APPLICATION OF FOAMS TO THE
PROCESSING OF FABRICS

PHASE-III

TECHNICAL PROGRESS REPORT

For Period September 1, 1979 to February 28, 1981

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March 1981

Prepared For

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U.S. Department Of Energy
Industrial Programs
Office Of Assistant Secretary
Conservation And Solar Energy
Washington, D. C. 20585

Under Contract No. DE-AC02-77CS40056-A001

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1.0 EXECUTIVE SUMMARY

By the end of February 1981 approximately 500,000,000 yards of fabric had been foam finished.

A number of finish formulations were optimized and second generation foam formulations have been introduced since September 1979.

Plant energy data from three UM & M plants has been collected which illustrates the savings achievable by converting from wet to foam processing. Considerable work has been done by our engineering department on developing applicators to apply dye and finish uniformly to flat goods.

Simultaneous tinting and foam finishing by means of a tripod shows promise. Large scale trials are scheduled in the plant.

Much of our effort in foam dyeing has been in the evaluations of various application techniques to produce commercially acceptable dyeings. These are discussed in this report. Foam dyeing of nylon carpets is in production and approximately 4 million pounds of carpet have been foam dyed in one U.S. plant. The above production dyeings are for multi-colored carpets and developmental trials to produce plain shades are in progress in the plants.

Nylon flock fabric dyeing has been scaled-up in pilot plant and plant trials.

Foam dyeing of 100% polyester non-woven blankets utilizing pigment foam and disperse dye foam and acrylic blankets with pigment foam are in production in one textile mill. Also a polyester non-woven innerlining fabric is being commercially foam dyed using disperse dye in another plant.

Energy savings from production speed increased are realized.

Foam pigment dyeing of flat goods by horizontal pad application shows promise by the traverse application of foam on both sides of fabric. Development trials have demonstrated the feasibility of wet on wet foam dyeing of prepared wet fabrics.

Wet on wet foam dyeing would eliminate one drying step from the present flow of fabric in a finishing plant.

A polyester/cotton narrow width industrial toweling is now being foam dyed and finished simultaneously at a non U.M. & M. plant.

Foam printing using engraved rolls continues in production and thus far 4 million yards of fabric has been printed where foam is used for blotch patterns. Energy savings by foam printing measured was 37% at a speed gain from 60 to 80 yds./min. in the plant.

The utilization of foam in fabric preparation is under investigation and feasibility has been established. Plant trials are being conducted on gingham fabric.

Foam sizing trials utilizing foamed synthetic sizing systems are being conducted at a weaving mill. Initial plant trials demonstrated that equipment modifications were required to apply foam to yarns. These modifications were made and more recent trials show the commercial feasibility of foam sizing.

2.0 OBJECTIVES

The primary objective of this project is to reduce the energy requirements in fabric finishing by drastically reducing the water required to wet process the fabrics. Since less water is used, less energy is consumed in the evaporation of water. This is accomplished by replacing much of the water with air, by converting the concentrated finish to foam and using it as the application medium.

For the eighteen months period (September 1, 1979 to February 28, 1981) of Phase III of the Contract, the specific objectives were:

1. To commercially demonstrate continuous foam dyeing process on single fiber synthetics and 100% cellulosic fabrics on plant equipment.
2. To run plant trials, including economic and energy evaluations, the foam dyeing of blend fabrics, particularly polyester/cotton or polyester/rayon blend types.
3. To conduct feasibility studies on foam preparation of fabrics (desizing, scouring and bleaching).
4. To run plant trials, including economic and energy evaluations on foam printing of fabrics.
5. To demonstrate sequential or simultaneous foam dyeing and foam finishing.
6. Commercial demonstration of foam dyeing of blends: polyester/cotton or polyester/rayon blends.
7. Pilot plant studies on foam fabric preparation: Desizing, Scouring, Bleaching.
8. Commercial demonstration of foam printing.
9. Commercial demonstrations of sequentially/simultaneously foam dyeing and foam finishing.
10. Plant trials on simultaneously foam dyeing and foam finishing of blends: Polyester/cotton or polyester/ rayon blends.

11. Plant trials on fabric preparation: Desizing, scouring and bleaching: Economics and energy evaluation.
12. 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 established that foam technology could be used 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. Disperse, acid, direct, reactive, cationic dyes and pigments were successfully adapted to foam application.

Fabrics were also printed with foams. Pigments, disperse dyes, Rapidogens and acid dyestuffs were among those coloring agents used to print fabrics with foams. One of the features of foam printing is the fact that auxilliary thickeners are not used to control the viscosity of the print paste. Instead the viscosity is controlled by the amount of air incorporated into the system. The side benefit of such a system is that no after-washing is required to remove the gums normally used in print paste. Even where after-washing is-needed to remove unfixed dyes as in the case of Rapidogen and reactive dyes the absence of printing gums greatly facilitates the after-washing step.

The work done by UMRC during this period has resulted in the issuance of U.S. Patent Nos. 4,118,526, 4,193,762, 4,208,173 and notice of allowance has been received on three additional U.S. Patents.

In the report issued in December, 1979, for the Phase I and II of this contract we reported the progress through September of 1979. From October 1977 to September 1979 of the contract period, we have established in actual commercial and pilot trials the following:

1. Substantial energy savings can be achieved by converting from regular to foam finishing. Additionally, in many instances, productivity can be increased by faster range speeds. It is also true in some cases that dryer efficiencies can be significantly improved with foam. This results from lower temperatures and higher speeds besides the obvious less heat for "less water to evaporate". These combined factors results in significant overall cost reduction.
2. In order to achieve maximum energy savings, the drying and curing steps should be separated. That is, the tenter frame should be used for drying only. When this practice is followed, it has been possible to both lower oven temperatures and double range speeds leading to as much as an 86% reduction in the energy consumption per unit of fabric dried.

Foam processing itself cannot lead to energy savings in the common thermal curing step since it involves dry fabric. If greater overall energy savings are to be achieved, new non-conventional energy efficient curing systems need to be coupled with foam processing.

These could include low temperature curing systems, two package systems, "hot" catalysts, or more significantly, radiation curable systems. The demonstrated bench feasibility of hot catalysts for low temperature curing is being extended to the pilot plant.

3. Pile fabrics, such as carpets, flocked fabrics, woven velvets and sliver knits, have been successfully dyed in pilot plant trials on the UMRC range. These dyeings were achieved by knife application of foamed formulations onto one side, or "face", of the fabrics.

All of the foam dyeings described above can be considered ready for commercial practice. For flat goods, where equal shade is required for both sides, one side knife applications have led to front to back shading and occasionally to streakiness.

4. Foam printing has progressed much faster than originally anticipated. Commercial scale trials with foam gravure type printing have shown reduction in both color and binder consumption. Foam printing, in some cases, will allow increased productivity by allowing higher speeds where drying capacity is fixed (i.e., steam cans). Up to September of 1979 approximately 800,000 yards have been printed using foam color for the blotch patterns.

A number of companies are currently using foam fabric finishing as a commercial production process. Commercial acceptance continues to grow. An estimated cumulative total of over 200,000,000 yards of fabric had been foam finished by September of 1979.

4.0' DISCUSSION OF EXPERIMENTAL RESULTS

4.1 FORMULATION EVALUATION PROCEDURES

The formulation evaluation procedures were discussed in detail in the December, 1979 final report covering Phase I and Phase II of the project. For obtaining detailed information, please refer to the above mentioned report.

4.2 CHEMICAL FORMULATION-FABRIC FINISHING

Chemical formulations for fabric finishing were discussed in the final report of December, 1979.

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

TABLE I

Plant Foamable Finish
Formulation

<u>Previous 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%

4.3 FABRIC PROCESSING-FINISHING

An estimated cumulative total of over 200,000,000 yards of fabric had been foam finished by September, 1979. The energy savings and production gains from plant data were reported in December 1979 covering from October 1977 through September 1979.

Additional plant data have been accumulated from three of UM & M finishing plants and are listed in Table II.

By the end of February 1981, approximately 500,000,000 yards of fabric had been finished with foam.

The foam finishing program at one of UM & M finishing plants include the following areas of investigations:

Cost Accounting
Process-Optimization
Formulation-Optimization
Equipment-Engineering

TABLE II

Plant Energy Data - UM & M Plants

<u>Month</u>	<u>Year</u>	<u>Plant A</u>		<u>Plant B</u>		<u>Plant C</u>	
		<u>Yards Processed using foam</u>	<u>BTU Saved</u>	<u>Yards Processed using foam</u>	<u>BTU Saved</u>	<u>Yards Processed using foam</u>	<u>BTU Saved</u>
Oct.	1979	995,972	194,384,615	1,059,395	563,921,100	1,480,589	277,218,164
Nov.	1979	1,299,902	216,348,432	1,520,981	840,842,550	1,296,210	300,334,465
Dec.	1979	1,512,610	257,497,552	2,785,829	1,059,356,250	1,685,466	300,923,897
Jan.	1980	1,077,638	178,733,594	2,616,401	1,022,708,250	2,250,951	446,220,626
Feb.	1980	880,868	139,451,616	2,155,549	783,457,535	2,974,894	562,419,744
March	1980	1,521,782	296,899,668	904,050	481,225,815	3,477,836	651,050,899
April	1980	1,424,906	277,999,160	1,011,468	538,404,416	2,696,928	504,864,921
May	1980	994,307	193,989,295	1,277,556	680,043,058	2,964,718	554,995,209
June	1980	1,748,792	341,189,319	1,477,917	786,695,219	2,706,174	506,595,772
July	1980	2,001,907	390,572,055	1,150,313	610,541,672	2,139,583	401,529,937
Aug.	1980	1,879,867	366,574,065	959,484	510,445,488	2,046,595	382,713,285
Sept.	1980	1,729,968	340,518,457	1,008,076	536,800,470	4,141,758	776,330,098
Oct.	1980	2,225,994	440,914,294	848,750	451,959,375	3,886,871	727,622,251
Nov.	1980	2,684,160	523,679,616	1,633,588	859,885,610	4,802,197	898,971,278
Dec.	1980	2,162,343	412,373,119	894,481	476,311,132	2,835,324	530,772,653
Jan.	1981	1,948,490	371,380,194	741,160	394,667,700	2,676,869	501,109,877
Feb.	1981	2,124,406	414,471,610	921,437	490,665,202	2,237,761	418,908,859
TOTAL		28,213,912	5,356,976,661	22,966,435	11,090,930,842	46,300,724	8,732,581,935
(Oct. 79-Feb. 81)							

Combined total yardage 97,481,071

Total energy savings 25.2 x 10⁹ BTU

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

TABLE III

Summary-Cost Evaluation

<u>Fabric Wt.</u>	<u>Finish No.</u>	<u>Machine No.</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. By July of 1981, 100% capability is anticipated.

A number of finish formulations were optimized and second generation formulations were introduced. Two specific areas need to be resolved - tint formulations and certain deep shade knit finishing. There are mark-off and crock problems to be solved for dark shades.

Considerable work has been done on equipment development from an engineering standpoint. Several foam application systems are being investigated under this program.

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

The selection of wet pick-up for foam finishing has 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. Preliminary data appears to confirm this hypothesis.

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 is in progress to determine the most effective wet pick-up for foam finishing. Initial 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-I). Both 100% cotton and cotton/polyester blends are being studied.

FIGURE I - WET PICK-UP VS. D.P. RATINGS

4.5 FABRIC PROCESSING-SIMULTANEOUSLY TINTING AND FINISHING

Significant developmental efforts were carried out on the simultaneous foam tinting 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 tint 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-warp (see figure) 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.

FIGURE II-TRIPAD FOAM APPLICATION

The above simultaneous tinting and foam finishing trials demonstrated that the predryers can be eliminated or bypassed 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.

Production trials of foam tinting/finishing are scheduled at Clearwater Finishing Plant.

4.6 FABRIC PROCESSING-DYEING

The status of foam dyeing through September 1979 was discussed in the report issued in December 1979. Nylon carpet dyeing with acid dyes is commercial and approximately 4 million pounds of carpets has 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 UM & M pilot range for over a dozen carpet mills and there is much interest in the industry to adapt foam dyeing systems for carpets. In addition foam dyeing of polyester non-woven blankets using disperse dyes and pigments is commercial. Dyeing of non-woven acrylic blankets is also commercial at the same plant. 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:

TABLE IV

<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 sq. yards of nylon shag were used. Greige carpet without prewetting 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.

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 by using disperse dye foam and also by using pigment foam. Also acrylic blankets are presently 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 by foam was 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 thermosoled (cured) to fix the color.

Developmental work on foam dyeing of acrylic felt with cationic dyes is in progress. Pilot plant trials were carried out to foam dye dark shades. Horizontal pad application of cationic dye foam followed by steam fixation of dyestuff on the acrylic fibre was carried out continuously on our pilot range. There was a high degree of width shrinkage on the felt material during steaming. Trials were carried out to minimize shrinkage in the width by reducing tension along the fabric. Also investigations were made to frame the goods to normal width on the tenter during drying. Fairly successful dyeings were obtained by minimizing tension. On the felt, horizontal pad application of foam by transversely feeding foam on both sides gave uniform color application. For darker shades of cationic dyes a prolonged steaming time is required to fix the color on the acrylic fabric in a continuous foam dyeing operation.

Formulation modifications and optimization of steaming time to fix color in continuous dyeing were explored. A prolonged steaming time would be required to fix dark shades of cationic dyes on acrylic materials. The non-woven felt during steam fixation of color, has shrinkage problems and work is

continuing on the pilot range to obtain level dye application on 60" wide acrylic felts by using a horizontal padder.

(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 knife coat foam with a knife over roll coater. The foam coated carpet is pulled 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:

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 were 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 into the drain.

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 give 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.

Horizontal pad application of pigment foam and disperse dye foam to non-woven polyester blankets gave uniform dyeings. The fastness of pigments on polyester blankets was improved by formulation modification and the foam dyeings of blankets are in production at one textile plant. In another plant an innerlining fabric of non-woven polyester is presently foam dyed with disperse dyes by horizontal pad application.

A polyester narrow width industrial toweling is now commercially foam pigment dyed and finished simultaneously. Due to the open weave construction of the fabric, foam application by horizontal padding method gives uniformity on this type of narrow width fabrics.

Developmental work continues on the foam dyeing of rayon felt using direct dyes and of acrylic felt using cationic dyes by horizontal pad application of foam on both sides of fabric and steam fixation of color.

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 planned.

For uniform color application the tripad arrangement is being 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-warp 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 V

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
Cotton, Rayon	Pigments	Woven	Horizontal Pad
Cotton, Rayon	Sulfur	Corduroy	Knife, Vacuum, Pad
Cotton, Rayon	Pigment	Flannel	Knife, Vacuum, Pad
Cotton, Rayon	Pigment	Flannel	Horizontal Pad
Cotton, Rayon	Reactive	Upholstery	Knife, pad
Polyester/ Cotton Blend	Pigment	Woven	Knife, Pad
Polyester/ Cotton Blend	Pigment	Woven	Tripad-S-Warp
Polyester/ Cotton Blend	Pigment	Woven	Knife, Vacuum, Pad

<u>Fiber Type</u>	<u>Dyes</u>	<u>Fabric Construction</u>	<u>Foam Application Methods Investigated</u>
Polyester/ Cotton Blend	Pigment	Woven	Horizontal Pad
Polyester/ Cotton Blend	Pigment	Woven	Floating Knife
Polyester/ Cotton Blend	Pigment	Woven	Engraved Roll
Polyester/ Cotton Blend	Pigment	Woven	Slotted Pipes
Acrylics and Modacrylics	Cationic	Carpets, Blankets	Knife, Vacuum, Pad
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

Modifications were made to up-date our pilot plant range tripad in order to accelerate scale-up work in dyeing and for simultaneously tinting and finishing of fabrics.

4.7 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 shows 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.

Further study on sequential wet on wet application will continue.

4.8 FOAM DYEING 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 is to study the feasibility of foam dyeing prepared, wet fabrics. Work is currently in progress on foam dyeing wet on wet by prewetting fabrics to various moisture levels and applying pigment foam by horizontal padding. Initial results indicate 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 aid level dyeing.

4.9 FABRIC PROCESSING-PRINTING

The status of foam printing up to September, 1979 was reviewed in the report of December, 1979.

Blotch pigment colors are being roller printed on flat goods. To date, about 4 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. Vary preliminary studies on the pilot plant print machine have confirmed the estimated 35-37% energy savings, at least on the selected patterns printed. Additional energy studies were made on a production printing machine in the plant and are included in this report.

There are still problems to overcome to improve foam roller printing. One of the mechanical problems is to control the foam color feed to the furnisher brush. There are modifications being made to prevent over-flow of foamed color from the color box. Modified pigment color system for foam printing of dark shades are under investigation.

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.

Investigations are also made to improve the foam printing system to eliminate rheology changes inside the rotary screen.

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 will be necessary for plant production.

4.10 ENERGY SAVINGS-FOAM PRINTING

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

Also from the present data, a production speed gain of up to 20 yards/min. i.e. speed increase from 60 yds./min. to 80 yards was obtained by using foam pigment print system. This data is from preliminary energy measurements and greater savings and production speed gain are anticipated.

4.11 FABRIC PROCESSING-FOAM PREPARATION

Feasibility studies on preparation of fabrics utilizing foam are in progress. The laboratory developmental efforts with foam preparation are 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 Soluble Sizes

1. Laboratory Study on Peroxide Pad Batch System

The procedure investigated for removing water soluble sizes 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 hrs. 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 VI and VII compare conventional vs. foam preparation on 50/50 polyester/cotton fabric and 100% cotton fabric.

TABLE VI

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

Sample No.	Process Sequence	% Residual Size Left on Fabric After Preparation	
		4 Hr. Peroxide Batching	6 Hr. Peroxide Batch.
1	Greige 50/50 polyester/ cotton (not prepared)	- - -	12.7% (init. size)
2	Conventional peroxide treatment and conventional caustic pad- steaming	1.58%	1.44%
3	Foam peroxide treatment and con- ventional caustic pad steaming	1.21%	1.37%
4	Foam peroxide treatment and foam caustic pad-steaming	1.79%	1.37%

TABLE VII

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

Sample No.	Process Sequence	% Residual Size Left on Fabric After Preparation	
		4 Hr. Peroxide Batching	6 Hr. Peroxide Batch.
1	Greige 100% cotton (not prepared)	- - -	14.4% (init. size)
2	Conventional peroxide treatment and caustic pad-steaming	4.08%	2.39%
3	Foam peroxide treatment and con- ventional caustic pad-steaming	2.52%	2.65%
4	Foam peroxide treatment and foam caustic pad-steaming	2.61%	2.76%

Investigations will continue with the following objectives:

Selection of most efficient sequence of operation:
Removal of starch; Absorbency; Whiteness.

Optimize chemical requirements:
Peroxide; Silicate; Caustic, Solvents and Foaming Agents.

Optimize process parameters:
Steaming time; Batching Time; Washing off requirements, etc.

Compare efficiency of foam system with conventional preparation.

To prepare fabrics continuously with foam.

Energy savings in foam preparation would not be significant; since the fabric has to be thoroughly washed to remove the solubilized sizes. If wet on wet foam dyeing can be accomplished continuously on prepared wet fabrics there would be substantial energy savings.

4.12 FOAM SIZING

Feasibility studies on foam sizing of yarn are in progress. Studies show that synthetic sizes (latexes) can be formulated into foamable sizes, (Table VIII). 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 IX).

TABLE VIII

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)

TABLE IX

Foam Sizing Trials on 65/35 Blend

<u>Trial No.</u>	<u>Pad Pressure</u>	<u>Blow Ratio</u>	<u>Range Speed y/min.</u>	<u>% Size Add-On</u>	<u>Tensile lbs.</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

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 sizeing machine. More recent trials show commercial feasibility of foam sizeing 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 of minimum amount of water in desizing operation will result in reduced effluent problems.

5.0 GENERAL

Papers Presented On Foam Processing Since September, 1979

I. By Dr. R. S. Gregorian

- a.) Low wet pick-up processing
N.C. State University; November 29, 1979
Raleigh, N.C.
- b.) Foam Finishing
Georgia Institute of Technology; January 17, 1980
Atlanta, Ga.
- c.) Wet Processing of Textile Utilizing Foams
2nd Franco-American Conference on Industrial Energy
Conservation, Washington, D. C.
February 14, 1980

II. By Dr. R. A. Bafford

Low wet pick-up processing for finishing,
dyeing and printing
American Chemical Society National Meeting
Houston, Texas;
March 23-28, 1980

III. By W. Iannone

Theory and Technology of Foam Processing
Clemson University
December 12-13, 1979

IV. By R. Lyons

- a.) Applications and Techniques in Foam Processing
Clemson University
December 12-13, 1979
- b.) Foam Processing-a developmental assessment
AATCC National Technical Conferences
October 15-17, 1980

UM & M PATENTS ON FOAM PROCESSING (Since September, 1979)

1. U.S. P. 4,193,762 Textile Treatment Process
March 18, 1980
C. G. Namboodri, assigned to United Merchants & Manufacturers.
2. U.S. P. 4,208,173 Method for Treating Fabrics
June 17, 1980, R. S. Gregorian and C. G. Namboodri
assigned to United Merchants & Manufacturers.
3. Notice of allowance has been received on three
U.S. Patent assigned to United Merchants.
4. One British Patent has been allowed.