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Liquid Ammonia Mercerisation of Cotton

Part III: The Influence of Anhydrous Liquid Ammonia on the Physical Properties of Cotton Fabrics.

by

F.A. Barkhuysen

SOUTH AFRICAN WOOL AND TEXTILE RESEARCH INSTITUTE OF THE CSIR

P. O. BOX 1124
PORT ELIZABETH
REPUBLIC OF SOUTH AFRICA

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LIQUID AMMONIA MERCERISATION OF COTTON

PART III : THE INFLUENCE OF ANHYDROUS LIQUID AMMONIA ON THE PHYSICAL PROPERTIES OF COTTON FABRICS

by F.A. BARKHUYSEN

ABSTRACT

Certain physical properties of cotton fabrics were improved by a treatment with liquid ammonia. Although liquid ammonia mercerisation did not improve the breaking strength of the fabrics, it had a desirable effect on other properties such as extension, tear strength and flex abrasion. It also was found that fabrics treated with liquid ammonia compared very well with fabrics which had been mercerised commercially with sodium hydroxide. In some cases the liquid ammonia treatment was found to be better than the sodium hydroxide treatment.

Different processing parameters used during liquid ammonia mercerisation did not produce significant differences in the physical properties of the fabrics. There was little difference between fabrics whether the ammonia was removed from the fabrics by heat, cold water or hot water. Heat removal of ammonia, however, resulted in a fabric with a much higher crease recovery angle. Different contact times and degrees of stretch applied to the fabrics also did not result in any significant differences in fabric properties. Stretch applied to the fabrics, however, was found to be a prerequisite for improving the physical properties of cotton fabrics.

INTRODUCTION

The cotton fibre is composed of a multitude of strong crystalline fibrils. These, however, are not spatially arranged in such a way that the optimum fibre strength is achieved. In the unopened boll the growing fibre has a nearly circular diameter. Due to this symmetry each fibril can take its own share of any load and the fibre is, therefore, quite strong in this state. When the boll opens and the fibre gets dehydrated, however, this symmetry is lost and a relatively weak, non-uniform structure is formed[1].

The original symmetry and uniformity of the fibrillar structure of the cotton fibre, which is present at the growing stage, can be recovered by swelling or mercerisation. It has been stated that by a suitable choice of mercerising conditions it is possible to achieve a stress/strain curve for the cotton fibre similar to that of a high tenacity polyester fibre[1]. The most obvious way to achieve a re-orientation of the fibre structure is to swell the fibre into a cylindrical form and then to recrystallise it in a more uniform way. This can be achieved by swelling the fibre in a swelling agent, applying tension and then removing the swelling agent while the tension is maintained.

The most promising and interesting results have been obtained from experiments involving the mercerisation of *fibres, rovings* or *yarns.* When fibres are processed in the form of *fabrics,* however, there are serious constraints, such as the tightness of the weave and twist of the yarn, that can hinder swelling. In fabric mercerisation, the improvements in tensile and tear strength which have been achieved have not really been sufficient to arouse commercial interest[2].

Aqueous solutions of sodium hydroxide have been used mainly for the mercerisation of cotton fabrics. This process is, however, not very efficient due to the fact that the treatment is not very uniform. Sodium hydroxide has a maximum swelling effect on the fibres at the surface of the fabric and this effect diminishes from the outside to the inside of the yarn. When the fabric enters the mercerising liquor the fibres on the surface of the fabric swell very rapidly and give rise to a blocking effect at the periphery of each yarn, thus hindering further penetration of the liquor into the interior of the yarns and the fabric.

To obtain more uniform mercerisation, which is desirable in view of the potential benefits in terms of improved mechanical performance, it seems logical to attempt to reduce the degree of swelling and to increase the rate of penetration of the liquor in the early stages of the treatment.

It has been claimed that the penetration of sodium hydroxide into the cotton fibre can be improved by using sodium hydroxide solutions of mercerising strength at elevated temperatures[3]. The penetration was found to be extremely rapid, thorough and uniform, especially under relaxed fabric conditions.

Another method to improve the uniformity of mercerisation of cotton fabrics with sodium hydroxide has also been developed[4]. This is obtained by a two-step process. The first high temperature step allows good penetration and distribution of the sodium hydroxide solution while a maximum swelling effect is obtained in the second low temperature step.

Sodium hydroxide solutions can also be applied to cotton fabrics by the vacuum impregnation method[5]. It is claimed that this method reduces the dwell time due to the more rapid saturation and also resulted in a better uniformity of impregnation.

Sodium hydroxide has been used since 1850 for the mercerisation of cotton, and only in the latter few years has liquid ammonia emerged as a possible rival.

It is known that liquid ammonia penetrates the cotton fibre rapidly and evenly[6]. Research workers have studied the reactions of sodium hydroxide and liquid ammonia with cotton cellulose, and the two systems were found to be completely different [7]. Sodium hydroxide enters the fibre as a large dipole hydrate and this accounts for the inefficient swelling. The liquid ammonia molecule, on the other hand, is relatively small, and this gives rise to a *lower degree* of swelling. The swelling in liquid ammonia, however, is more *even* than in sodium hydroxide.

The purpose of this study was, therefore, to investigate the effect of liquid ammonia on the physical properties of cotton fabrics, since swelling will have a definite effect on the physical properties of the fabric. It was also the purpose of the investigation to compare the mercerisation of cotton fabrics in sodium hydroxide with mercerisation in liquid ammonia in terms of the expected changes in the physical properties of the fabrics.

EXPERIMENTAL

Materials:

The machine, materials and processing parameters used were the same as those described before[8, 9].

Test Methods:

The breaking strength and breaking extension of the fabrics were determined on an Instron Tensile Tester according to the ISO Draft Standard[10].

The tear strength and bursting strength of the fabrics were determined on an Elmendorf Tear Strength Tester and a Mullen Tester, respectively[11,12].

The flex abrasion of the fabrics was determined on a Stoll Quartermaster Tester[13]. The determination of the resistance to flat abrasion of the fabrics was measured on a Martindale Abrasion Resistance Tester[14].

The percentage mass loss after 5000 cycles was taken as a measure of the abrasion resistance, since only some of the samples withstood 10 000 cycles.

The Monsanto crease recovery angle of the fabrics was measured on a Monsanto Wrinkle Recovery Tester[15]. The fabrics were dried in an oven for 90 minutes at 40°C before they were conditioned (65 *per cent* relative humidity and 20°C) for testing. Results are given as the total of the warp and weft crease recovery angle.

The mass/unit area of the fabrics was determined according to standard procedures.

The bending length of the samples was determined by the Cantilever method[16].

The lightweight plain fabric was subjected to physical tests directly after the ammonia treatment. The heavyweight plain and twill fabrics were first relaxed and decatised after the ammonia treatment since it was decided that testing of the fabrics at this particular stage would be closer to commercial practice.

All the physical tests were carried out under standard atmospheric conditions i.e. 65 *per cent* relative humidity and a temperature of 20°C.

RESULTS AND DISCUSSION

1. THE INFLUENCE OF DIFFERENT PROCESSING PARAMETERS DURING LIQUID AMMONIA MERCERISATION ON THE PHYSICAL PROPERTIES OF FABRICS

Many claims have been made that the treatment of cotton in certain swelling agents increases the strength of the cotton fibre. It has been stated, for example, that liquid ammonia increases the strength of cotton threads when processed according to the Prograde Process[17]. The effect of liquid ammonia mercerisation on cotton fabrics is given in Tables I, II and III for the lightweight plain, heavyweight plain and twill fabrics, respectively. These results were analysed statistically to establish the relative importance of the various parameters investigated.

(a) Lightweight Plain Fabric

For the lightweight plain fabric (Table I) it was found that stretching the fabrics in the absence of ammonia generally gave the same results as that found for the untreated control fabric. No water was added to the stretched control fabrics as it passed through the machine. The tear strength and flex abrasion of the stretched fabrics, however, were increased significantly whereas the bursting strength was decreased slightly. The observed increases in fabric tear strength cannot be explained, but it is known that mechanical stretching techniques, such as the microstretching process[18], sometimes improve certain fabric properties. In the case of the two heavyweight fabrics (Tables II and III), however, no differences were found between the properties of the unstretched fabric and the untreated, stretched control fabrics. It is, furthermore, clear (Table I) that treatment of the fabrics with liquid ammonia under tension decreased the breaking or tensile strength of the fabrics in the warp

TABLE I

PHYSICAL PROPERTIES OF THE LIGHTWEIGHT PLAIN FABRIC AFTER DIFFERENT WAYS OF TREATMENT IN LIQUID AMMONIA AND AFTER MERCERISATION IN SODIUM HYDROXIDE

TREATMENT	CONDITIONS OF TREATMENT: ESTIMATED CONTACT TIME (SEC)	CONDITIONS OF TREATMENT: STRETCH (%)	CONDITIONS OF TREATMENT: AMMONIA REMOVED BY	PHYSICAL PROPERTIES: BREAKING STRENGTH (kgf) Warp	BREAKING STRENGTH (kgf) Weft	EXTENSION AT BREAK (%) Warp	EXTENSION AT BREAK (%) Weft	BURSTING STRENGTH (kgf/cm^2)	TEAR STRENGTH (hectograms) Warp	TEAR STRENGTH (hectograms) Weft	FLEX ABRASION (cycles to rupture) Warp	FLEX ABRASION (cycles to rupture) Weft	STIFFNESS (cm) Warp	STIFFNESS (cm) Weft	CREASE RECOVERY ANGLE (degrees)
Untreated Control				49,8	46,2	7,4	23,0	6,5	10,3	13,1	613	491	2,4	1,9	193
Stretched Control *				49,2	42,1	6,2	21,5	6,0	14,1	18,1	1057	875	2,3	1,8	192
Liquid Ammonia	15	0	Heat	52,1	44,6	15,3	26,4	9,7	11,7	12,9	–	–	1,7	1,6	221
	15	4	Heat	43,0	37,7	5,3	22,5	5,4	14,0	18,5	1349	1114	2,2	2,3	223
	15	6	Heat	43,5	36,5	5,4	22,6	5,5	15,7	19,6	1988	1553	2,3	2,1	223
	5	0	Heat	48,5	40,4	13,9	25,2	9,3	12,1	12,9	–	–	1,7	1,6	231
	5	4	Heat	43,5	41,6	5,0	20,8	5,2	14,4	17,0	1250	1069	2,6	2,4	219
	5	6	Heat	42,8	42,7	5,0	22,7	5,5	14,1	19,7	1704	1055	2,4	2,2	190
	3	4	Heat	44,1	40,4	4,7	23,6	4,9	13,6	15,0	873	902	2,8	2,3	227
	3	6	Heat	42,5	39,3	4,8	22,3	5,1	14,7	19,2	1301	1296	2,4	2,3	233
	15	4	Water	41,6	42,8	5,4	23,7	5,5	13,8	17,6	921	1184	2,5	2,1	200
	15	6	Water	43,8	41,9	5,3	22,6	5,4	13,6	17,9	879	1105	2,6	2,1	213
	5	4	Water	44,8	41,0	5,7	22,7	5,8	14,9	17,4	1211	1033	2,1	2,6	207
	5	6	Water	46,4	40,3	5,3	23,6	5,7	14,9	17,1	687	975	2,7	2,2	197
	3	4	Water	45,5	41,6	5,4	23,2	6,0	13,0	16,2	1127	1276	2,7	2,1	205
	3	6	Water	47,2	38,7	5,8	24,1	6,0	14,3	17,8	1412	797	2,7	2,1	200
Sodium Hydroxide				54,4	43,0	8,7	25,9	8,0	11,6	12,0	429	438	3,0	2,0	180

* Average value of the stretched control fabrics

and weft directions by about 11 and 12 *per cent,* respectively. Removal of ammonia by either heat or water did not influence the physical properties of the fabrics. Practically no difference was found between the warp breaking strength of the fabrics stretched to 4 and 6 *per cent,* respectively. The slack mercerised fabrics (nil *per cent* stretch) had higher breaking strength in the warp direction than the fabrics to which 4 and 6 *per cent* stretch had been applied. They had approximately the same warp breaking strength as the untreated control or stretched control fabrics. This was probably due to the shrinkage of the slack mercerised fabric in the liquid ammonia. Comparing sodium hydroxide and liquid ammonia mercerisation, the analysis showed that for this particular fabric, sodium hydroxide mercerisation resulted in a 10 *per cent* increase in breaking strength in the warp direction, while liquid ammonia mercerisation resulted in an 11 *per cent* decrease. The increase in the warp breaking strength of the sodium hydroxide mercerised fabric could be the result of the shrinkage of the fabric during the treatment. Both treatments decreased the weft breaking strength, with the liquid ammonia treatment resulting in a larger decrease.

Treatment of the fabrics with liquid ammonia under tension resulted in a considerable reduction of extension in the warp direction, but in the weft direction, however, it remained about the same as that for the untreated control fabric. Excluding the slack mercerised fabric, liquid ammonia reduced the warp extension by about 28 *per cent.* Sodium hydroxide mercerisation produced a fabric with higher warp and weft extension than the untreated control fabric. Slack mercerisation, on the other hand, produced a fabric with a warp extension double that of the control fabric. Again, heat or water removal of ammonia did not differ significantly in their effect on the extension of the fabrics.

The bursting strength of the fabrics showed the same tendency as the extension. The slack mercerised fabric had a much higher bursting strength than the untreated control fabric, whereas the other liquid ammonia treatments resulted in a decrease in bursting strength. Water removal of ammonia from the fabrics resulted in a decrease of approximately 12 *per cent* in bursting strength whereas heat removal gave an approximate 18 *per cent* decrease. The bursting strength of the sodium hydroxide treated fabric was about 23 *per cent* higher than that of the untreated control fabric. The increase in the bursting strength of the sodium hydroxide mercerised and slack mercerised fabrics can probably be attributed to the higher shrinkage encountered during processing.

It is also clear that treating the fabrics in liquid ammonia increased the tear strength by about 48 and 36 *per cent* in the warp and weft directions, respectively. In general, treatment of the fabrics at low speeds (i.e. long contact times) and at high degrees of stretch produced the highest strengths.

No difference between the respective effects of heat or water removal of ammonia could be detected.

Slack mercerisation in liquid ammonia produced a fabric with inferior tear strength compared with the fabrics stretched in the ammonia. The same applies to the sodium hydroxide mercerised fabric. When the sodium hydroxide treated fabric is compared with the untreated control fabric, however, it can be seen that the sodium hydroxide treatment resulted in a small increase in tear strength in the warp direction and a small decrease in the weft direction.

Treatment in liquid ammonia resulted in an increase in resistance to flex abrasion in the warp and the weft directions, especially at a high degree of stretch. Liquid ammonia treatment produced an approximate 100 and 126 *per cent* increase in resistance to flex abrasion in the warp and weft directions, respectively, when compared with the untreated control fabric. In general, heat removal of ammonia gave the best resistance to flex abrasion. The sodium hydroxide treated fabric had much lower resistance to warp and weft flex abrasion than the liquid ammonia treated fabrics and seemed to have a lower resistance to flex abrasion than the untreated control fabric.

The results for fabric stiffness showed that the removal of liquid ammonia by water or heat produced fabrics with approximately the same stiffness. The stretched fabrics were, however, stiffer than the slack mercerised fabric. The sodium hydroxide treatment produced a fabric which was slightly stiffer in the warp and slightly less stiff in the weft than the fabric from the liquid ammonia treatment.

It was found that the treatment of fabrics with liquid ammonia increased the crease recovery angles. A study of the effect of the different treatments on the crease recovery angles of the fabrics showed that heat removal of the ammonia resulted in significantly higher crease recovery angles (20° – 30°) than water removal of ammonia. It is also clear that the sodium hydroxide treatment gave an inferior crease recovery angle when compared with the ammonia treatments.

In the case of the heavyweight plain and twill fabrics the treatment at the higher speed i.e. contact time of about 3 seconds, was excluded. This was due to the fact that the ammonia could not be removed efficiently from the heavier fabrics at such a high speed.

(b) Heavyweight Plain Fabric

From Table II it is clear that the treatment of the heavyweight plain fabric with liquid ammonia in the slack state as well as under tension increased the warp breaking strength by about 12 *per cent* compared with the untreated control fabric. In general, heat removal of the ammonia from the fabrics increased the breaking strength in the warp direction to a greater extent than water removal of ammonia. The sodium hydroxide treatment increased the warp breaking strength by approximately the same degree as the liquid ammonia treatment.

The weft breaking strength of both the liquid ammonia and the sodium hydroxide treated fabrics was inferior to that of the untreated control fabric. In the case of the slack mercerised fabrics, however, the weft breaking strength was unchanged while the warp breaking strength was increased. Statistical analysis showed that the treatment of the fabrics at a lower speed and a higher degree of stretch gave a similar effect to the treatment at a higher speed and lower degree of stretch. Both these conditions of treatment resulted in an increase in the breaking strength of the fabrics.

The breaking extension results generally showed the same tendency as that found for the lightweight plain fabric. It was found, however, that water removal of ammonia gave slightly higher breaking extension values than heat removal, whereas no differences were observed in the case of the lightweight plain fabric. Liquid ammonia treatment increased the bursting strength by about 14 *per cent*. The same was found for the sodium hydroxide treatment. Slack mercerisation in liquid ammonia, however, reduced the bursting strength of the fabrics by about 9 *per cent*.

The tear strength values showed that the liquid ammonia treatment increased the warp tear strength by approximately 17 *per cent* and the weft tear strength by about 27 *per cent*. The slack mercerised fabric, on the other hand, gave the same results as the control fabric, showing the importance of stretching the fabrics during mercerisation. The sodium hydroxide treated fabric had an inferior tear strength compared with the liquid ammonia treated fabrics.

It was found that the liquid ammonia treatment increased the warp flex abrasion of the fabrics, while sodium hydroxide mercerisation decreased it. The weft flex abrasion of the fabric was, however, not significantly affected by the various treatments. Heat or water removal of ammonia did not differ significantly in their effect

TABLE II

PHYSICAL PROPERTIES OF THE HEAVYWEIGHT PLAIN FABRIC AFTER DIFFERENT WAYS OF TREATMENT IN LIQUID AMMONIA AND AFTER MERCERISATION IN SODIUM HYDROXIDE

TREATMENT	CONDITIONS OF TREATMENT			PHYSICAL PROPERTIES												
	ESTIMATED CONTACT TIME (SEC)	STRETCH (%)	AMMONIA REMOVED BY	BREAKING STRENGTH (kgf)		EXTENSION AT BREAK (%)		BURSTING STRENGTH (kgf/cm²)	TEAR STRENGTH (hectograms)		FLEX ABRASION (cycles to rupture)		STIFFNESS (cm)		CREASE RECOVERY ANGLE (degrees)
				Warp	Weft	Warp	Weft		Warp	Weft	Warp	Weft	Warp	Weft	
Untreated Control				72,7	48,3	17,6	10,7	10,5	18,5	13,0	920	388	2,0	1,9	180
Stretched * Control				75,2	48,2	17,3	10,9	10,6	18,0	13,8	555	445	2,0	1,9	177
Liquid Ammonia	15	0	Heat	82,1	49,9	27,5	20,1	9,8	17,2	15,4	–	–	1,9	1,8	227
	15	6	Heat	90,1	42,4	12,1	11,0	11,9	24,4	16,8	907	576	2,4	1,7	214
	15	8	Heat	82,7	41,7	11,4	10,3	11,9	22,8	16,8	1300	586	1,9	1,6	212
	5	0	Heat	82,8	49,7	28,3	21,2	9,4	18,6	14,3	–	–	1,8	1,9	232
	5	6	Heat	79,2	43,8	11,7	11,4	12,2	18,1	15,7	761	414	2,3	1,8	216
	5	8	Heat	88,5	39,9	11,0	10,5	12,3	24,4	17,2	1417	426	2,2	1,9	219
	15	6	Water	80,9	42,8	12,5	12,0	12,0	19,5	19,9	1536	406	2,6	2,0	194
	15	8	Water	72,9	42,5	11,6	11,2	12,6	22,8	15,9	1131	595	2,1	1,7	209
	5	6	Water	79,1	48,6	13,5	12,3	11,7	21,0	15,2	826	415	2,3	1,8	190
	5	8	Water	81,1	43,8	12,8	11,3	11,8	21,6	15,4	984	409	2,2	1,9	206
	Sodium Hydroxide			83,4	40,3	16,5	25,8	11,7	17,9	11,6	505	387	2,5	2,0	176

* Average value of the stretched control fabrics

on the flex abrasion of the fabrics.

The statistical analysis showed that liquid ammonia mercerisation produced a more flexible fabric than the sodium hydroxide treatment. A lower speed and a higher degree of stretch produced a softer fabric than a higher speed and a lower degree of stretch. Heat or water removal of the ammonia from the fabrics did not differ significantly as far as their effect on fabric stiffness was concerned.

The crease recovery angles of the heavyweight plain fabrics after the different treatments followed the same trend as was observed with the lightweight plain fabric. Liquid ammonia produced significantly higher crease recovery angles than sodium hydroxide, and heat removal of the ammonia resulted in higher crease recovery angles than the water removal.

(c) Twill Fabric

Statistical analysis also showed that, as was found for the heavyweight plain fabric, liquid ammonia mercerisation increased the warp breaking strength of the *twill fabric* (Table III). In this case it was found, however, that sodium hydroxide mercerisation did not increase the warp breaking strength. Treatment of the fabrics with sodium hydroxide as well as with liquid ammonia reduced the weft breaking strength. Slack mercerisation in liquid ammonia, however, increased the weft breaking strength significantly. Once again, there was no significant difference in this respect between the removal of ammonia by heat or water.

The results for breaking extension show that the different treatments in liquid ammonia (except for slack mercerisation) had a similar effect on the extension of the fabrics. Liquid ammonia treatment, on the average, produced fabrics with lower warp extension than that of the untreated control or the sodium hydroxide treated fabrics. No differences, however, were observed in the weft direction. Slack mercerisation produced fabrics with significantly higher extension values in both the warp and weft directions than any of the other treatments.

The bursting strength results show that the treatment of fabrics in liquid ammonia under tension resulted in higher bursting strength than was found for the sodium hydroxide treatment, or for the slack mercerisation treatment in ammonia. Once again, the degree of stretch (6 or 8 *per cent*), different processing speeds and heat or water removal of ammonia had no significant effect on fabric bursting strength.

TABLE III

PHYSICAL PROPERTIES OF THE TWILL FABRIC AFTER DIFFERENT WAYS OF TREATMENT IN LIQUID AMMONIA AND AFTER MERCERISATION IN SODIUM HYDROXIDE

TREATMENT	CONDITIONS OF TREATMENT			PHYSICAL PROPERTIES											
	ESTIMATED CONTACT TIME (SEC)	STRETCH (%)	AMMONIA REMOVED BY	BREAKING STRENGTH (kgf)		EXTENSION AT BREAK (%)		BURSTING STRENGTH (kgf/cm^2)	TEAR STRENGTH (hectograms)		FLEX ABRASION (cycles to rupture)		STIFFNESS (cm)		CREASE RECOVERY ANGLES (degrees)
				Warp	Weft	Warp	Weft		Warp	Weft	Warp	Weft	Warp	Weft	
Untreated Control				98,6	52,9	18,7	12,4	13,9	54,3	42,6	1577	565	2,1	1,8	187
Stretched Control *				99,7	53,8	18,1	12,7	14,4	50,8	45,1	1728	901	2,1	1,7	185
Liquid Ammonia	15	0	Heat	100,3	62,0	25,4	30,1	14,0	45,8	39,1	–	–	2,0	1,7	236
	15	6	Heat	107,0	47,8	13,3	11,7	17,0	59,1	52,7	2768	1077	2,1	1,6	225
	15	8	Heat	113,6	44,1	13,3	11,0	16,4	59,1	53,9	2404	839	2,2	1,6	222
	5	0	Heat	93,9	65,8	26,3	29,9	14,3	44,6	36,7	–	–	2,1	1,7	213
	5	6	Heat	82,6	41,4	11,0	11,3	16,8	50,3	47,5	2112	956	2,1	1,7	240
	5	8	Heat	103,4	42,0	12,8	10,8	15,6	57,5	51,2	3531	1136	2,4	1,6	211
	15	6	Water	114,6	44,2	13,0	13,0	17,0	60,3	48,4	2877	1466	2,4	1,8	201
	15	8	Water	106,2	45,7	11,4	12,1	17,2	57,1	56,6	2738	888	2,3	1,9	191
	5	6	Water	112,0	47,2	12,7	13,6	17,2	55,5	42,2	2050	880	2,6	2,0	193
	5	8	Water	108,2	45,6	13,0	12,2	16,5	60,8	50,5	3663	1190	2,3	1,8	210
Sodium Hydroxide				93,9	45,1	15,4	12,2	15,8	44,5	36,5	852	609	2,5	2,0	185

* Average value of the stretched control fabrics

In establishing the effect of the various treatments on the tear strength of the twill fabric it was found that liquid ammonia treatment gave higher tear strength values in both the warp and weft directions than the sodium hydroxide treatment. The slack mercerised fabrics again had inferior tear strengths. Heat or water removal of the ammonia from the fabrics did not differ significantly in their effect on the tear strength of the fabrics.

Liquid ammonia mercerisation also proved to be significantly better than sodium hydroxide mercerisation as far as flex abrasion was concerned. The flex abrasion results obtained after the different treatments, in general, followed the same trend as was found for the tear strength results.

As far as the stiffness and crease recovery angles of the twill fabric were concerned, the same trends were observed as those for the other two fabrics.

It can be concluded that liquid ammonia mercerisation appeared to improve the physical properties of cotton fabrics, especially the heavyweight plain and twill fabrics, to a greater extent than sodium hydroxide mercerisation. It was also obvious that heat or water removal of ammonia did not differ significantly as far as their effect on the fabric properties was concerned, except for crease recovery angles where heat removal produced better results than water removal. A large difference was also found between the slack mercerised fabrics and the fabrics stretched to various degrees. A slack treatment in liquid ammonia resulted in excessive shrinkage which, in turn, affected the physical properties of the fabrics. In the case where the fabrics were mercerised under tension, however, no significant differences were found between the fabrics which had been stretched to different degrees. Statistical analysis indicated that a slower speed produced slightly better results than a higher speed on this particular machine.

2. THE EFFECT OF COLD AND HOT WATER REMOVAL OF AMMONIA ON CERTAIN PHYSICAL PROPERTIES OF THE FABRICS AFTER FIVE SECONDS CONTACT TIME IN LIQUID AMMONIA

Table IV is a summary of the influence of hot and cold water removal of ammonia on certain physical properties of the fabrics. It is clear from this table that hot or cold water removal of ammonia did not produce significant differences in the physical properties of the lightweight plain fabric. In the case of the heavyweight plain fabric it would appear that hot water produced slightly lower warp and weft extension values than

TABLE IV

THE EFFECT OF COLD AND HOT WATER REMOVAL OF AMMONIA ON CERTAIN PHYSICAL PROPERTIES OF THE FABRICS

FABRIC	NH_3 REMOVED BY	PHYSICAL PROPERTIES						
		EXTENSION AT BREAK (%)		TEAR STRENGTH (hectograms)		STIFFNESS (cm)		CREASE RECOVERY ANGLE * (degrees)
		Warp	Weft	Warp	Weft	Warp	Weft	
Lightweight plain fabric	Untreated Control	10,4	21,2	9,4	10,6	1,9	1,7	184
	Hot water	6,1	21,3	11,8	12,4	2,3	1,8	212
	Cold water	6,8	22,8	11,3	12,7	2,1	1,8	201
Heavy-weight plain fabric	Untreated Control	18,5	11,6	15,4	13,0	2,1	1,7	174
	Hot water	11,3	11,9	21,4	15,0	2,6	1,8	200
	Cold water	13,6	12,5	21,0	16,2	2,6	2,0	203
Twill fabric	Untreated Control	16,7	16,4	43,0	33,8	2,4	1,7	180
	Hot water	10,8	16,8	52,5	43,6	3,0	1,9	206
	Cold water	13,5	17,4	50,7	39,5	3,0	2,0	194

* Total in warp and weft directions

the cold water. There were, however, no differences in the tear strength, fabric stiffness or crease recovery angles of the fabrics. In the case of the twill fabric the removal of the ammonia by hot water also produced lower warp and weft extension values than the removal of the ammonia by cold water. The hot water, furthermore, gave higher tear strength values than the cold water, especially in the weft direction. The other physical properties of the twill fabric were not affected significantly by hot or cold water.

Figure 1 shows the effect of hot and cold water on the bursting strength of the fabrics. It is quite clear that the difference between hot and cold water removal was small for the lightweight plain and heavyweight plain fabrics. For the twill fabric, however, the hot water removal of ammonia resulted in a 13 *per cent* increase in bursting strength over that found for cold water removal.

Figure 2 shows the effect of cold and hot water removal on the breaking strength of the fabrics. There was practically no difference between the warp breaking strength of the fabrics treated with cold and that of the fabrics treated with hot water. In the case of the weft breaking strength, however, the cold water gave slightly higher values for all three fabrics.

In Figure 3 the effect of cold and hot water removal of ammonia on the flex abrasion of the fabrics is shown. No differences were found between the two treatments in the case of the lightweight plain fabric. For the heavyweight and twill fabrics, however, cold water removal gave much higher flex abrasion values than hot water.

In conclusion it may be stated that, in general, there was little difference between the removal of ammonia from the lightweight plain fabric by *hot* or *cold* water. Certain fabric properties seemed to be improved slightly by cold water, while others seemed to be improved by hot water in the case of heavyweight plain and twill fabrics.

Although the effect of cold or hot water removal of ammonia from the fabrics was small, it must be emphasised that this machine was running at a relatively slow speed. At higher production speeds, it may be beneficial to use hot water for the removal of the ammonia due to the better quenching action that can be obtained with hot water.

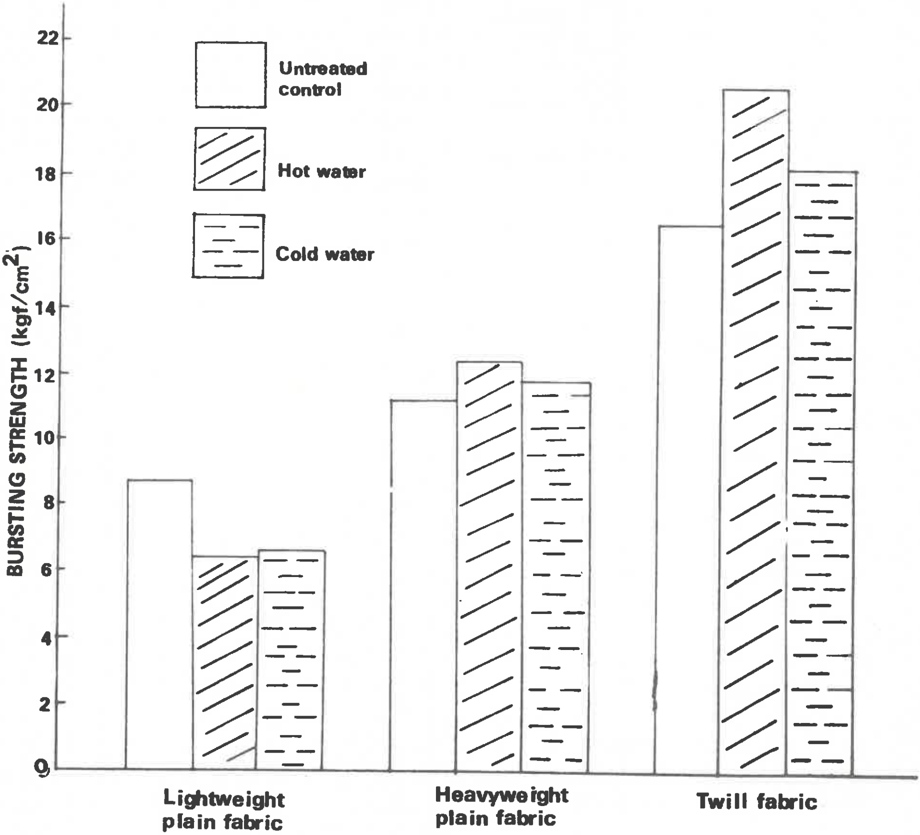


Figure 1 *The effect of cold and hot water removal of ammonia on the bursting strength of the fabrics*

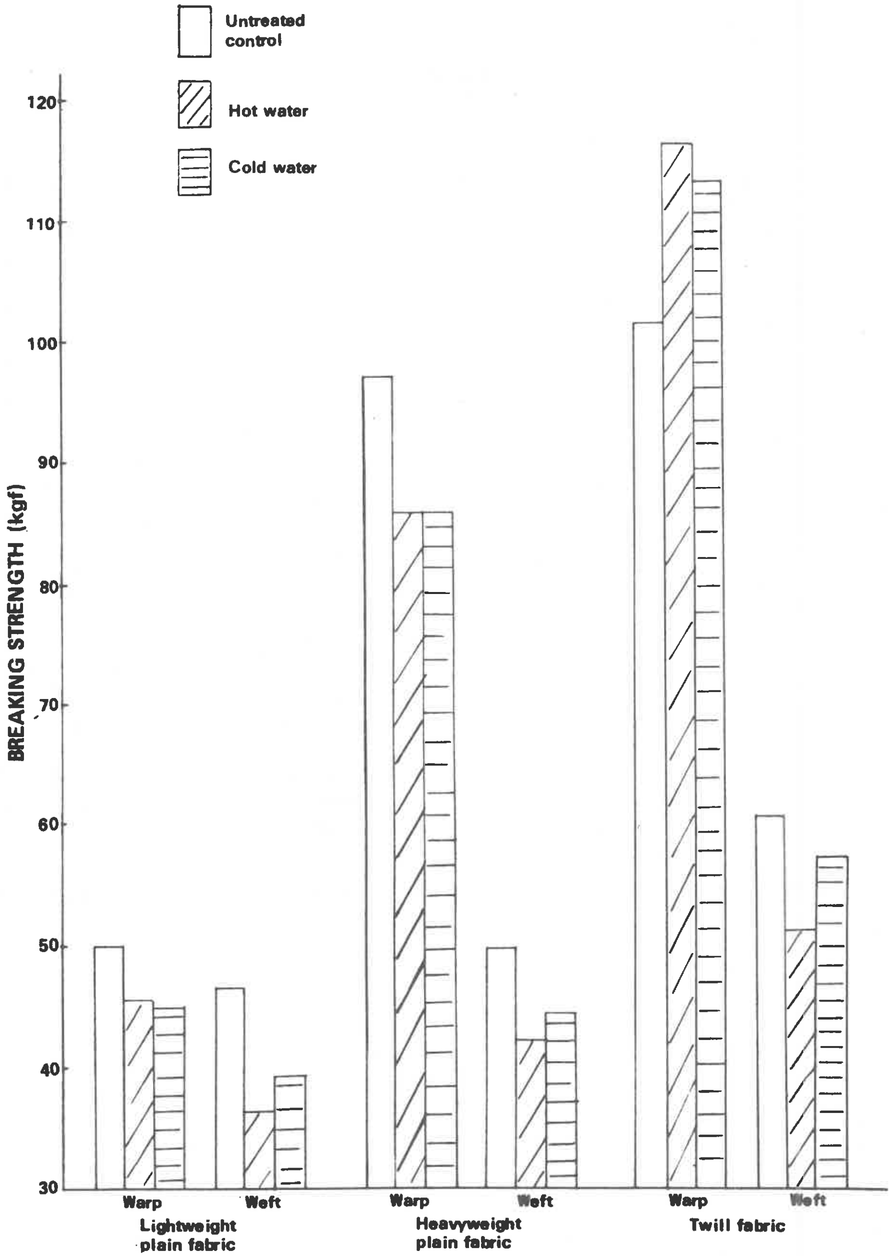


Figure 2 The effect of cold and hot water removal of ammonia on the breaking strength of the fabrics

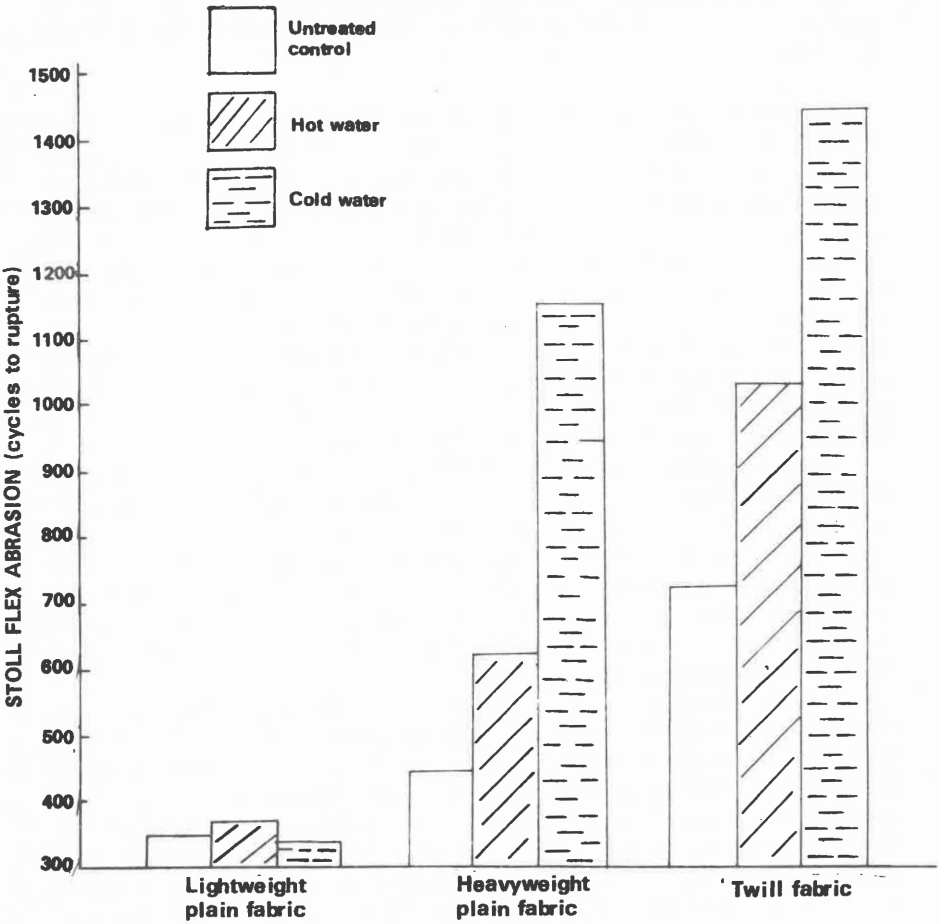


Figure 3 *The influence of cold and hot water removal of ammonia on the flex abrasion of the fabrics in the warp direction*

3. A COMPARISON BETWEEN LIQUID AMMONIA MERCERISATION, WITH HOT WATER REMOVAL OF THE AMMONIA AND SODIUM HYDROXIDE MERCERISATION.

Figure 4 shows the effect of different percentages of stretch applied to the fabrics and different contact times in liquid ammonia on the bursting strength of the fabrics. For both fabrics the bursting strength increased when the degree of stretch was increased. Different contact times in liquid ammonia had practically no effect on the bursting strength of the twill fabric, but the shorter contact time resulted in a higher bursting strength for the plain weave fabric. In the case of the twill fabric, all the liquid ammonia treatments produced fabrics with higher bursting strengths than those for the sodium hydroxide treatment. In the case of the plain weave fabric, however, only the highest degree of stretch with the shortest contact time in liquid ammonia produced better results than the sodium hydroxide treatment.

Figure 5 shows the effect of hot water removal of ammonia under different conditions of treatment on the tear strength of the fabrics in the warp direction. As was observed for the bursting strength of the fabrics, it was found that the tear strength increased when the degree of stretch was increased. In general, the higher processing speed gave higher tear strength results. As was found before, the liquid ammonia treatment increased the tear strength of the fabrics to a greater extent than the sodium hydroxide treatment.

Figures 6 and 7 show the effect of the different treatments on the flex abrasion of the fabrics in the warp and weft directions, respectively. Only the twill fabric showed significant effects, the greatest effect being found in the warp direction. A higher stretch at the higher processing speed was found to be the most advantageous as far as flex abrasion was concerned. When the twill fabric was treated for five seconds in ammonia and stretched to 8 *per cent*, the resistance to warp flex abrasion was about five times higher than that of the untreated control fabric and about two and a half times higher than that of the fabric mercerised with sodium hydroxide. No significant differences in the warp and weft flex abrasion of the heavyweight plain fabric were produced by the different treatments. The same was found for the weft flex abrasion of the twill fabric, except that the fabric which had been processed at 8 *per cent* stretch and 5 seconds contact time, seemed to have a superior resistance to flex abrasion.

The crease recovery angles of the two fabrics after different conditions of treatment are given in Figure 8. The liquid ammonia mercerisation generally produced much higher crease recovery angles than the

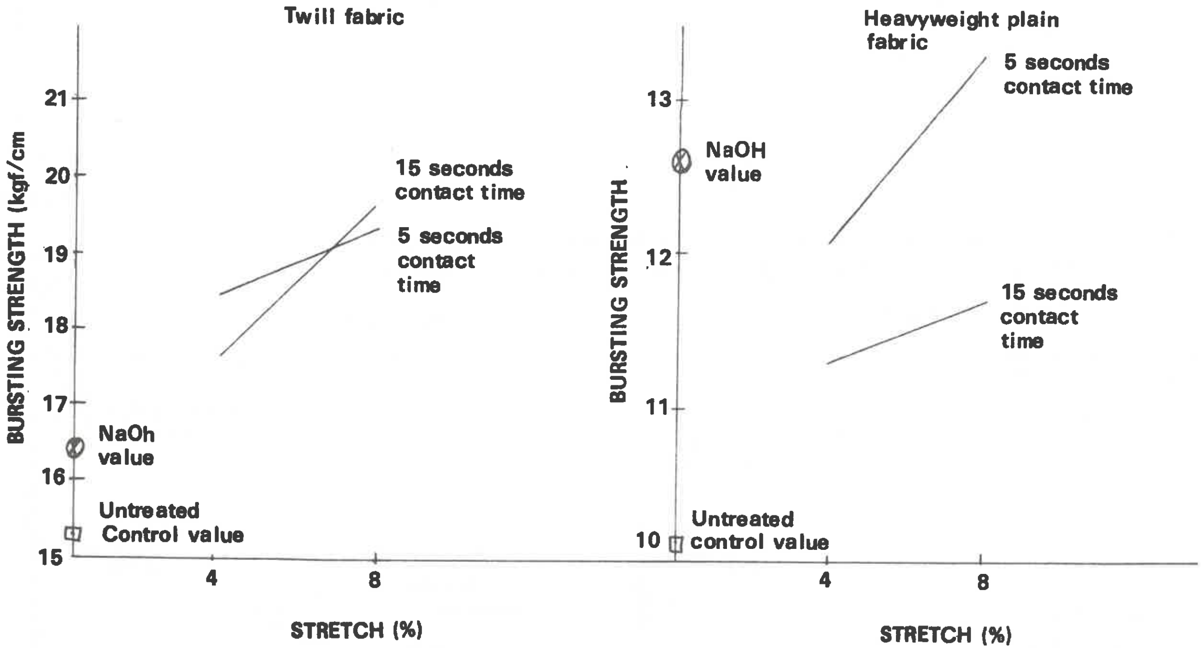


Figure 4 The effect of stretch applied to the fabrics on the bursting strength after hot water removal of the ammonia from the fabrics

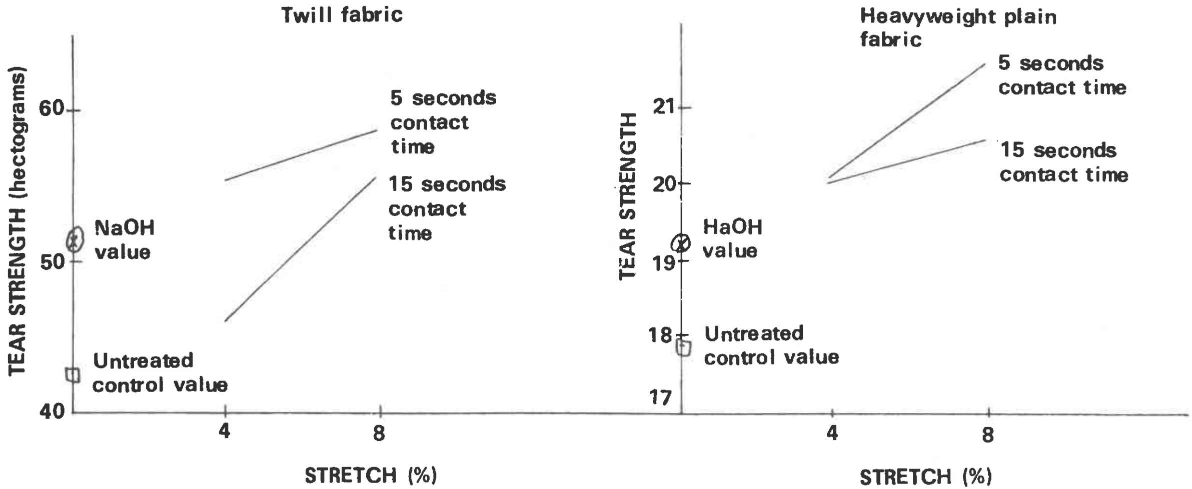


Figure 5 *The effect of stretch applied to the fabrics on the warp tear strength after hot water removal of the ammonia from the fabrics*

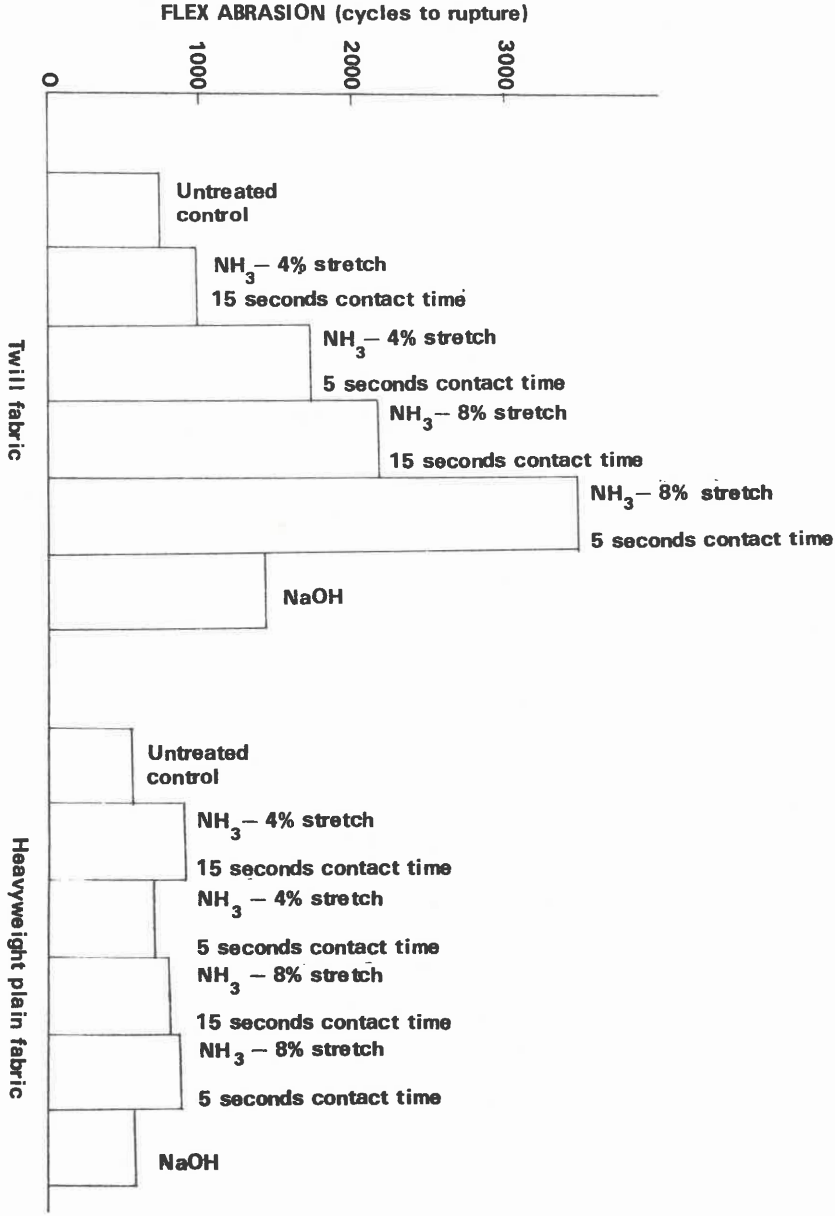


Figure 6 The effect of hot water removal of ammonia from the fabrics after different degrees of stretch and contact times on warp flex abrasion

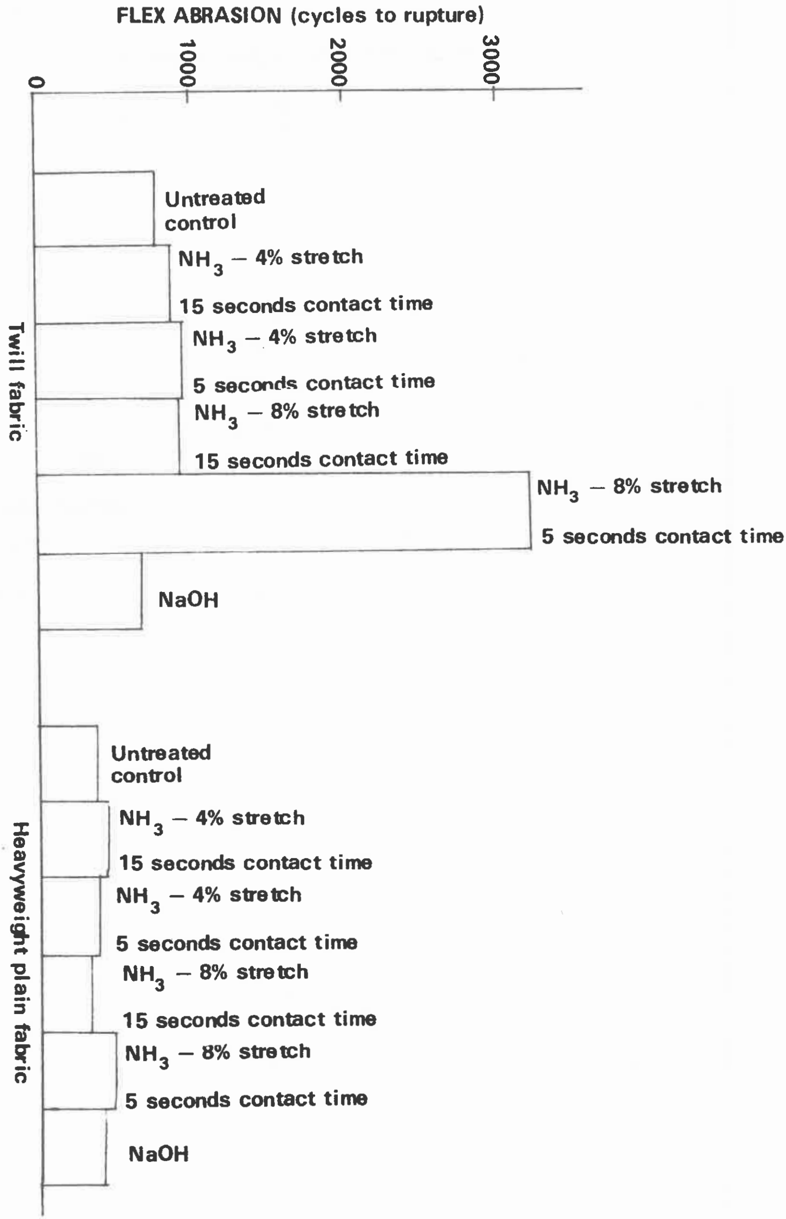


Figure 7 The effect of hot water removal of ammonia from the fabrics after different degrees of stretch and contact times on weft flex abrasion

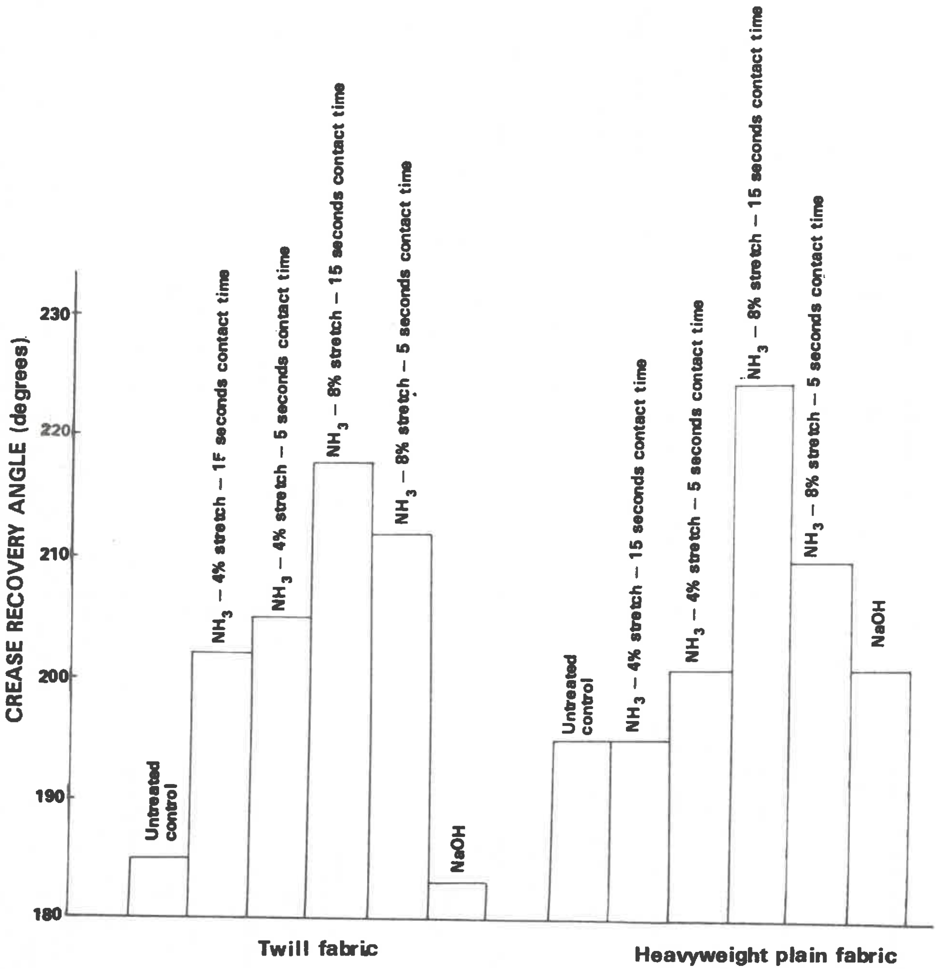
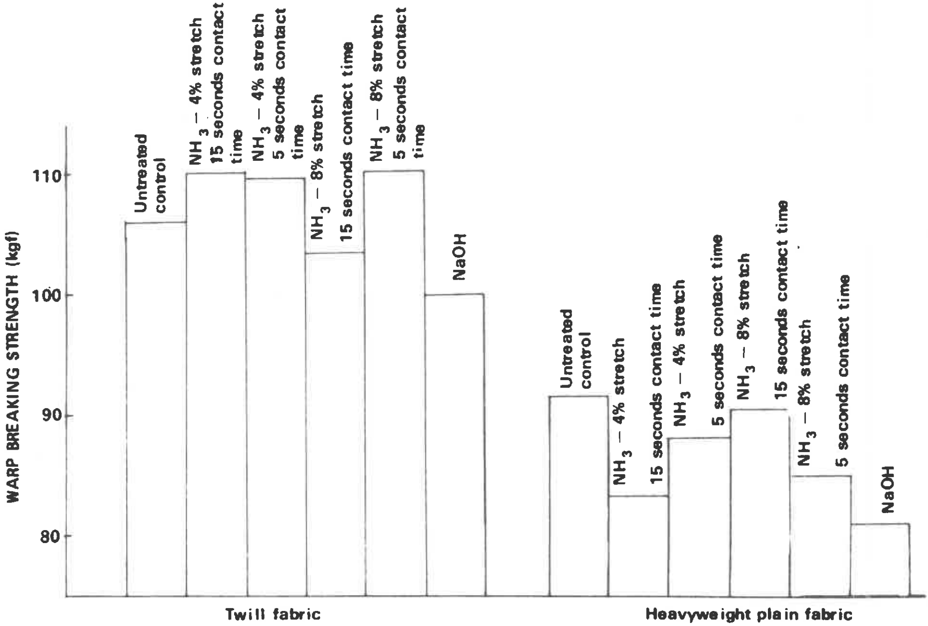


Figure 8 *The effect of hot water removal of ammonia from the fabrics after different contact times and degrees of stretch on the crease recovery angles of the fabrics*



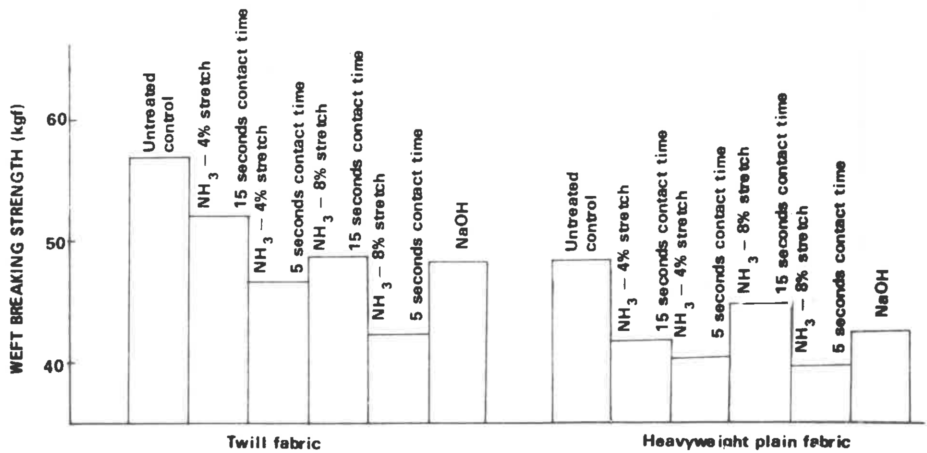


Figure 9 *The effect of hot water removal of ammonia from the fabrics after different contact times and degrees of stretch on the breaking strength of the fabrics*

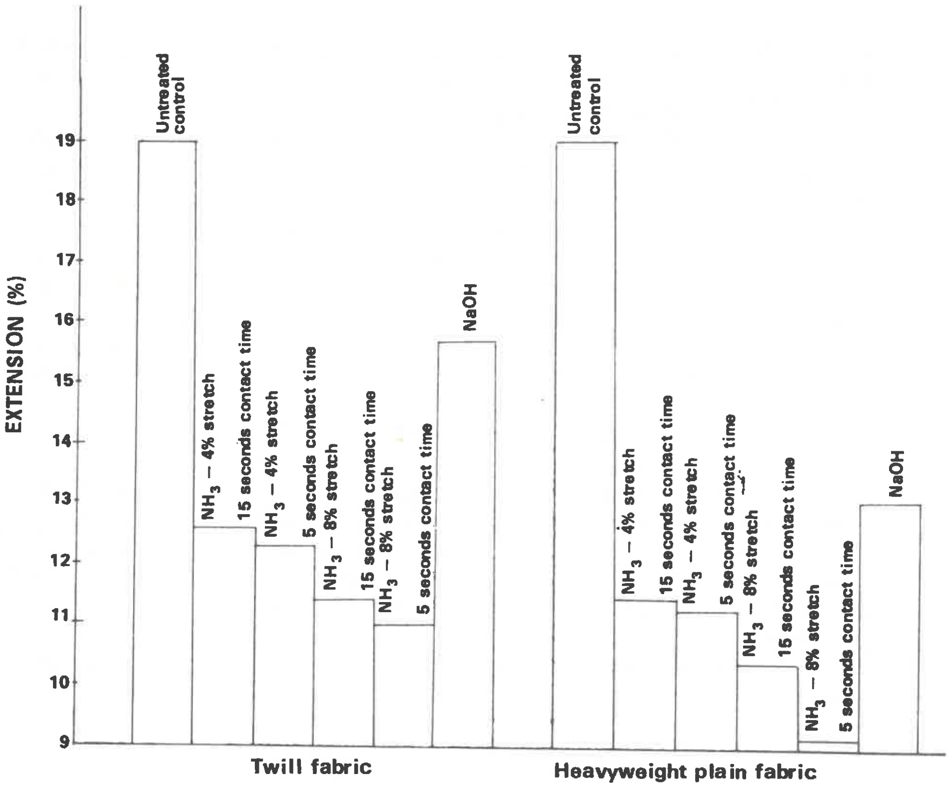


Figure 10 The effect of hot water removal of ammonia from the fabrics on the extension of the fabrics in the warp direction

sodium hydroxide mercerisation, especially in the case of the twill fabric. The highest crease recovery angles were obtained when the fabrics were stretched to 8 *per cent*.

The effect of the hot water removal of ammonia after mercerisation on the breaking strength of the fabrics is shown in Figure 9. Liquid ammonia mercerisation generally seemed to result in fabrics with higher breaking strength values than the sodium hydroxide mercerisation. For the twill fabric, liquid ammonia mercerisation produced fabrics with slightly higher warp breaking strength, but lower weft breaking strength than the untreated control fabric. In the case of the heavyweight plain fabric, liquid ammonia mercerisation as well as sodium hydroxide mercerisation, decreased the warp and the weft breaking strength when compared with the control fabric.

Figure 10 shows the effect of the various conditions of treatment on the warp breaking extension of the fabrics. It is obvious that the extension of the fabrics was reduced by liquid ammonia as well as by sodium hydroxide mercerisation. In both cases the liquid ammonia treatment reduced the breaking extension to a greater extent than the sodium hydroxide treatment. The warp breaking extension seemed to decrease as the degree of stretch was increased and the contact time in ammonia was decreased.

The extension of the fabrics in the weft direction generally showed a trend similar to that found in the warp direction.

SUMMARY AND CONCLUSIONS

Cotton fabrics of different densities and constructions were treated with liquid ammonia on a pilot plant chainless merceriser. The physical properties of untreated and mercerised fabrics were determined in order to evaluate the liquid ammonia mercerisation process.

It was found that a treatment with liquid ammonia generally had a beneficial effect on fabric properties. Although the general claim that liquid ammonia increases the breaking strength of a cotton fibre was not confirmed when cotton fabrics were treated with liquid ammonia, it was, however, found that other fabric properties were improved. It was also found that the fabrics treated with liquid ammonia compared very well with those fabrics treated commercially with sodium hydroxide. In all cases it was found that the breaking extension, and in some cases the breaking strength of the sodium hydroxide treated fabrics, were higher than those of the liquid ammonia treated fabrics. In all cases the tear strength and the resistance to flex abrasion of the liquid ammonia treated fabrics were significantly higher than those of the sodium hydroxide treated fabrics. It was also found that liquid ammonia mercerisation gave a fabric with the same, or sometimes even lower stiffness than that from a sodium hydroxide mercerisation.

Practically no differences were observed between the physical properties of the fabrics from which the ammonia was removed by heat, and those of the fabrics from which the ammonia was removed by cold water. The only exception was that heat removal of ammonia resulted in higher crease recovery angles than water removal. Hot water, on the other hand, generally seemed to produce the same effect as cold water removal of ammonia. For the lightweight plain fabric, no differences were observed between hot and cold water treatments, but in the case of the heavier fabrics, hot water seemed to produce slightly better results than cold water. Contact time and degree of stretch applied to the fabrics did not have such a large effect, as was expected, on the physical properties of the fabrics. Differences were, however, observed between the slack mercerised fabrics and fabrics mercerised under tension. Slack mercerisation of fabrics resulted in excessive shrinkage and also had an adverse effect on certain fabric properties.

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