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APPLICATION OF FOAMS TO THE PROCESSING OF FABRICS

Final Report for the Period October 1, 1977--September 30, 1981

By
Chettoor G. Namboodri

October 1981

Work Performed Under Contract No. AC02-77CS40056

United Merchants and Manufacturers
United Merchants Research Center
Langley, South Carolina

U. S. DEPARTMENT OF ENERGY

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FINAL REPORT

For period October 01, 1977 to September 30, 1981

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October 1981

Prepared For

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1.0 EXECUTIVE SUMMARY

In October of 1977, a federal contract was granted by the U. S. Department of Energy to United Merchants and Manufacturers to accelerate the development of the foam processing of textiles. As a result of the work carried out under the contract, commercialization of foam finishing took place in 1978, at least five years earlier than projected if only private funding had been available. This accelerated development of foam processing promoted competitive activity leading to the development of alternative foam processes by chemical manufacturers as well as textile machinery companies.

The process is now commercially used in textile mills for finishing, dyeing and printing of fabrics. The essential feature of the United Merchants process is to mechanically foam a concentrated finish mix and to apply the foam to textile fabrics in place of conventional impregnation and squeezing off excess liquid. Since air replaces water as the medium for distributing the finishing chemicals, substantial energy savings are realized in the drying of fabrics.

Foam processing is now accepted throughout the textile industry as a commercially viable process for saving energy. Other demonstrated advantages of foam processing are more efficient utilization of finishing chemicals and increased productivity. The process is applicable to a broad range of fabric weights and constructions. Finishes such as durable press, shrink resistant finishes, softeners, water repellants and hand builders are being applied to fabrics by the process. By September of 1981, approximately 600,000,000 yards of fabric have been foam finished in the U. S. by U. M. & M. and customer mills of its chemical division. A substantial yardage has also been foam finished by other processes developed subsequent to the United Merchants' process.

In commercial practice, energy consumption is reduced by 40 to 80% by converting from conventional wet finishing to foam finishing. The amount of energy savings is dictated by the extent to which the wet pick-up can be reduced, by the weight and construction of the fabric being finished and by the minimum oven temperature needed to dry the fabric.

The state of the art of foam dyeing has not progressed as rapidly as that of foam finishing. However, foam dyeing is being commercially practiced with certain textiles. Foam dyeing of nylon carpet is commercial at one domestic plant and United Merchants is pre-

sently working with a dyestuff manufacturer and a machinery company to promote the commercial production of foam dyed carpets.

Polyester and acrylic non-woven blankets, non-woven inner lining fabrics and polyester/cotton narrow width industrial toweling are now commercially foam dyed. Flocked and velour type plush fabrics have been successfully foam dyed in limited production trials.

The foam dyeing of flat woven goods is not yet commercial. The major hurdle has been the design of a foam applicator device which will produce a uniformly dyed fabric with no perceptible shade variation either side to side or front to back of fabric.

Where multiple wetting and drying steps are involved in converting greige goods to a finished textile product, it is now possible to completely eliminate some drying operations by practicing "wet on wet" foam processing. In "wet on wet" processing, the wet fabric as from a dyeing operation is not dried before the finish is foam applied. This practice was generally not possible in conventional processing.

Foam printing progressed much faster than originally programmed. Foamed printing inks are now being used to print fabrics by the intaglio process. Since 1979, over five million yards of fabric have been foam printed at U. M. & M. plants. At present, foam printing is being used to pigment print blotch patterns. Both cotton and polyester/cotton blend fabrics are foam printed by using engraved rolls. Foam printing with rotary screens is not yet viable. Mechanical modifications of the foam feed system are needed to overcome streakiness on the printed fabrics.

Foam printing with wet colors such as disperse dyes on polyester, acid dyes on nylon and Rapidogen colors on cotton has been scaled-up successfully, but is not yet in commercial production.

While not as dramatic as for foam finishing, foam printing energy savings of 35% have been demonstrated in commercial trials. Where printing range line speed has been limited by oven drying capacity, 30 to 35% increases in line speed have been achieved with foam printing.

The feasibility of utilizing foams in fabric preparation has been demonstrated. Plant trials were conducted to foam prepare polyester/cotton gingham fabrics.

Energy savings by foam preparation would not be significant, since the fabric has to be thoroughly washed to remove the solubilized sizes prior to drying for subsequent finishing operations.

The application of warp sizes from a foam medium is under study. Plant trials have been conducted, but the process is not yet commercial.

2.0 INTRODUCTION

The primary objective of this project has been to reduce the energy consumed in the wet processing of fabrics where wet processing encompasses those processes used to convert loomstate (greige) goods to finished textile products. This includes desizing, scouring, bleaching, dyeing, printing and finishing of fabrics. The energy intensive step in most of these processes is drying the fabric. By having less water on the fabric as it enters a drying oven, proportionately less energy is consumed in drying the fabric.

The specific route used in this project to accomplish this objective has been to use air to distribute the finish, dye or printing ink onto the fabric. Rather than saturating the fabric with a dilute finish formulation, a concentrated formulation is mechanically foamed, air serving as the diluting medium and the foam applied to the fabric. In this manner, the water content of the fabric as it enters the drying oven is reduced by as much as 80% thereby leading to a corresponding reduction in the energy required to dry the fabric.

The specific objectives for this project were:

1. To complete up-grading of the UMRC finishing range to operating condition with commercial speed capability.
2. To optimize specific foam finish formulations to readiness for pilot plant fabric runs. Durable press, hand modification and water repellancy type finishes were to be optimized. Pilot plant finishing trials were to be run. Plant trials were to be run, including economic and energy evaluations, and commercial demonstrations were to be run.
3. To optimize specific foam dyeing formulations for selected dyes and fiber types for pilot plant runs. Fibers were polyester, nylon, acrylic, cellulose acetate, wool, cotton and rayon. Dye classes were disperse, acid, direct, cationic, reactive and pigments as applicable to specific fibers. Pilot plant dyeing trials were to be run. Plant trials were to be run, including economic and energy evaluations, and commercial demonstrations were to be run.

To commercially demonstrate continuous foam dyeing process on single fiber synthetics and 100% cellu-

losic fabrics on plant equipment.

To run plant trials, including economic and energy evaluations, the foam dyeing of blend fabrics, particularly polyester/cotton or polyester/rayon blend types.

4. To optimize foam printing formulations for selected pigments and dyes for printing various substrates. Pigment formulations for cellulosics, polyesters and their blends, acid dye formulations for nylon, vat dye formulations for cellulosics and cationic dye formulations for acrylics were to be optimized. Pilot plant trials, including economic and energy evaluations, were to be made.

Commercial demonstration of foam printing.

5. To determine the feasibility of foam fabric preparation including the operations of desizing, scouring and bleaching.

Pilot plant studies on foam fabric preparation: desizing, scouring and bleaching.

Commercial demonstration of foam preparation.

6. To demonstrate sequential or simultaneous foam dyeing and foam finishing.

Commercial demonstration of foam dyeing of blends: polyester/cotton or polyester/rayon blends.

Commercial demonstrations of sequentially/simultaneously foam dyeing and foam finishing.

Plant trials on simultaneously foam dyeing and foam finishing of blends: polyester/cotton or polyester/rayon blends.

To demonstrate entire preparation, dyeing (printing) and finishing sequentially by the foam process.

7. Exploratory studies on low temperature finishing, dyeing and coating.

3.0 BACKGROUND

In the period of 1972 to October 1976, investigations at the United Merchants Research Center demonstrated the feasibility of using foam technology to finish, dye and print a great variety of fabrics ranging from carpets and sliver knits to light weight goods such as 2 oz. per yard polyester/cotton sheeting. Foam finishing was used to apply softeners, durable press resins, water repellants and stain repellants to a variety of fabrics. Both natural and synthetic fibers and their blends were dyed with suitable dyestuffs. Foam dyeing was carried out with disperse acid, direct, reactive, cationic dyes and pigments.

Fabrics were also printed with foams. Pigments, disperse dyes, Rapidogens and acid dyestuffs were among those coloring agents used to print fabrics with foams.

Since, by using foam, the wet pick-up of the fabric could be reduced by as much as 60%, it was obvious that this technique could lead to significant energy savings for the textile industry and contribute to the national effort to conserve energy.

In order to accelerate the development and utilization of this technology throughout the textile industry, a proposal was submitted to the Department of Energy.

In October of 1977, a two year contract was granted by the Department of Energy and was later extended for an additional two year period.

4.0 DISCUSSION OF EXPERIMENTAL RESULTS

Data and discussion given covers contract work from October 01, 1977 to September 30, 1981.

4.1 DESCRIPTION OF THE U. M. FOAM PROCESS

The United Merchants Foam Process consists of the following steps:

- a). Formulation of a foamable finish* concentrate.

*The term finish will be used in a generic sense to include anything applied to a woven or non-woven substrate to confer certain desired physical or esthetic properties to the substrate.

- b). Conversion of the concentrate to a foam.
- c). Application of the foam to the substrate.
- d). Collapse of the foam.
- e). Drying of the substrate.

In the conventional wet finishing process, the substrate is immersed in a dilute solution of the finish formulation, the saturated fabric is squeezed between pad rolls to remove excess liquor and the fabric containing 80 to 100% based on fabric weight of wet finish is dried in an oven. Typically 90 to 98% of the finish is water.

In the foam process, the concentrated finish is formulated with suitable foaming agents. The mix is mechanically foamed, the foam containing from 70 to 95% by volume of air. The foam is applied to either one or both sides of the fabric. The foam is collapsed by applying a mechanical force such as passing the foam coated fabric through pad rolls. In this process, the pad rolls are not squeezing any liquor from the fabric but serve only to collapse the foam. The fabric, now with a wet pick-up of only 20 to 50% is dried in the oven.

The fabric is dried in the conventional manner. Any subsequent processing of the fabric such as a curing operation is carried out in the same manner as for wet finished fabrics.

4.2 FORMULATION EVALUATION PROCEDURES

Overall foam evaluation begins in the laboratory using kitchen type planetary mixers to prepare the foams and knife coating of the foam onto test fabrics. Pilot plant trials, mill trials and commercial production follow sequentially with energy measurements being made in these three stages.

Initial formulation work consisted of taking a proven conventional formula for wet finishing, removing as much of the water of dilution as possible and then adding appropriate foaming agents and stabilizers. The solids multiplication governs the reduction of water - a "2X" solids type will be foam applied at one-half the normal wet pick-up. In a hypothetical mix containing 10% solids, 90% of the applied mix is water. When solids are doubled and wet pick-up is halved, only 40% of the applied mixture (foam) is water or a reduction of 55.6% of water applied. Other additives, such as foaming systems and stabilizers, will increase solids slightly and further reduce the water content.

The reformulated finish is initially checked for foamability and shelf stability. The latter is a critical test since the reactive ingredients are in a very concentrated form.

In a large number of cases, the foam finished fabric did not match the control especially with respect to esthetic properties such as handle, scroop, etc. The property alterations are due to the presence of foaming agents and foam stabilizers. The mixes were then modified so as to match the control.

Thus, it is evident that conventional finish systems can not be converted to foamable systems merely by removing water and adding a foaming agent.

Foam cell size is judged subjectively - fine, medium or coarse. This is quick and quite acceptable in textile technology - shade matching, hand evaluation and durable press ratings are considered precise and are routinely measured subjectively by trained personnel.

Foam consistency can be judged either subjectively or by measurement of its viscosity with a Stormer or Brookfield viscometer. The half life of a foam is defined as the time required for half the foam volume to collapse. However, a more suitable measure of foam stability for this project was the determination of foam density and viscosity as a function of time. In the

foam processing of fabrics, the foaming systems influence both foam characteristics (i.e., for effective coating) and fabric properties. Additionally, the foaming system will dictate the running conditions for the range foamer.

For example, highly alkaline foaming systems can inhibit curing of the resin, while those containing certain nitrogen compounds can lead to fabric discoloration.

A pilot study on the range Oakes foamer was run to establish those factors which influence the production of a satisfactory foam. A constant base formulation of glyoxal resin, melamine resin, catalyst and softener was made up with three different foaming systems. The first was a mixed anionic-nonionic of high alkalinity, the second was a nonionic of slight alkalinity (ring nitrogen) and the third was a neutral pH nonionic. None were applied to fabric since only foaming characteristics were determined.

The experimental conditions for foaming were:

- a) A fixed rate of feed to the foamer - 0.85 lbs./min.
- b) A fixed rotor speed in the foaming head - 750 rpm.
- c) Line air pressure - 100 psig.
- d) Air input - 0.2 and 0.3 cu. ft./min.
- e) Delivery hose diameters - 0.25, 0.375, 0.5, 0.625 and 0.75 in.
- f) Delivery hose length - fixed for all hoses at 50 feet.

The effect of varying conditions d and e on the quality of the foam was studied. In addressing the quality of a foam the following factors were considered:

- a) Blow ratio - the ratio of the weight of the unfoamed liquid to the weight of an equal volume of foamed liquid.
- b) Cell size.
- c) Foam viscosity.
- d) Blow-by - an undesirable condition in which the foam extruded from the foamer contains large air bubbles.
- e) Back pressure - the pressure of the foam as it exits the foaming chamber.

The study lead to the following observations:

1. Hose Diameter

Decreasing hose diameter leads to:

- a) Increased back pressure.
- b) Higher foam viscosity at a given blow ratio.
- c) Finer cell size.
- d) Blow-by if decreased too far.

2. Air Input

For a given hose diameter, increasing air input leads to:

- a) Higher blow ratio.
- b) Increased back pressure.
- c) Minor improvement in foam stability.

3. Back pressure should be kept between 20% and 70% of the line air pressure in order to maintain stable foam formation.

4. For a given base finish and at equivalent back pressures during foaming, foam properties are independent of the foaming system used. However, fabric esthetics and physicals are strongly influenced by the type of foaming system used.

The techniques used are to precisely set up the critical parameters of wet pick-up, foam type, fabric type, application method, speed, oven temperature and oven air circulation pattern. The run is started and Polaroid pictures are taken of the gas meter at stop watch timed intervals. At the moment the run is stopped, residual moisture, if any, is determined in the dried fabric.

From the data obtained, simple arithmetic allows calculation of energy used per fabric unit - i.e., cubic feet of gas or B.T.U. per yard. Also, it is possible to calculate an efficiency figure for the dryer under the conditions used. As we use it, we define oven efficiency as the theoretical energy required to evaporate the water on the fabric divided by actual energy used and expressed as per cent. Further discussion of and data for such measurements are included later in this report.

4.3 CHEMICAL FORMULATION - FABRIC FINISHING

As a starting point for the formulation of practical foamable finishes, an analysis of finish utilization at United Merchants' Clearwater Finishing Plant was made. In a printing and finishing plant such as Clearwater, literally hundreds of finish formulations are in their repertory.

Fifty-four foamable finishes suitable for about 35% of their 1977-78 fabric production were developed. If tinted versions of these finishes are included, the figure is about 50% total production.

The majority of finish components used are those manufactured by the Valchem division of U. M. & M.

For a typical foamable durable press finish, the component breakdown is as follows;

Resin	6-10%
Softener	2-6
Hand Builder, Soluble	0-3
Hand Builder Emulsion Polymer	0-10
Resin Catalyst	1-2
Foaming System	0.1- 1.0

For foam finishes evaluated to date, the active materials have ranged from a high of 80% to a low of less than 10%. Some lower concentration mixes require thickeners or foam stabilizers for foam stability. Some typical agents of this type are cellulose ethers, alginates, polyethylene oxide polymers and ammonia activated acrylics.

The development of foamable finishes has followed two paths, a foamable fully compounded system to which only water is added at the mill location and mutually compatible foamable building blocks which the mill chemist or finisher can use to design his own systems. Some typical products are listed in Tables I and II.

TABLE I

FULLY COMPOUNDED SYSTEMS

1. Valfoam SF - a durable press, shrinkage control finish for polyester/cotton sheeting.
2. Valfoam CCF - a fabric stabilization finish for corduroys.
3. Valfoam P - a stabilization and hand building finish for light weight corduroys.
4. Valfoam 117 - a stabilization and softener finish for polyester/cotton flannels.

TABLE II

FOAMABLE BUILDING BLOCKS

1. Resins - Valrez FG-1, FG-2, 313-106, 291-143 and 313-74.
2. Softeners - Valsof FNS, FCS, PFC, FPE and 313-109.
3. Handbuilders - Valbond F-3, F-7, 313-107, PVF, 313-108 and 271-156.

An example of a special finish, a water repellant/soil release finish suitable for foam application to pile fabrics is shown in Table III.

TABLE III

WATER REPELLANT/SOIL RELEASE FINISH

	<u>%</u>
Scotchgard ^R FC-210	5.0
Valthick-70 (Acrylic acid copolymer latex)	3.0
Valmel-40 (An etherified methylol melamine)	2.0
Ammonium Chloride	0.05
Ammonium Hydroxide (28%)	0.5
Ammonium Stearate (33%)	3.0
Water	86.45

This finish was foamed to a 4:1 blow ratio and knife coated onto an acrylic/polyester sliver knit. The wet pick-up was 45%. The fabric after drying and curing met both water repellant and soil release requirements.

A foamable napping softener for flannels was developed which could be applied at a 20-30% wet pick-up.

The plant trial results for many of these finishes will be discussed under "Fabric Processing".

It has been established that foam processing techniques can be utilized to actually eliminate intermediate drying steps by "Wet-On-Wet" application of foam.

Most fabrics are dyed in machines which deliver fabrics literally dripping wet. These are mechanically extracted, with padding or hydroextraction to a minimum water level. This is usually the same level as that to which a wet finished fabric is padded, i.e., 65-100% of fabric weight depending on fiber content. New high extraction pads are now available which reduce this level down to the 30-35% range.

In conventional finishing, these fabrics must be dried before they are finished by immersion in a finish bath, followed by padding, drying and curing.

Immersion of wet fabrics into a finish bath would lead to dilution of the bath by water on the fabric and often to bleeding of color into the bath.

In "Wet-On-Wet" finishing, a foamed finish can be applied to the fabric without an intermediate drying. Since the exact quantity of finish is applied directly to the fabric, there is no dilution of a finish bath. A very concentrated finish is foamed, applied to the wet fabric at low wet pick-up and the water already present helps to diffuse the finish after the foam is collapsed.

Carrying this wet-on-wet procedure one step further, it is possible to foam dye, leave the fabric wet after steaming, foam finish and dry only once. This was demonstrated on the old UMRC range (at slow speed) by applying a foamed disperse/direct dye mixture onto a polyester/cotton blend, steaming, foaming on D.P. finish, drying and curing. Curing of the resin also thermoset the disperse dye.

Three finishes have been evaluated in this foam wet-on-wet area. First, napping softener has been applied onto polyester/cotton blends for subsequent brushing or napping. Secondly, a non-polymeric dye fixative has been foam applied onto direct dyed wet cotton. Thirdly, D.P. finish was applied onto wet polyester/cotton. It was found that in this case less dry resin add-on was

required to meet finished fabric specifications than would be required by conventional finishing.

Printed nylon flocked fabrics are being foam finished using a "Wet-on-Wet" technique.

This printed fabric requires a vigorous washing after printing and dye fixation to remove the print gums. In a normal operation the washed fabric is dried, and then a fluorocarbon finish is applied to give water and oil repellancy to the fabric. With foam we were able to apply the fluorocarbon to the wet fabric, thus eliminating entirely one drying operation.

Preliminary laboratory data had suggested that more effective utilization of finish occurred in foam finishing. The first plant trial corroborated this. It is now well established that foam finishing leads to improved utilization of finishing chemicals (1,2).

The initial formulation approach of adding foaming systems to concentrated wet pad systems led to establishment of energy savings and validity of commercial foam finishing. However, many of the formulae were not optimized and required changes. Cost effectiveness improvement and correction of fabric property alterations have been accomplished in a number of instances:

- a) A major portion of fabric finish types have been successfully formulated to increased solids foamable finishes.
- b) Fabric physical and esthetic properties equivalent to those by conventional wet processes have been obtained via foam processing under mill production conditions.

Additional work in this area includes work on second generation formulations where the objective was to design foamable finishes from scratch instead of converting an existing resin or softener formulation to a foamable system.

TABLE IV
PLANT FOAMABLE FINISH FORMULATION

<u>Previous Formula</u>		<u>New Formula</u>	
Resin	6-10%	New Foamable Resin	4-8%
Softener	2-6%	New Foamable Softener	2-4%
Hand Builder	0-3%	New Foamable Hand Builder	0-3%
Hand Builder (Emulsion polymer)	0-10%	New Foamable Hand Builder (Emulsion polymer)	0-10%
Catalyst	1-2%	Catalyst	1-2%
Foaming System	0.1-1%	Foaming System	0.1-1%

4.4 FABRIC PROCESSING - FINISHING

The primary objective of the work under this contract is to demonstrate that foam processing is a commercially viable, energy conserving alternative to conventional wet processing.

When it became apparent that the pilot range would not be operational in the first six month's period, it was decided to run foam finishing trials on commercial ranges at U. M. & M.'s Clearwater, Old Fort Finishing, and Arkwright Finishing Plants. These initial trials were sufficiently successful, that foam finishing was adopted as a commercial process by these plants on a limited number of styles.

The results from a number of finishing trials at these plants are summarized in the next sixteen tables. The foam trials were initially conducted by breaking into conventional finishing production runs (which served as controls) and applying the finish as a foam. The only dryer conditions varied were temperature and throughput. No attempts were made to optimize air flow or the degree of air recirculation.

The procedure for calculating per cent oven efficiency has been applied to energy data on foam finished production runs.

Previously these data were presented showing savings (percentage) of gas when the wet pad process was converted to a foam process. The savings varied from

26% (low) up to 86% (high) and reflect a savings in all cases. However, when the oven efficiencies (energy for water evaporation divided by total energy input) are calculated, they ranged from a low of 6% to a high of 90%.

In the design of tenter frames it is now customary to specify a minimum drying capacity. With continuous operation of burners delivering a specified number of B.T.U.'s per hour, the frame must evaporate a specified amount of water. Customarily, also, the conditions state a given fabric at a specific wet pad moisture pick-up and frame temperature. For some years U. M. & M.'s engineers required design drying capacity minimum that calculates in 40-45% oven efficiency range. The UMRC range calculates to about 52-53% with its short length of 21 feet.

A detailed study of energy consumption as a function of wet pick-up, range speed and oven temperatures was carried out on the UMRC pilot range. The first objective was to determine if short yardage runs correlate with production energy data. To do this with the technique described earlier, a foamable softener was applied onto 3.2 oz/yd² 50/50 polyester/cotton print cloth. Low level, non-reactive solids are deliberately used to avoid effects such as chemical crosslinking and finish migration in the dryer. Typical data from the trials are shown in Table V.

TABLE V

PILOT PLANT DRYER DATA - FINISHING

<u>Wet Pick-up</u>	<u>Type</u>	<u>Range Speed</u>	<u>Temp. °F</u>	<u>Ft.³ of Gas/yd.</u>	<u>Residual Moisture</u>
85%	Conventional	20 ypm	350	0.420	Dry*
81.4	Conventional	25	350	.422	7.6%
35	Foam	59	350	.169	Dry
32	Foam	40	225	.081	Dry
28	Foam	59	225	.080	4.9%

*Residual moisture less than 4%

In the determination of dryer energy data to date on the UMRC range, one exploratory run was quite thought provocative. The temperature was set at 175°F, the lowest controllable set point on the burners. At 28% wet pick-up and 20 yards/minute speed, the fabric dried and the oven efficiency was calculated at 100.4%. From a thermal standpoint this is not possible due to radiant and mechanical heat losses from the chain, the dryer walls, air exhaust and exiting fabric. Then it was realized the recycle air of 30,000 cfm. could be effecting some of the drying.

Table VI compares the composition of a conventional durable press finish with its foamable counterpart. Table VII summarizes the plant data where this finish was applied to a 3 oz/s.yd. printed polyester/cotton fabric. In the first and second trial (columns 1 and 2), the oven temperature was maintained at 350°F solely to overcome a heat set put into the fabric during a high temperature curing of the printed pigments. In the next trial (Column 3), where the oven was only used for drying, it was possible to operate the oven at its lowest temperature and still increase range speed. The increase in energy savings achieved by lowering the temperature was quite dramatic. The oven efficiencies are directly related to the indicated operating conditions.

TABLE VI
DURABLE PRESS FINISH

<u>Wet Process</u>	<u>Foam Process</u>	
Valbond 6061	Valbond F-74	
Valrez 99H	Valrez F-T4	
Valcat AH	Valcat F-A4	
Valsof G-2	Valsof FNS	
Valsof PE	Modified Starch	
Modified Starch		
Valwet P-35		
	<u>Wet</u>	<u>Foam</u>
Wet-Pick-up (on wt. of fabric)	<u>60%</u>	<u>30%</u>
Calculated Water Pick-up	55.9%	26.5%

TABLE VII

DRYER DATA

50/50 Polyester/Cotton

(Wt. 3 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>	<u>Foam</u>
Finish Pick-up on weight of Fabric	60%	30%	30%
Calculated Water Pick-up	56%	26%	26%
Oven Temperature, °F.	350	350	225 (1)
Speed, yds./min.	92	98	115 (2)
% Speed Change		+6.5	+25
Nat. Gas Consumption (ft. ³ /yd.)	1.38	0.71	0.39
BTU/yd	1428	734	403
Energy Savings		47.6%	73.6%
Oven Efficiency, %	10%	9%	16%

(1) Minimum operating temp.

(2) Maximum speed

The same finish (Table VI) was applied to a heavier (6.6 oz/yd²) polyester/cotton fabric. Again, it was possible to reduce oven temperature and increase range speed and demonstrate significant energy savings. The data are summarized in Table VIII, and show with "drying only" how oven efficiency, productivity and energy savings are all significantly increased.

TABLE VIII

DRYER DATA

50/50 Polyester/Cotton

(Wt. 6.6 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>
Finish-Pick-Up on Weight of Fabric	60%	30%
Calculated Water Pick-up	56%	26%
Oven Temperatures, °F.	350	250
Speed, yds/min.	57	110
% Speed Change		+93%
Natural Gas Consumption (ft ³ /yd)	2.26	0.31
BTU/yd	2239	326
Energy Savings		86%
Oven Efficiency %	12.7%	43%

The next three tables (IX, X, and XI) summarize the results of a number of trials in which a durable press, fabric stabilization finish was applied to polyester/cotton fabrics of various weights. The major conclusion drawn from this work is that while productivity (range speed) was significantly improved by switching to foam finishing, energy savings, while reasonable, were disappointing. Energy savings calculated on the basis of reduced water pick-up should be about 54%. In all three of the runs, oven efficiencies actually drop in going from wet pad to foams. Energy savings are realized but are below the expected levels.

In explanation, these runs were from the first significant yardages (350,000) of foam finishing run within U. M. & M. in 1977. At the time we did not realize the full value of simultaneously increasing speed and decreasing temperature in foam processing to get the highest energy savings. Frame temperatures were not dropped but speeds were roughly doubled. Actually, although energy was saved, total oven efficiency dropped (Tables IX, X, and XI) due to heat losses from the dryer. The mill was quite happy at that time since both gas was saved and labor and overhead cut (by doubling speed). Similar finishing is now being run in the particular mill at lower dryer temperatures.

TABLE IX
DRYER DATA

50/50 Polyester/Cotton

(Wt. 4.0 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>
Finish-Pick-Up on Weight of Fabric	60%	30%
Calculated Water Pick-up	56	26
Oven Temperatures, °F.	320/350/360*	320/350/360
Speed, yds/min	46	94.6
% Speed Change		+105%
Liquid Propane Consumption (ft. ³ /yd)	.0018	.0011
BTU/yd	1231	752
Energy Savings		39%
Oven Efficiency %	14%	11%

*Three zone dryer

TABLE X

DRYER DATA

50/50 Polyester/Cotton

(Wt. 7.5 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>
Finish-Pick-Up on Weight of Fabric	60%	30%
Calculated Water Pick-Up	56%	26%
Oven Temperatures, °F.	330/370/380	330/370/380
Speed, yds/min	40	80.7
% Speed Change		+101%
Liquid Propane Consumption		
(Ft ³ /yd)	.0021	.0013
BTU/yd	1437	889
Energy Savings		38%
Oven Efficiency %	23%	17%

TABLE XI

DRYER DATA

50/50 Polyester/Cotton

	<u>Conventional</u>	<u>Foam</u>
Finish-Pick-Up on Weight of Fabric	60%	30%
Calculated Water Pick-up	56	26
Oven Temperatures, °F.	320/340/340	320/340/340
Speed, yds/min	51	89.5
% Speed Change		+75%
Liquid Propane Consumption (ft. ³ /yd)	.0017	.0012
BTU/yd	1163	821
Energy Savings		29%
Oven Efficiency %	9%	6%

Table XII compares the composition of a conventional top softener for cotton flannel and its foamable counterpart. Such a finish is dried only.

As is again demonstrated in Table XIII, high energy savings are achieved when increased range speed is coupled with reduced oven temperatures.

Also, the oven efficiency of the foam system shows a high degree of optimization for both energy savings and productivity (top speed of machine).

TABLE XII
FLANNEL - TOP SOFTENER FINISH

	<u>Wet Process</u>	<u>Foam Process</u>
	Valsof G-2	Valsof FNS-43
	Valwet RW	Valsyl F-40
	Syton DS	
Wet Pick-Up	68.4%	25%
Calculated Water Pick-Up	67.6%	24.4%

TABLE XIII
DRYER DATA
COTTON FLANNEL
(Wt. 4.2 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>
Finish-Pick-Up on Weight of Fabric	68.4%	25%
Calculated Water Pick-up	67.6%	24.4%
Oven Temperatures, °F.	345/380	260/265
Speed, yds/min	60	107
% Speed Change		78.3%
Natural Gas Consumption (ft ³ /yd)	0.409	0.089
BTU/yd	423	92
Energy Savings		78.2%
Oven Efficiency %	54%	90%

A foamable hand builder/fabric stabilization finish was formulated (Table XIV) for application to 100% cotton print cloth. In this trial, the oven was used to both dry and cure the fabric.

TABLE XIV

HAND BUILDER/FABRIC STABILIZATION FINISH

Wet Process

Glorez FN

Valcat AH

Valbond-54

Valsof-421

PVA

Foam Process

Valrez UFF

Valcat 4-AF

Valbond VAF-4

Valsof F-421

PVA

Again, the data of Table XV clearly illustrates that the use of the same oven for drying and curing even with the foam system is energy wasteful.

In a drying operation, large volumes of air are heated to carry off the water and fumes. Once dried, however, the fabric needs only to be heated to effect cure and, clearly, to use the drying oven to effect cure will be an energy inefficient process.

The reduction in oven efficiency and rather modest energy savings for this finish plus no speed or temperature advantages sharply contrast with the "dry only" gains on the cotton flannel (Table XV compared to Table XIII).

Even as a separate curing operation, heating a fabric to 300°F to 400°F is wasteful of energy. There is a need to couple foam finishing with non-conventional methods of curing such as radiation curing which is a room temperature process.

TABLE XV

DRYER DATA

100% COTTON

(Wt/ 2.7 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>
Wet Pick-up on Weight of Fabric	69.9%	30%
Calculated Water Pick-up	68.5	28.7
Oven Temperature, °F.	350	350
Speed, yds/min	121	118
Gas Consumption (ft. ³ /yd)	0.234	0.173
BTU/yd	242	179
Energy Savings		26%
Oven Efficiency	61	25%

Tables XVI, XVII, and XVIII give comparative data from substantial yardage, in-plant, trials on heavier weight fabrics finished by both wet pad and foam finishing processes. Though frame drying and frame curing were accomplished in a single frame run substantial energy savings were achieved. In addition, cost savings were realized from increased frame speeds and reduced chemical consumption.

TABLE XVI

DRYER DATA

75/25/2 Polyester/Cotton/Rayon

(Wt. 6.75 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>
Finish Pick-up on Weight of Fabric	58%	28%
Calculated Water Pick-up	54%	25%
Oven Temperature, °F.	350	350
Speed, yds/min	55.6	76.4
% Speed Change		+37%
Liquid Propane Consumption (ft. ³ /yd)	.0014	.00073
BTU/yd	957	501
Energy Savings		48%

TABLE XVII

DRYER DATA

50/38/12 Polyester/Cotton/Wool

(Wt. 7.4 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>
Finish Pick-up on Weight of Fabric	61%	30%
Calculated Water Pick-up	56%	26%
Oven Temperatures, °F.	350	350
Speed, yds/min	42.5	62.5
% Speed Change		+48%
Liquid Propane Consumption (ft. ³ /yd)	.0015	.00087
BTU/yd	1026	595
Energy Savings		42%

TABLE XVIII

DRYER DATA

78/18/6 Polyester/Cotton/Wool

(Wt. 6.9 oz/yd²)

	<u>Conventional</u>	<u>Foam</u>
Finish Pick-up on Weight of Fabric	59%	26%
Calculated Water Pick-up	55%	24%
Oven Temperature, °F.	350	350
Speed, yds/min	36	48
% Speed Change		+33%
Liquid Propane Consumption (ft. ³ /yd)	.0012	.0009
BTU/yd	821	616
Energy Savings		25%

Arkwright, Clearwater Finishing, and Old Fort Finishing plants of U. M. & M. have done extensive work on design and modification of foam applicators for foam finishing. Their efforts are toward improving evenness of application and wet pick-up control. It is hoped that these newer application methods will also be an aid to more uniform foam dyeing of flat fabrics.

The three United Merchants finishing plants presently have eleven finishing ranges equipped for foam finishing. Additional ranges will be equipped for foam application at these U. M. & M. plants.

Additional plant data have been accumulated from the three U. M. & M. finishing plants and are listed in Table XIX.

By the end of September, 1981, approximately 600,000,000 yards of fabric had been finished in the industry with foam by using U. M. & M. system.

The foam finishing program at one of U. M. & M. finishing plants include the following areas of investigation:

Cost Accounting
Process-Optimization
Formulation-Optimization
Equipment-Engineering

TABLE XIX

Plant Energy Data - U. M. & M. Plants

		<u>PLANT A</u>	
<u>Quarterly Months</u>	<u>Year</u>	<u>Yards Processed Using Foam</u>	<u>BTU Saved</u>
Oct-Dec	1979	3,808,484	668,230,599
Jan-March	1980	3,480,288	615,084,878
April-June	1980	4,168,005	813,177,774
July-Sept	1980	5,611,742	1,097,684,577
Oct-Dec	1980	7,072,497	1,376,967,029
Jan-March	1981	6,764,611	1,310,736,229
April-June	1981	5,894,357	1,149,399,615
July-Sept	1981	4,485,430	875,058,850

TABLE XIX Continued

<u>PLANT B</u>			
<u>Quarterly Months</u>	<u>Year</u>	<u>Yards Processed Using Foam</u>	<u>BTU Saved</u>
Oct-Dec	1979	5,366,205	2,464,119,900
Jan-March	1980	5,676,000	2,287,391,600
April-June	1980	3,766,941	2,005,142,693
July-Sept	1980	3,117,873	1,657,787,630
Oct-Dec	1980	3,376,819	1,788,156,117
Jan-March	1981	2,795,334	1,487,948,986
April-June	1981	5,018,513	2,669,848,916
July-Sept	1981	3,948,341	2,097,517,412

<u>PLANT C</u>			
<u>Quarterly Months</u>	<u>Year</u>	<u>Yards Processed Using Foam</u>	<u>BTU Saved</u>
Oct-Dec	1979	4,462,265	878,476,526
Jan-March	1980	8,703,671	1,659,691,269
April-June	1980	8,367,820	1,566,455,902
July-Sept	1980	8,327,936	1,560,573,320
Oct-Dec	1980	11,524,392	2,357,366,182
Jan-March	1981	7,471,047	1,398,072,715
April-June	1981	7,626,434	1,426,143,158
July-Sept	1981	13,267,908	2,481,098,796

A two month period of industrial engineering study of foam finish cost data evaluation from two machines is summarized in Table XX.

TABLE XX

Summary-Cost Evaluation

<u>Fabric Weight</u>	<u>Finish Number</u>	<u>Machine Number</u>	<u>% Energy Saved by Using Foam</u>	<u>BTU/yd</u>	<u>Energy Saved ¢ yd.*</u>
4 oz/sq yd	1	5	21.4%**	129.8	0.034
4 oz/sq yd	2	5	71.1%	641.2	0.168
4 oz/sq yd	3	6	21.7%**	83.9	0.022
4.13 oz/sq yd	4	6	61.5%	221.3	0.058
3.01 oz/sq yd	5	6	61.5%	347.3	0.091
3.01 oz/sq yd	6	6	30.4%	190.9	0.050

*\$2.62/1,000 f³ for gas

**Lower energy savings due to higher wet pick-ups.

At this finishing plant presently four machines (in Feb. 1980, only three machines) are equipped for foam finishing capability and with a finishing capacity 1,000,000 + yds/week using foam. There are nine finishing units in total at this plant and the objective is to install additional foamers so that 80% of all goods processed will be with foam.

A number of finish formulations were optimized and second generation formulations were introduced.

4.5 FABRIC PROCESSING- SELECTION OF WATER PICK-UP IN FINISHING

The selection of wet pick-up for foam finishing had been largely empirical. Our initial approach was to half the wet pick-up when converting from conventional to foam finishing. This approach was very successful in that it permitted quick introduction of foam finishing into the mills. However, when feedback from the plants indicated improved utilization of finishing chemicals, it was hypothesized that for a given dry add-on there is an optimum water pick-up which will give the best balance of textile properties.

Improved utilization of chemicals by foam finishing is attributed to reduced migration of finishes to the surface of fabric during drying. The less water that is present during drying, the less the migration of finish chemicals. A detailed study was conducted to determine the most effective wet pick-up for foam finishing (2). Results indicate that most efficient finish utilization measured from durable press rating on cotton fabric occurs at about 30% wet pick-up for a given dry add-on (Figure 1). Both 100% cotton and 50/50 cotton/polyester blends gave similar results. Less strength loss at a given d.p. rating and reduced dusting were obtained by foam finishing at about 30% wet pick-up (Figures 2 and 3).

FIGURE 1 - WET PICK-UP VS. DP RATINGS

FIGURE 2 - DP RATING VS. TEAR STRENGTH

FIGURE 3 - WET PICK-UP VS. DUSTING

4.6 FABRIC PROCESSING- SIMULTANEOUSLY TINTING AND FINISHING

To produce printed fabrics on a colored ground, white goods are usually printed and then tinted by incorporating a coloring agent into the finishing formulation. This is more economical than printing pre-dyed grounds.

Significant developmental efforts were carried out on the simultaneous foam tinting (dyeing) and finishing of fabrics. This is accomplished by incorporating pigments into the foam finish formulations. Chemical modification of formulations was necessary to incorporate pigments and resin finishes in one foam composition. The trials were carried out mostly on pigment printed 50/50 polyester/cotton blend fabrics. Various methods of application were studied to establish which technique gives the most uniform coloration at least on one side (the printed side) of the fabrics. The results of these trials indicate the following:

One side uniformity of color can be obtained by using a tripad and feeding foam to one side of the fabric at the horizontal pad nip. The second nip of the tripad arrangement, "S-wrap" (Figure 4) is found to give better uniformity compared to the single nip at the top horizontal pad rolls. The technique for delivery of foam to the horizontal padder was found to be critical in obtaining uniformity of application.

Simultaneous tinting and foam finishing trials demonstrated that the predryers can be eliminated with substantial energy savings. The trials also demonstrated that higher range speeds can be used at lower oven temperatures for drying-curing of the simultaneously applied pigment and finish.

FIGURE 4
TRIPAD FOAM APPLICATION

4.7 LOW TEMPERATURE FINISHING

Exploratory studies on low temperature foam finishing were conducted.

Study indicates feasibility of incorporating hot catalysts in the foam finishing formulation. The hot catalysts (highly acidic catalysts) aid lower temperatures for curing. Thus far, a foam finish system containing magnesium chloride and citric acid as hot catalyst with the resin showed that curing temperatures can be lowered by 25°F to 30°F from the 325°F to 350°F temperatures normally required.

4.8 FABRIC PROCESSING - DYEING

The two principal processes for dyeing fabrics are beck dyeing and continuous dyeing. In beck dyeing, a small amount of dyestuff and auxiliary additives are dissolved or dispersed in large amounts of water and the dyestuff is exhausted onto fabrics. Thus, per pound of fabric, 40-50 pounds of water are consumed for the dyeing and scouring cycles in a beck. At least 98% of this water is waste water which must be processed before returning it to the stream.

One route to reduce water consumption in beck dyeing is the Sancowad^R process, where dye stuffs and auxiliaries are circulated at a lower liquor ratio by using a foam medium. At a reduced liquor ratio, considerable reduction in the amount of water used is achieved as compared to conventional beck dyeing.

In conventional continuous dyeing of fabrics, a small amount of dye is dissolved or dispersed in large amounts of water and is applied by impregnation and padding. Then fabric is subjected to color fixation followed by a washing operation. Thus per pound of fabric, 20-25 pounds of water is consumed in continuous dyeing, of which only approximately 4% is evaporated and the remaining 96% of water adds to waste effluents.

In contrast, for continuous foam dyeing, water consumption can be less than one-half pound per pound of fabric in those cases where no after-washing is required. Virtually all of this water is removed by evaporation thereby largely eliminating waste effluents. Since the major portion of energy consumed in the dyeing of fabrics is associated with the heating and evaporation of water, then significant reduction in water usage leads to corresponding reduction in energy consumption.

Because continuous foam dyeing resembles continuous dyeing, it will be well to describe the two processes pointing out the similarities and differences.

In continuous dyeing, the dyes and auxiliary additives are dissolved or dispersed in a large volume of water and the fabric is impregnated and padded. The wet pick-up of dye liquor on fabrics in continuous dyeing is of the order of 70-100% for woven and knits and up to 300-400% for high pile fabrics such as carpets. Then the fabric is subjected to color fixation either by steaming and drying or by drying and thermofixing depending on the dyestuffs.

The essential steps in continuous foam dyeing are summarized as follows:

- Prepare Foamable Composition
- Foaming the Composition
- Applying the Foam
- Collapsing Foam and Distributing Dyestuff
- Fixation of Dye

The wet pick-up of foam dye application ranges from 20-50%, the proper amount being dictated by the fabric construction, weight of fabric and the depth of shade desired. The various fibers and fabric constructions foam dyed and the corresponding dyestuffs are listed as follows:

<u>Fiber Type</u>	<u>Dye Types</u>	<u>Fabric Construction</u>
Polyester	a,b	Pile fabrics, flat goods, knits, non-wovens
Nylon	c,d,a	Carpets, woven, non-woven, flocked
Cellulosics	e,f,g,h,j,b	Corduroy, flocked goods, flannels, wovens
Acrylic	i	Carpets, sliver knits, knits
Modacrylic	i,b	Sliver knits, non-woven blankets
Acetate	a	Wovens, knits
Qiana	a	Knits

a - Disperse; b - Pigments; c - Acids; d - Premetallized;
e - Directs; f - Reactive; g - Sulfur; h - Vats; i - Cationic;
j - Rapidogen (Azoics)

The following factors determine the depth of dye shade in foam dyeing:

Dye concentration in the foamable mixture
Blow ratio
Amount of foam applied

The wet pick-up is determined by the blow ratio and amount of foam applied to the fabric.

In dyeing fabrics by the foam method, the blow ratio is partially dictated by the weight and fabric construction. The range of blow ratios used for various fabric constructions are given in Table XXI. In dyeing a very open construction, a higher blow ratio with its higher viscosity would be used. For heavier weight fabrics or those of tight construction, a lower blow ratio is used.

TABLE XXI

FABRIC CONSTRUCTION VS. BLOW RATIO

<u>Fabric Construction</u>	<u>Blow Ratio Range</u>
Wovens	6:1 - 12:1
Knits	6:1 - 12:1
Sliver Knits	4:1 - 10:1
Carpets	4:1 - 10:1
Flocked/Loop	6:1 - 10:1
Upholstery	4:1 - 8:1
Open Weave (Drapes)	8:1 - 15:1
Non-Woven	4:1 - 8:1

After the dye application, both foam and traditional continuous dyeing methods use the fixing conditions which are appropriate for the dyestuff in question. For example, disperse dyes are fixed on polyesters by thermofixation or by high temperature steaming.

With direct dyes, a continuous steam fixation procedure is used. The reactive dyes may be fixed by continuous steaming or thermosoling or by cold batching depending on dye and catalyst system used. For cationic dyes on acrylics, continuous steaming is used for dye fixation.

Where the dyestuff has to be developed by a subsequent chemical treatment, we have found that the dye developing agent can also be applied by the foam process. For example, cotton corduroys can be first impregnated with formulated reduced sulfur dye and then after steaming, oxidized with foamed hydrogen peroxide without an intervening drying step. Azoics which have been applied to fabrics as a foam have been developed with acetic or formic acid also in foamed form, thus eliminating the need of an acid ager. As has been stated before, in most dyeings, light to medium shades do not require an afterwash. However, on occasions, a foamed detergent after-clearing operation has been found to be beneficial.

Nylon carpet dyeing with acid dyes is commercial and approximately five million pounds of carpets have been foam dyed at one U. S. plant. The foam dyeings are to produce multicolor effects. Work is in progress at this plant on plain shade dyeings of carpets. Also, demonstration trials have been carried out on the U. M. & M. pilot range for over a dozen carpet mills and there is much interest in the industry to adapt foam dyeing systems to carpets.

Subsequent to our initiation of work on foam dyeing of carpet, several major machinery manufacturers have also entered the field. Küsters and Mitter have developed foam application machinery for carpet dyeing.

Foam dyeing of an industrial toweling is commercial in a textile mills plant. In another plant, a non-woven polyester inner lining material is now commercially foam dyed with disperse dyes.

(a) FOAM DYEING OF CARPETS

A typical production formulation for nylon carpet dyeing using the foam system is listed in the following table:

<u>TABLE XXII</u>	
<u>Carpet Dyeing Formulation</u>	
Water	80-X%
Valfoam CD	20%
ph 5.0 with Acetic Acid	
Acid Dyes	X%

The formulation is foamed to a blow ratio of 4:1 to 10:1 depending on the weight of carpet and construction. The foam is coated and mechanically collapsed on the carpet distributing dyestuffs uniformly on the carpet pile. The carpets are then continuously steamed for color fixation. For light to medium shades, an after washing is not necessary. Energy savings from commercial runs are not available at this time.

Large scale production foam dyeing trials were carried out at one carpet mill on full width nylon shag carpet to produce plain shade dyeings. A Kuster continuous steaming range was used for trials. Approximately 3500 square yards of nylon shag were used. Greige carpet without pre-wetting was dyed. At about 65% wet pick-up, the foam dyed nylon shag had good coverage. The trials ran smoothly at about 30 feet/min. range speed. The only limitation in range speed was the foamer output (a larger foamer would be required for increased production speeds). On examination of continuously foam dyed carpet, there was some unevenness on dyed pile. The problem was later identified as due to pile distortion in the greige carpets possibly caused during storage of rolls. Mechanical modifications at the entrance end of the foam dyeing range should eliminate this problem. Secondly, a pre-steaming operation of the carpet prior to foam coating should aid plain shade foam dyeings of full width carpets.

A continuous foam dyeing range is being installed at this carpet mill. This range will incorporate the features discussed above.

Traditionally a dyed carpet is washed, vacuum extracted and sprayed with a fluorochemical soil releasing agent as a topical finish. The recent trend in the carpet industry is the use of nylon fibers containing built in soil releasing agent. Nylon shags made from such fibers (Anso #4 from Allied) were subjected to foam dyeing trials. Initial pilot plant trials show that foam dyeing is suitable for such fibers containing soil releasing agents. Developmental work will continue to establish commercial feasibility.

(b) FOAM DYEING OF NON-WOVEN FABRICS

Foam dyeing of non-woven blankets is presently in production at one textile plant. Polyester blankets are foam dyed using either disperse dye foam or pigment foam. Acrylic blankets are also presently being foam dyed. For the blankets, foam is applied by horizontal padding on both sides and the fabrics are dried and cured.

Production speeds have been doubled in this plant by changing from conventional to foam dyeing. At one plant blanket dyeing speeds were increased to 45 yds./min. from the conventional speed of 20 yards giving a production speed gain of over 100% and more than 50% energy savings.

In another textile plant an innerlining fabric of non-woven polyester is commercially foam dyed by using disperse dyes. Foam is applied to both sides using a horizontal pad. The fabric is then dried and thermo-soled (cured) to fix the color.

Developmental work on foam dyeing of acrylic felt with cationic dyes is in progress.

(c) FOAM DYEING OF FLOCKED FABRICS

Another area of single fiber dyeing with foam which is close to commercial application is nylon flock fabric dyeing using acid dyes. Pilot plant and plant trial scale-up have been carried out on the foam dyeing of nylon flock fabrics. Light to medium shades of acid dyes on nylon flock fabric do not require after washing. Darker shades, depending on the depth, may require an after washing operation to remove unfixed dyes.

(d) APPLICATION TECHNIQUES FOR FOAM DYEING

Much of our effort in foam dyeing has been in the evaluation of various application techniques in order to produce commercially acceptable dyeings.

In the foam dyeing of substrates that require color application to only one side such as a carpet, nylon flocked fabric or rayon upholstery fabric it has been found that the best method of color application is to coat foam with a knife over roll coater. The foam coated carpet is drawn over a vacuum slot to pull the foam into the pile and to initiate foam collapse. The carpet is then padded to complete collapse of the foam and to distribute dyestuff. The carpet is steamed to fix the dye and finally dried. On short pile fabrics such as nylon flock fabric or rayon pile upholstery fabric the procedure is similar to that of carpet dyeing except vacuuming is not required to collapse the foam for dye penetration. Nylon flocked fabric are uniformly dyed by this method. Cotton and rayon velour upholstery fabrics were also found to give uniform dyeing using direct dyes by the method.

One of the objectives of this project, the commercialization of foam dyeing of flat goods has not yet been achieved. Commercially acceptable dyed flat goods must be uniform in color from side to side and from front to back.

Uniform dyeing of one side of the fabric has been achieved by several application techniques described below. However, uniform dyeing front to back has been more difficult and while considerable progress was made, none of the techniques have met with commercial acceptance.

The dyeing of flat woven fabrics requires even dyeing on the face and back of the fabric as well as side to side uniformity. In order to achieve uniform dyeing the following processing schemes have been investigated:

1. Knife coating and padding.
2. Knife coating, vacuuming and padding.
3. Floating knife.
4. Dip and pad-vertical pad.
5. Engraved roll.
6. Horizontal pad application of foam.
7. Slotted pipe application of foam on both sides.
 - (A). regular slots
 - (B). diagonal slots
8. Tripad.

Knife over roll application of dye foam to flat woven goods has been investigated on the pilot range and in plant trials. The knife over roll application gives good side to side uniformity but it results in large front to back shade variation which is unacceptable in the trade.

In the next series of trials, knife over roll coating of dye foam, followed by vacuuming from the back side and padding was investigated. This application gave better front to back uniformity than the knife coating and padding of foam. In this application precise control of vacuum force is found necessary to avoid color loss. An excess vacuum force will extract color from the fabric.

By the use of a floating knife, uniform color application was obtained on one side of fabric. Floating knife application of foam to one side gives little penetration of color to opposite side. Wet pick-ups

are generally lower than in any other application. The floating knife application of foam to both sides of fabric in a two step application can produce front to back uniformity. Simultaneous floating knife application of foam on front and back is yet to be explored since mechanical modifications would be required for the pilot range.

Dipping fabric through foam and padding using a vertical pad has been investigated. Trials resulted in high wet pick-ups and poor control of shade from start to finish.

Engraved roll application of pigment foam to flat fabrics on a roller printing machine was found to give uniform color applications to one side of fabric. Here again similar to floating knife application there was little color penetration to the back side. Where the requirement was only one side dyeing, as on a nylon mattress ticking, the method was found ideal. Some production trials have been run at our printing plant by using engraved roll application.

Slotted pipe application of foam to both sides of fabric for dyeing was investigated. The trials resulted in streaky dyeings.

Recent developmental trials using horizontal pad application of pigment foam to cotton and polyester/cotton blend fabrics were found to give fairly uniform dyeings. In order to obtain uniformity of foam application traversing feeds were used on both sides of fabric at the padder nip. Further developmental work using horizontal pad is needed.

For uniform color application the tripad arrangement was extensively studied. Application of dye foam on both sides of the fabric by using the horizontal pad followed by a second nip on the tripad S-wrap is also being investigated to give uniform color application. Pigment foam by tripad is found to give fairly uniform dyeing. The dyed fabrics still show some front to back shading. The effect of pad roll hardness on front to back uniformity of dye application will be studied.

The various fibers, fabric constructions, corresponding dyestuffs and methods of foam application investigated are summarized in the following table.

TABLE XXIII

Methods of Foam Application in
Foam Dyeing

<u>Fiber Type</u>	<u>Dyes</u>	<u>Fabric Construction</u>	<u>Foam Application Methods Investigated</u>
Polyester	Disperse	Pile Fabric	Knife, Vacuum, Pad
Polyester	Disperse	Flat Goods	Knife, Vacuum, Pad
Polyester	Disperse	Flat Goods	Horizontal Pad
Polyester	Pigments	Blankets	Knife, Vacuum, Pad
Polyester	Pigments	Blankets	Horizontal Pad
Polyester	Pigments	Sheer Fabric	Horizontal Pad
Nylon	Acid	Carpets	Knife, Vacuum, Pad
Nylon	Acid	Flocked	Knife, Pad
Nylon	Disperse	Carpets	Knife, Vacuum, Pad
Nylon	Acid	Velour Upholstery	Knife, Pad
Nylon	Premetallized	Carpets	Knife, Vacuum, Pad
Nylon	Pigments	Mattress Ticking	Engraved Roll
Cotton, Rayon	Direct	Upholstery	Knife, Pad
Cotton, Rayon	Direct	Blankets, Felt	Horizontal Pad
Cotton, Rayon	Pigments	Blankets, Felt	Horizontal Pad

TABLE XXIII CONTINUED

<u>Fiber Type</u>	<u>Dyes</u>	<u>Fabric Construction</u>	<u>Foam Application Methods Investigated</u>
Cotton, Rayon	Pigments	Woven	Horizontal Pad
Cotton, Rayon	Sulfur	Corduroy	Knife, Vacuum, Pad
Cotton, Rayon	Pigments	Flannel	Knife, Vacuum, Pad
Cotton, Rayon	Pigments	Flannel	Horizontal Pad
Cotton, Rayon	Reactive	Upholstery	Knife, Pad
Polyester/ Cotton Blend	Pigments	Woven	Knife, Pad
Polyester/ Cotton Blend	Pigments	Woven	Tripad-S-wrap
Polyester/ Cotton Blend	Pigments	Woven	Knife, Vacuum, Pad
Polyester/ Cotton Blend	Pigments	Woven	Horizontal Pad
Polyester/ Cotton Blend	Pigments	Woven	Floating Knife
Polyester/ Cotton Blend	Pigments	Woven	Engraved Roll
Polyester/ Cotton Blend	Pigments	Woven	Slotted Pipes
Acrylics and Modacrylics	Cationic	Carpets, Blankets	Knife, Vacuum, Pad

TABLE XXIII CONTINUED

<u>Fiber Type</u>	<u>Dyes</u>	<u>Fabric Construction</u>	<u>Foam Application Methods Investigated</u>
Acrylics and Modacrylics	Cationic	Sliver Knits	Knife, Vacuum, Pad
Acetate	Disperse	Woven, Knits	Knife, Pad
Qiana	Disperse	Knits	Knife, Pad
Acetate	Pigments	Drapery	Horizontal Pad

4.9 FOAM DYEING - ENERGY CONSERVATION

Energy measurement studies for foam pigment dyeing of polyester/cotton blend fabrics vs. conventional pigment pad dyeing, were conducted on UMRC pilot plant range. The measurements were conducted by monitoring gas consumption in the drying oven. Results indicate from the gas consumption that the energy savings by foam pigment dyeing over conventional dyeing are similar to the savings by foam resin finishing over conventional finishing; the lower the wet pick-up, the less gas consumption in the drying operation (tables V and XXIV).

TABLE XXIV PILOT PLANT DRYER DATA - DYEING

<u>Wet Pick-up</u>	<u>Type of Application</u>	<u>Range Speed yds/min</u>	<u>Temp. °F.</u>	<u>Ft. ³ of gas/yd</u>	<u>Residual Moisture</u>
70.3%	Pad (conventional)	25	350°	.452	Dry (< 4%)
32.0%	Foam	50	250°	.136	Dry (< 4%)
*32.0%	Foam	50	320°	.289	Dry (< 4%)

*Temperature raised to dry and cure pigment in one pass. Both of the other two runs would require a separate pass to cure pigment.

At present, we do not have actual measured energy data for foam dyeing of carpets and pile fabrics. By considering the low wet pick-up in foam dyeing of carpets, substantial energy savings are realized. Table XXV shows the calculated energy required to heat up a 25 oz. carpet in the steamer for color fixation for both foam and conventional dyeing.

The dye fixation time in the steamer is inversely proportional to the water content of the carpet as it enters the steamer (Figure 5). It is reasonable to conclude that the reduced fixation time at low wet pick-ups is due to the fact that carpet reaches the fixation temperature much sooner. The energy required to dry carpets foam dyed and conventional are compared in Table XXVI.

At 300% wet pick-up, nylon carpets require $7\frac{1}{2}$ times more energy to dye compared to 40% wet pick-up with foam in the steamer.

For other types of fabrics such as woven, knit, flock or upholstery fabric where the wet pick-ups are one-half or less compared to conventional, the energy requirement to fix color in steamer would also be 50% less than conventional.

TABLE XXV

NYLON CARPET: STEAM

FIXATION - ENERGY COMPARISON

CONVENTIONAL VS. FOAM

<u>Description</u>	<u>Conventional</u>	<u>Foam</u>
Nylon Carpet Weight	25 oz/sq. yd	25 oz/sq. yd
% Wet Pick-up O.W.G.	300%	40%
Energy required to heat up from 70 - 212°F for color fixation*	667.5 BTU/sq.yd.	89 BTU/sq.yd.

*For the conventional dyeing, the energy required for color fixation is $7\frac{1}{2}$ times higher than foam dyeing.

TABLE XXVI

ENERGY REQUIRED IN DRYING

FOAM VS. CONVENTIONAL

<u>Description</u>	<u>Conventional</u>	<u>Foam</u>
Nylon Carpet Weight	25 oz/sq.yd.	25 oz/sq.yd.
% Wet Pick-up O.W.G.	80%*	42%**
Energy required to raise carpet temperature from 70 - 212 °F	190 BTU/sq.yd.	- - - - -
Energy required to raise temperature from 180-212°F***	- - - - -	20 BTU/sq.yd.
Energy for evaporation of water	1216 BTU/sq.yd.	638 BTU/sq.yd.
Total Energy in Drying	1406 BTU/sq.yd.	658 BTU/sq.yd.

*After washing and vacuum extraction

**In foam after steaming including 2% gain

***Temperature drop as carpet passes from steamer to dryer

FIGURE 5

CARPET DYEING

COLOR FIXATION TIME vs. WET PICK-UP

*Time in atmospheric steam required to fix dye

4.10 FOAM DYEING AND FINISHING - SEQUENTIAL APPLICATION

Application of foamed fluorocarbon finishes were investigated on nylon carpets on the pilot plant range after the steam fixation step. The nylon carpet yardage 72" wide, was first foam dyed on the range and subjected to steam fixation of color. As the carpet exited from the steamer, foamed fluorocarbon finish was applied and the carpet was dried. The sequentially foam dyed and foam finished carpet possessed satisfactory oil and water repellancy. Steps for the above investigation were as follows:

1. Apply foam color on nylon carpet or upholstery fabric.
2. Collapse foam and distribute color.
3. Steam fix.
4. Apply fluorocarbon foam on wet carpet or fabric.
5. Dry.

4.11 FOAM DYEING OR FINISHING OF WET GOODS

Conventionally, fabrics are scoured, bleached and dried before dyeing. The ability to foam dye wet goods would eliminate a drying operation.

The purpose of this work was to study the feasibility of foam dyeing prepared, wet fabrics. Initial work consisted of prewetting fabrics to various moisture levels and applying pigment foam by horizontal padding. Results indicated the feasibility of foam dyeing polyester/cotton or cotton woven fabrics containing up to 25-35% moisture level. Optimum moisture levels have not been determined. It was observed that small amounts of moisture on the fabric also aid level dyeing.

The foam application of napping softener to prepared wet goods is now a commercial practice. This has eliminated an intermediate drying step.

4.12 FABRIC PROCESSING - PRINTING

Foam printing has progressed at a more rapid pace than projected in the project timetable. Formula optimization work yielded print foam systems which, in plant trials, have been successfully printed by both intaglio

and screen printing techniques on production equipment.

Blotch pigment colors are being roller printed on flat goods. To date, about five million yards of fabric has been foam printed at our Clearwater printing plant. A savings of 15-20% in color cost has been achieved by pigment foam printing. We are currently pursuing energy savings studies on our pilot plant roller printing machine. Preliminary studies on the pilot plant print machine have confirmed the estimated 35-37% energy savings, at least on the selected patterns printed. The energy savings will, of course, be proportional to the print coverage. Additional energy studies were made on a production printing machine in the plant and are included in this report.

The desired stability of a foaming system for textile processing is dictated by the function of the system. For foam finishing and dyeing, the foamed system need only have a useable lifetime on the order of minutes. In both cases the foam is consumed as rapidly as it is formed.

On the other hand, foamed printing systems in the context of textile printing operations must have a minimum useable life of 8 to 10 hours. The criteria of useability is that the printing system after being foamed shows no significant change in blow ratio or viscosity for the desired period of time.

Typical viscosity stability curves for acceptable and unacceptable foamed printing systems are illustrated in Figure 6. Whereas the blow ratios of both foams were unchanged over the six hour period, in the control there was a coalescing of the bubbles from an initial size of 50 to 100 microns in diameter to about 400 microns. The viscosity of a foam is inversely proportional to its cell size.

In order to maintain good print definition and uniform cover, a 50 to 100 micron cell size is needed. Printing with a 400 micron foam leads to a motley appearance.

FIGURE 6

Thus far we have not been able to rotary screen print successfully in the plant. Streaky prints from foam printing with rotary screens appear to be due to the foam feed and distribution system inside the screen. Mechanical modifications are being tried by our engineering department to overcome this problem. Recent trials at Clearwater Finishing Plant indicate that further modifications are required to print foam satisfactorily by the rotary screen method.

Wet colors such as disperse dyes on polyester, acid dyes on nylon and Rapidogen color on cotton are in pilot plant stage of development. Scale-up work is underway.

4.13 ENERGY SAVINGS - FOAM PRINTING

From production runs, energy savings with foam were measured on a roller printing machine. These studies were made from steam consumption, on steam heated drying cans. The data showed that by using foam for blotch patterns, in place of print paste, energy savings up to 37% were obtained.

A production speed gain of up to 20 yards/min., i.e., speed increase from 60 yd/min to 80 yd/min was obtained by using foam pigment print system. The following data is an average of several plant energy determinations on foam roller printing.

TABLE XXVII - FOAM PRINTING:

ENERGY SAVINGS DATA

<u>ITEMS</u>	<u>SAVINGS BY FOAM PRINTING OVER CONVENTIONAL</u>
Steam (Energy) Savings	35%
Speed Gain (Production)	+35%
Overall Cost Savings from Foam Printing	32.5%

This data is from energy measurements for blotch patterns printed with foam and greater savings and production speed gain are anticipated for multi patterns.

4.14 FABRIC PROCESSING - FOAM PREPARATION

Feasibility studies on preparation of fabrics utilizing foam were carried out. The laboratory developmental efforts with foam preparation concentrated on two types of fabric sizes.

A) Fabric containing synthetic sizes: PVA, CMC, etc.

B) Fabric containing starch and modified starch sizes.

A) Fabric Containing Synthetic Sizes: PVA, CMC, etc.

1. Laboratory Study on Peroxide Pad Batch System

The procedure investigated for removing water soluble synthetic sizes such as PVA, CMC, uses foamed alkaline hydrogen peroxide. Fabrics such as polyester/cotton blend gingham (yarn dyed check fabrics) were investigated in this work. The method consisted of foaming hydrogen peroxide and sodium silicate (or orthosilicate). The foam is applied on the yarn dyed greige check fabrics. The foam coated fabrics are then batched 4-6 hours and then the solubilized sizes are washed off.

2. Plant Trials

A plant trial was carried out with foam at our Arkwright Finishing Plant on polyester/cotton gingham fabric.

From this trial, foam desizing/bleaching appears to have certain advantages over the conventional process:

- a) less color bleeding from dyed yarns and absence of staining of white yarns.
- b) better whiteness of the undyed yarns due to the higher activity of peroxide at the low moisture level.

Investigations are continuing in this area of removal of soluble sizes by the use of foamed hydrogen peroxide and foamed sodium percarbonate (per oxygen compounds).

B) Fabrics Containing Starch and Modified Starch Sizes

Three different approaches for the preparation of starch and modified starch size containing fabrics of cotton and polyester/cotton blends were under investigation:

- I - Foam enzyme application followed by caustic foam scouring (Batch Process).
- II - Foam enzyme application followed by peroxide foam bleaching (Batch Process).
- III - Foam peroxide applications followed by caustic foam scour-steam-cold water wash (semi-continuous operation).

Good absorbency (for dyeing), whiteness and removal of starch are the parameters for evaluation. Laboratory results indicate that of the three foam treatment methods, procedure III was giving the best absorbency and removal of starch. Tables XXVIII and XXIX compare conventional vs. foam preparation on 50/50 polyester/cotton fabric and 100% cotton fabric.

TABLE XXVIII

Foam Preparation vs. Conventional - Starch
Size on 50/50 Polyester/Cotton Blend

<u>Sample No.</u>	<u>Process Sequence</u>	<u>% Residual Size Left on Fabric after Preparation</u>	
		<u>4 Hour Peroxide Batching</u>	<u>6 Hour Peroxide Batching</u>
1	Greige 50/50 polyester/ cotton (not prepared)	- - - -	12.7% (init. size)
2	Conventional peroxide treatment and convention- al caustic pad-steaming	1.58%	1.44%
3	Foam peroxide treatment and conventional caustic pad-steaming	1.21%	1.37%
4	Foam peroxide treatment and foam caustic pad- steaming	1.79%	1.37%

TABLE XXIX

Foam Preparation vs. Conventional Preparation-
Starch Size on 100% Cotton Fabric

<u>Sample No.</u>	<u>Process Sequence</u>	<u>% Residual Size Left on Fabric after Preparation</u>	
		<u>4 Hour Peroxide Batching</u>	<u>6 Hour Peroxide Batching</u>
1	Greige 100% Cotton	- - - -	14.4% (init. size)
2	Conventional peroxide treatment and caustic pad-steaming	4.08%	2.39%
3	Foam peroxide treat- ment and convention- al caustic pad-steam- ing	2.52%	2.65%
4	Foam peroxide treat- ment and foam caustic pad-steaming	2.61%	2.76%

While foam preparation offers several advantages over conventional preparation, energy savings would not be significant, since the fabric has to be thoroughly washed to remove the solubilized sizes.

4.15 FOAM SIZING

Application of sizes to warped yarns is another area where foam application methods could be efficiently utilized. In conventional warp sizing the warped yarns are impregnated in size formulation and excess liquid is squeezed off. Here the wet pick-ups are of the order of 70-100%. By converting to foam system and reducing the wet pick-up, considerable energy savings are anticipated.

Feasibility studies on foam sizing of yarn are in progress. Studies show that synthetic sizes (latexes) can be formulated into foamable sizes, (Table XXX). Yarns can be immersed in foamed size and subsequently padded to collapse foam. In production trials this application method gave slightly higher add-on than expected from pilot trials, (Table XXXI).

TABLE XXX

Foamable Size Formulations

Water	45 parts
Valchem 326-101 Size	50 parts
Valfoam 59 (Foam Stabilizer)	5.0 parts (Blow ratio 4:1-8:1)

Chemical modifications to the synthetic sizes were made for improved sizing properties. Also equipment modifications for foam size applications were made on a plant warp sizing machine. More recent trials show commercial feasibility of foam sizing of yarns. Work is currently in progress to apply foamed sizes at reduced wet pick-ups to obtain higher energy savings. Our efforts are centered not only on the energy savings in drying the size but also on the use of minimum amount of water to remove size from the yarns. Use minimum amount of water in desizing operation will result in reduced effluent problems.

TABLE XXXI

Foam Sizing Trials on 65/35 Blend

<u>Trial No.</u>	<u>Pad Pressure</u>	<u>Blow Ratio</u>	<u>Range Speed yds/min</u>	<u>% Size Add-On</u>	<u>Tensile Pounds</u>
1	15 psi	4:1	40	15.8	5.3
2	30 psi	8:1	70	17.0	6.4
3	30 psi	8:1	80	14.4	5.0
Regular Size Conventional	-----	---	40	11.7	6.1
Control (No Size)	-----	---	--	----	5.1

5.0 GENERAL

Publications on Foam Processing from U. M. & M.

(1) Air In, H₂O Out in Wet Processing

By R. S. Gregorian and C. G. Namboodri
Textile Industries; 141; 10; p 61-65 (1977)

(2) Continuous Foam Dyeing of Carpets

By C. G. Namboodri and R. S. Gregorian
American Dyestuff Reporter; 67; p 27-34 (1978)

(3) An Experimental Foam Printing System

By C. G. Namboodri, J. Johnson, and R. S. Gregorian
Textile Chemist and Colorist 10; p 19-20; (1978)

(4) Processing Textiles With Foam System

By T. W. Carter
American Dyestuff Reporter; 67;12; p 48-57; (1978)

(5) Foam Finishing of Cotton-Containing Textiles

By C. G. Namboodri and M. W. Duke
Textile Research Journal; 49; p 156-162; (1979)

(6) Utilization of Foam in the Wet Processing of Textiles

By R. S. Gregorian, R. A. Bafford and C. G. Namboodri
ACS Symposium Monograph; No. 107; p 145-154; (1979)

(7) Foam Processing Technology

By. R. J. Lyons
American Dyestuff Reporter; 69; 4; p 220; (1980)

(8) Foam Processing - A Developmental Assessment

By R. J. Lyons and C. G. Namboodri
AATCC National Meeting Monograph; p 116-124; (1980)

(9) Foam Finishing: Effect of Wet Pick-up

By R. S. Gregorian and C. G. Namboodri
Textile Chemist and Colorist; 13; 8; p 28-31; (1981)

(10) Application of Foams to the Processing of Fabrics

By Marshall W. Duke
U. S. Department of Energy Contract Report
No: COO-4527-4, December (1979)

U. S. Patents on Foam Processing
Assigned to U. M. & M.

- (1) U.S.P. 4,118,526 - Method of Treating Fabrics - 10/2/1978
R. S. Gregorian and C. G. Namboodri
- (2) U.S.P. 4,193,762 - Textile Treatment Process - 3/18/1980
C. G. Namboodri
- (3) U.S.P. 4,208,173 - Method of Treating Fabrics - 6/17/1980
R. S. Gregorian and C. G. Namboodri
- (4) U.S.P. 4,266,976 - Fabric Treating Composition - 5/12/1981
R. S. Gregorian and C. G. Namboodri
- (5) U.S.P. 4,270,915 - Fabric Printing Process - 6/2/1981
J. Johnson and C. Mixon
- (6) U.S.P. 4,282,729 - Foam Random Dyeing System - 8/11/1981
L. G. Smith
- (7) Two additional U. S. Patents have been allowed

Papers Presented on Textile Foam Processing

By: Mr. C. G. Namboodri

Experimental Foam Printing System Development

1. AATCC Printing Symposium, New York City 1/11-1/13/78
2. Printing Symposium, Clemson University 4/4-4/6/78

Continuous Foam Dyeing of Carpets

Carpet Technology Symposium, Clemson University 2/14-2/15/78

Foam Dyeing

Chemistry of Dyeing Seminar, Clemson University 5/30-6/1/78

Foam Finishing Cotton Textiles

Natural Fiber Textile Conference, Atlanta, 9/26-9/28/78

Foam Dyeing of Carpets

Carpet Technology Symposium, Clemson University 2/79

Foam Finishing: Effect of Water Pick-Up

ACS National Meeting: Atlanta 3/81

By: Dr. R. S. Gregorian

The Use of Foams in the Wet Processing of Textiles

Energy Workshop, N. C. State University 1/24-1/25/78

The Utilization of Foams in the Wet Processing of Textiles

American Chemical Society, National Meeting, Miami 9/11-9/14/78

The Utilization of Foams in the Wet Processing of Textiles

DOE International Conference on Energy Conservation and Solar Energy, Milan, Italy 3/27/79

Low Wet Pick-Up Processing

N. C. State University; 11/29/79, Raleigh, N. C.

Foam Finishing

Georgia Institute of Technology; Atlanta 1/17/80

Wet Processing of Textile Utilizing Foams

2nd Franco-American Conference on Industrial Energy
Conservation, Washington, D.C. 2/14/80

By: Mr. W. Iannone

Theory and Technology of Foam Processing
Clemson University 12/12-12/13/79

By: Dr. R. A. Bafford

The Use of Foams in the Wet Processing of Textiles

DOE/Georgia Tech./Clemson Energy Symposium, Atlanta
2/14-2/15/78

Foam Processing Route to Energy Conservation in the
Textile Industry

AATCC Meeting, Florida State University 2/22/79

Utilization of Foam in Wet Processing of Textiles

Graduate Seminar, Florida State University 2/23/79

Low Wet Pick-up Processing for Finishing, Dyeing and
Printing

American Chemical Society National Meeting, Houston,
Texas 3/23-28/80

Foam Wet Processing

Textile Research Institute, 51st Annual Conference,
New York 4/81

By: Mr. R. Lyons

Foam Processing of Textiles

AATCC Regional Meeting (Rhode Island) Seckonk, Mass.
2/28/78

Processing of Textiles with Foam Systems

ATMI-Engineering Sub-Committee on Energy - Hilton Head, S.C.

Foam Processing of Textiles

Seminar on "Innovations in Textile Processing", N.C.
State University 8/10-8/11/78

Processing Textiles with Foam Systems

Palmetto/Piedmont AATCC Sections, Rock Hill, S.C.
10/14/78

Applications and Techniques in Foam Processing

Clemson University 12/12-13/79

Foam Processing - A Developmental Assessment

AATCC National Technical Conference 10/15-17/80

Advances in the Textile Wet Processing With Foamable
Composition

ACS National Meeting, Atlanta 3/81

6.0 APPENDIX

UP-GRADED PILOT DYEING AND FINISHING RANGE

The up-graded range is capable of running a wide variety of foam and conventional processes. Figure 7 schematically shows the layout of present components. Some components are fixed and others variable as outlined in Appendices I, IA and II. Some can be optional depending on the particular process under study.

To illustrate the range's versatility the following operations can be performed:

1. Finish or Dye Application

- a) Knife Over Roll - This is a knife applicator with a supporting bottom roll. In processing substrate travels between knife and bottom roll. Chemical application is to one side of substrate.
- b) Floating knife (one or two) - This is a knife applicator with height adjustments (for tension control only). Substrate travels unsupported under the knife. Chemical application is to one side of substrate.
- c) Horizontal Pad - Except for some tubular knit finishing, horizontal pads are not normally used in textile pad finishing or pad dyeing applications. This type pad can be used for foam application and foam collapsing.
- d) Vertical Pad - This type pad is normally used in textile wet processing. It can be used to collapse foam previously applied to substrate.

2. Extraction

Vacuum Slot - This type extraction is not normally used in textile pad finishing or pad dyeing applications. It can be used to increase penetration of foam applied to one side of substrate (as with knife over roll application).

3. Steamer

Some dyes (acid dyes, for instance) require steaming for dye fixation. UMRC's steamer will be used primarily in dyeing trials in our pilot range.

4. Drying (Tenter Frame)

Tenter frame drying is normal to fabric finishing methods. Fabric is held to finish width while being transported through the dyeing zone(s).

5. Foamers (Two)

We have two foam generating units for use with the Pilot Plant Range. With two foamers we can apply foam to two different applicators (floating knives, for instance) at the same time.

The main function of the up-graded range is to demonstrate the commercial feasibility of foam dyeing and finishing processes and demonstrate that energy savings are feasible with these processes.

As outlined, the range was designed to fulfill this function by being versatile and subject to easy modification. A major need will be the development of foam application systems to uniformly apply color. Some work will go into foam delivery devices to supply the applicators.

The use of the range for demonstration purposes is most helpful in developing trade acceptance of the foam processes. Outside company representatives have observed both flat goods and carpet processing under several range conditions. In addition, other representatives have observed at U. M. & M.'s Clearwater, Arkwright and Old Fort Finishing Plants foam finishing applications. However, these applications have been restricted to use of horizontal pads. Since completion of the up-graded UMRC range, we have been able to demonstrate other foam publications such as knife over roll and floating knife.

FIGURE 7

1. FABRIC LET OFF	7. FLOATING KNIFE [⊙]
2. KNIFE OVER ROLL COATER	8. STEAMER
3. VACUUM SLOT [⊙]	9. TENTER DRYER
4. FLOATING KNIFE	10. FABRIC TAKE-UP
5. HORIZONTAL PAD	11. FOAMERS(2)
6. VERTICAL PAD	

([⊙]CAN BE RELOCATED)

PILOT RANGE FOR FOAM APPLICATIONS

APPENDIX 1

FIXED COMPONENTS OF UMRC RANGE

<u>Fabric Feed</u>	Roll let-off, scray, fabric straightners and tension devices.
<u>1</u>	(See Appendix 1-A) (See Appendix II)
<u>Vertical Pad</u>	Five ton, bottom roll metal, top roll fiber.
<u>2</u>	(See Appendix II)
<u>Steamer</u>	Twenty-three yards capacity, variable and metered steam supply. Can be by-passed.
<u>3</u>	(See Appendix 1-A) (See Appendix II)
<u>Tenter Frame</u>	Twenty foot, two zone - room temperature to 400°F. (204°C). Pins and clips on chain variable internal air flow and exhaust. Incinerator burners. Fractional up to 60 yards/minute.
<u>Fabric Take-Up</u>	"Pre-set", but variable, tension-any speed.

APPENDIX 1-A

FOAM MAKE-UP SYSTEMS

APPENDIX II

PROJECTED VARIABLE COMPONENTS OF UMRC RANGE

1. Foam Applicators - Knife over roll and vertical pad. Various foam delivery devices - slotted tube, fixed pipes, oscillating pipe, sprays, etc.

Vacuum Slot - Optional dependent on fabric construction.
2. Wet Fabric Take-Up - For cold batching processes.

Fabric Invertor - Device for reversing (face side up) fabric - i.e., knife coat at 1, reverse, knife coat back side at 3.
3. Knife Coater - Floating knife type. Movable to position I.

7.0 REFERENCES

1. E. Linwood Wright
Textile Research Journal
Vol: 51, No: 4 p 251-155, 1981
2. R. S. Gregorian and C. G. Namboodri
Textile Chemist and Colorist
Vol: 13, No: 8 p 28-31, 1981