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Liquid Ammonia Mercerisation of Cotton

Part II: The Influence of Anhydrous Liquid Ammonia on the Dimensional Stability of Cotton Fabrics.

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LIQUID AMMONIA MERCERISATION OF COTTON
PART II : THE INFLUENCE OF ANHYDROUS LIQUID AMMONIA ON THE DIMENSIONAL STABILITY OF COTTON FABRICS

by F.A. BARKHUYSEN

ABSTRACT

Cotton fabrics of different structures and densities were treated with liquid ammonia. The effect of different contact times, different percentages of stretch applied to the fabrics, removal of ammonia from the fabrics by heat, cold or hot water and different pressures exerted by the top on the bottom rollers on the consolidation of the fabrics, were investigated.

It was found that treatment in liquid ammonia produced a fabric which was dimensionally more stable than a treatment in sodium hydroxide. A prerequisite was, however, that stretch had to be applied to the fabrics during the liquid ammonia treatment. The differences observed when the ammonia was removed from the fabric by heat, cold and hot water were relatively small. Different contact times of the fabric with liquid ammonia also had a relatively small effect on fabric consolidation.

INTRODUCTION

Cotton possesses many highly attractive characteristics and is still a very important textile fibre despite inroads made into its market by the synthetic fibres. To maintain its position in the market, however, every attempt must be made to allow cotton to meet modern textile demands. In particular, the swelling of cotton in swelling agents is very important as it plays a vital rôle in cotton technology especially in the well-known mercerisation process.

Mercerisation can produce profound changes in the structure and morphology of cotton fibres. The most promising and interesting results have been obtained from experiments involving the mercerisation of fibres, rovings or yarns. When cotton is processed in the form of fabrics, however, there are serious constraints, such as tightness of the weave and yarn twist, that can impede fibre swelling.

Shrinkage is one of the main problems encountered in the finishing of cotton goods. Fabrics are normally woven to certain standard widths and failure to maintain these dimensions during finishing, especially in the weft direction, can complicate subsequent processing, especially in the makingup trade. The consumer too does not want end-commodities which will shrink during home laundering. It is, therefore, important that the fabric dimensions be stabilised during finishing. There are some commercially available processes such as Sanforizing, in use for the stabilisation of cotton fabrics[1]. It has been claimed, however, that the treatment of cotton fabrics with liquid ammonia can, amongst other desirable properties imparted to the fabrics, reduce the shrinkage and stabilise the fabrics dimensionally. Furthermore, a considerable improvement has been achieved by the preservation of the original appearance of the fabric after ammonia treatment[2]. Yarns appear to be permanently set during treatment. The set imparted by the treatment is retained throughout multiple launderings with the result that the character of the weave persists throughout the fabric's life. Blue Bell Inc., makers of the famous Wrangler Brand in the United States decided to launch a new range of denim jeans treated with liquid ammonia. They are the first manufacturing licensees for the liquid ammonia treatment of fabrics and claim to offer a standard of dimensional stability never before achieved in denims[3]. This process will be licensed world-wide by the Sanforized Company and will be marketed under three trade marks: "Sanforset", "Duralized" and "Sanfor-Duralized", depending on the specific fabric requirements. Fabrics processed with liquid ammonia will be trademarked "Duralized", but the "Sanforset" trademark will be used for fabrics that meet the firm's new tumble-dry shrinkage-control standards. To meet these standards, the Duralized finish must be followed by a compressive shrinkage. It was stated that the treatment of cotton fabrics with liquid ammonia followed by a compressive shrinkage yields a wrinkle-free, soft fabric which fits, feels and looks better in garment form than the typical denim jean which tends to feel stiff and which requires multiple launderings to become soft. It was stated also that the area shrinkage of ammonia treated garments is approximately 5 *per cent* and that the treated garments do not require ironing after laundering to restore the dimensions.

A reduction of the potential washing shrinkage can also be achieved by allowing the fabric to contract during the ammonia treatment. The equipment used for the treatment of fabrics with liquid ammonia will allow some control of warp shrinkage but weft shrinkage cannot be controlled. Since weft shrinkage of woven fabrics is quite important it is claimed that the shrinkage can be restricted by limiting the time of contact of the fabric with liquid ammonia, i.e. the time from impregnation until removal of the ammonia. The contact time varies between 0,6 and 9,0 seconds[5].

The potential market for garments treated with liquid ammonia seems enormous[6]. The annual consumption of cotton denim for jeans in the U.S.A. is, for example, about 40 million metres. Together with corduroy, chambray and related heavyweight constructions the total volume could reach a billion metres.

The purpose of the present study, therefore, was to investigate the effect of anhydrous liquid ammonia on the consolidation and stabilisation of cotton fabrics on the machine described in Part I of this series.

EXPERIMENTAL

The fabrics used for the evaluation of the liquid ammonia mercerisation process were the following:

(i) a lightweight plain cotton fabric (mass/unit area 128 g/m^2),

(ii) a 2/1 twill cotton fabric (mass/unit area 223 g/m^2), and

(iii) a heavyweight plain cotton fabric (mass/unit area 185 g/m^2).

The loomstate specifications of the above fabrics were:

(i) 29 ends and 24 picks per centimetre with a yarn linear density of 19 tex and 25 tex for the warp and weft, respectively.

(ii) 32 ends and 16 picks per centimetre with 42 tex yarns in the warp and weft directions.

(iii) 40 ends and 17 picks per centimetre with a warp and weft yarn linear density of 28 tex and 33 tex, respectively.

These fabrics were woven, scoured, bleached and desized at a South African textile mill. Desizing of the fabrics was very thorough and practically all the size was removed as indicated by a potassium iodide-iodine spot test. The desizing treatment was performed to avoid any possible interference of the size with the mercerisation process as well as with subsequent tests performed on the samples.

These fabrics were treated on the machine described in a previous report[7].

Some of the fabrics used were mercerised under conventional conditions with sodium hydroxide at a local mill. These fabrics were used to compare the effect of a liquid ammonia treatment on cotton with that of a conventional sodium hydroxide treatment.

Commercial grade anhydrous liquid ammonia was used for the treatment of the cotton fabrics.

Method of Threading the Fabric on the Machine

To determine the amount of stretch which could be applied to a fabric on the machine, the extension at break of the fabric was determined on an Instron apparatus. The fabric was then threaded to apply a stretch equivalent to approximately 60 *per cent* of the original extension at break. It was decided to apply only about 60 *per cent* of the maximum stretch which could be applied to prevent tearing of the fabric due to weak places that might have been present.

The fabrics entered the machine at different positions, depending on the amount of stretch that was applied. The following sequence was used when threading a fabric on the machine. The fabric was passed over the first top roller selected, underneath the first bottom roller selected, over the following top roller and underneath the following bottom roller. This sequence was followed until the fabric was threaded to the point where the required amount of stretch was applied. The fabric was then rolled onto a batching roller and, after treatment, could be removed from the machine. Theoretically a total of 14 *per cent* stretch could be applied to a fabric which was passed through and over all the rollers.

Details of different processing conditions during liquid ammonia treatment

Fabric lengths of 5,5 m each (approximately 55 cm wide) were treated on the machine. Leader fabrics were employed to process the different lengths of fabric through the machine.

Due to the fact that the cellulosic material is wetted out almost instantaneously in liquid ammonia, only *one ammonia bath* was used for each treatment. In all the different treatments, the fabrics left the machine after passing the sixth bottom roller, whereupon they were wound onto the batching roller. When 4 *per cent* stretch was applied to a fabric, the ammonia was introduced into the *third* ammonia bath. In this case the fabric was fed into the machine between the third top roller and the fourth bottom roller. When 6 or 8 *per cent* stretch was applied to the fabric, the ammonia was introduced into the *second* and *first* ammonia baths, respectively. In these cases the fabrics were fed into the machine between the second top roller and third bottom roller or between the first top roller and second bottom roller.

When heat was used to remove the ammonia from the fabric, the infrared heaters were placed above the fifth top roller. Where the ammonia was removed from the fabric by water, either hot or cold water was introduced into the first water bath, situated underneath the fifth bottom roller, by means of the water sprays described in Part I of this series.

Where heat was used to terminate the reaction between the cellulose and liquid ammonia, the fabrics were subsequently steamed for 5 minutes on a Hoffman press to remove the ammonia (approximately 5 *per cent*[8]) which the fibres still retain after the evaporation treatment.

The following processing conditions were investigated:

(i) Certain fabrics were mercerised in the slack state, i.e. they were treated with liquid ammonia and the ammonia was removed from the fabrics without the application of any stretch. In other words, after passing through the first pair of rollers (one top and one bottom roller), and into the first ammonia bath, the fabric moved directly over the next top roller onto the batching roller. In this case the ammonia was removed from the fabric by heat.

(ii) Other fabrics were mercerised under tension. Two lengths of the light-weight plain fabric was stretched to 4 and 6 *per cent* theoretical stretch, respectively. Three lengths each of the other two fabrics were stretched to 4, 6 and 8 *per cent* theoretical stretch, respectively.

(iii) Some treatments were carried out with the top rollers in the "free position", while others were carried out with the top rollers pressing down on the bottom rollers. Different pressure conditions between the top and bottom rollers were obtained by applying a torque of 10 or 20 newton metres to the adjusting screws of the top rollers.

(iv) Processing took place at three different speeds, viz. one, three and five metres/minute. These speeds resulted in a contact time of 15, 5 and 3 seconds respectively, between the fabric and the ammonia in the ammonia bath.

(v) Fabrics were also processed through the merceriser under the same conditions as described above, but without being wetted out in liquid ammonia. No heat or water was applied to these fabrics, which acted as the stretched control fabrics.

(vi) For all the experiments, samples of the untreated fabrics, as received from the textile mill, were used as the control fabrics. These fabrics were not processed through the machine at all.

Consolidation Measurements

To determine to what extent the cotton fabrics were consolidated by the liquid ammonia treatment, squares (21 cm x 21 cm), parallel to the warp and weft directions, were marked on the fabrics before treatment. After the liquid ammonia treatment, the fabric dimensions were measured again. To determine whether dimensional changes brought about by the liquid ammonia would persist during subsequent washing treatments, samples of the fabrics were subjected to different washing conditions. The samples were first relaxed in a Cubex apparatus[9], containing 25 litres of water at 50°C plus 1 g/ℓ of soap. The load in the Cubex was kept constant at 500 g, half of which comprised the cotton samples and the other half polyester makeweights. The fabrics remained static in the above solution for 15 minutes followed by tumbling for 5 minutes. After drying the samples were decatised (6 minutes steaming time, 3 minutes cooling time) and the dimensions determined again. The samples were then subjected to severe washing conditions i.e. tumbling for another 2 hours at 50°C in the Cubex containing 15 litres of water and 1 g/ℓ of soap. The fabric dimensions were measured after 30, 60 and 120 minutes. The samples were not decatised again after the above washing treatments. The changes, if any, in dimensional properties after the various washing tests, were based on the original measurements before liquid ammonia treatment. Negative consolidation values indicate stretch in the given directions.

RESULTS AND DISCUSSION

THE EFFECT OF TOP ROLLER PRESSURE ON FABRIC DIMENSIONS DURING LIQUID AMMONIA AND SUBSEQUENT WASHING TREATMENTS

Some initial trials were carried out to evaluate the effect of various machine settings on the processing performance of the machine. The pressure exerted by the top rollers on the bottom rollers was the first factor to be considered. Three different pressures were employed by setting the top rollers in the free position (zero torque), or by applying 10 and 20 newton metre (N.m.) torque to the top roller adjusting screws. The lightweight plain fabric was then processed through the machine at a speed of 3 metres/minute and stretched to 6 *per cent* (theoretical). The ammonia was removed from the fabric with cold water. The shrinkage of the fabrics in the warp and weft directions was determined after the ammonia treatment and after subsequent relaxation and washing treatments. The results obtained are given in Figures 1 and 2. From Figure 1 it is clear that the top roller pressure had no influence on the warp shrinkage of the fabrics processed through the machine in the absence of ammonia, and these fabrics all shrank approximately to the same extent during relaxation and washing. When the fabrics were treated with ammonia, however, marked differences were observed between different roller pressure settings. With top rollers in the free position (zero torque) the fabric shrank about 5 *per cent* in the warp direc-

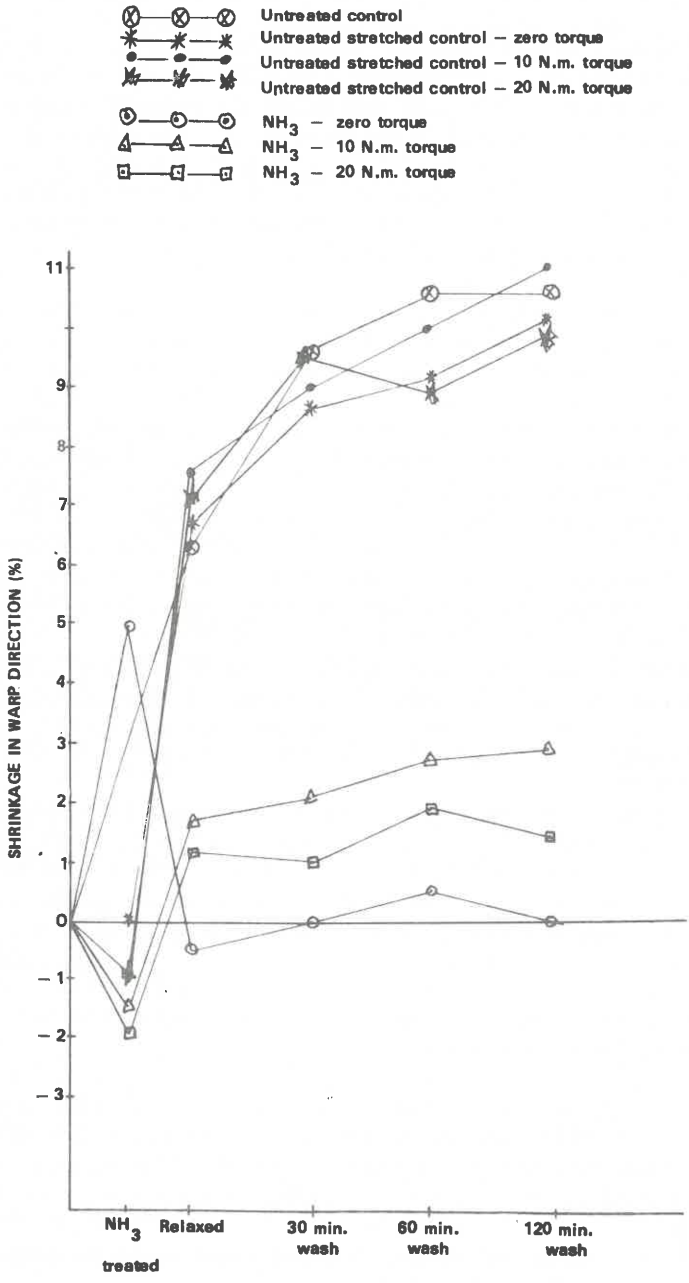

Figure 1 The effect of roller pressure on the warp dimensions after liquid ammonia and washing treatments

tion during the ammonia treatment. When torque was applied, however, the shrinkage of the fabric was prevented and the desired effect in fact was obtained i.e. the fabric was stretched during the ammonia treatment. The 10 and 20 N.m. torque produced approximately the same shrinkage values during ammonia treatment, while a 20 N.m. torque gave slightly lower shrinkage values in subsequent washing treatments. The zero torque setting gave the lowest warp shrinkage values in subsequent washing treatments but it resulted in shrinkage instead of stretching of the fabric in the warp direction during the ammonia treatment.

The change in weft dimensions is given in Figure 2. Fabrics processed through the machine in the absence of ammonia did not change much in the weft direction during processing, and expanded slightly during subsequent washing tests. Fabrics treated in the presence of ammonia, however, shrank considerably during the ammonia treatment. The largest shrinkage during the ammonia treatment was obtained in the case when no torque was applied. This fabric was also the most unstable during subsequent washing treatments and expanded by about 5 *per cent* in the weft direction. The weft shrinkage of the fabric during the ammonia treatment was slightly less when 10 N.m. torque was applied instead of 20 N.m. torque. In subsequent washing tests, however, the fabric that had been treated under 10 N.m. torque expanded a little, while that treated under 20 N.m. torque shrank a little. The average shrinkage of these two fabrics during subsequent washing was, however, approximately the same. Some treatments were also carried out by removing the ammonia from the fabric by heat instead of water. The shrinkage of the fabric in the warp and weft directions followed the same tendency in both cases.

The effect of the pressure exerted by the top rollers on the bottom rollers may be explained in the following way: when no pressure was applied, the 6 *per cent* stretch applied to the fabric in the warp direction was not sufficient to prevent it from shrinking in the liquid ammonia. Shrinkage of the fabric in the warp and weft directions occurred, and possibly also some slippage of the fabric over the rollers in the warp direction. When pressure was applied, however, the fabric was nipped between the top and bottom rollers. Shrinkage of the fabric in the weft direction was reduced and the fabric was stretched in the warp direction.

There was little difference between the results obtained with 10 and 20 N.m. torque settings. It was decided to use the 20 N.m. torque setting for all further treatments where stretch was applied to the fabrics. The higher torque was selected because fabrics of different constructions and densities were used. The heavier fabrics would probably exhibit higher shrinkage forces in the ammonia which would require a higher pressure between the top and bottom rollers to prevent shrinkage and slippage of the fabric on the rollers.

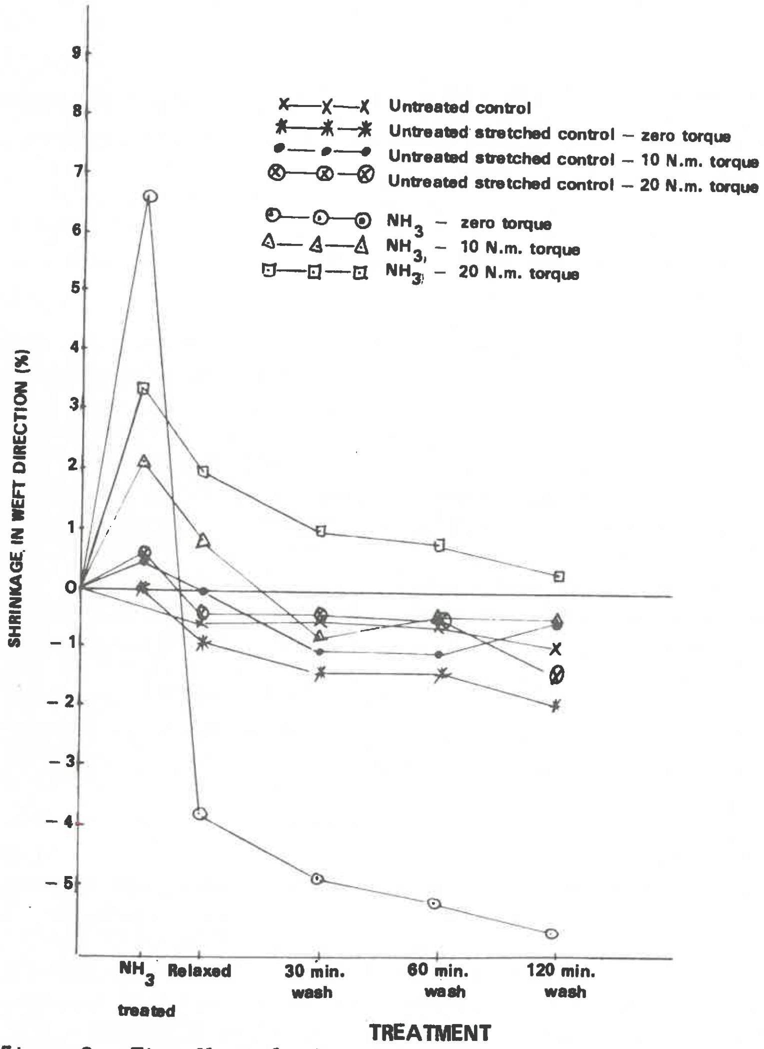

Figure 2 *The effect of roller pressure on the weft dimensions after liquid ammonia and washing treatments*

THE INFLUENCE OF DIFFERENT PROCESSING PARAMETERS DURING LIQUID AMMONIA MERCERISATION ON THE DIMENSIONAL STABILITY OF THE FABRICS

Trials were carried out to determine the influence of various processing parameters during liquid ammonia mercerisation on the dimensional stability of cotton fabrics. The effect of time of contact of the fabric in ammonia, different degrees of stretch and heat or water removal of ammonia on the consolidation of the fabrics during the ammonia treatment and subsequent washing tests, were investigated. The results obtained for the lightweight plain, heavyweight plain and twill fabrics are given in Tables I, II and III, respectively.

It is clear from Table I that the stretched control fabrics showed the same tendency as the untreated control fabric and the stretch applied did not stabilise the fabric in any way. Table I also shows that mercerisation of the fabrics in the slack state, i.e. no stretch, resulted in excessive shrinkage, even in the case of a contact time of only 5 seconds. The fabrics shrank about 8 *per cent* in the warp and the weft directions in the ammonia, and the percentage area shrinkage of the fabric after a 120 minute wash test was about the same as that of the untreated control fabric. The high shrinkage of the fabrics mercerised in the slack state was also reflected in the mass/unit area of the fabrics, which increased from 128 g/m^2 for the untreated control to approximately 150 g/m^2. The mass/unit area of the different samples treated under tension in liquid ammonia remained fairly constant, indicating that the fabric shrinkage was kept to a minimum during treatment. Unfortunately, it was not possible to determine the degree of shrinkage of the fabric treated commercially with sodium hydroxide directly after mercerisation, but the Finishing Manager of the particular firm stated that the fabric shrank approximately 10 *per cent* in area. This was supported by the approximately 10 *per cent* increase in mass/unit area (from 128 g/m^2 to 140 g/m^2) found for this fabric after mercerisation.

A statistical analysis of variance of the results in Table I showed that the longest contact time of the fabric in ammonia gave the highest degree of stretch of the fabrics in the warp direction and the lowest degree of shrinkage in the weft direction, especially where 4 *per cent* stretch was applied to the fabrics. This was found for both heat and water removal of ammonia from the fabrics. Contact time had no effect, however, on dimensional stability in subsequent washing treatments. The analysis also showed that the 4 or 6 *per cent* stretch applied to the fabric did not differ significantly as far as their effect on dimensional stability was concerned. The difference between heat or water removal of the ammonia from the fabric was small.

TABLE I

DIMENSIONAL CHANGES OF THE LIGHTWEIGHT PLAIN FABRIC AFTER MERCERISATION IN LIQUID AMMONIA AND SODIUM HYDROXIDE

TREATMENT	CONDITIONS OF TREATMENT			DIMENSIONAL CHANGES											
	ESTIMATED CONTACT TIME (SEC)	STRETCH (%)	AMMONIA REMOVED BY	CONSOLIDATION (%) AFTER:										AREA SHRINKAGE (%) AFTER 120 MINUTES WASHING	FABRIC MASS/UNIT AREA AFTER AMMONIA TREATMENT (g/m²)
				AMMONIA TREATMENT		RELAXATION		30 MINUTES WASHING		60 MINUTES WASHING		120 MINUTES WASHING			
				Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft		
Untreated Control						6,2	−0,5	9,6	−0,5	10,5	−0,5	10,5	−0,9	9,6	128
Stretched Control *				−0,9	0,6	7,3	0,5	9,0	−0,4	9,5	−0,8	10,7	−0,8	9,9	126
Liquid Ammonia	15	0	Heat	8,6	7,6	10,0	4,6	9,1	−0,3	9,5	−0,3	9,8	−0,3	9,5	148
	15	4	Heat	−3,6	2,4	1,0	1,0	1,4	0,8	1,9	0,5	2,2	0,5	2,7	128
	15	6	Heat	−1,9	2,9	1,4	0,5	2,9	0,5	2,4	0	3,8	0	3,8	130
	5	0	Heat	7,9	8,1	9,1	5,3	8,3	0,7	8,5	0,5	8,3	0	8,3	150
	5	4	Heat	−3,3	2,9	1,7	1,2	1,9	0,3	2,9	0	2,7	−0,3	2,4	130
	5	6	Heat	−3,3	3,1	1,4	1,4	1,4	0	2,2	0,5	1,7	−0,3	1,4	132
	3	4	Heat	−2,7	3,3	1,2	0,8	2,4	0	2,9	0	3,8	0	3,8	128
	3	6	Heat	−3,8	3,1	1,0	1,2	1,2	−0,3	2,4	0,3	3,1	0,3	3,4	129
	15	4	Water	−2,4	2,2	0,5	1,0	0,5	0,5	1,2	0,5	0,8	−0,3	0,5	132
	15	6	Water	−1,0	3,3	1,9	0	1,9	0	2,4	0	1,9	−0,5	1,4	130
	5	4	Water	−1,5	3,4	0,3	1,2	0,7	0,8	1,2	0,8	1,0	0,3	1,3	126
	5	6	Water	−1,9	3,4	1,2	2,0	1,0	1,0	1,9	0,8	1,4	0,3	1,7	129
	3	4	Water	−0,8	3,1	1,2	1,4	1,9	1,0	1,9	0,8	2,4	0,5	2,9	132
	3	6	Water	−1,5	3,6	1,0	2,4	1,2	1,5	1,0	1,4	1,7	1,0	2,7	131
Sodium Hydroxide						1,9	−6,2	3,8	−4,3	3,8	−5,7	3,8	−5,7	−1,9	140

* Average value of the control fabrics stretched to 4 & 6% theoretical stretch at the three different speeds.
No ammonia was applied to these fabrics.

TABLE II

DIMENSIONAL CHANGES OF THE HEAVYWEIGHT PLAIN FABRIC AFTER MERCERISATION IN LIQUID AMMONIA AND SODIUM HYDROXIDE

TREATMENT	CONDITIONS OF TREATMENT			DIMENSIONAL CHANGES											
	ESTIMATED CONTACT TIME (SEC)	STRETCH (%)	AMMONIA REMOVED BY	CONSOLIDATION (%) AFTER										AREA SHRINKAGE (%) AFTER 120 MINUTES WASHING	FABRIC MASS/UNIT AREA (g/m^2) AFTER DECATIZING
				AMMONIA TREATMENT		RELAXATION + DECATIZING		30 MINUTES WASHING		60 MINUTES WASHING		120 MINUTES WASHING			
				Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft		
Untreated Control						8,1	0	11,9	0,5	11,4	0	12,8	0	12,8	188
Stretched Control *				–1,7	0,2	7,8	–0,2	11,6	0,5	12,0	0,3	12,4	0,4	12,8	188
Liquid Ammonia	15	0	Heat	16,9	1,9	14,5	2,1	15,3	0,3	15,0	0,3	14,5	0	14,5	210
	15	6	Heat	–4,7	0,7	1,7	1,2	5,0	0,9	5,5	0,9	5,2	0,9	6,1	179
	15	8	Heat	–6,0	0,5	1,7	0,5	4,5	1,4	4,5	1,0	4,7	0,7	5,4	177
	5	0	Heat	20,0	1,9	16,5	1,2	14,1	0,3	14,1	0	13,8	–0,3	13,5	215
	5	6	Heat	–4,7	0,9	1,2	1,2	2,6	1,7	4,5	1,4	5,5	1,4	6,9	182
	5	8	Heat	–6,0	0,9	0,3	0,9	4,2	0,9	4,2	1,2	5,0	1,4	6,4	175
	15	6	Water	–1,7	0,9	1,9	1,4	3,6	1,7	4,0	1,4	4,2	1,2	5,4	180
	15	8	Water	–3,1	0,5	1,4	0,7	3,8	1,9	2,8	0,9	3,6	1,2	4,8	180
	5	6	Water	–1,0	0,9	2,7	0,9	3,6	0,9	3,8	1,4	4,3	1,2	5,5	181
	5	8	Water	–1,7	0,7	1,4	0,5	2,7	0,7	3,6	1,4	3,8	0,5	4,3	178
Sodium Hydroxide						–3,8	3,8	–2,9	4,8	–2,9	4,8	–2,9	4,8	1,9	185

* Average value of the control fabrics stretched to 6 and 8% theoretical stretch at the two different speeds. No ammonia was applied to these fabrics,

TABLE III

DIMENSIONAL CHANGES OF THE TWILL FABRIC AFTER MERCERISATION IN LIQUID AMMONIA AND SODIUM HYDROXIDE

TREATMENT	CONDITIONS OF TREATMENT			DIMENSIONAL CHANGES											
				CONSOLIDATION (%) AFTER:										AREA SHRINKAGE (%) AFTER 120 MINUTES WASHING	FABRIC MASS/UNIT AREA (g/m²) AFTER DECATIZING
	ESTIMATED CONTACT TIME (SEC)	STRETCH (%)	AMMONIA REMOVED BY	AMMONIA TREATMENT		RELAXATION + DECATIZING		30 MINUTES WASHING		60 MINUTES WASHING		120 MINUTES WASHING			
				Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft		
Untreated Control						8,6	–3,3	11,4	–2,4	11,4	–1,9	10,9	–1,9	9,0	226
Stretched Control *				–1,3	–0,2	10,7	–2,1	10,8	–1,5	11,5	–1,5	11,7	–1,6	10,1	229
Liquid Ammonia	15	0	Heat	14,1	2,4	14,3	0,5	13,1	–1,4	13,4	–1,7	13,6	–1,7	11,9	258
	15	6	Heat	–5,0	0,7	5,2	–1,0	2,4	–0,3	2,8	–0,3	2,7	–0,5	2,2	225
	15	8	Heat	–6,2	0,5	6,2	–1,0	2,4	0	2,7	–0,3	2,7	–0,3	2,4	228
	5	0	Heat	16,7	2,2	15,9	0	15,0	–1,4	14,8	–1,4	15,0	–1,7	13,3	263
	5	6	Heat	–3,8	0,8	6,2	–2,4	2,1	–1,4	3,1	–0,5	3,3	–1,0	2,4	222
	5	8	Heat	–5,7	1,7	5,7	–1,9	2,6	–1,0	3,1	–1,0	3,1	–1,0	2,1	225
	15	6	Water	–1,7	0,5	3,3	–0,5	1,7	–0,5	2,7	–0,8	2,4	–1,0	1,4	218
	15	8	Water	–3,3	0,3	4,8	–1,0	1,2	–0,3	1,4	–0,5	1,4	–0,5	0,9	219
	5	6	Water	–0,3	1,4	3,3	–1,0	2,4	0,5	2,4	0,5	2,7	0	2,7	198
	5	8	Water	–1,7	0,5	4,3	–1,4	1,7	–0,5	1,9	–0,5	1,9	–0,8	1,1	220
Sodium Hydroxide						4,7	–4,3	7,6	–3,8	8,1	–3,3	8,5	–3,8	4,7	219

* Average value of the control fabrics stretched to 6 and 8% theoretical stretch at the two different speeds. No ammonia was applied to these fabrics.

TABLE IV

THE EFFECT OF HOT AND COLD WATER REMOVAL OF AMMONIA FROM THE COTTON ON THE CONSOLIDATION OF THE FABRICS

FABRIC	AMMONIA REMOVED BY	CONSOLIDATION (%) AFTER NH_3 TREATMENT		AFTER RELAXATION + DECATIZING		AFTER 30 MINUTES WASHING		AFTER 60 MINUTES WASHING		AFTER 120 MINUTES WASHING		AREA SHRINKAGE (%) AFTER 120 MINUTES WASHING	FABRIC MASS/UNIT AREA (g/m^2)
		Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft		
Light Weight plain fabric	Untreated Control			5,2	0	8,6	–0,5	9,5	–0,5	10,0	–0,5	9,5	137
	Hot water	–2,9	2,4	–0,7	1,9	1,5	0	1,5	0	1,7	0,5	2,2	134
	Cold water	–1,9	3,8	0	1,7	1,4	0,7	1,4	0,7	1,4	0,7	2,1	138
Heavy-Weight plain fabric	Untreated Control			8,1	0	11,4	0,5	12,4	0,5	12,8	0,5	13,3	186
	Hot water	–3,5	1,1	0	0,5	1,7	1,4	1,9	1,4	2,2	1,4	3,6	178
	Cold water	0	1,1	1,9	0,7	3,1	0,7	3,1	0,7	3,3	0,7	4,0	178
Twill fabric	Untreated Control			8,1	–1,4	11,9	–0,9	12,4	–0,9	12,4	–1,9	10,5	227
	Hot water	–2,0	1,1	0	–0,5	2,1	–0,9	2,1	–0,7	2,7	–0,9	1,8	216
	Cold water	0	0,7	2,9	–1,5	2,8	–1,5	3,8	–1,5	4,7	–1,5	3,2	221

The heat removal gave a slightly better performance in the ammonia treatment stage, but in subsequent washing treatments the difference was not significant.

Statistical analyses showed trends for the heavyweight plain and twill fabrics (Tables II and III) similar to those found for the lightweight plain fabric. Excessive shrinkage occurred when these fabrics were treated in liquid ammonia in the *slack* state. The average shrinkage in the warp direction was 18,5 *per cent* for the heavyweight plain fabric and 15,4 *per cent* for the twill fabric. When tension was applied to the fabrics during the ammonia treatment, warp shrinkage was avoided and the fabrics were, in fact, stretched in the warp direction. The weft shrinkage was also reduced significantly. The fabrics mercerised under tension were more stable in the subsequent washing tests than the slack mercerised and untreated control fabrics. The statistical analysis showed that in subsequent washing treatments virtually no differences existed between the heat and water removal of the ammonia from the twill fabric, whereas the water removal gave a slightly better performance in the case of the heavyweight fabric. It is also clear that the area shrinkage of the heavyweight plain fabric after a 2 hour washing test was found to be higher than that for the other two fabrics.

It is obvious from Tables I, II and III that all the different treatments in liquid ammonia (except for slack mercerisation), irrespective of contact time, percentage stretch applied, or heat or water removal of ammonia, produced a dimensionally stable fabric when compared with the untreated control fabric. Apart from the fabrics treated in the slack state, the average area shrinkage of the three different fabrics was approximately 3 to 4 *per cent* after a 2 hour washing test. During the ammonia treatment the fabrics were stretched in the warp direction, while the weft shrinkage was kept to a minimum. It is clear, therefore, that the liquid ammonia treatment not only stabilised the fabric dimensions but that the stable structure persisted throughout subsequent washing treatments.

The average area shrinkage of the sodium hydroxide treated fabrics after 120 minutes washing did not differ much from that of the liquid ammonia treated fabrics. When the warp or weft shrinkage values after washing for 120 minutes are considered, however, the sodium hydroxide treatment gave either high stretch or shrinkage values in the warp and the weft directions. The liquid ammonia treatment, on the other hand, gave significantly lower shrinkage or stretch values in both the warp and weft directions.

The above results show that the liquid ammonia mercerisation generally produced fabrics which were dimensionally more stable than those from a sodium hydroxide mercerisation.

THE DIFFERENCE BETWEEN COLD AND HOT WATER REMOVAL OF AMMONIA FROM THE FABRICS

It has been recommended that hot water should be used to remove the ammonia from the cotton after mercerisation. Because of technical reasons, cold water was used for the removal of ammonia in the work carried out so far. The merceriser was, however, modified and some studies were then carried out to establish whether cold or hot water removal of the ammonia would affect the fabric properties to different degrees. The three fabrics were processed through the merceriser at a speed of 3 m/min i.e. a contact time of five seconds between the fabric and the liquid ammonia. The fabrics were stretched to 6 *per cent* stretch before removal of ammonia by either hot or cold water.

The effect of cold and hot water removal of ammonia from the fabrics on the consolidation properties of the fabrics is given in Table IV. It is clear that there was no difference between the removal of the ammonia by hot or cold water in the case of the lightweight plain fabric. The consolidation of the fabric in the warp and weft directions, the area shrinkage after washing for two hours as well as the fabric mass/unit area showed no difference between the two treatments. For the heavyweight plain and twill fabrics it would seem that *hot water* removal of ammonia resulted in a slightly more stable fabric than a cold water removal especially in the warp direction. The warp shrinkage after the different washing treatments was always higher for the fabric where the ammonia was removed by cold water. The final area shrinkage, however, showed little difference between hot and cold water removal of the ammonia. It is clear, however, that a better stretching effect was obtained on all three of the fabrics during the mercerisation stage, when hot water was used to remove the ammonia.

At higher production speeds it may be beneficial to use hot water because of the better quenching action that can be obtained with hot water.

THE EFFECT OF HOT WATER REMOVAL OF AMMONIA FROM THE FABRICS, AFTER DIFFERENT CONTACT TIMES AND STRETCH VALUES ON THE CONSOLIDATION OF THE FABRICS

Since there was little difference between the physical properties of the lightweight plain fabric when the ammonia was removed by hot or cold water, it was decided to use only the two heavyweight fabrics for further investigations of the effect of hot water removal of the ammonia after mercerisation. The twill and heavyweight plain fabrics were stretched to 4 and 8 *per cent* theoretical stretch at two different speeds. The fabrics were quenched in hot water to remove the ammonia. Table V shows the effect of the above

TABLE V

THE EFFECT OF HOT WATER REMOVAL OF AMMONIA FROM THE FABRICS, AFTER DIFFERENT CONTACT TIMES AND STRETCH VALUES, ON THE CONSOLIDATION OF THE FABRICS

FABRIC	CONDITIONS OF TREATMENT: SPEED (M/MIN)	CONTACT TIME (SEC)	STRETCH (%)	CONSOLIDATION (%): AFTER NH_3 TREATMENT Warp	AFTER NH_3 TREATMENT Weft	AFTER RELAXATION + DECATIZING Warp	AFTER RELAXATION + DECATIZING Weft	AFTER 30 MINUTES WASHING Warp	AFTER 30 MINUTES WASHING Weft	AFTER 60 MINUTES WASHING Warp	AFTER 60 MINUTES WASHING Weft	AFTER 120 MINUTES WASHING Warp	AFTER 120 MINUTES WASHING Weft	AREA SHRINKAGE (%) AFTER 120 MINUTES	FABRIC MASS/UNIT AREA (g/m²) AFTER DECATIZING
Twill fabric		Untreated Control				9,7	–1,9	11,5	–2,4	11,9	–1,9	12,9	–1,9	11,0	230
	1	15	4	–3,1	1,0	1,5	–0,3	1,7	–0,8	2,1	–1,5	2,7	–1,2	1,5	230
	1	15	8	–3,8	1,2	0,3	0	1,9	–1,0	2,1	–0,8	2,4	–0,5	1,9	224
	3	5	4	–3,1	0,7	1,4	–0,3	1,4	–0,8	2,1	–0,8	2,7	–1,7	1,0	227
	3	5	8	–4,5	1,0	–0,5	–0,5	0,8	–1,0	1,0	–0,8	1,4	–0,8	0,6	220
Sodium Hydroxide				–	–	6,7	–3,4	7,2	–3,8	7,7	–3,8	8,7	–3,8	4,9	222
Heavy-Weight plain fabric		Untreated Control				8,6	–1,0	11,0	–0,5	11,5	–0,5	12,4	–0,5	11,9	188
	1	15	4	–2,9	1,2	2,1	0,8	2,1	1,0	2,1	1,0	2,7	1,0	3,7	181
	1	15	8	–4,3	1,0	0,5	0,5	2,7	0,5	2,7	0,5	2,9	0,3	3,2	178
	3	5	4	–3,5	0,8	1,2	0,3	1,7	0	1,9	0	1,9	0,3	2,2	180
	3	5	8	–5,0	1,0	–1,7	0,8	1,0	0,5	1,2	0,5	1,7	0,5	2,2	175
Sodium Hydroxide				–	–	6,7	–2,4	6,7	–3,3	6,7	–3,3	6,7	–2,9	3,8	193

conditions on the consolidation properties of the fabrics.

The observation made previously, namely, that liquid ammonia mercerisation produced a more stable fabric than sodium hydroxide mercerisation, once again was supported by these consolidation results. The largest degree of stretch of the fabrics in the warp direction during the ammonia treatment occurred at the higher speed, which appeared to produce slightly more stable fabrics than the lower speed. The different stretch values, however, did not have a large effect on the consolidation of the fabrics during washing.

SUMMARY AND CONCLUSIONS

A prototype machine was built and cotton fabrics of different constructions and densities were treated with liquid ammonia. The influence of different processing parameters on the dimensional stabilisation of the fabrics was then investigated.

It was found that liquid ammonia mercerisation produced a more stable fabric than sodium hydroxide mercerisation. The fabric was stabilised by the liquid ammonia treatment and the fabric dimensions did not change significantly during subsequent washing tests. A prerequisite was, however, that stretch had to be applied to the fabrics during the ammonia treatment. Fabrics treated with liquid ammonia in a slack state shrank during the treatment and showed excessive shrinkage during subsequent washing tests. The effect of the different conditions of treatment such as different degrees of stretch, contact time and different ways of removing the ammonia on the dimensional stability of the fabrics was, however, relatively small.

The longer contact times in liquid ammonia generally gave a slightly higher degree of stretch in the warp direction and a lower degree of shrinkage in the weft direction, than the shorter contact times. The contact time had practically no effect, however, on the dimensional stability of the fabrics in subsequent washing treatments.

Removal of ammonia from the fabric by heat gave a slightly higher degree of stretch in the warp direction than removal by cold water. There was, however, little difference between the two treatments in subsequent washing tests. For the heavyweight plain fabric, water produced slightly better results than heat.

In the case of the lightweight fabric there was no difference between the results obtained with cold or hot water removal of ammonia, whereas hot water gave slightly better results in the case of the heavyweight fabrics.

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