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Liquid Ammonia Mercerisation of Cotton

Part I:

Construction of a Pilot Plant Chainless Merceriser

by

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LIQUID AMMONIA MERCERISATION OF COTTON

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ABSTRACT

The construction of a pilot plant chainless merceriser for the liquid ammonia treatment of fabrics is described. Basically the machine comprises two rows of rubber coated rollers. The bottom rollers are driven by means of a chain drive so as to effect an incremental increase in speed of two per cent between each successive roller. The top rollers are placed in the gaps formed between each pair of bottom rollers. The top rollers may be placed in any of the following three positions: without touching any of the bottom rollers, or with each top roller touching one bottom roller, or with each top roller touching two bottom rollers. The liquid ammonia is introduced into stainless steel troughs which are placed underneath certain of the bottom rollers. After treatment the ammonia can be removed from the fabric by either heat or water. A scrubbing tower in which the ammonia gas, which escapes from the machine, is absorbed by water is also described.

INTRODUCTION

Highly desirable properties, such as improved strength, lustre and greater depth of shade can be imparted to cotton by the well-known mercerisation process. Although various chemicals can be employed in this process, sodium hydroxide was the only reagent used commercially for the mercerisation of cotton until the late 1950's. During the early sixties Messrs J. and P. Coats started an intensive research programme to establish the effects of liquid ammonia on cellulosic materials. Their studies were concerned mostly with the treatment of cellulosic *yarns* with liquid ammonia[1]. It was established that the treatment of cellulosic yarns with liquid ammonia gave beneficial properties to cotton similar to those obtained with the conventional sodium hydroxide mercerisation process. The mercerisation of cotton yarn with liquid ammonia offers many advantages compared with sodium hydroxide and is at present used commercially. The process is known as the Prograde Process.

During 1963 the Norwegian Textile Research Institute and the Central Institute for Industrial Research started research work to determine the effect of liquid ammonia on woven cellulosic *fabrics*. The results obtained were considered

encouraging and in 1966 the rights to the liquid ammonia mercerising process were transferred to Messrs Tedeco Textile Development Company, Oslo, Norway. In 1970 a full-scale prototype machine was built to evaluate the liquid ammonia process[1, 2, 3]. The Tedeco company claims that over one million metres of fabric have been successfully mercerised with liquid ammonia on this prototype machine. To date, however, no commercial concern has installed such a mercerising plant.

It has been claimed that liquid ammonia may cause excessive shrinkage of, especially, knitted fabrics. Attempts to limit shrinkage of fabrics by the application of tension have not been successful as yet. To avoid the application of weft tension, Messrs Cluett, Peabody & Co. Inc. patented a process to mercerise cellulosic fabrics in liquid ammonia whereby the ammonia is removed rapidly from the fabric to prevent shrinkage[4]. The first stage in the operation is the impregnation of the fabric with liquid ammonia. The fabric then passes over a bow roller, through a pair of squeeze rollers and over a second bow roller and is then delivered into a heated blanket dryer. The fabric is conveyed on a dry blanket over the dryer drum from which it is collected for further processing. The residence time (i.e. the time that elapses from impregnation until removal of ammonia) varies from 0,6 to 9,0 seconds. The machine is enclosed in a chamber which is at a slightly negative pressure to prevent ammonia from leaking out.

The Sanforized Co., a division of Cluett, Peabody & Co., recently announced that the liquid ammonia process, trademarked as *Sanfor-Set*, is going into full-scale production at Burlington Industries' Erwin Mills in the U.S.A.[5]. About 23 million metres of jean fabric will be processed annually. Briefly, the process consists of pre-drying the fabric to remove moisture, followed by impregnation in ammonia. The fabric passes over two blanketed drying cylinders where the fabric width is controlled to the desired dimensions while the ammonia is driven off. About five *per cent* ammonia remains in the fabric and is removed in an adjoining chamber by a light steaming treatment. Fabrics processed by this liquid ammonia process will be trademarked as *"Duralized"*. The "Sanfor-Set" trademark will be used for fabrics that meet the firm's shrinkage control standards. To meet these standards, the Duralized finish must be followed by compressive shrinkage.

The USDA Southern Regional Research Centre (SRRC), New Orleans[6], developed and patented a chainless merceriser for the treatment of cotton. Basically this machine consists of a series of driven rollers of increasing diameter, mounted on a suitable frame in such a way that the rollers do not make contact. The percentage increase in the diameter of the rollers depends on the type of fabric to be processed, the mercerising agent and the operating conditions. The incremental increase in diameter of the rollers should not be more than 2 *per cent* between adjacent driven rollers, or more than 5 *per cent* between the smallest and largest

driven rollers of the series. Above this series of driven rollers is another series of idler rollers, positioned in the gaps formed above and between each pair of driven rollers. The idler rollers are uniform in diameter and are of the same, or approximately the same, diameter as any of the driven rollers. The idler rollers are fitted with alignment collars which allow them to maintain their proper alignment during operation. The idler rollers are free to move and are driven by surface contact with the driven rollers. The driven rollers are horizontally disposed and mounted in tandem. The drive train is powered by means of a variable speed motor, which is controlled by a silicone controlled rectifier drive.

The fabric to be mercerised is threaded under the bottom of the first driven roller, over the top of the first idler roller, which is positioned between the first and the second driven rollers and then passed under the bottom of the second driven roller and over the top of the second idler roller. This sequence is repeated until the desired degree of stretch has been attained, after which the fabric is either batched or removed for further processing.

The mercerising agent is applied to the fabric at some convenient location, usually in a trough located underneath the *second* driven roller. The mercerising agent causes the fabric to shrink and this shrinkage force tends to pull the top rollers towards the bottom rollers with a force equivalent to that due to the shrinkage of the fabric. Due to the progressive increase in driven roller diameter the fabric is stretched (or brought under tension) lengthwise. Widthwise the fabric is, however, not under tension and it will, therefore, tend to shrink. The amount of consolidation of the fabric in the width will be controlled by the force or the degree of tightness with which the fabric pulls the idler rollers down onto the driven rollers. The more firmly the idler rollers are pulled down onto the driven rollers, the less the widthwise shrinkage will be. It is clear that the tightness of the fabric on the rollers is governed primarily by the shrinkage force of the fabric during treatment. After passing through the required number of driven and idler rollers the mercerising agent is removed from the fabric either by quenching in hot water or by infrared heaters.

CONSTRUCTION OF THE SAWTRI LIQUID AMMONIA MERCERISER

The liquid ammonia merceriser built at SAWTRI is based on the chainless merceriser developed by the SRRC. There are, however, certain basic differences between the two machines. The following photographs illustrate the essential parts of the apparatus.

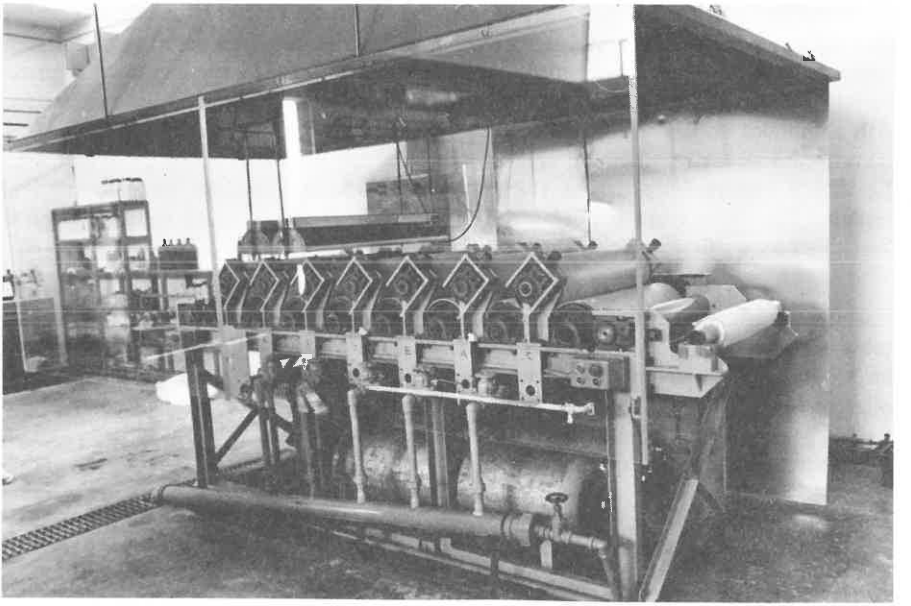

FIGURE 1

Figure 1 presents a general view of the machine with the most essential parts such as the rollers, infra-red heaters, switches, drain pipes, ammonia cylinders, canopy and perspex sheets clearly visible. The fabric is fed into the machine from the right hand side of the photograph

The SAWTRI mercerising machine consists of eight bottom driven rollers mounted with Y-sealed bearings (TU 108) on a steel frame. The rollers are covered with a nitrile rubber (14 mm thick) with a shore hardness of 60°. The gap between these rollers is 80 mm. The rollers have the same diameter and width, namely 224 mm and 755 mm respectively. The triplex chain, number 117/043, has a pitch of 12,7 mm. The machine is driven by a 2,9 kW motor, through a Carter F14 hydraulic infinitely variable speed drive. The rollers are driven by means of a chain and sprockets fitted to the main shafts of the rollers. The speed of the rollers can be varied and a maximum of 16 m/min can be obtained. The different speeds may be obtained by using certain press buttons which change the speed of the motor. The direction of rotation of the rollers can also be altered by pressing a reverse button. The maximum speed of the rollers in the reverse direction, however, is equal to only 40 *per cent* of the maximum forward speed. The control buttons are located in convenient positions at the feed and delivery ends of the machine. Four buttons are provided; one for starting the machine, one for increasing the speed in the forward direction, one for decreasing the speed in the forward direction or for reversing and one for stopping the machine. The surface speed of each successive

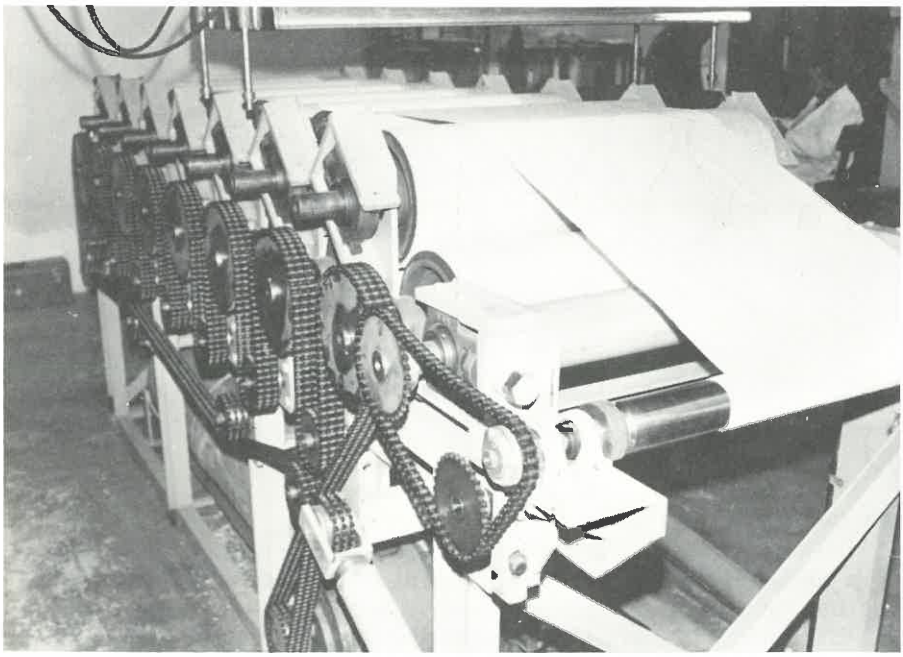

FIGURE 2

Figure 2 gives a view of the chain drive (at the back of the machine) used to drive the bottom rollers. The batch roller is on the right

bottom roller increases by approximately two *per cent*. This is made possible by progressively reducing the number of teeth on the sprockets. The sprocket fitted to the first bottom roller has 57 teeth, whereas the last bottom roller sprocket contains 50 teeth. The amount of stretch applied to the fabric depends on the number of rollers through which it is passed. Theoretically a total of 14 *per cent* stretch can be applied to a fabric which is passed through and over all eight bottom rollers. The fabric can be rolled on a batching roller and then removed (see Figure 3). Positioned on top, and between the gaps formed by each pair of bottom rollers, are seven non-driven rollers of the same dimensions and construction as the bottom rollers. The top rollers rotate freely and can be adjusted into three different positions.

Position 1:

The top rollers are *not* in contact with the bottom rollers (figure 3).

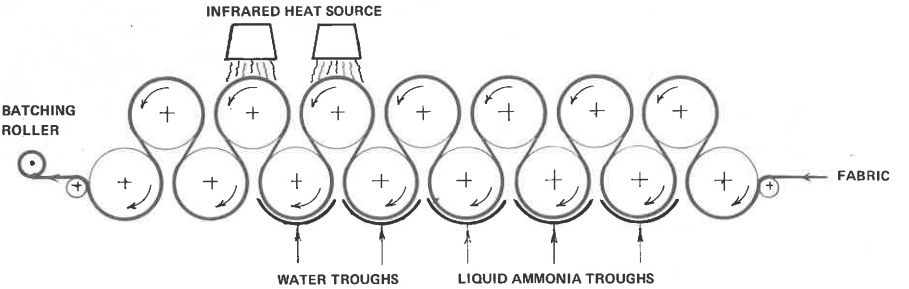

FIGURE 3

Position 1: Top rollers not in contact with bottom rollers

Position 2:

The top rollers are in contact with the successive bottom rollers (figure 4). This position is obtained by applying a certain torque to the adjusting screw, allowing the top roller to move down a slide placed at an angle of 45°. The torque applied, resulting in a certain pressure, will depend on the type of fabric which is to be treated.

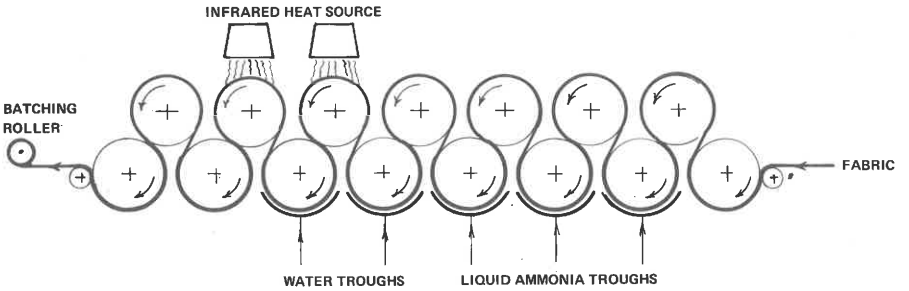

FIGURE 4

Position 2: Top rollers in contact with successive bottom rollers

Position 3:

Each top roller is in contact with two bottom rollers. This position (Figure 5) is achieved by removing the slides. (This position is used on the SRRC machine.)

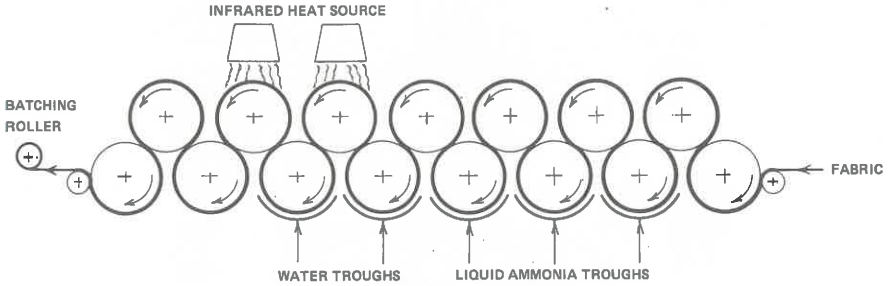

FIGURE 5

Position 3: Each top roller in contact with two bottom rollers

Stainless steel troughs are positioned underneath certain bottom rollers as shown in Figures 3–5. Liquid ammonia can be introduced into any one or all of the first three troughs for the treatment of the fabric. The level of the ammonia in the troughs can be determined by means of level glasses positioned on the side of the machine. After treatment, excess ammonia in the troughs is released directly into the drain pipe by opening certain taps.

After mercerisation the ammonia should be removed from the fabric. The ammonia can be removed by one of two methods. Firstly, infra-red lamps (6 000 W each) can be used to remove the ammonia from the fabric. Secondly, the reaction may be terminated by quenching the fabric in cold or hot water by means of water sprays situated in the stainless steel troughs as shown in Figures 3, 4 and 5. The sprays comprise a stainless steel pipe having holes of 1 mm diameter along its length. These sprays are fitted to the inside of the trough. The water which is sprayed onto the fabric is collected in the trough and removed continuously to prevent saturation with ammonia. This water at present is disposed into the drain pipe, but may be recovered if required.

The ammonia gas which escapes during the treatment poses a problem because of its air polluting effect and toxicity. This problem can be solved in three ways:

(a) The ammonia gas can be removed or eliminated by a *recovery plant* connected to the mercerising machine;
(b) it can also be *decomposed* with the aid of an iron catalyst into nitrogen and water or
(c) the ammonia gas can be *absorbed* in water in a scrubbing tower.

The latter method is currently being used at SAWTRI to remove the ammonia gas from the mercerising plant. The photograph in Figure 6 and schematic diagram in Figure 7 illustrate the construction of the scrubbing tower.

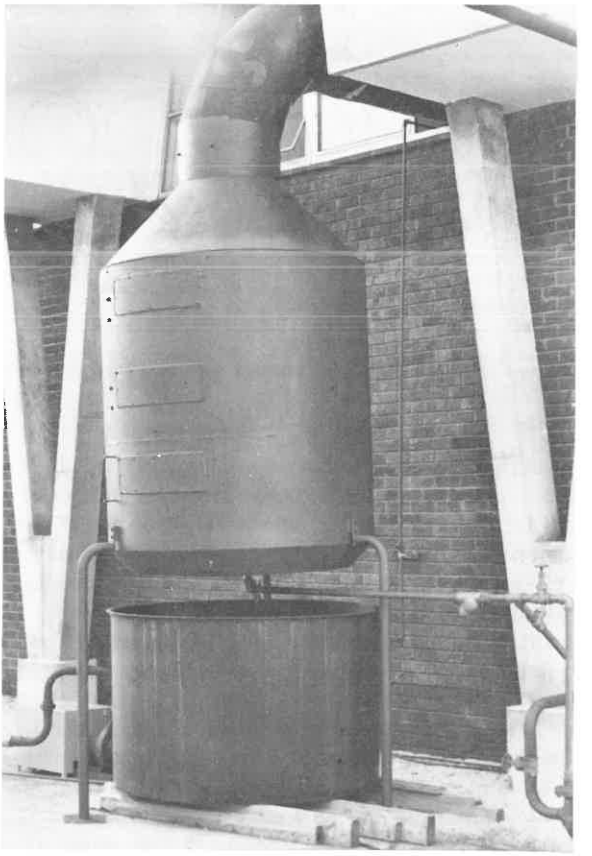

FIGURE 6
SCRUBBING TOWER

The mercerising plant is partially enclosed by means of a metal canopy and perspex sheets for effective extraction of the ammonia gas from the plant. The air/gas mixture is extracted at a rate of approximately 280 cubic m/min. by a suction fan and is forced down the tower where the ammonia is absorbed by water. The dimensions of the tower are as indicated in the diagram. Three layers of polyethylene pipe segments (Raschig rings) are placed on perforated steel screens inside the tower to increase the water/gas contact area. Water is sprayed into the tower at a rate of approximately 28 000 litres/hour by means of water sprays located above each layer of Raschig rings. Four water sprays are fitted to each yoke. The water is collected in a tank from where it is pumped to a drain. The ammonia can be re-

covered for re-use, or converted into a suitable by-product. The tower was increased considerably in diameter (see diagram) so as to reduce the air velocity from the fan thereby facilitating mixing of the ammonia gas with the water.

The tower operates efficiently and the concentration of ammonia in the air in the vicinity of the tower is well within the specified limits. The ammonia concen-

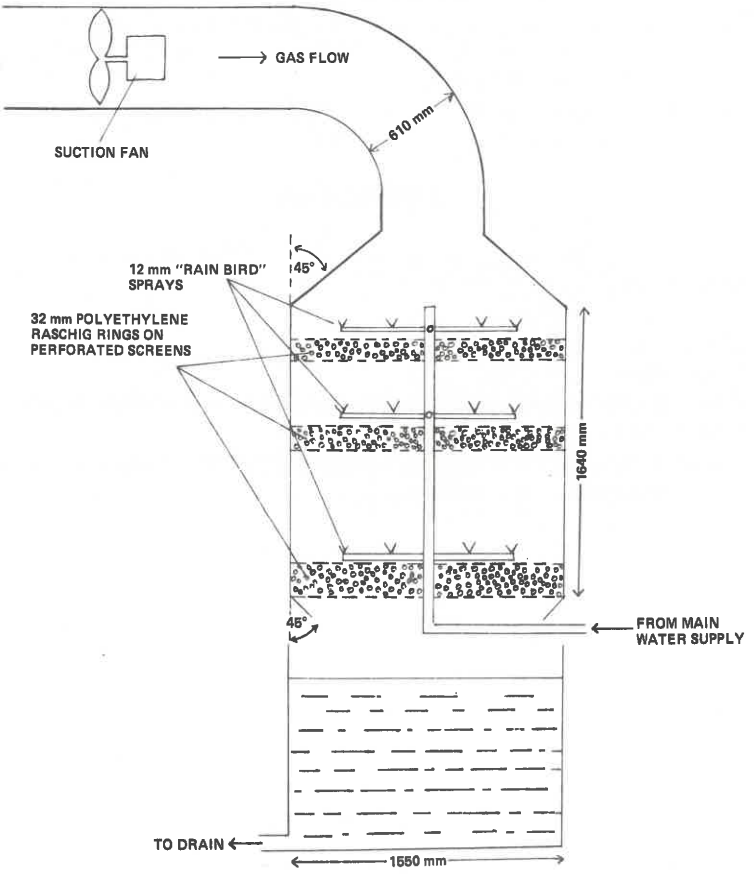

FIGURE 7
SCRUBBING TOWER (SCHEMATIC)

tration, as determined by a multi-gas detector, was approximately 50 ppm. The maximum concentration allowable for prolonged exposure is 85–100 ppm. The maximum concentration allowable for short exposures (½–1 hour) is 300–500 ppm.[7] The American Threshold Limit Value for ammonia is 50 parts per million. This refers to the concentration of gas in the air to which nearly all workers may be repeatedly exposed day after day without any adverse effect.

ACKNOWLEDGEMENTS

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SAWTRI is also indebted to the SRRC for their permission to build a machine along similar lines to their own patent.

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