Mandikos, G. J., "The Effect of Moisture Content on Water Resistance Tests", American Dyestuff Reporter, 37:584-594, September 6, 1948.

5. "Military Specification - Cloth, Cotton, Wind Resistant Sateen 9 Ounce, MIL-C-557, April 5, 1951", U.S. Government Printing Office.

6. "Federal Specification - Soap; Chip, P-S-566b, February 23, 1951", U.S.Government Printing Office.

7. "Federal Service Tests - Group 7000", Sub-Group 7420 - Laundering, Method 7451 - Laundry Test, Mobile, U.S.Army Quartermaster Corps.

8. Whittaker, C.M. and Wilcock, C.C., Dyeing with Coal-Tar Dyestuffs, London: Bailliere, Tindall and Cox, 1949, p.89.

General References

Horigan, F. D. and C.R. Sage, Waterproofing and Water Repellency of Textiles, Bibliographic Series Number 2, Philadelphia: Quartermaster Research and Development Laboratories, December 30, 1947.

Niven, W. W., Fundamentals of Detergency, New York: Reinhold Publishing Company, 1950.

Pingree, R. A., "Durable Fabric Finishes", Rayon Textile Monthly, 26: 241, May, 1945.

Simpson, J. E., "The Army's Water Repellent Clothing", American Dyestuff Reporter, 35:243 and 272, May 6, 1946 and May 20, 1946.

Slowinske, G. A., "The Evaluation of Water Resisting Textile Finishes", American Dyestuff Reporter, 30:6-14, January 6, 1941.

APPENDIX

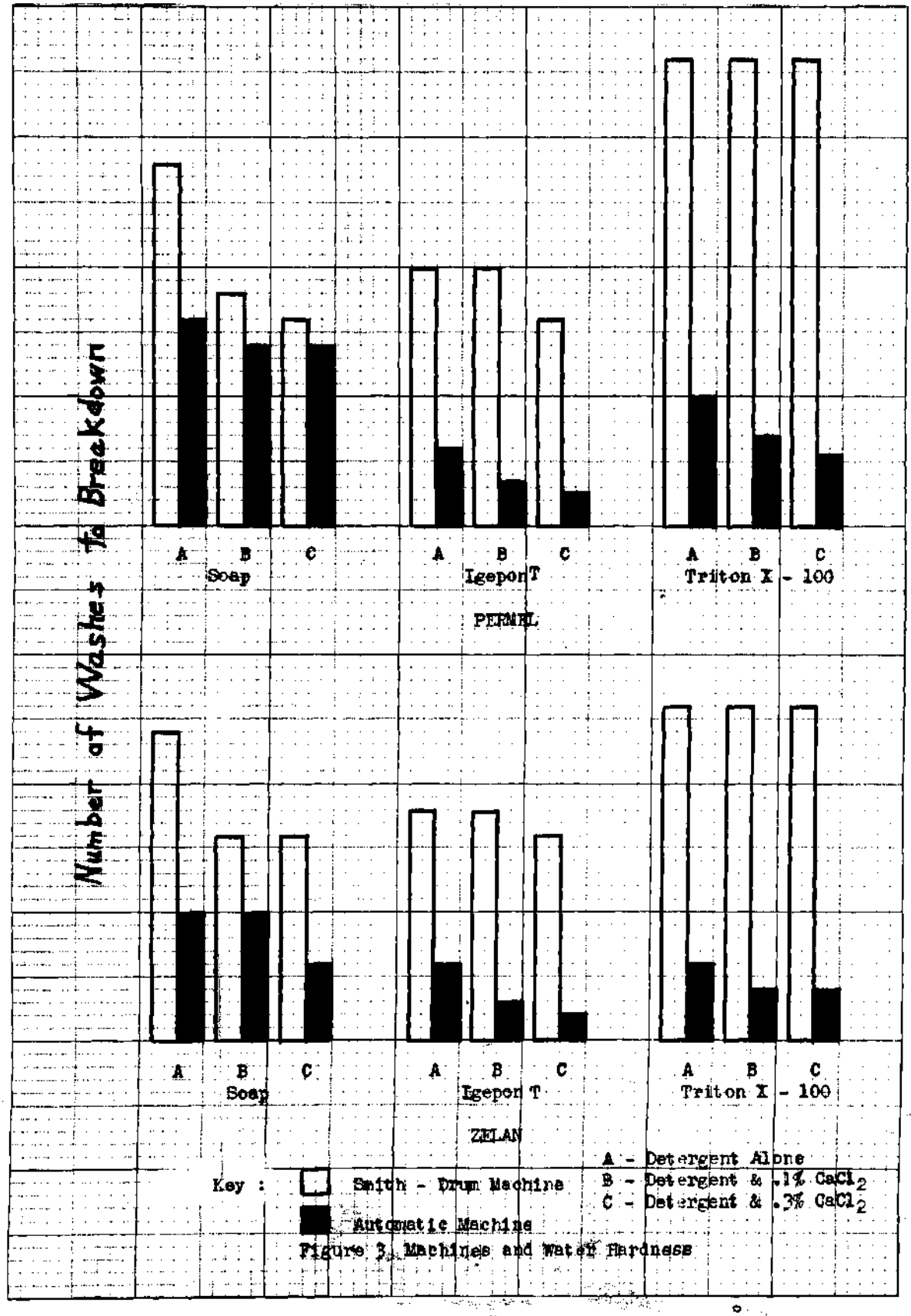

Figure 3. Machines and Water Hardness

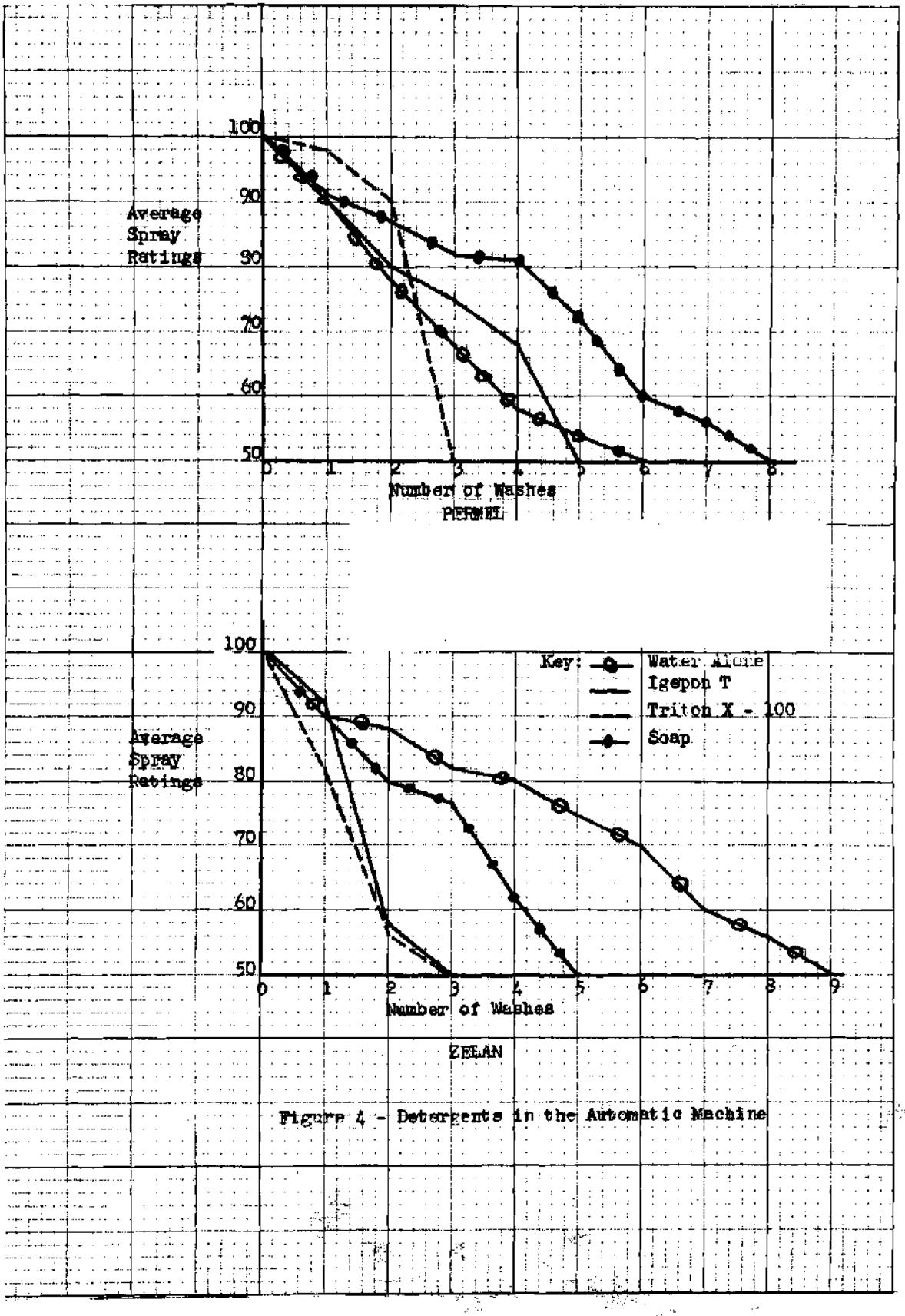

Figure 4 - Detergents in the Automatic Machine

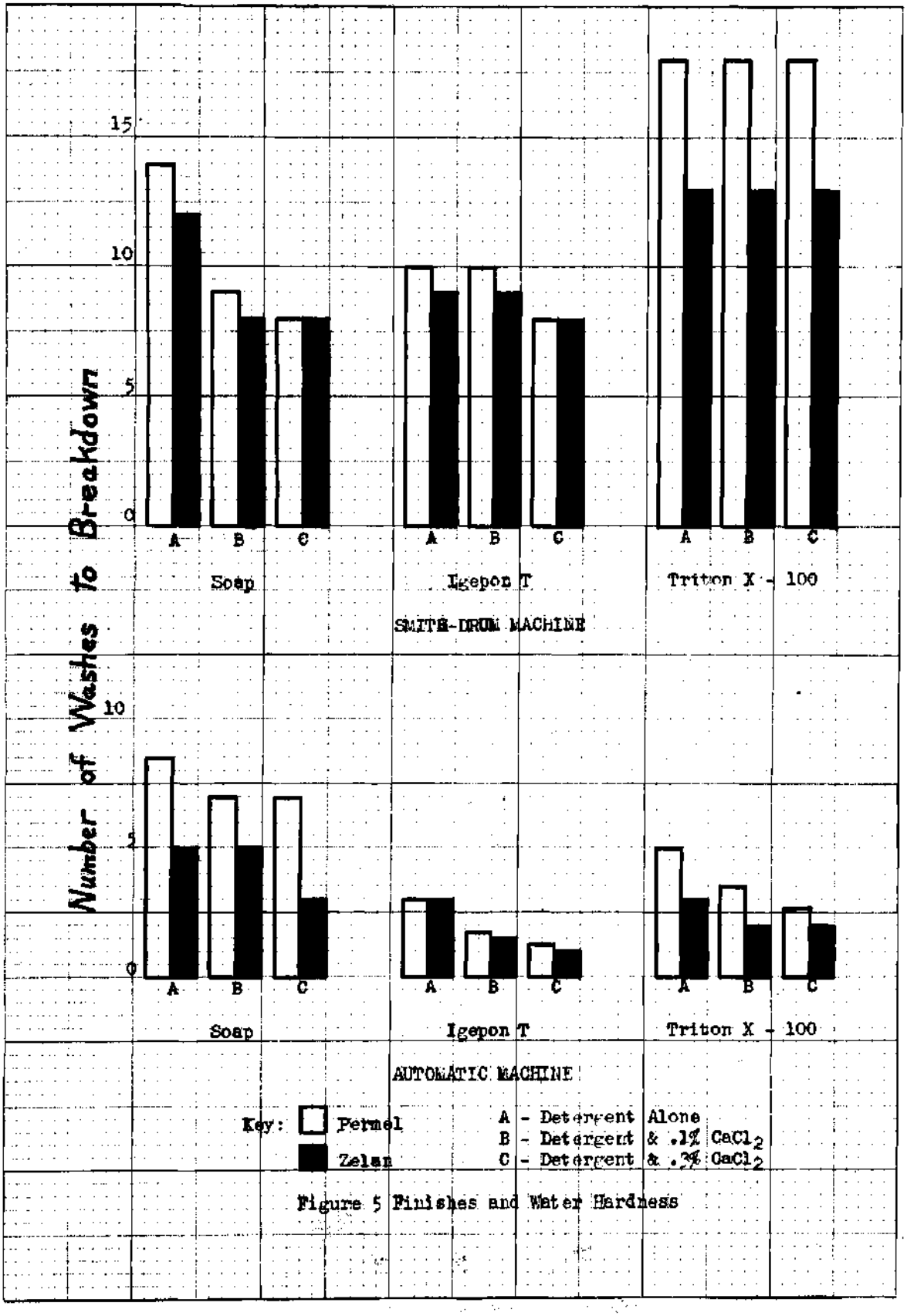

Figure 5 Finishes and Water Hardness

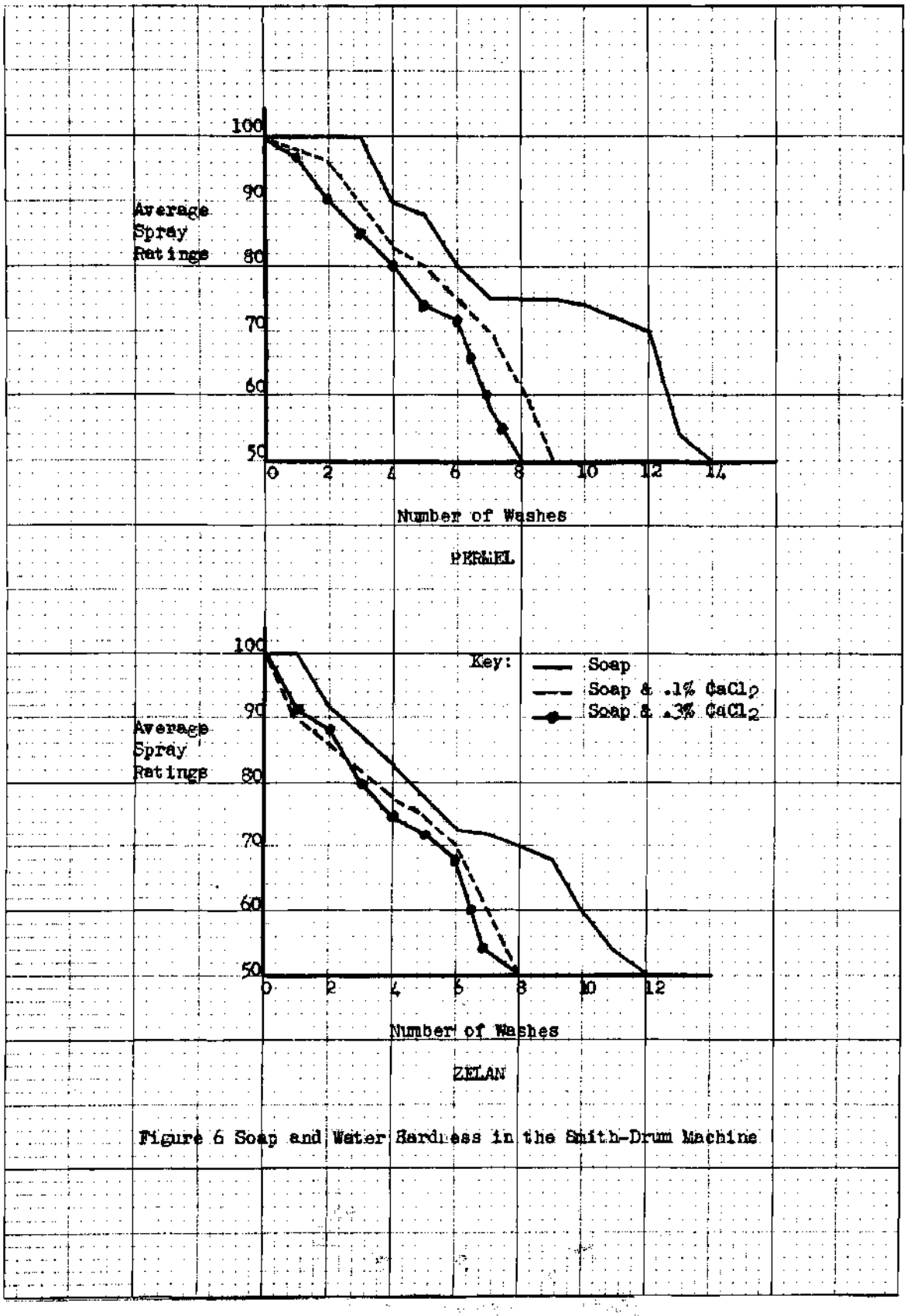

Figure 6 Soap and Water Hardness in the Smith-Drum Machine

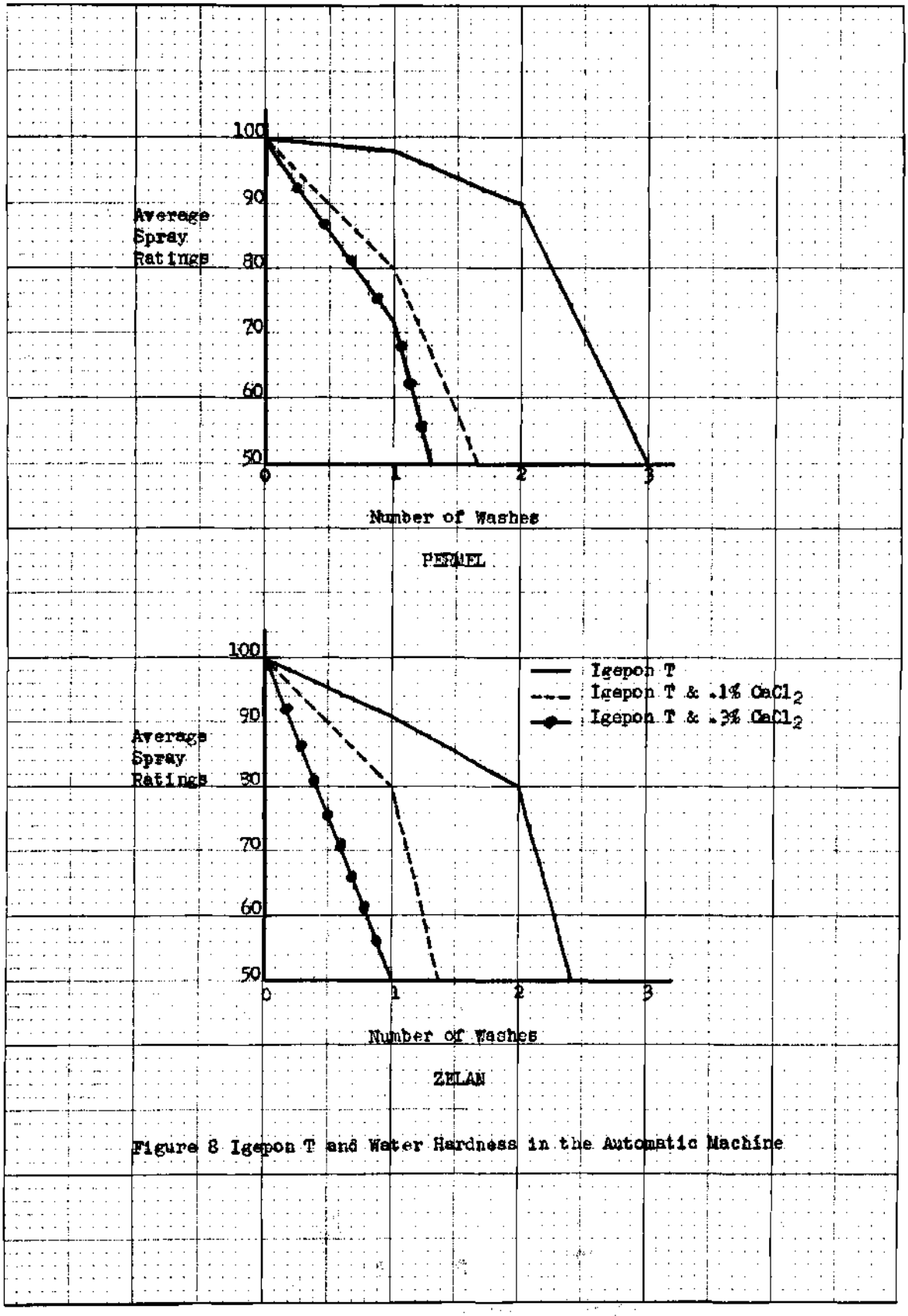

Figure 8 Igepon T and Water Hardness in the Automatic Machine

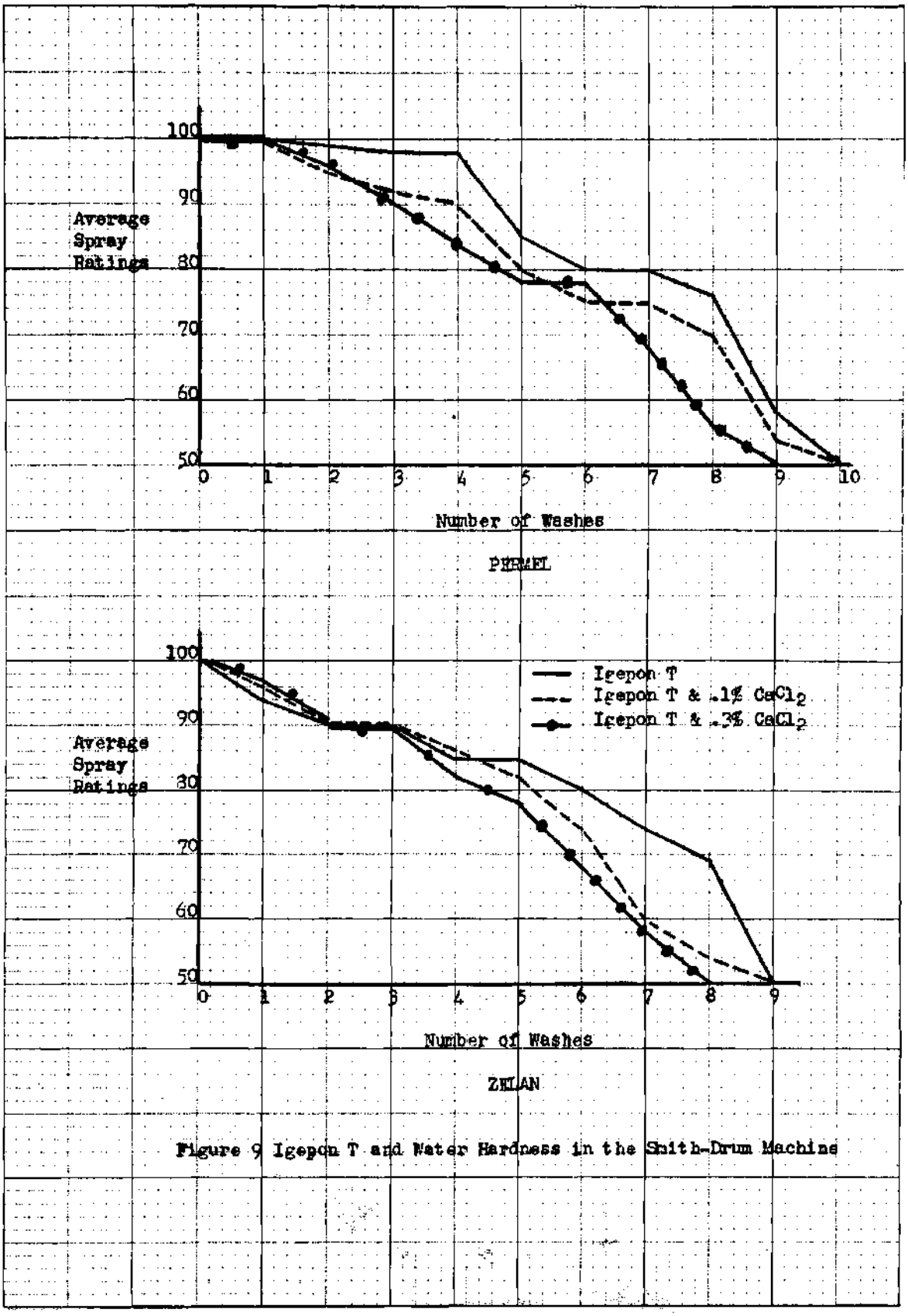

Figure 9 Igepon T and Water Hardness in the Smith-Drum Machine

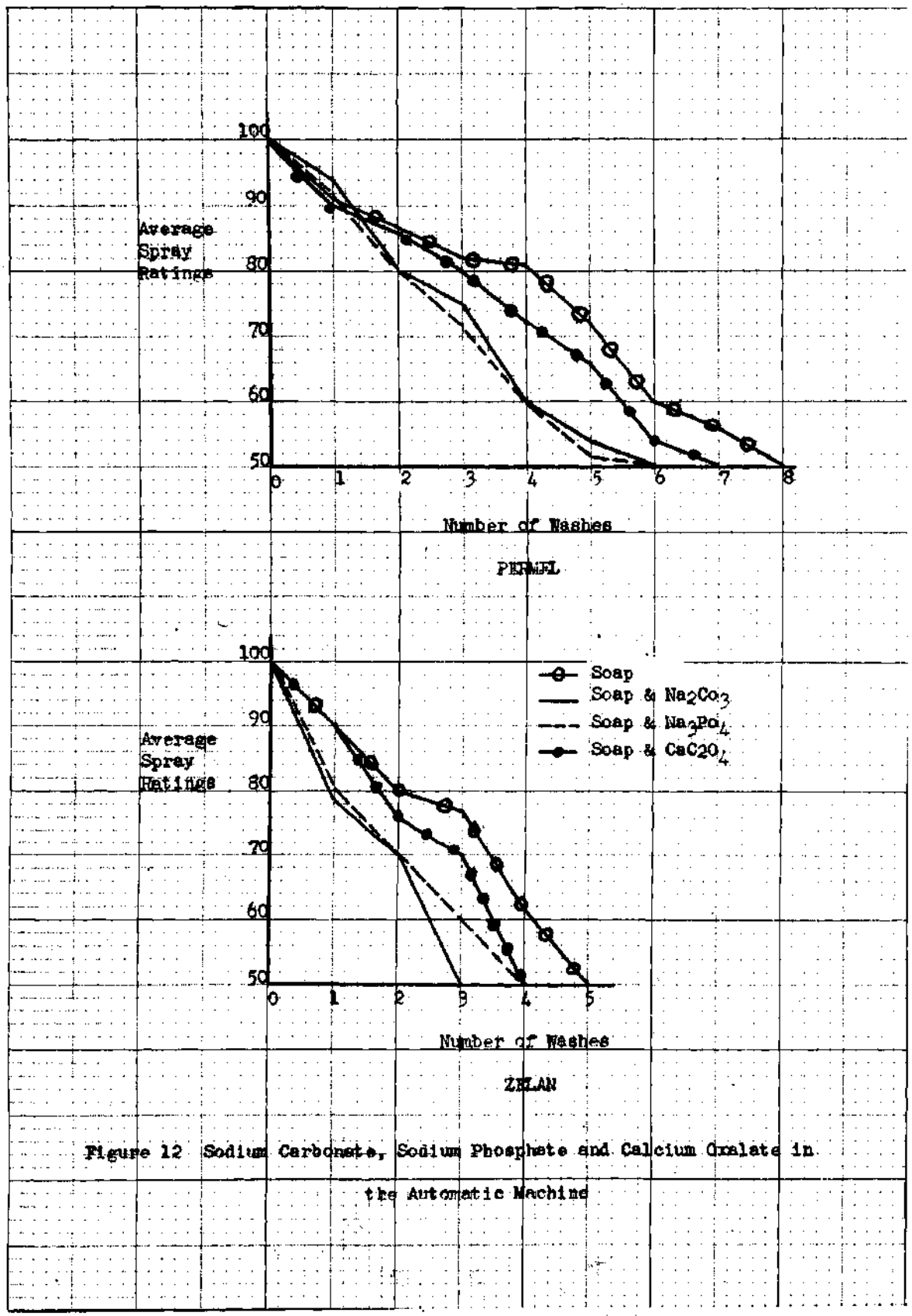

Figure 12 Sodium Carbonate, Sodium Phosphate and Calcium Oxalate in the Automatic Machine

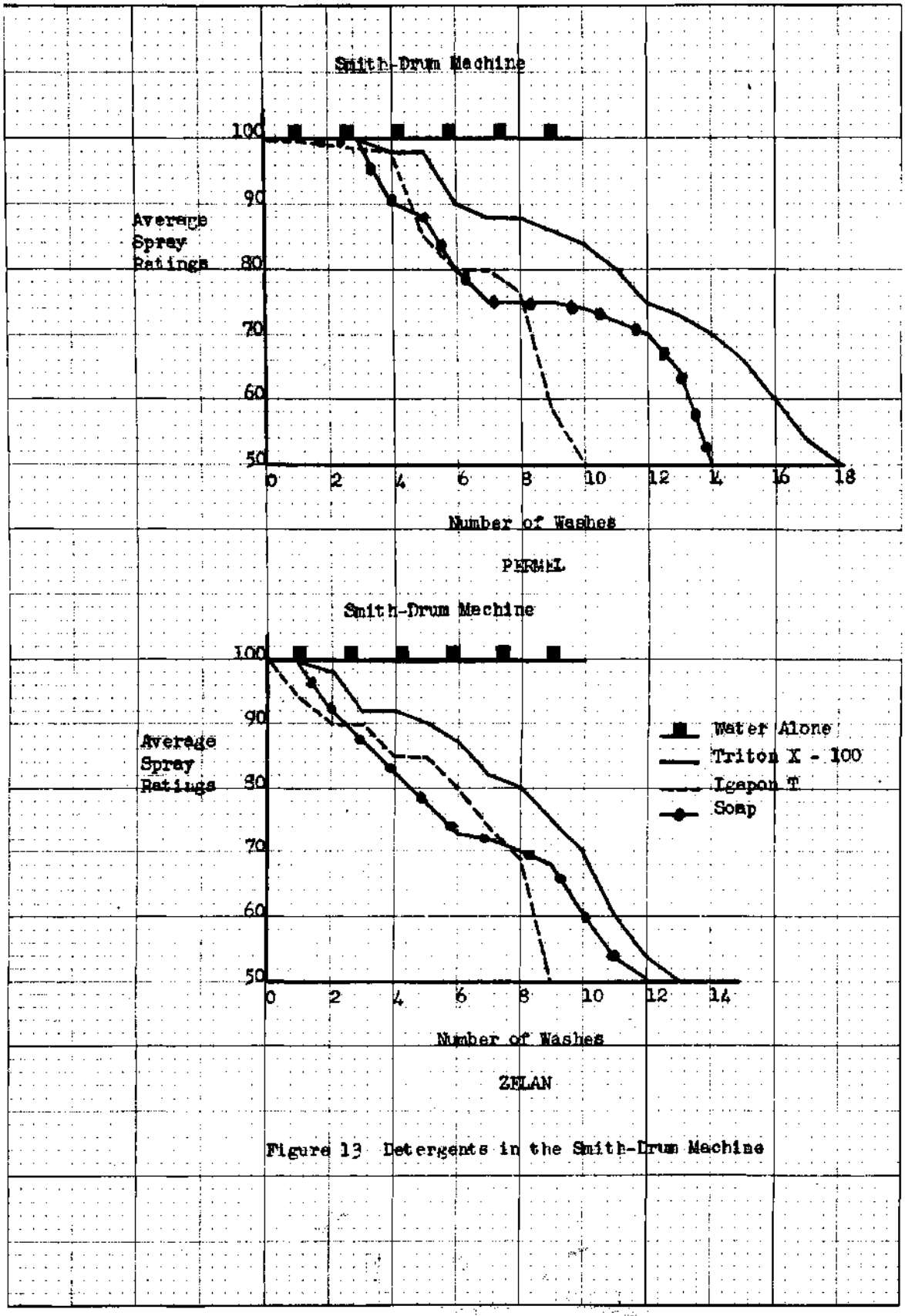

Figure 13 Detergents in the Smith-Drum Machine

TABLE 1

AVERAGE PENETRATION RATINGS OF FABRICS WASHED WITH 1½% SOAP

Number of washes	Permel		Zelan	
	Automatic	Smith-Drum	Automatic	Smith-Drum
1	0.0	0.0	0.0	0.0
2	0.0	0.0	0.1	0.0
3	0.1	0.1	0.1	0.1
4	0.1	0.1	0.1	0.1
5	0.1	0.1	0.1	0.1
6	0.1	0.1	---	0.1
7	0.1	0.1	---	0.1
8	0.1	0.1	---	0.1
9	---	0.1	---	0.1
10	---	0.1	---	0.1
11	---	0.1	---	0.1
12	---	0.1	---	0.1
13	---	0.1		
14	---	0.1		

TABLE 2

AVERAGE SPRAY RATINGS# OF FABRICS WASHED WITH 1½% SOAP IN THE SMITH-DRUM MACHINE

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
1	100	98	97	100	90	91
2	100	96	90	92	86	88
3	100	90	85	87	82	80
4	90	83	80	83	78	75
5	88	80	74	78	75	72
6	80	75	72	73	70	69
7	75	70	58	72	60	54
8	75	62	50	70	50	50
9	75	50	--	68	--	--
10	74	--	--	60	--	--
11	72	--	--	54	--	--
12	70	--	--	50	--	--
13	54	--	--			
14	50	--	--			

An average rating of 50 was considered as the point of breakdown of the water repellent.

* Hardness as $CaCl_2$.

TABLE 3

AVERAGE SPRAY RATINGS# OF FABRICS WASHED WITH
1½% SOAP IN THE AUTOMATIC MACHINE

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
1	91	92	94	90	83	90
2	87	90	83	80	80	76
3	82	84	80	77	70	50
4	81	80	75	62	56	--
5	72	70	70	50	50	--
6	60	60	60			
7	56	50	50			
8	50	--	--			

An average rating of 50 was considered as the point of breakdown of the water repellent.

* Hardness as $CaCl_2$.

TABLE 4

AVERAGE SPRAY RATINGS# OF FABRICS WASHED WITH 1/3% IGEPON T

SMITH-DRUM

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
1	100	100	100	94	96	97
2	99	95	96	90	90	90
3	98	92	90	90	90	90
4	98	90	84	85	86	82
5	85	80	78	85	82	78
6	80	75	78	80	74	68
7	80	75	68	74	60	58
8	76	70	56	69	54	50
9	58	54	50	50	50	--
10	50	50	--			

AUTOMATIC

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
1	98	80	72	91	80	50
2	90	35	0	80	0	--
3	50	--	--	10	--	--

An average rating of 50 was considered as the point of breakdown of the water repellent.

* Hardness as $CaCl_2$.

TABLE 5

AVERAGE SPRAY RATINGS# OF FABRICS WASHED WITH ½% TRITON X-100 IN THE SMITH-DRUM MACHINE

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
1	100	100	100	100	100	98
2	100	100	100	98	98	97
3	100	100	100	92	93	93
4	98	100	100	92	92	90
5	98	96	100	90	90	90
6	90	90	92	87	86	85
7	88	88	90	82	83	83
8	88	86	85	80	80	80
9	86	84	80	71	73	73
10	84	82	80	70	70	70
11	80	80	76	60	60	60
12	75	74	74	54	52	55
13	73	72	71	50	50	50
14	70	70	70			
15	66	68	65			
16	60	60	60			
17	54	56	54			
18	50	50	50			

#An average spray rating of 50 was considered as the point of breakdown of the water repellent.

*Hardness as $CaCl_2$.

TABLE 6

AVERAGE SPRAY RATINGS# OF FABRICS WASHED WITH ½% TRITON X-100 IN THE AUTOMATIC MACHINE

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
1	90	90	88	82	80	80
2	80	80	78	56	50	50
3	75	70	35	50	--	--
4	68	25	--			
5	50	--	--			

#An average spray rating of 50 was considered as the point of breakdown of the water repellent.

*Hardness as $CaCl_2$.

TABLE 7

AVERAGE IMMERSION RATINGS OF FABRICS WASHED WITH 1½% SOAP IN THE SMITH-DRUM MACHINE

Number of washes	Permel Hardness ©			Zelan Hardness ©		
	None	.1%	.3%	None	.1%	.3%
0	11.3	---	---	11.6	---	---
2	19.1	9.7	12.9	20.6	13.1	12.9
4	21.7	10.1	8.8	22.5	12.2	12.4
6	21.5	12.1	16.6	28.3	11.0	21.1
8	24.7	14.6*	13.1	22.1	17.2#	11.7
10	22.1	---	---	23.2	---	---
12	23.5	---	---	24.0	---	---
14	25.1	---	---			

* 9 washes

\# 7 washes

© Hardness as $CaCl_2$.

TABLE 8

AVERAGE IMMERSION RATINGS OF FABRICS WASHED WITH 1/3% IGEPON T

SMITH-DRUM

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
2	21.0	13.3	14.5	22.9	20.6	24.8
4	21.5	29.8	14.4	30.9	31.4	31.7
6	33.0	29.0	21.4	32.7	31.0	34.0
8	33.3	21.3	29.3	32.5	33.0	30.8
10	35.3	32.0	---	34.5	---	---

AUTOMATIC

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
2	23.3	26.2	35.5	33.1	31.3	35.1
3	25.1	---	---	41.5	---	---

*Hardness as $CaCl_2$.

TABLE 9

AVERAGE IMMERSION RATINGS OF FABRICS WASHED WITH
½% TRITON X-100

SMITH-DRUM

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
2	10.6	14.0	12.7	11.9	14.4	13.7
4	15.1	19.1	13.7	13.0	16.2	21.1
6	14.1	29.9	28.5	17.0	20.1	25.0
8	18.4	24.8	25.7	22.5	21.3	20.8
10	22.9	24.3	24.9	19.7	26.7	25.9
12	25.0	24.9	26.2	24.5	27.2	26.4
14	27.3	29.2	28.8			
16	30.1	28.5	29.0			
18	33.0	31.6	33.1			

AUTOMATIC

Number of washes	Permel Hardness*			Zelan Hardness*		
	None	.1%	.3%	None	.1%	.3%
2	28.0	24.8	25.6	26.6	29.9	34.4
4	31.5	34.1	33.1#	32.4#	----	----
5	32.9	----	----			

3 washes

* Hardness as $CaCl_2$.

TABLE 10

pH VALUES OF WASH SOLUTIONS

Solution Content	Automatic	Smith-Drum
Water alone	8.19	8.19
Soap	9.68	9.58
Soap & .1% hardness	9.23	9.38
Soap & .3% hardness	9.19	9.38
Soap & Calgon	8.00	8.70
Soap Na_2CO_3	9.69	----
Soap Na_3PO_4	9.90	----
Igepon T	7.40	7.41
Igepon T & .1% hardness	7.32	7.39
Igepon T & .3% hardness	7.25	7.51
Triton X-100	7.73	8.12
Triton X-100 & .1% hardness	7.75	8.21
Triton X-100 & .3% hardness	7.65	8.20

TABLE 11

AVERAGE SPRAY RATINGS* OF FABRICS WASHED WITH WATER ALONE

Number of washes	Permel		Zelan	
	Automatic	Smith-Drum	Automatic	Smith-Drum
1	90	100	90	100
2	78	100	88	100
3	68	100	82	100
4	58	100	80	100
5	54	100	75	100
6	50	100	70	100
7	--	100	60	100
8	--	100	56	100
9	--	100	50	100
10	--	100	--	100

*An average rating of 50 was considered as the point of breakdown of the water repellent.

TABLE 12

AVERAGE SPRAY RATINGS* OF FABRICS WASHED WITH 1½% SOAP, .1% HARDNESS AS $CaCl_2$ and CALGON

Number of washes	Permel		Zelan	
	Automatic	Smith-Drum	Automatic	Smith-Drum
1	88	100	82	100
2	80	98	75	97
3	78	98	56	85
4	72	80	50	75
5	68	72	--	70
6	58	56	--	54
7	54	50	--	50
8	50	--		

*An average rating of 50 was considered as the point of breakdown of the water repellent.

TABLE 13

AVERAGE SPRAY RATINGS OF FABRICS WASHED WITH CALCIUM OXALATE, TRISODIUM PHOSPHATE, AND SODIUM CARBONATE IN THE AUTOMATIC MACHINE

Number of washes	Permel			Zelan		
	CaC_2O_4	Na_2CO_3	Na_3PO_4	CaC_2O_4	Na_2CO_3	Na_3PO_4
1	90	94	92	90	79	80
2	86	80	80	76	70	70
3	80	75	72	60	50	60
4	72	60	60	50	--	50
5	66	54	52			
6	54	50	50			
7	50	--	--			