MASTER

APPLICATION OF FOAMS TO
THE PROCESSING OF FABRICS
PHASE-III

TECHNICAL PROGRESS REPORT

For Period Sept. 1, 1979 To Feb. 29, 1980

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Prepared For

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1.0 EXECUTIVE SUMMARY

By the end of February 1980 approximately 300,000,000 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 have been collected which shows great savings. Considerable work has been done by our engineering department on developing applicators to apply dye and finish uniformly to flat goods.

Much of our effort in foam dyeing has been in the evaluations of various application techniques to produce commercially acceptable dyeings and are discussed in this report. Foam dyeing of nylon carpets is in production and approximately 2 million pounds of carpets have been foam dyed in one U.S. plant. Nylon flock fabric dyeing has been scaled-up in pilot plant and plant trials.

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

Foam printing using engraved rolls continues to be in production and thus far 2 million yards of fabric has been printed where foam is used for blotch patterns.

The utilization of foams in fabric preparation is under investigation and feasibility has been established.

Investigations are also in progress to size yarns utilizing foamed synthetic sizing systems.

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, making foam and using it as an application medium.

For the six months' period (September 1, 1979 to February 29, 1980) 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, on 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.

3.0 BACKGROUND

In the period 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, cationic, reactive, sulfur, in fact, all known types of dyes and pigments were successfully adapted to foam application.

Fabrics were also printed with foams. Pigments, Rapidogens and acid dyestuffs were among those coloring agents used to print fabrics with foams. The uniqueness of foam printing technology rests on the fact that auxiliary 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 pastes. 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. Patents No. 4,118,526, and notice of allowance has been received on three additional U.S. Patents.

In the report issued in December, '79 for the Phase I and II of this contract we reported the progress made up to 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 result 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 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 programmed. 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 pattern.

A number of companies are currently using foam fabric finishing as a commercial production process. Commercial practice 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 include 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>		<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%

4.3 FABRIC PROCESSING-FINISHING

An estimated cumulative total of over 200,000,000 yards of fabrics had been foam finished by September 8, 1979. The energy savings and production gains from plant data were reported in December 1979 covering from October 1977 through September 1979.

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

By the end of February 1980 approximately 300,000,000 yards of fabric have been finished with foam.

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

- Cost Accounting
- Processing-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>
Sept.	1979	- -	- -	- -	- -	- -	- -
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	<u>880,868</u>	<u>139,451,616</u>	<u>2,155,549</u>	<u>783,457,535</u>	<u>2,974,894</u>	<u>562,419,744</u>
SUB TOTALS		5,766,990	986,415,809	10,138,151	4,270,285,685	9,688,110	1,887,116,896

Totals for Three Plants 25,593,251 yds. 7,143,818,390 BTU's saved or
6,929,018 ft.³ of natural gas saved

NOTE: Yardage vs. BTU's saved cannot be compared from one plant to another because of fabric widths, weights and differences in drying equipment.

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>Energy Saved BTU/yd.</u>	<u>¢/yd.*</u>
4 oz./sq. yd.	1	5	21.4%**	129.8	0.034
" "	2	5	71.1%	641.2	0.168
" "	3	6	21.7%**	83.9	0.022
4.13 oz./sq. yd.	4	6	61.5%	221.3	0.058
3.01 "	5	6	61.5%	347.3	0.091
3.01 "	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 three machines are equipped with foam finishing capability and are capable of finishing 800,000 + 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 area needs 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 stand point. Several foam application systems are being investigated under this program.

4.4 FABRIC PROCESSING-DYEING

The status of foam dyeing through September 1979 was discussed in the report issued in December 1979.

To date foam dyeing is in production only in the area of nylon carpet dyeing with acid dyes and approximately 2 million pounds of carpets has already been foam dyed in one U.S. plant. 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 system for carpets.

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

TABLE IV

Carpet Dyeing
Formulation

Water	80-X%
Valfoam CD	20%
pH 5.0 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 carpet face is knife coated with the foam. A vacuum is then applied from the back of the carpet to pull the foam into the pile and finally the foam coated carpet is padded to collapse the foam and distribute the dye liquor. The carpets are then continuously steamed for color fixation. In most cases an after washing is not necessary. Energy savings from commercial runs are not available at this time.

Another area of single fiber dyeing with foam which is close to commercial is nylon flock fabric dyeing using acid dyes. Pilot plant and plant trial scale-up has been carried out to foam dye 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.

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 vacuumed from the backside followed by padding to collapse 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 process 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

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 gives poor 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 produces 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 higher wet pick-ups and poor control of shade from start to end.

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 the color penetration to the back side was poor. Where the requirement was only one side dyeing, as on a nylon mattress ticking, the method was found ideal. Some production trials were run at our printing plant by using engraved roll application.

More 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 a horizontal pad is planned.

Horizontal pad application of pigment foam to non-woven polyester blankets gave uniform dyeings. The fastness of pigments on polyester blankets was found to be unsatisfactory and development work is in progress to improve the fastness properties. Also development work is continuing on the foam dyeing of rayon felt using direct dye foam from a horizontal pad application.

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

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
"	"	Flat Goods	Knife, vacuum, pad
Polyester	"	"	Horizontal pad
"	Pigments	Blankets	Knife, vacuum, pad
"	"	"	Horizontal pad
Polyester	"	Sheer Fabric	"
Nylon	Acid	Carpets	Knife, vacuum, pad
"	"	Flocked	Knife, pad
Nylon	Disperse	Carpets	Knife, vacuum, pad
"	Acid	Velour Upholstery	Knife, pad
Nylon	Premetalized	Carpets	Knife, vacuum, pad
"	Pigments	Mattress Ticking	Engraved roll

TABLE V
(Continued)

Cotton Rayon	Direct	Upholstery	Knife, pad
" "	"	Blankets, felt	Horizontal pad
" "	Pigments	" "	" "
" "	"	Woven	" "
Cotton, Rayon	Sulfur	Corduroy	Knife, vacuum, pad
" "	Pigment	Flannel	Knife, vacuum, pad
" "	"	"	Horizontal pad
" "	Reactive	Upholstery	Knife, pad
Polyester/cotton Blend	Pigment	Woven	Knife, pad
" "	"	"	Knife, vacuum, pad
" "	"	"	Horizontal pad
" "	"	"	Floating Knife
Polyester/cotton Blend	Pigment	Woven	Engraved roll
" "	"	"	Slotted pipes
Acrylics and Modacrylics	Cationic	Carpets, blankets	Knife, vacuum, pad
"	"	Sliver knits	Knife, vacuum, pad
Acetate	Disperse	Woven, knits	Knife, pad
"	Pigments	Drapery	Horizontal pad
Qiana	Disperse	Knits	Knife pad

4.5 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 feasibility of foam dyeing prepared, wet fabrics. Developmental 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. The results on 50/50 polyester/cotton blends and cotton woven fabrics indicate the feasibility of foam dyeing wet fabrics containing up to 25-35% moisture level. The results indicate that prepared wet fabrics can be foam dyed, though optimum moisture levels have not been determined. Also it was observed that small amounts of moisture on the fabric aid level dyeings.

4.6 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 2 million yards of fabric has been foam printed at our Clearwater printing plant. A savings of 15-20% in color cost has been obtained by pigment foam printing. Thus far we have not been able to collect energy savings data, since the drying cans are steam heated and not yet instrumented. An estimated energy savings from increased production speeds show an energy savings up to 35% during drying. We are currently pursuing energy savings studies on our pilot plant roller printing machine.

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.

4.7 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 soluble sizes in PVA, CMC etc.
- b.) Fabric containing starch and modified starch sizes.

a.) Fabric Containing Soluble Sizes

The procedure investigated for removing water soluble sizes is the use of 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 then applied on the yarn dyed greige check fabrics. The foam applied fabrics are then batched 4-6 hrs. and then the solubilized sizes are washed off.

In addition to energy savings, foam desizing/bleaching appear to have certain advantages over the conventional process.

- i.) Less color bleeding from dyed yarns and absence of staining of white yarns.
- ii.) 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.

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 are 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 absorbancy (for dyeing), whiteness and removal of starch are the parameters for evaluation. Laboratory results indicate that procedure iii was giving the best absorbency and removal of starch. These results are very preliminary. Investigations will continue with the following objectives.

- i.) Selection of most efficient sequence of operation: removal of starch; absorbency; whiteness.
- ii.) Optimize chemical requirements: peroxide; silicate; caustic, solvents and foaming agents.
- iii.) Optimize process parameters: steaming time; batching time; washing off requirements etc.
- iv.) Compare efficiency of foam system with conventional preparation.
- v.) To prepare fabrics continuously with foam.

4.8 FOAM SIZING

Feasibility studies on foam sizing of yarn are in progress. Studies show that synthetic sizes (latexes) can be formulated into foamable sizes. Yarns can be immersed in foamed size and can be padded to collapse foam. In a production trial this application method gave slightly higher add-on than expected from pilot trials: work is currently in progress to apply foamed size to yarn by horizontal pad application in order to reduce wet pick-up.

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 Technologh; January 17, 1980
Atlanta, Ga.
- c.) Wet Processing of Textiles Utilizing Foams
2nd Franco-American Conference on Industrial
Energy Conservation, Washington, D. C.
February 14, 1980

II. By W. Iannone

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

III. By R. Lyons

Applications and Techniques in Foam Processing
Clemson University "Foam" Seminar
December 12-13, 1979

PATENTS ON FOAM PROCESSING (Since September, 1979)

- 1. Notice of allowance has been received on three
U.S. patents assigned to United Merchants.
- 2. One British Patent has been allowed.