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Foam-Dyeing

Part I: The Application of Some Reactive Dyes to Cotton Fabrics

by

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PART I: THE APPLICATION OF SOME REACTIVE DYES TO COTTON FABRICS

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ABSTRACT

Different cotton fabrics, ranging from 91 to 330 g/m², were foam-dyed on a laboratory scale FFT machine using various reactive dyes. The dyes were applied at different wet pick-up levels (from 10% to 40%) to either one or both sides of the fabrics using the single or the dual applicator system. After the application of the dye the fabrics were batched, or steamed or baked. For purposes of comparison the reactive dyes were also applied to the fabrics by the conventional padding process.

In general, the foam treatments produced level dyeings, except for those treatments carried out at very low wet pick-up levels (10%). A wide range of cotton reactive dyes differing in reactivity and affinity was applied successfully to cotton. In general, foam-dyeing produced slightly higher dye fixation values than conventional pad-dyeing. The fastness ratings were in general similar.

The results show that, for the same depth of shade, foam-dyeing, at relatively low wet pick-ups, utilized less dye than conventional pad-dyeing. Furthermore, the amount of alkali required for foam-dyeing was considerably lower than that used for conventional pad-dyeing.

INTRODUCTION

The application of durable-press resins and other finishing agents, such as softeners, to textile fabrics by foam is well established[1]. Foam-dyeing, on the other hand, has received very little attention to date. There are various possible reasons for this, the most important probably being the fact that the requirements for the application of dyes are much more critical than those for the application of finishing chemicals. It has been reported[2] that the evenness of application in the case of foam-dyeing is very critical and slight variations in the level of application would result in unacceptable colour differences.

One of the first processes for the foam-dyeing of textiles, namely the Sancowad process, a discontinuous foam dyeing process, was developed in the early 1970's by Sandoz[3,4]. The Sancowad process describes the dyeing of garments with foam in a perforated stainless-steel drum rotating in an enclosed chamber. The dye liquor is sprayed onto the garments, followed by a raise in temperature inside the chamber by means of hot air and steam to facilitate dye fixation. Other dyestuff manufacturing companies, such as Hoechst[5-11], were also active in the development of foam-dyeing and were granted several patents.

Some of these patents are dealing with the discontinuous dyeing of knitted garments in a rotating drum with a foam. After dye application the drum is heated to fix the dye. Another approach is to apply the foam to a moving substrate by means of a foam application and distribution chamber. Baffle plates positioned inside the chamber ensure a better distribution of foam in the chamber, while an adjustable doctor blade fitted to the chamber, controls the add-on levels. The amount of foam applied is determined by the pressure exerted on the foam and by the height of the doctor blade. In another patent a continuous process is described where two foams, each containing a different dye, are applied simultaneously, one to each side of the substrate to obtain a two-sided colour shade effect. Alternatively, different amounts of a foam can be applied simultaneously to each side of the substrate to obtain a two-sided colour depth effect.

The most significant progress in foam-dyeing, however, was made in the field of carpets, with some American and German companies playing a leading rôle in developing novel techniques of foam application and carpet foam-dyeing machines[12]. One of the main reasons for the growing popularity of foam-dyeing of carpets is the fact that the wet pick-up can be reduced from 300%-500% to as low as 30%-50%[13], which results in a significant reduction in the drying energy consumption[14,15]. Further advantages are claimed to be a reduction[16] or even a total elimination of thickening agents[17-19], no washing-off in the case of pale shades[20,21], improved rubbing fastness[18] and better fixation of acid dyes on nylon and basic dyes on acrylic carpets[22,23]. Furthermore, one-sided applications of dyes are possible[18]. In general, some of the disadvantages of foam-dyeing are reported to be the instability of alkaline dye liquors[18], limitations in the case of dyestuff solubility when dyeing deep shades[17], and difficulties in matching of shades[24].

From the literature it is clear that much progress has been made in the foam-dyeing of carpets, pile and upholstery fabrics, but little information is available about the foam-dyeing of apparel fabrics. It was decided, therefore, to study the foam-dyeing of such fabrics in more detail and this report describes the results obtained on different cotton fabrics.

EXPERIMENTAL

Fabrics

Plain weave all-cotton fabrics of 91 g/m^2 and 185 g/m^2 and a twill all-cotton fabric of 330 g/m^2 were used in this investigation. The fabrics were woven, desized, scoured and bleached at a local textile mill.

Dye Liquor

Dye liquors containing various reactive dyes were prepared according to procedures recommended by the dyestuff manufacturers. In most cases the prescribed concentration of alkali was used in the dye liquors, but in a few cases different alkali concentrations were employed. The dyes were generally applied to the fabrics at a dye add-on level of 1,0% (on the mass of the fabric), except in some cases where the add-on was varied from 0,3% to 3,0%. In the case of conventional pad-dyeing the liquor contained 0,1% ®Tergitol TMN-6 (m/v) as wetting agent.

Conventional Pad-Dyeing

A Benz laboratory 2-roll horizontal padder was used for padding the dye liquors onto the fabrics at a wet pick-up of 80%. The reactive dyes were applied according to the pad-batch, pad-bake and pad-steam dyeing processes, using the conditions recommended by the dyestuff manufacturers. Normally the dye liquor was applied immediately after preparation, but in one case dye liquors containing different reactive dyes were allowed to stand for 6 hours before application. In the case of the pad-batch dyeings, the fabrics were batched for 24 hours at room temperature, but some fabrics were batched for 6 hours. The fabrics dyed according to the pad-steam process were dried at 100°C for 3 minutes, followed by steaming at 102°C for 1 minute, and those dyed by means of the pad-bake process were dried at 100°C for 3 minutes, followed by baking at 150°C for 1 minute. For this purpose a Benz drying and steaming unit was used. Washing-off of the fabrics concluded the dyeing process.

Foam-Dyeing

A laboratory Gaston County foam finishing (FFT) machine equipped with dual applicators was used to apply the dye either to one or both sides of the fabric (using either a single or dual applicators). The speed of the fabric and the liquor flow to the foam generator were adjusted to give the required predetermined wet pick-up values, ranging from 10% to 40%. A number of commercial foaming agents were used to evaluate their compatibility with the dyes and to establish whether a foam of the required properties could be produced. Foams produced by 1,5% ®Tergitol TMN-6 (m/v) and 0,25% ®Niaproof A7 (m/v) had the required foam properties, viz. a uniform bubble size with the required stability ($t_{50\%}$ about 8 min.), as well as the required foam density (0,08 g/cm³ and 0,06 g/cm³) when the single and dual applicators were used, respectively.

After applying the various reactive dyes the fabrics were batched, steamed or baked in an identical manner as was the case with the conventional pad-dyeings.

Test Methods

The dyed fabrics were soaped at the boil for 20 minutes with 0,5% ®Ultravon HD (m/v). The dye fixation was determined in the usual manner from absorbance measurements of the soaping liquors. To determine the percentage covalent dye fixation the fabrics were extracted with 20% pyridine solution (v/v), followed by spectrophotometric analysis.

Fastness of the dyed fabric to washing (ISO 3), wet and dry rubbing (ISO R105-1959 E) and light (ISO VII-1972E - Part 4) were also determined. The colour difference values were determined on a Hunter laboratory D25-2 colorimeter.

RESULTS AND DISCUSSION

Colour Difference Values

During some preliminary trials, the mediumweight cotton fabric (185 g/m^2) was dyed with C.I. Reactive Red 2 on the FFT machine at different wet pick-ups, using either the single or dual applicators, followed by batching for 24 hours. In all cases level dyeings were obtained, except for the treatments carried out at 10% wet pick-up. In the case of the single applicator only the face of the fabric (side facing the bottom applicator slot) was dyed, whereas both sides were dyed in the case of the dual applicator. From the colour difference values (ΔE) in Table I it is clear that there was a difference between the depth of shade of the face and back of the fabrics, especially those dyed with the single applicator. In general, the depth of shade between the face and back decreased (i.e. ΔE decreased) when the wet pick-up increased. In other words, the degree of penetration of the dye through the fabric increased as the wet pick-up was increased. It is clear, however, that in the case of the single applicator there was still a slight difference in colour between the face and back of the fabric, even at a wet pick-up of 40%. In the case of the dual applicator, on the other hand, the differences between the face and back of the fabrics were generally much smaller and decreased rapidly with increasing wet pick-up. For this particular fabric there was practically no colour difference between the face and the back when dyed at a wet pick-up of 20% or higher. The fact that there were some differences between the face and the back of the fabrics at lower wet pick-ups is probably due to small differences in the wet pick-ups produced by the two applicator slots.

In some further work the colour difference values were determined between the fabrics dyed by the foam process and those dyed by the conventional pad-batch process. In the case of foam-dyeing 0,5% C.I. Reactive Red 2 was applied at different wet pick-ups, whereas in the case of the conventional dyeings, different dye add-on levels were applied at 80% wet pick-up. In both cases the undyed fabric was used as a reference for the colour difference

TABLE I

THE EFFECT OF WET PICK-UP ON THE COLOUR DIFFERENCE BETWEEN THE FACE AND BACK OF A COTTON FABRIC DYED WITH C.I. REACTIVE RED 2*

WET PICK-UP (%)	COLOUR DIFFERENCE VALUE (ΔE)**	
	FOAM APPLICATOR	
	SINGLE	DUAL
10	45,4	9,6
15	37,1	4,1
20	27,5	2,5
30	14,7	0,8
40	3,6	0,2

* 0,5% Dye Add-on

** Face of fabric taken as reference

determinations. Although all the colour difference values were determined, only the lightness difference values (ΔL) are shown in Figure 1. The results show that, in general, the face of the fabric dyed by foam using the single applicator became darker (higher ΔL values), whereas the back became lighter as the wet pick-up decreased. This indicates that for this particular fabric more dye was deposited on the face with less dye penetrating through to the back of the fabric as the wet pick-up was decreased. In the case of the dual applicator similar trends were observed. The colour differences (ΔL), however, were in general smaller than those obtained with the single applicator. The results show that, as expected, the conventionally-dyed fabrics became darker as the dye add-on level increased. Comparing the lightness difference values (ΔL) of the foam-dyed fabrics with those of the conventionally-dyed fabrics, it is clear that there were significant differences between the fabrics. When the face side of the foam-dyed fabrics was considered, there was little difference in lightness between foam- and conventionally-dyed fabrics at 30% and 40% wet pick-up. As the wet pick-up decreased to 20% and 10%, however, the former fabrics became significantly darker. In fact, at a wet pick-up of 20%, the ΔL value of the foam-dyed fabric was about the same as that of a conventionally-dyed fabric using 0,7% dye, while

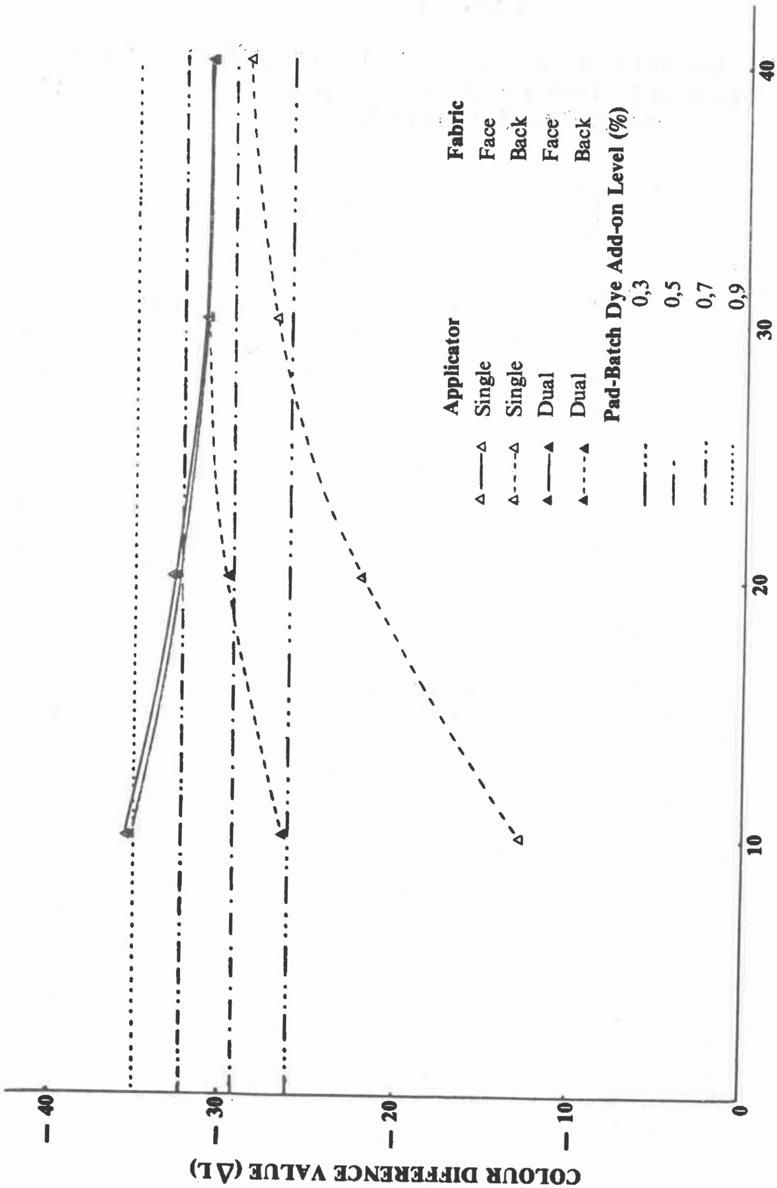

Fig. 1 – The colour difference value (ΔL) of fabrics dyed at different wet pick-ups.

at a wet pick-up of 10% it was similar to a conventional dyeing using 0,9% dye. It is clear, therefore, that if only one side of the fabric is to be dyed, a considerable saving of dye could be obtained by foam-dyeing. The back of the fabrics dyed with the single applicator was always somewhat lighter than that of the conventionally-dyed fabrics, whereas the dual applicator produced similar lightness values at high wet pick-ups (30% and 40%).

Fabric Mass

The results obtained so far show that the difference in colour between the face and back of the fabrics depended on the wet pick-up. Further studies showed that the colour difference also depended on the fabric mass. To illustrate this effect, three different fabrics (91, 185 and 330 g/m^2) were dyed with 0,5% C.I. Reactive Red 2, followed by batching for 24 hours. The results in Table II show the dye fixation, colour difference values (between the face and back) and some fastness properties of the fabrics dyed with foam at different wet pick-ups, or pad-dyed at 80% wet pick-up. In general, level dyeings were obtained, except in the case of the fabrics dyed with foam at a wet pick-up of 10%. The dye fixation was about slightly higher for foam-dyeing than for pad-dyeing. In the case of foam-dyeing, wet pick-up did not seem to affect dye fixation. The wash fastness ratings of foam- and pad-dyed fabrics were similar and were not dependent on wet pick-up. Rubbing fastness of the unsoaped fabrics seemed to deteriorate somewhat as the wet pick-up decreased. After soaping, however, only the lowest wet pick-up foam-dyeing (10%) seemed to give marginally lower ratings than the pad-dyeing. As before, the colour difference between the face and back of the fabrics decreased with increasing wet pick-up. The colour difference values generally increased as the fabric mass increased, for all the different wet pick-ups investigated.

Steaming

For many end-products only one side of a fabric has to be dyed, but for others there should be no colour difference between the face and back of the fabric. It is well-known that for certain low add-on techniques, such as loop-transfer and Triatex MA, steaming is used to improve the penetration of chemicals and to improve the uniformity of the treatment. It was decided, therefore, to steam some of the fabrics (185 g/m^2) immediately after foam-dyeing, prior to batching for 24 hours in an attempt to reduce the difference in colour between the face and back of the fabric. The results in Figure 2 show the effect of steaming on the colour difference values between the face and back of the fabrics dyed with 0,5% C.I. Reactive Red 2 on the FFT machine using the single applicator. The steam was passed through the fabric from the face (dyed) side. It is clear that steaming reduced the colour difference values significantly.

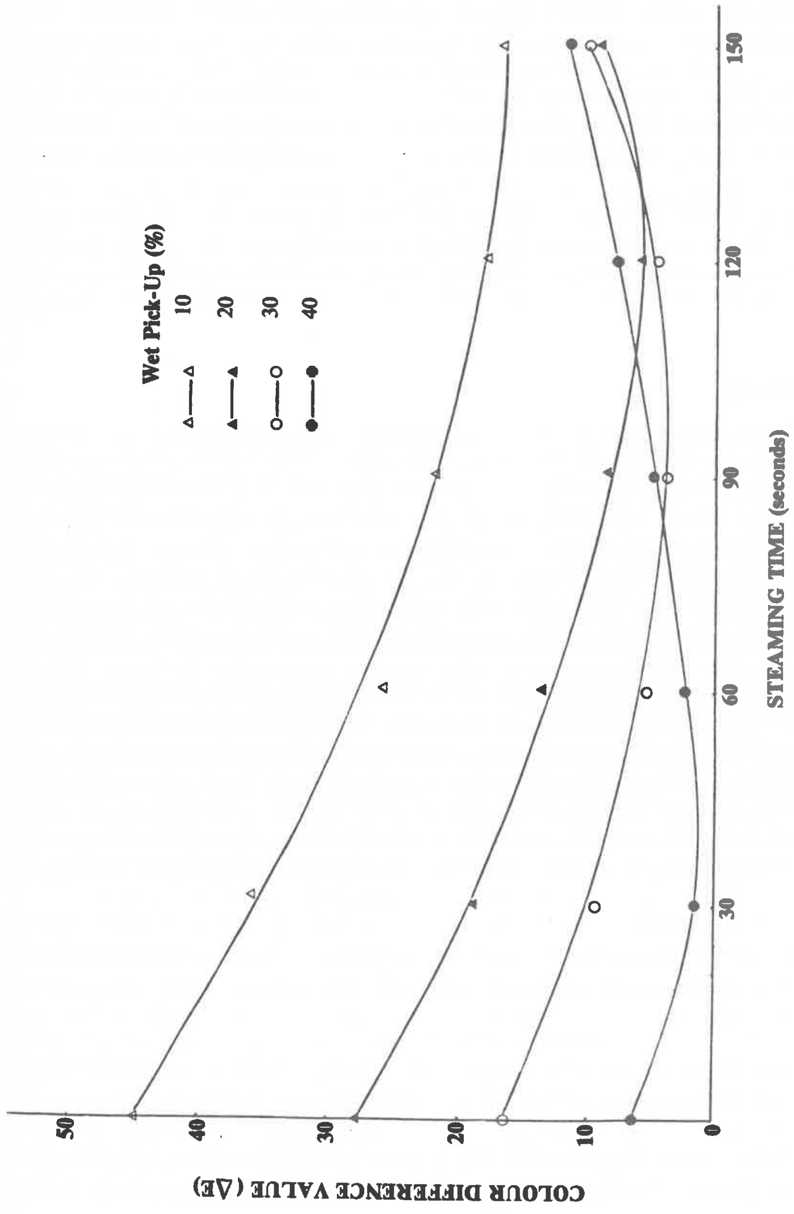

Fig. 2 – The effect of steaming time on the colour difference values (ΔE)

An increase in steaming time progressively reduced the colour difference values of fabrics dyed at the lowest wet pick-up value (10%), up to a steaming time of 150 seconds. The levelness of the dyeings was also improved by steaming. In the case of the higher wet pick-ups, however, the colour difference values initially decreased, followed by a slight increase when the steaming time was increased. This indicates that, for the smallest colour difference between the face and back of the fabric, there is an optimum steaming time, which depends on wet pick-up. It would obviously also vary for different fabrics. It seems that the steam carries the dye from the face side into the fabric, and eventually through to the other side. Too long a steaming time could, therefore, lead to the excessive transport of dye from the face to the back of the fabric, resulting in the face side to become lighter.

Dye Reactivity

In the next stage of this investigation the performance of different reactive dyes was evaluated. Two dyes were selected from different reactive dye types on the basis of their respective *reactive groups*[25,26]. These reactive groups largely fall into classes of high reactivity (dichlorotriazines, difluorochloropyrimidines), medium reactivity (vinyl sulphones, difluoropyrimidines, fluorotriazines, dichloroquinoxalines) and low reactivity (monochlorotriazines). The fabric was dyed with 1% dye at a wet pick-up of 30% by the foam process using the single applicator and at a wet pick-up of 80% using the conventional padding process, followed by batching for 24 hours. The dye fixation and covalent fixation and some fastness properties are given in Table III. Level dyeings were obtained in all cases. A comparison between the foam- and conventional-padding processes shows that foam-dyeing, on average, gave slightly higher dye fixation and covalent fixation values than conventional pad-dyeing. The fastness ratings of the cotton dyed with the various reactive dyes were very good and there was practically no difference between the foam-dyed and pad-dyed fabrics. It is clear, therefore, that dyes varying widely in reactivity can be successfully applied to cotton by foam application techniques.

In some further work, the two most reactive dyes (C.I. Reactive Blue 4 and C.I. Reactive Blue 163) and the two least reactive dyes (C.I. Reactive Blue 13 and C.I. Reactive Red 58), shown in Table III, were selected to dye (1% add-on) the cotton fabric at different wet pick-ups using either the single or the dual applicator. The results in Table IV show the effect of wet pick-up on dye fixation and on some fastness properties. In general, there appeared to be little difference in either the percentage dye fixation or the percentage covalent fixation of the fabrics dyed at the different wet pick-ups. Furthermore, the fastness ratings of the dyed fabrics were high and did not appear to be affected by wet pick-up or application process. A comparison between the foam-dyed and pad-dyed fabrics showed that the percentage dye fixation and the percentage covalent fixation values were, in general, slightly higher (about 5%) in the case of foam-dyeing.

The study was then extended to two dyes containing the same *chromophoric group* but different reactive groups, one containing a monofluorotriazine reactive group (C.I. Reactive Red 184) and the other a monochlorotriazine reactive group (C.I. Reactive Red 29). A cotton fabric was foam-dyed at different wet pick-ups using the single as well as the dual applicators. For purposes of comparison, the fabric was dyed by the conventional padding process. The results in Table V show no significant difference in the percentage dye fixation, covalent fixation, dry and wet rubbing fastness, wash fastness and fastness to light of the fabrics which were dyed by the foam process at different wet pick-ups. Furthermore, there was no difference between the fabrics dyed with the single applicator and those dyed by the dual applicator. It is interesting to note that the percentage dye fixation and covalent fixation of the fabrics dyed by the foam process were generally higher than those of the fabrics dyed conventionally. The difference was more pronounced in the case of the monochlorotriazine containing dye (C.I. Reactive Red 29) where foam-dyeing gave a covalent fixation of about 20% higher than conventional pad-dyeing.

In order to evaluate the behaviour of reactive dyes differing in their *affinity* towards cotton, a number of vinyl sulphone reactive dyes with different affinities[27] were selected to dye the fabric (1,0% dye add-on) at a wet pick-up of 30% on the FFT machine using the single applicator, and at a wet pick-up of 80% by padding. In the case of foam-dyeing, the concentration of alkali in the dye liquor was used as recommended by the dyestuff manufacturers for the conventional pad-dyeing process (i.e. 25 g/ℓ NaOH (38° Be) and 50 g/ℓ sodium silicate). The results in Table VI show the fixation values and some fastness properties of the dyed fabrics. In general, all the dyeings were level. It is clear that variations in the dye affinity did not have an effect on the results. In all cases, foam dyeing produced higher dye fixation and covalent fixation values than conventional pad dyeing. The percentage covalent fixation was, on average, about 5% higher in the former case. Some of the dyes were also applied to the cotton fabric at different wet pick-ups using the single applicator. In this case the reactive dyes showing the highest and lowest affinities were selected. The results, given in Table VII, show that as far as foam dyeing was concerned, the wet pick-up had no significant effect on dye fixation and covalent fixation, as well as the fastness properties of the fabrics. Furthermore, the fabrics which were foam-dyed generally showed slightly higher fixation values than those dyed by the conventional padding process. The fastness properties, on the other hand, did not differ significantly.

TABLE V

THE EFFECT OF WET PICK-UP ON SOME PROPERTIES OF FABRICS DYED WITH A MONOFLUOROTRIAZINE AND A MONOCHLOROTRIAZINE DYE

DYE	Process	Wet Pick-up (%)	Foam Applicator	Dye Fixation (%)	Covalent Fixation (%)	RUBBING FASTNESS				WASH FASTNESS (ISO 3)			FASTNESS TO LIGHT
						Dry		Wet		Effect of Shade	Cotton Staining	Wool Staining	
						Face	Back	Face	Back				
C.I. Reactive Red 184	Foam	20	Single Dual	73,4 72,7	70,2 70,7	5 5	5 5	3-4 3	5 3-4	5 5	5 5	5 5	4-5 4-5
		30	Single Dual	74,5 65,4	72,6 62,2	4-5 5	5 5	3-4 3-4	4-5 3-4	5 4-5	5 5	5 5	4-5 4-5
		40	Single Dual	68,7 74,2	66,6 71,3	4-5 5	5 5	3 3-4	4-5 4-5	4-5 4-5	5 5	5 5	4-5 4-5
	Pad	80	—	64,6	61,8	5	—	3	—	5	5	5	4-5
C.I. Reactive Red 29	Foam	20	Single Dual	75,2 72,4	72,8 70,7	4-5 5	5 5	3 3-4	4-5 3-4	5 4-5	5 5	5 5	5 5
		30	Single Dual	73,9 71,0	71,6 67,5	5 4	5 4-5	3 3	3-4 3	5 4-5	5 5	5 5	5 5
		40	Single Dual	73,3 70,8	71,1 68,0	5 4-5	5 5	3 3	4-5 3	4-5 5	5 5	5 5	5 5
	Pad	80	—	54,8	52,3	5	—	3	—	4-5	5	5	5

TABLE VI

THE FIXATION VALUES AND SOME FASTNESS PROPERTIES OF VINYLSULPHONE DYES WITH DIFFERENT AFFINITIES

DYE	Affinity	Process	Dye Fixation (%)	Covalent Fixation (%)	RUBBING FASTNESS		WASH FASTNESS (ISO 3)			FAST-NESS TO LIGHT
					Dry	Wet	Effect of Shade	Cotton Staining	Wool Staining	
C.I. Reactive Orange 82	Very High	Foam Pad	89,2 83,4	86,8 81,0	4-5 5	4 3-4	5 3-4	5 5	5 5	4 4-5
C.I. Reactive Blue 19	Very High	Foam Pad	87,1 81,1	82,4 70,7	4 4	4-5 4-5	4-5 4-5	5 5	5 5	7 7
C.I. Reactive Blue 38	High	Foam Pad	75,1 67,9	71,9 65,3	4 3-4	4-5 4-5	3 4	5 5	5 5	6-7 6-7
C.I. Reactive Blue 27	High	Foam Pad	75,6 66,4	73,0 63,6	4-5 4	4-5 4-5	4-5 4-5	5 5	5 5	6-7 7
C.I. Reactive Yellow 37	Medium	Foam Pad	88,1 80,4	86,2 78,4	4-5 4-5	4-5 4-5	5 5	5 5	5 5	6 6
C.I. Reactive Red 23	Medium	Foam Pad	78,3 77,9	75,7 74,8	4-5 4	4-5 4	5 4	5 5	5 5	6 6-7
C.I. Reactive Yellow 42	Low	Foam Pad	83,6 80,9	81,5 79,5	4-5 4-5	4-5 4-5	2-3 3-4	5 5	5 5	6 6
C.I. Reactive Orange 15	Low	Foam Pad	76,5 75,9	74,7 74,4	4 4-5	4 4	3-4 3-4	5 5	5 5	6 6

TABLE VII

THE EFFECT OF WET PICK-UP ON SOME PROPERTIES OF THE FABRICS DYED WITH DIFFERENT VINYLSULPHONE DYES

DYE	Process	Wet Pick-up (%)	Dye Fixation (%)	Covalent Fixation (%)	RUBBING FASTNESS		WASH FASTNESS (ISO 3)		
					Dry	Wet	Effect of Shade	Cotton Staining	Wool Staining
C.I. Reactive Orange 82	Foam	20	83,5	80,6	4	4	5	4	5
		30	89,2	86,8	4-5	4	5	5	5
		40	85,8	82,6	4-5	4	4-5	4	5
	Pad	80	83,4	81,0	5	3-4	3-4	5	5
C.I. Reactive Blue 19	Foam	20	86,8	81,2	5	4-5	5	5	5
		30	87,1	82,4	4	4-5	4-5	5	5
		40	78,0	78,0	5	4-5	5	5	5
	Pad	80	81,1	70,7	4	4-5	4-5	5	5
C.I. Reactive Yellow 42	Foam	20	81,5	78,9	5	5	4-5	5	5
		30	83,6	81,5	4-5	4-5	2-3	5	5
		40	82,2	79,7	5	4-5	4-5	5	5
	Pad	80	80,9	79,5	4-5	4-5	3-4	5	5
C.I. Reactive Orange 15	Foam	20	69,3	67,2	5	4-5	4-5	5	5
		30	76,5	74,7	4	4	3-4	5	5
		40	77,3	75,2	4-5	4	5	5	5
	Pad	80	75,9	74,4	4-5	4	3-4	5	5

Alkali Concentration

There are various possible reasons for the relatively high covalent fixation values of the fabrics dyed by the foam process. Amongst others, it could have been due to the fact that the concentration of alkali in the dye liquors differed for the two processes. It is common practice to increase the alkali concentration when the dye concentration is increased. In view of the fact that the dye liquors were much more concentrated in the case of the foam process (because of the low wet pick-ups employed), these liquors also contained more alkali (expressed on a mass/volume basis) than the conventional pad liquors. On the other hand, when the concentration of alkali was calculated on the mass of dye in the liquor, it was lower than that used conventionally. This effect is clearly illustrated in Table VIII, which shows the concentration of dye and alkali in the liquors used for the different dyeings. In some further work cotton was then dyed with two different dyes using various concentrations of alkali for both foam- and conventional pad-dyeings. In the case of the foam-dyeing the single applicator was used at a wet pick-up of 30%, while the wet pick-up on the conventional padder was set at 80%. The dye add-on was 1,0% in all cases. The results in Figure 3 show an increase in the percentage covalent fixation as the alkali concentration was increased. The most important point which emerges, however, is the fact that for a given alkali concentration, foam-dyeing gave a significantly higher percentage covalent fixation than conventional pad-dyeing. Alternatively, for the same percentage dye fixation, considerably less alkali was required for foam-dyeing than with conventional pad-dyeing. It is clear, therefore, that foam-dyeing could lead to a substantial saving in dyestuff and alkali, compared to conventional pad-dyeing.

With reference to Table VI, it was noticed that the fabrics which had been foam-dyed with dyes such as C.I. Reactive Blue 38 and C.I. Reactive Blue 27 were slightly lighter in shade than the conventional pad-dyed fabrics. Subsequently, the concentration of alkali in the dye liquors was increased from 25 g/ℓ to 40 g/ℓ. The fabrics were foam-dyed (1,0% dye add-on) at a wet pick-up of 30%. The results are shown in Table IX. The fabrics which has been conventionally pad-dyed with a dye liquor containing 25 g/ℓ sodium hydroxide (38° Be) were taken as a reference for the colour measurement. The results show that the colour difference values for both dyes decreased when the concentration of the alkali was increased. In fact, in the case of the 40 g/ℓ sodium hydroxide treatments there was very little difference between the colour of the fabrics dyed by the foam process and that of the fabrics which had been pad-dyed. The amount of alkali used for foam-dyeing (based on the mass of dye) was still considerably lower than that used for conventional pad-batch dyeing. It is clear, therefore, that foam-dyeing would lead to a substantial saving in alkali. The amount of alkali required for foam-dyeing, however, will have to be established

TABLE VIII

THE CONCENTRATION OF DYE AND ALKALI USED FOR DYEING AT DIFFERENT WET PICK-UPS

WET PICK-UP (%)	C.I. REACTIVE RED 184			C.I. REACTIVE RED 29				
	Dye Concen-tration* (g/ℓ)	Sodium Carbonate		Dye Concen-tration* (g/ℓ)	Sodium Chloride		Sodium Hydroxide	
		In Liquor (g/ℓ)	On Mass of Dye (%)		In Liquor (g/ℓ)	On Mass of Dye (%)	In Liquor (g/ℓ)	On Mass of Dye (%)
80	12,5	11,5	92	12,5	11,0	88	16,0	128
40	25,0	16,0	64	25,0	16,0	64	16,0	64
30	33,3	18,0	54	33,3	18,0	54	18,0	54
20	50,0	22,0	44	50,0	20,0	40	20,0	40

* For a 1,0% dye add-on

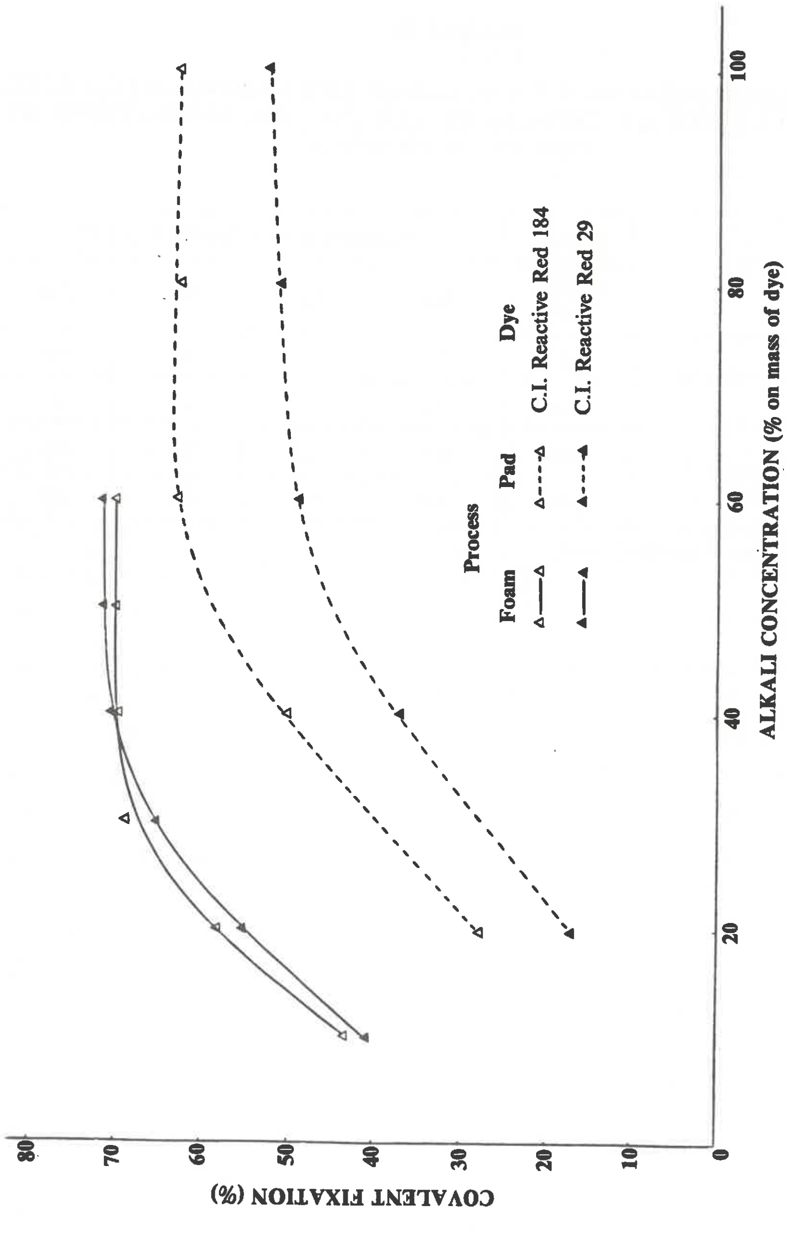

Fig. 3 – The effect of alkali concentration on covalent fixation

TABLE IX

THE COLOUR DIFFERENCE VALUES OF THE FABRICS DYED WITH REACTIVE DYES AT DIFFERENT ALKALI CONCENTRATIONS BY THE FOAM PROCESS

DYE	Sodium Hydroxide (38° Be) (g/ℓ)	COLOUR DIFFERENCE VALUE*			
		ΔE	ΔL	ΔC	ΔH
C.I. Reactive Blue 38	25	10,6	-5,1	9,3	0,6
	40	1,6	0,8	1,4	-0,1
C.I. Reactive Blue 27	25	4,5	3,8	2,4	-0,6
	40	0,6	0,1	0,5	0,3

* With reference to pad-dyed fabric

for various dyes before dyeing is commenced.

Hydrolysis of Dye

A further aspect of foam-dyeing which has received little attention so far is the hydrolysis of the dye in the liquors, which are normally much more concentrated than conventional dye liquors. Consequently a number of different reactive dyes were selected from Table III. The dye liquors were made up as before and were then applied to the fabrics immediately after preparation, or after they were allowed to stand for 6 hours at room temperature. The percentage covalent fixation values are given in Table X. The results show that, for both the foam- and pad-dyeings, the fixation values were lower when the dye liquor was allowed to stand for 6 hours before it was applied to the fabric. The decrease in the percentage covalent fixation was, however, significantly lower in the case of foam-dyeing (about 8% compared with 18% for pad-dyeing). These results indicate that the rate of hydrolysis of the dye in the liquor used for foam-dyeing was lower than that used for conventional pad-dyeing. Apart from the hydrolysis which took place in the liquors before application to the fabrics, some further hydrolysis of the dye could have taken place on the fabric during batching. In the case of foam-dyeing the wet pick-up was very low (30%) and it is likely that most of the dye liquor which was applied to the fabric diffused into the fibres (the water of imbibition value for cotton is about 30%), thus facilitating the reaction between the dye reactive group and the cellulosic hydroxyl groups. At the higher wet pick-ups used for conventional pad-dyeing (i.e. 80%), the excess water could not be absorbed by the fibre, and consequently some water containing dye was present on the surface of the fibre. This dye could have been hydrolysed before it could diffuse into the fibre to react with the hydroxyl groups of the cotton. Hydrolysis of the dye would result in a reduction in the percentage covalent fixation.

Dye Add-on Level

The effect of dye concentration (add-on level) on the fixation and some fastness properties was then determined. The results obtained at 30% wet pick-up by the foam process using the single applicator and at 80% wet pick-up by the conventional padding process are given in Table XI. The percentage fixation and covalent fixation of the fabrics dyed by the foam process were slightly higher than that of the pad-dyed fabrics, up to 2,5% dye add-on, whereafter there was practically no difference. For both dyeing processes the fixation values increased with increasing dye add-on up to about 1,5% dye, whereafter there was a slight decrease. As far as the rubbing fastness ratings before soaping were concerned, the foam-dyed fabrics showed slightly higher ratings than the pad-dyed fabrics, but after soaping there was no difference between the two dyeing techniques.

TABLE X

THE EFFECT OF WET PICK-UP ON THE HYDROLYSIS OF DIFFERENT REACTIVE DYES

DYE	Process	Wet Pick-up (%)	DYE FIXATION (%)		Covalent Fixation (%)	
			Dyed After		Dyed After	
			0 hrs	6 hrs	0 hrs	6 hrs
C.I. Reactive Blue 163	Foam Pad	30 80	53,1 53,6	46,6 41,0	52,0 51,9	45,2 40,5
C.I. Reactive Red 147	Foam Pad	30 80	88,0 83,3	85,8 73,6	85,7 80,9	83,8 71,1
C.I. Reactive Blue 120(S)	Foam Pad	30 80	89,6 89,2	89,6 83,5	87,3 86,3	86,6 81,2
C.I. Reactive Red 183	Foam Pad	30 80	87,5 89,2	84,5 73,3	85,7 86,8	83,6 71,1
C.I. Reactive Blue 29	Foam Pad	30 80	83,1 82,9	73,2 49,5	81,2 80,5	69,4 45,9
C.I. Reactive Yellow 42	Foam Pad	30 80	83,6 74,0	73,0 50,6	81,5 71,2	70,4 49,2
C.I. Reactive Blue 13	Foam Pad	30 80	64,5 62,8	53,8 35,8	62,6 60,7	52,6 34,6

TABLE XI

THE EFFECT OF DYE ADD-ON ON FIXATION AND SOME FASTNESS PROPERTIES (C.I. REACTIVE RED 184)

Dye Add-on (%)	Process	Dye Fixation (%)	Covalent Fixation (%)	RUBBING FASTNESS				WASH FASTNESS (ISO 3)			Fastness to Light
				Before Soaping		After Soaping		Effect of Shade	Cotton Staining	Wool Staining	
				Dry	Wet	Dry	Wet				
0,5	Foam	71,1	68,3	5	4-5	5	4-5	5	4-5	4-5	4
	Pad	68,8	63,7	4-5	4	5	4-5	5	4-5	5	4
1,0	Foam	83,6	81,8	4-5	4	5	4-5	5	4-5	5	4
	Pad	71,8	70,3	4-5	3-4	5	4-5	5	4-5	5	4
1,5	Foam	80,1	78,9	5	4	5	4-5	5	4-5	5	4
	Pad	74,9	73,8	4	3	5	4-5	5	4-5	5	4-5
2,0	Foam	72,6	71,8	4-5	3	5	4	5	4-5	5	4-5
	Pad	60,5	65,7	3-4	2-3	5	3-4	5	4-5	4-5	5
2,5	Foam	69,9	69,8	4-5	3	5	3-4	5	4-5	4-5	4-5
	Pad	67,5	66,4	3	2	5	3-4	5	4-5	5	5
3,0	Foam	66,9	65,4	4-5	2-3	5	3-4	5	4-5	5	4-5
	Pad	67,3	66.4	3	2	5	3-4	5	4-5	4-5	5

The wash fastness and fastness to light ratings were similar for both dyeing techniques.

Batching Time

In order to establish the effect of shorter batching times on dye fixation, some reactive dyes containing different reactive groups, namely dichlorotriazine (C.I. Reactive Blue 1 and C.I. Reactive Red 2), monofluorotriazine (C.I. Reactive Blue 183 and C.I. Reactive Red 184) and vinyl sulphone (C.I. Reactive Blue 19 and C.I. Reactive Red 23), were selected and applied to the fabrics at a wet pick-up of 30% by the foam process and at a wet pick-up of 80% by the conventional padding process. After application of the dye the fabrics were batched for various periods up to 6 hours. The results, given in Figures 4 to 6, show that the percentage covalent fixation of the fabrics dyed by the foam process was generally higher than those dyed conventionally, even for relatively short batching times.

Pad-Steam and Pad-Bake Dyeing Processes

Finally, a comparison was carried out between foam and conventional pad-steam and pad-bake dyeing processes. In the case of the foam-dyeing, the fabrics were dyed at different wet pick-ups using both the single and dual applicators, followed by steaming or baking, whereas a wet pick-up of 80% was used for the conventional pad-steam and pad-bake dyeings. The results of the foam- and pad-steam dyeings are shown in Table XII. In general, foam-dyeing gave slightly higher dye fixation and covalent fixation values than the conventional pad-steam process.

Fastness properties were similar, excepting for rubbing fastness after soaping, where foam dyeing produced somewhat higher ratings than pad-steam dyeing. The results for foam- and pad-bake dyeings are given in Table XIII and show the same trend as in the case of the pad-batch and pad-steam dyeing, i.e. little difference between the fixation values of the fabrics dyed by the foam process and those dyed by the pad-bake process (excepting in the case of the foam dyeings at 20% wet pick-up which gave somewhat lower values). The fastness ratings of all the dyed fabrics were, however, practically the same.

SUMMARY AND CONCLUSIONS

Different cotton fabrics were dyed on a Gaston County laboratory foam finishing (FFT) machine using various reactive dyes. The dyes were applied to the fabrics at different wet pick-up values (ranging from 10% to 40%) using either a single or dual applicator. After application of the dyes, the fabrics were either batched, steamed or baked, followed by washing off. For purposes of comparison, the different reactive dyes were also applied to the fabrics by the

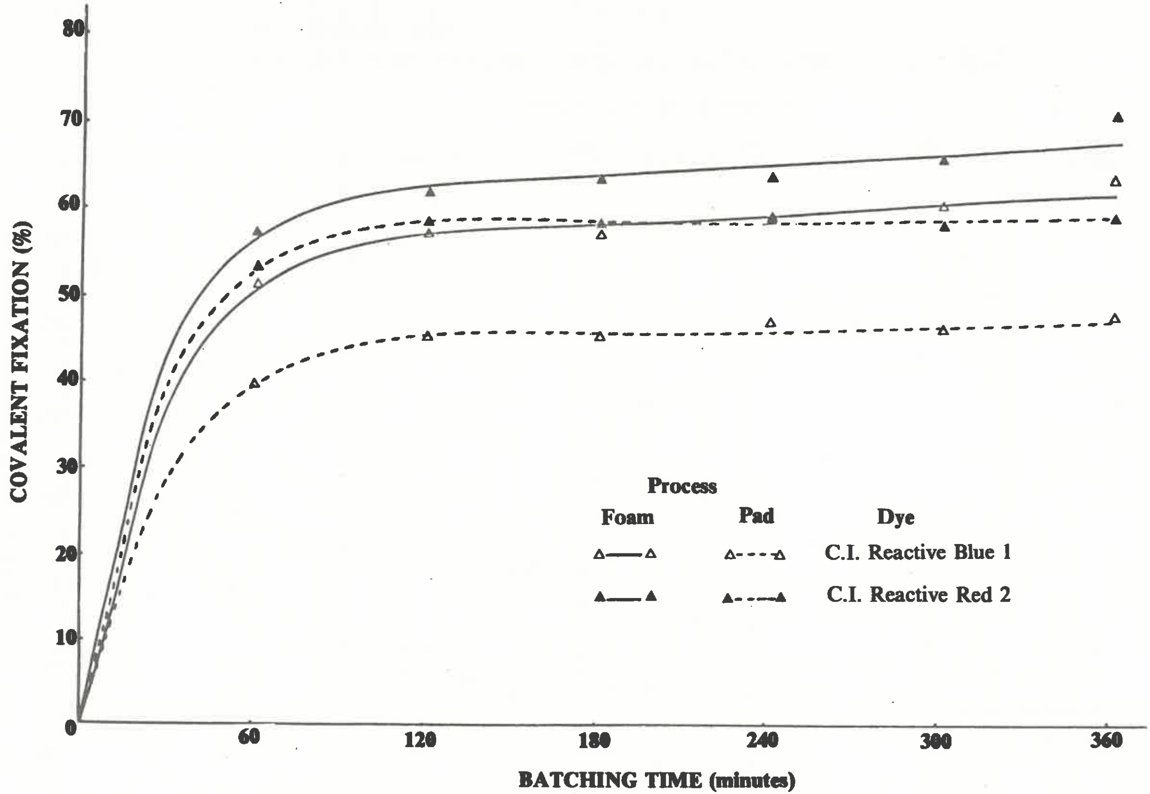

Fig. 4 – The effect of batching time on the percentage covalent fixation of dichlorotriazine dyes.

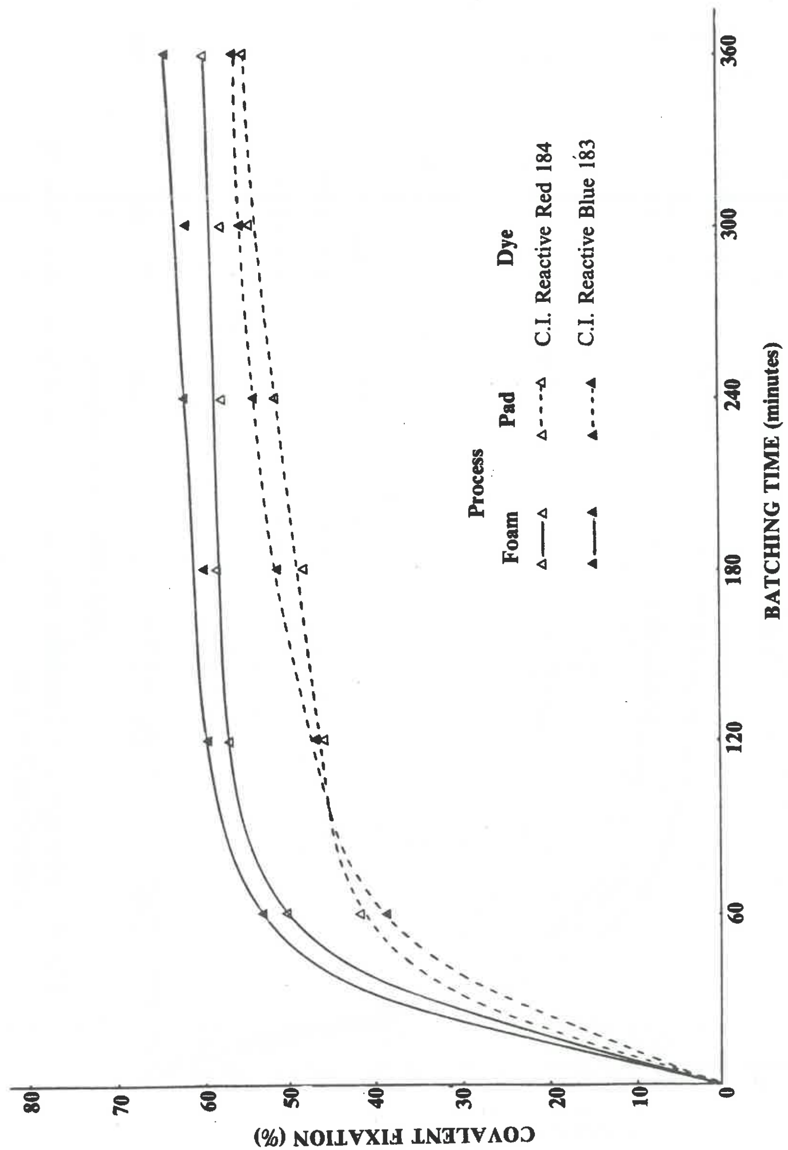

Fig. 5 – The effect of batching time on the percentage covalent fixation of mono fluorotriazine dyes

In some further work dyes having the same chromophoric group (structure), but different reactive groups (a monofluorotriazine and monochlorotriazine reactive dye) were selected to dye the cotton. It was found that the fixation values of the foam-dyed fabrics were higher than those of the conventionally-dyed fabrics, while the fastness ratings were similar in both cases. In some further studies vinyl sulphone reactive dyes with different applied to the fabrics by the foam process or by conventional pad-batch dyeing. Apart from the higher fixation values of the fabrics dyed by the foam process, no differences were observed in the fastness properties of the fabrics. In an attempt to explain the higher fixation values obtained by the foam process some dyeings were carried out using different concentrations of alkali in the dye liquor. It was found that the foam process consistently produced higher fixation values than the conventional pad-batch dyeing process for the same concentrations of alkali. This applied to all the alkali concentrations investigated. In practice, foam-dyeing could therefore result in a substantial saving in chemical cost. It is also important that the amount of alkali which is required for foam-dyeing with reactive dyes should be established by small scale trials before dyeing is commenced.

It is well-known that the presence of alkali in the dye liquor can cause hydrolysis of dye, leading to lower covalent fixation values. In some further work the dye liquors were prepared and some of the liquor was used immediately, while the rest was allowed to stand for 6 hours prior to application. In the case of the foam-dyeing, the covalent fixation values were, on average, 8% lower when the dye liquor was allowed to stand for 6 hours, against a decrease of 18% in the case of the conventional pad-dyeings. It is clear, therefore, that a lower degree of dye hydrolysis had occurred in the case of the foam-dyeing. This is probably due to the fact that dye liquor was much more concentrated in the case of foam-dyeing, and furthermore, considerably less water was applied to the cotton than was the case with pad-dyeing. In some further studies the effect of batching time on the percentage covalent fixation was investigated. In general, it was found that the percentage covalent fixation increased with increasing batching time, being higher for the fabrics dyed by the foam process.

The effect of dye add-on level on the fixation and fastness properties of foam- and pad-dyed fabrics was then investigated. It was found that, up to 2,5% dye, the fabrics dyed by the foam process gave slightly higher fixation values, whereafter there was practically no difference. The dry and wet rubbing fastness (before soaping) of the fabrics dyed by the foam process were slightly higher than those of the fabrics dyed conventionally. The wash fastness and fastness to light ratings were similar.

Finally, a comparison was carried out between foam-dyeing and conventional pad-steam and pad-bake dyeing. In general, foam-dyeing gave slightly higher dye fixation values, while the fastness ratings were approximately

TABLE II

SOME DYE AND FASTNESS PROPERTIES OF DIFFERENT FABRICS DYED AT DIFFERENT WET PICK-UPS WITH C.I. REACTIVE RED 2

Process	Wet Pick-up (%)	Foam Applicator	Dye Fixation (%)	Covalent Fixation (%)	Colour Difference Value (ΔE)	RUBBING FASTNESS								WASH FASTNESS (ISO 3)		
						Before Soaping				After Soaping				Effect of Shade	Cotton Staining	Wool Staining
						Dry		Wet		Dry		Wet				
						Face	Back	Face	Back	Face	Back	Face	Back			
Foam	10	Single	63,1	61,2	32,1	4	4-5	2	2-3	4-5	4-5	4	4-5	5	5	5
		Dual	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20	Single	64,6	62,0	19,1	5	5	3	3-4	5	5	4-5	5	5	5	5
		Dual	63,7	61,2	3,5	5	5	2-3	3	5	5	4-5	5	5	5	5
	30	Single	66,7	63,4	7,7	5	5	3	4	5	5	4-5	5	5	5	5
		Dual	64,5	62,9	0,4	5	5	3	3-4	5	5	4-5	4-5	5	5	5
	40	Single	65,1	63,5	1,0	5	5	4	4	5	5	5	5	5	5	5
		Dual	64,2	62,6	0,4	5	5	4	4	5	5	4-5	4-5	5	5	5
Pad	80	—	52,6	50,4	0,2	5	—	4	—	5	—	4-5	—	5	5	5
Foam	10	Single	67,1	65,4	45,4	3-4	5	2	4-5	4-5	5	3-4	5	5	5	5
		Dual	66,6	64,5	9,6	4-5	5	2	2-3	4-5	4-5	4	4	5	5	5
	20	Single	68,5	66,2	27,5	4-5	5	3-4	4-5	4-5	5	4-5	5	5	5	5
		Dual	67,1	65,6	2,5	5	5	4	4	5	5	4-5	5	5	5	5
	30	Single	66,1	64,5	14,7	5	5	4-5	4-5	5	5	4-5	5	5	5	5
		Dual	66,9	64,6	0,8	5	5	4	4	5	5	4-5	4-5	5	5	5
	40	Single	67,5	65,1	3,6	5	5	4	4-5	5	5	4-5	5	5	5	5
		Dual	66,0	64,2	0,2	5	5	4	4-5	5	5	4-5	4-5	5	5	5
Pad	80	—	53,2	51,4	0,3	5	—	4	—	5	—	—	—	5	5	5
Foam	10	Single	68,5	65,9	61,4	4-5	5	2	5	5	5	3-4	5	5	5	5
		Dual	67,1	65,2	4,9	5	5	2-3	3	4-5	5	4	3-4	5	5	5
	20	Single	68,1	66,1	51,0	5	5	3	5	5	5	4-5	5	5	5	5
		Dual	68,6	66,2	2,3	5	5	3	3	5	5	4-5	4-5	5	5	5
	30	Single	66,9	64,5	34,3	5	5	4	5	5	5	4-5	5	5	5	5
		Dual	67,2	64,9	2,1	5	5	3-4	4-5	5	5	4-5	4-5	5	5	5
	40	Single	67,5	65,7	8,6	5	5	4	4-5	5	5	4-5	4-5	5	5	5
		Dual	67,9	66,2	1,1	5	5	4	4	5	5	4-5	4-5	5	5	5
Pad	80	—	52,0	50,8	0,6	5	—	4	—	5	—	4-5	—	5	5	5

TABLE III

THE EFFECT OF DYE REACTIVITY ON FIXATION AND SOME FASTNESS PROPERTIES

DYE	Reactivity	Process	Wet Pick-up (%)	Dye Fixation (%)	Covalent Fixation (%)	RUBBING FASTNESS								WASH FAST	
						Before Soaping				After Soaping				Effect of Shade	Cott Stain
						Dry		Wet		Dry		Wet			
						Face	Back	Face	Back	Face	Back	Face	Back		
C.I. Reactive Blue 4	DECREASING REACTIVITY ↓	Foam	30	62,1	56,7	5	5	4-5	4-5	5	5	5	5	4-5	5
		Pad	80	52,8	50,4	5	—	4-5	—	5	—	5	—	4-5	5
C.I. Reactive Blue 163		Foam	30	52,7	51,9	5	5	3	4	5	5	4	5	3-4	5
		Pad	80	54,0	52,8	5	—	2-3	—	4-5	—	3-4	—	4-5	5
C.I. Reactive Red 147		Foam	30	86,4	83,9	5	5	4-5	4	4-5	4-5	4-5	4-5	4-5	5
		Pad	80	83,3	80,6	5	—	4	—	4-5	—	4	—	4-5	5
C.I. Reactive Yellow 25		Foam	30	90,8	82,6	5	5	4-5	5	5	5	4-5	5	4-5	5
		Pad	80	85,3	79,4	5	—	4-5	—	5	—	4-5	—	4	5
C.I. Reactive Blue 120 (S)		Foam	30	87,7	84,9	5	5	3-4	4-5	5	5	4	5	5	5
		Pad	80	86,8	83,3	5	—	4-5	—	5	—	4-5	—	4	5
C.I. Reactive Red 123 (S)		Foam	30	84,8	81,9	5	5	3-4	4-5	5	5	3-4	5	4-5	5
		Pad	80	84,4	81,0	5	—	3-4	—	4-5	—	4-5	—	5	5
C.I. Reactive Orange 91		Foam	30	80,1	78,2	5	5	3-4	4-5	5	5	4-5	5	4-5	5
		Pad	80	78,9	76,1	5	—	4	—	5	—	4-5	—	5	5
C.I. Reactive Red 183		Foam	30	88,0	86,3	5	5	3	4-5	5	5	4	4-5	4-5	5
		Pad	80	91,6	89,7	5	—	4-5	—	5	—	4-5	—	5	5
C.I. Reactive Red 40		Foam	30	88,8	87,4	5	5	3	5	5	5	4	4-5	5	5
		Pad	80	80,0	74,0	5	—	3-4	—	5	—	4-5	—	5	5
C.I. Reactive Blue 29		Foam	30	80,7	79,1	5	5	4-5	4-5	5	5	4-5	5	5	5
		Pad	80	80,4	78,5	5	—	4	—	5	—	4-5	—	4-5	5
C.I. Reactive Yellow 42		Foam	30	83,6	81,5	5	5	4	4-5	5	5	4-5	5	4	5
		Pad	80	80,9	79,5	4-5	—	3	—	4-5	—	4-5	—	4	5
C.I. Reactive Blue 19		Foam	30	87,1	82,4	5	5	4	5	5	5	4	4-5	5	5
		Pad	80	81,1	70,7	5	—	4	—	4-5	—	4	—	5	5
C.I. Reactive Blue 13		Foam	30	66,5	65,2	5	5	3	4	5	5	4	4-5	4	5
		Pad	80	64,8	63,8	5	—	3-4	—	5	—	4-5	—	4	5
C.I. Reactive Red 58		Foam	30	79,8	78,1	5	5	3	4	4-5	5	4	4-5	4-5	5
		Pad	80	68,8	66,8	4-5	—	3	—	5	—	4	—	4-5	5

TABLE IV

THE EFFECT OF WET PICK-UP ON SOME PROPERTIES OF FABRICS DYED WITH DICHLOROTRIAZINE AND MONOCHLOROTRIAZINE DYES

Process	Wet Pick-up (%)	Foam Applicator	Dye Fixation (%)	Covalent Fixation (%)	RUBBING FASTNESS								WASH FASTNESS (ISO 3)			FASTNESS TO LIGHT
					Before Soaping				After Soaping				Effect of Shade	Cotton Staining	Wool Staining	
					Dry		Wet		Dry		Wet					
					Face	Back	Face	Back	Face	Back	Face	Back				
Foam	20	Single	72,2	67,9	5	5	4-5	4-5	5	5	4-5	5	4-5	5	5	5-6
		Dual	67,7	62,5	5	4-5	4-5	4	5	5	5	5	4-5	5	5	5-6
	30	Single	62,1	56,7	5	5	4-5	4-5	5	5	5	5	4-5	5	5	5-6
		Dual	64,6	61,0	5	5	4-5	4-5	5	5	5	5	4-5	5	5	5-6
	40	Single	61,6	58,2	5	5	4-5	4-5	5	5	5	5	4	5	5	5-6
		Dual	65,7	62,1	5	5	4-5	4-5	5	5	4-5	5	4	5	5	5-6
Pad	80	—	52,8	50,4	5	5	4-5	4-5	5	5	5	5	4-5	5	5	5-6
Foam	20	Single	58,1	57,1	4-5	5	4	4-5	5	5	4	5	4-5	5	5	5-6
		Dual	49,6	48,5	4-5	5	3-4	4	5	5	4-5	4-5	4-5	5	5	5-6
	30	Single	52,7	51,9	5	5	3	4	5	5	4	5	3-4	5	5	5-6
		Dual	52,0	50,2	4-5	4-5	3-4	4	5	5	4-5	4-5	4	5	5	5-6
	40	Single	52,7	50,8	4-5	4-5	4	4	5	5	4-5	5	4-5	5	5	5-6
		Dual	52,9	50,8	5	4-5	4	4	5	5	4	4-5	4-5	5	5	5-6
Pad	80	—	54,0	52,8	5	5	2-3	2-3	4-5	4-5	3-4	3-4	4-5	5	5	6
Foam	20	Single	62,5	61,2	4-5	4-5	4	4	5	5	4-5	5	4	5	5	5
		Dual	61,2	59,7	5	5	4	4	5	5	4-5	5	4	5	5	5
	30	Single	66,5	65,2	5	5	3	4	5	5	4	4	4	5	5	5
		Dual	64,9	63,7	5	5	4	4	5	5	4-5	4	4	5	5	5
	40	Single	75,0	73,3	5	5	4-5	4-5	5	5	4-5	4-5	5	5	5	5
		Dual	76,1	74,7	5	5	4	4	5	5	5	4-5	5	5	5	5
Pad	80	—	64,8	63,8	5	5	3-4	3-4	5	5	4-5	4-5	4	5	5	5
Foam	20	Single	73,8	72,3	5	5	3-4	4-5	4-5	5	3-4	4-5	5	5	5	4
		Dual	74,9	72,7	4-5	5	3-4	3-4	5	5	4	4	5	5	5	4
	30	Single	79,8	78,1	5	5	3	4	4-5	5	4	4-5	4-5	5	5	4
		Dual	72,6	70,7	4-5	4-5	3-4	3-4	5	5	4	4-5	5	5	5	4
	40	Single	79,1	77,3	5	5	3-4	4-5	4-5	5	4	4-5	4-5	5	5	4
		Dual	72,3	70,1	4-5	5	4	4	4-5	5	3-4	4	5	5	5	4
Pad	80	—	68,8	66,8	4-5	4-5	3	3	5	5	4	4	4-5	5	5	4

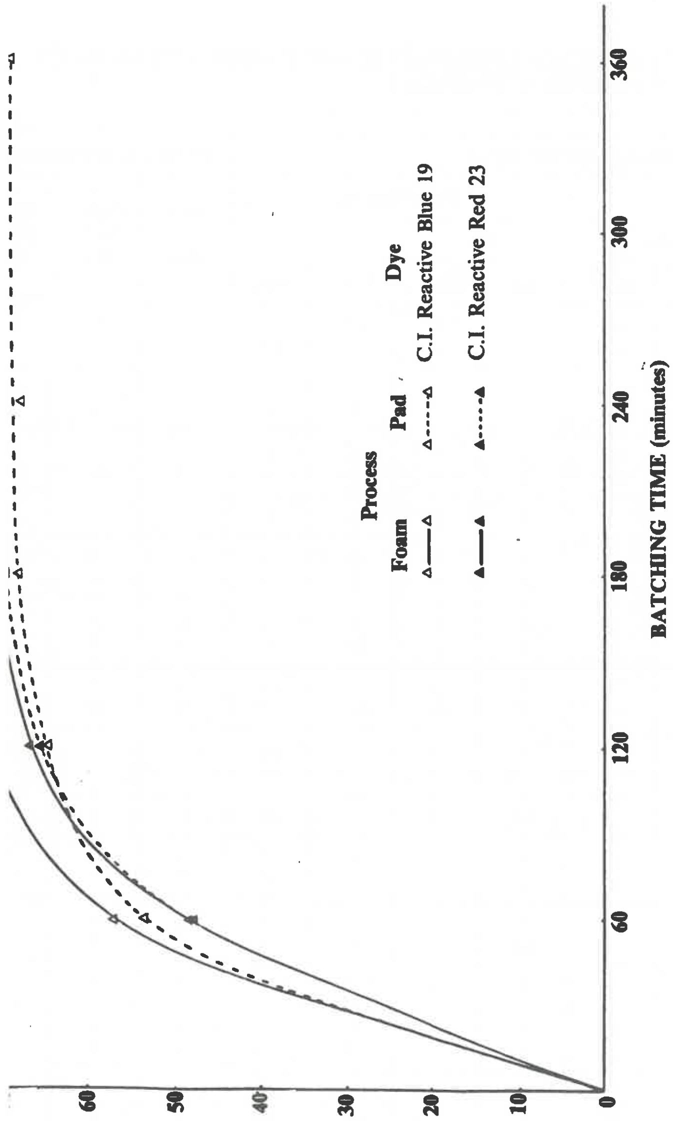

Fig. 6 – The effect of batching time on the percentage covalent fixation of vinyl sulphone dyes.

TABLE XII

THE EFFECT OF WET PICK-UP ON FIXATION AND SOME FASTNESS PROPERTIES OF FABRICS DYED WITH REACTIVE DYES BY THE PAD-STEAM PROCESS

DYE	Process	Wet Pick-up (%)	Foam Applicator	Dye Fixation (%)	Covalent Fixation (%)	RUBBING FASTNESS								WASH FASTNESS (IS		
						Before Soaping				After Soaping				Effect of Shade	Cotton Staining	Wo Sta in
						Dry		Wet		Dry		Wet				
						Face	Back	Face	Back	Face	Back	Face	Back			
C.I. Reactive Red 40	Foam	20	Single	90,8	88,7	5	5	4-5	4-5	5	5	4-5	5	5	5	5
			Dual	88,2	85,8	5	5	4-5	4-5	5	5	4-5	4-5	5	5	5
		30	Single	86,2	84,3	5	5	4-5	4-5	5	5	4-5	5	5	5	5
			Dual	89,2	87,1	5	5	4-5	4-5	5	5	5	5	5	5	5
		40	Single	91,6	89,0	5	5	4-5	4-5	5	5	4-5	5	5	5	5
			Dual	91,3	89,4	5	5	4-5	4-5	5	5	5	5	5	5	5
	Pad	80	—	86,3	80,2	5	5	4	4	5	5	4	4	5	5	5
C.I. Reactive Blue 29	Foam	20	Single	87,1	84,3	5	5	4-5	5	5	5	4-5	5	5	5	5
			Dual	85,6	83,6	5	5	4-5	4-5	5	5	5	5	5	5	5
		30	Single	88,9	86,8	5	5	4-5	5	5	5	5	5	5	5	5
			Dual	88,6	86,4	5	5	4-5	4-5	5	5	4-5	5	5	5	5
		40	Single	89,6	86,9	5	5	4-5	5	5	5	4-5	4-5	5	5	5
			Dual	88,4	85,8	5	5	4-5	4-5	5	5	4-5	4-5	5	5	5
	Pad	80	—	86,8	83,9	5	5	4-5	4-5	5	5	4-5	4-5	5	5	5
C.I. Reactive Red 147	Foam	20	Single	77,7	77,2	5	5	3-4	4-5	5	5	4-5	5	5	5	[illegible]
			Dual	77,0	75,9	4-5	5	4	4	4-5	5	4	4	5	5	[illegible]
		30	Single	76,0	74,7	4-5	5	4	4-5	5	5	4-5	5	5	5	[illegible]
			Dual	73,1	71,4	4-5	5	4	4-5	5	5	4-5	4-5	5	5	[illegible]
		40	Single	79,1	77,3	5	5	4	4-5	5	5	3	3	5	5	[illegible]
			Dual	76,6	74,8	5	5	4	3-4	4-5	5	4	4	5	5	[illegible]
	Pad	80	—	67,8	66,6	4	4-5	3	3	4	4	3	3	5	5	[illegible]
C.I. Reactive Yellow 25	Foam	20	Single	81,7	80,6	5	5	4	4-5	5	5	5	5	5	5	[illegible]
			Dual	79,6	78,1	5	5	4	4-5	5	5	4-5	4-5	5	5	[illegible]
		30	Single	88,5	85,8	5	5	4-5	4-5	5	5	5	5	5	5	[illegible]
			Dual	88,0	85,1	5	5	4	4-5	5	5	4-5	4-5	5	5	[illegible]
		40	Single	92,9	89,6	5	5	4	4-5	5	5	4-5	5	5	5	[illegible]
			Dual	91,0	88,4	5	5	4-5	4-5	5	5	5	4-5	5	5	[illegible]
	Pad	80	—	87,0	84,9	5	5	4	4	5	5	4	4	5	5	[illegible]

TABLE XIII

THE EFFECT OF WET PICK-UP ON FIXATION AND SOME FASTNESS PROPERTIES OF FABRICS DYED WIT REACTIVE DYES BY THE PAD-BAKE PROCESS

DYE	Process	Wet Pick-up (%)	Foam Applicator	Dye Fixation (%)	Covalent Fixation (%)	RUBBING FASTNESS								WASH FASTNESS (I	
						Before Soaping				After Soaping				Effect of Shade	Cotton Staining
						Dry		Wet		Dry		Wet			
						Face	Back	Face	Back	Face	Back	Face	Back		
C.I. Reactive Red 40	Foam	20	Single	84,6	82,1	5	5	4-5	4-5	5	5	4-5	5	5	5
			Dual	79,4	77,2	4-5	5	4-5	4-5	5	5	4-5	4-5	5	5
		30	Single	91,6	89,1	5	5	4-5	4-5	5	5	4-5	5	5	5
			Dual	94,4	90,7	5	5	4-5	4-5	5	5	4-5	4-5	5	5
		40	Single	92,6	87,4	5	5	4-5	4-5	5	5	4-5	4-5	5	5
			Dual	93,9	92,5	5	5	4-5	4-5	5	5	5	4-5	5	5
	Pad	80	—	93,3	91,7	5	5	4	4	5	5	4	4	5	5
C.I. Reactive Blue 29	Foam	20	Single	80,2	77,1	5	5	4-5	4-5	5	5	4-5	5	5	5
			Dual	76,5	72,8	5	5	4-5	4-5	5	5	4-5	4-5	5	5
		30	Single	86,7	83,3	5	5	4-5	5	5	5	4-5	5	5	5
			Dual	88,8	84,4	5	5	4-5	4-5	5	5	4-5	4-5	5	5
		40	Single	88,6	85,7	5	5	4-5	5	5	5	4	4	5	5
			Dual	89,2	87,4	5	5	4-5	4-5	5	5	4-5	4-5	5	5
	Pad	80	—	86,9	83,7	5	5	4	4	5	5	4-5	4-5	5	5
C.I. Reactive Red 147	Foam	20	Single	71,8	70,1	4-5	5	4	4-5	4-5	5	4	5	5	5
			Dual	67,0	65,0	4-5	5	4	4	4	5	4-5	4-5	5	5
		30	Single	82,4	80,7	4-5	5	4	4-5	4-5	5	4-5	5	5	5
			Dual	84,2	82,3	5	5	4	4-5	4-5	5	4-5	4-5	5	5
		40	Single	82,2	80,5	5	5	4	4-5	5	5	4-5	4-5	5	5
			Dual	85,6	84,1	5	5	4	4-5	4	5	4-5	4-5	5	5
	Pad	80	—	84,1	82,3	5	5	4	4	4-5	4-5	4-5	4-5	5	5
C.I. Reactive Yellow 25	Foam	20	Single	72,5	70,2	5	5	4-5	4-5	5	5	5	5	5	5
			Dual	70,2	68,3	5	5	4	4-5	5	5	4-5	4-5	5	5
		30	Single	83,4	80,5	5	5	4-5	4-5	5	5	4-5	5	5	5
			Dual	85,9	83,1	5	5	4-5	4-5	5	5	4-5	4-5	5	5
		40	Single	89,4	86,9	5	5	4-5	4-5	5	5	5	5	5	5
			Dual	88,1	86,2	5	5	4-5	4-5	5	5	5	5	5	5
	Pad	80	—	91,1	88,3	5	5	4	4	5	5	4-5	4-5	5	5

conventional padding process at a wet pick-up of 80%.

Initial trials showed that the FFT machine produced level dyeings on cotton fabrics. In the case of the single applicator the face of the fabric was dyed, whereas both sides were dyed using the dual applicator. Treatments at 20%, 30% and 40% produced level dyeings, but when the wet pick-up was reduced to 10%, the dyeings tended to be unlevel. The degree of penetration of dye into and through the fabric increased when the wet pick-up increased. In the case of the single applicator, there was still a difference between the face and back of the fabric, even at a wet pick-up of 40%. With the dual applicator, some differences between face and back were noticed up to a wet pick-up of 20%, whereafter there was no difference. A comparison between the colour difference values of the fabrics dyed by the foam process and those dyed by the conventional pad-batch process, showed that, for the same dye add-on, the foam-dyed fabrics were dyed to a deeper shade than the conventionally dyed fabrics. A substantial saving in dye could be made when the fabric was dyed at the lowest wet pick-up possible using the single applicator.

A number of cotton fabrics differing in mass (ranging from 91 to 330 g/m^2) was foam-dyed and batched for 24 hours. In general, the fabrics dyed by the foam process showed higher dye fixation values than the pad-dyed fabrics. The fastness ratings of the foam- and pad-dyed fabrics were generally similar. The colour difference between the face and back of the foam-dyed fabrics decreased with decreasing fabric mass, as well as with increasing wet pick-up. Furthermore, the colour difference values were smaller in the case of the dual applicator dyeings than with the single applicator. The colour difference between the face and back of the fabrics dyed by the single applicator, could be reduced by steaming the fabrics after foam-dyeing. The results showed that for the smallest colour difference there was an optimum steaming time, which depended on wet pick-up. In some cases steaming initially decreased the colour difference, followed by a slight increase as the steaming time was increased. Steaming improved dye levelness of the fabrics dyed at a wet pick-up of 10%.

A range of dyes with different reactivities (classified according to their specific reactive groups) were selected for foam-dyeing (at 30% wet pick-up, using the single applicator) and pad-batch dyeing (80% wet pick-up). In general, the foam-dyed fabrics had slightly higher fixation values (on average about 5%) than those dyed conventionally. Certain specific dyes showed fixation values up to 12% higher in the case of foam-dyeing. The fastness properties, however, did not differ significantly. The work was then extended by selecting the two most reactive dyes and the two least reactive dyes to dye a cotton fabric at different wet pick-ups (20%, 30% and 40%) using the single applicator as well as the dual applicator. Results showed that wet pick-up had no noticeable effect on the fixation values and the fastness properties of the dyes. Once again, dyeing by foam resulted in slightly higher fixation values than conventional pad-batch dyeing.

the same.

From the results it is clear that foam-dyeing offers several advantages. Apart from the energy savings, less dye and alkali can be used.

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THE USE OF PROPRIETARY NAMES

The names of proprietary products where they appear in this report are mentioned for information only. This does not imply that SAWTRI recommends them to the exclusion of other similar products.

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