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ENERGY

CONSERVATION

REPORT OF THE PROCEEDINGS OF THE DEPARTMENT OF ENERGY WORKSHOP ON ENERGY CONSERVATION IN THE TEXTILE INDUSTRY

MASTER

January 24 and 25, 1978

Work Performed Under Contract No. W-31-109-ENG-38

Washington Scientific Marketing, Incorporated
Washington, D. C.

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Division of Industrial Energy Conservation

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Report of the Proceedings of the Department of Energy Workshop on Energy Conservation in the Textile Industry

January 24 and 25, 1978

Prepared for:

The Department of Energy
Division of Industrial Energy Conservation

Prepared by:

Washington Scientific Marketing, Inc.
Washington, D.C.

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Introduction

The workshop on Energy Conservation in the Textile Industry was held on January 24 and 25, 1978 at the Jane S. McKimmon Center of North Carolina State University. The workshop was sponsored by the Department of Energy, Division of Industrial Conservation as a means of identifying opportunities of energy conservation research, development, and demonstration (RD&D) in the textile industry.

The goal of the Division of Industrial Energy Conservation is to provide an advanced technological base for improved energy use efficiency in industry and agriculture. The Division supports RD&D in areas which have high potential benefit in terms of national energy savings, which will result in the implementation of a technology at an earlier date than presently expected to increase energy savings, and which will be economically viable. This workshop has been one of many which have been sponsored to encourage a dialogue between the Department of Energy and industry to ensure that the ideas, priorities and concerns of the private sector are reflected in the Division's research programs, and that the best conservation opportunities are addressed.

We would like to extend our thanks to the following organizations and individuals for their assistance:

American Association of Textile Chemists and Colorists
American Association for Textile Technology
American Textile Machinery Association
American Textile Manufacturers Institute
Carpet and Rug Institute
Georgia Textile Manufacturers Association
Dr. Mary Carter
    USDA-Southern Regional Research Center
Dr. Morton Shaw
    North Carolina State University
Dr. Perry Grady
    North Carolina State University

Organization

This workshop was planned, organized, and conducted by Washington Scientific Marketing, Inc., under the direction of the program managers from the Division of Industrial Energy Conservation. Mr. James Lowry of Booz, Allen, and Hamilton assisted in the development of the participant list and in planning the workshop structure. North Carolina State University's School of Textiles assisted in facilities arrangements at the Jane S. McKimmon Center for Continuing Education.

A list of participants was developed through contacts with trade associations, professional societies, individual researchers, the Department of Energy and other Federal agencies. Fifty individuals representing the textile industry, equipment manufacturers, and universities were in attendance. During the opening session, John Rossmeissl, the textile program manager for the Division of Industrial Energy Conservation, gave an overview of the reorganization of Federal energy efforts with the establishment of the Department of Energy and of the role of the Division. Presentations were then made of Division funded projects.

The workshop participants were divided into four discussion groups consisting of 9 to 16 individuals. These groups were:

Textile Energy Management Systems
Preparation and Dyeing
Finishing
Textile Yarn and Fabric

This format was choosen to simulate informal round table discussions and a team type approach. Each group was asked to document a number of RD&D project ideas which the Department of Energy should consider in its program. Each project idea includes the parameters to be investigated, the best guess estimates of energy conservation potential, and project costs. The chairman of each of the panels was choosen in advance and was responsible for directing the group's discussions and summarizing their deliberations.

TEXTILE ENERGY MANAGEMENT SYSTEMS

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Heat Recovery of Contaminated Exhausts	High	25% of dryer energy consumption	R-2 yrs D-1 yr D-1 yr		R-100% D- 75% D- 50%	Page 37
Development of Co-generation System	High	30% of mill electric demand	D-2 yrs D-2 yrs	D-$1 MM D-$500 M	D- 50% D- 50%	37
Energy Analysis of Textile Processes	High		R-3 to 5 yrs	R-9 man yrs	R-100%	38
Development of Coal Boiler	High		R-1 yr D-2 yrs D-2 yrs	R-2 man yrs D-20 man yrs D-$3.5 MM	R-100% D-100% D- 75%	38
Improvement of Drying Technology	High	20% of drying energy	R-1 yr D-2 yrs D-1 yr	R-4 man yrs D-$250 M D-$150 M	R-100% D- 75% D- 75%	39

PREPARATION AND DYEING

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Moisture Analyzer	1	.0025 Quad	R-2 yrs D-1 yr D-1 yr	R-$180 M D- $90 M D- $90 M	R- 85% D- 85% D- 0%	43

PROJECT OVERVIEW MATRIX

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Exhaust Gas Incineration	2	1.1×10^{13} Btu's	R-1 yr	R-$250 M	R-100% D-100% D- 20%	43
Pad/Batch Preparation and Dyeing	3	.0033 Quads	R-2 yrs D-2 yrs D-1 yr	R-$250 M D-$250 M D-$500 M	R- 80% D- 60% D- 50%	44
Energy Optimization in Textile Scouring	4	.0576 Quads	R-2 yrs D-1 yr D-1 yr	R-$500 M D-$500 M D-$1 MM	R-100% D- 80% D- 60%	44
Energy Efficient Moisture Removal Systems	5	10-25% of energy consumed for moisture removal	R-2 yrs D-1 yr D-1 yr	R-$200 M D-$100 M D-$200 M	R-100% D- 90% D- 50%	45
Cleaning Exhaust Emissions for Heat Recovery	6	7.1×10^{12} Btu's	R-1 yr D-1 yr D-1 yr	R- $50 M D- $50 M D-$200 M	R-100% D-100% D- 50%	46
Direct Application of Process Chemicals	7	0.4×10^{6} BOE	R-4 yrs D-2 yrs D-1 yr	R-$400 M D-$200 M D-$200 M	R-100% D- 80% D- 50%	46
Low-Energy Continuous Dye Systems	8	.0268 Quads	R-2 yrs D-1 yr D-1 yr	R-$500 M D-$500 M D-$1 MM	R- 80% D- 65% D- 50%	47
Sludge Incineration	9	1.4×10^{12} Btu's	D-2 yrs		D-100% D- 20%	47
Anerobic Digestion of Sludge	9	1.5×10^{12} Btu's	D-2 yrs	D-$500%	D-100% D-100%	47

TEXTILE YARN AND FABRIC

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
State-of-the-art Review of Energy Use in Textiles	High	2.5×10^{9} kWh	R-1 yr		R-100%	53
Power Measurement Equipment	High		R-1 yr D-1 yr D-1 yr	R- $50 M D-$150 M D- $50 M	R-100% D-100% D-100%	53
Energy Conservation in Weaving	Medium	0.8×10^{9} kWh/yr	R-1 yr D-1 yr D-1 yr	R- $60 M D- $60 M D- $60 M	R-100% D-100% D-100%	54
Energy Conservation in Texturing	Medium	1.8×10^{9} kWh/yr	R-1 yr D-1 yr D-1 yr	R- $50 M D- $80 M D- $80 M	R-100% D-100% D-100%	55
Energy Conservation in Yarn Forming & Preparation	High	2.0×10^{9} kWh/yr	R-1 yr D-1 yr D-1 yr	R- $60 M D- $70 M D-$100 M	R-100% D-100% D- 90%	55
Low Energy Sizing	High	4.0×10^{9} kWh/yr	R-2 yrs D-3 yrs D-2 yrs	R-$250 M D-$500 M D-$300 M	R-100% D-100% D- 80%	56
Curriculum for Fixers & Changers	High		D-2 yrs D-1 yr	D-$100 M D-$537 M	D-100% D- 80%	56
Electrostatic Waste Removal	High			D- $85 M D- $15 M		57
Computer Model of Energy Needs of a Mill	Medium	10^{7} kWh/yr	R-½ yr D-1 yr D-½ yr	R- $25 M D- $50 M D- $25 M	R-100% D-100% D-100%	57

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Optimizing Power Needs of Greige Mill	High	675×10^6 kWh/yr	D-1 yr	D-$250 M	D- 75%	57
Energy Conservation via Lubricants	Medium	5% of textile mill energy use	R-1 yr D-1 yr D-1 yr	R- $50 M D-$100 M D- $50 M	R-100% D-100% D- 80%	58
Tuft to Yarn System	High		R-3 yrs D-2 yrs D-1 yrs			59
Electrostatic Spinning	Medium	30% of energy used by present Equipment	R-3 yrs D-2 yrs D-1 yr			59

FINISHING

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Low Temperature Curing	High	0.6×10^6 BOE/yr	R-2 yrs D-1 yr D-1 yr	R-$320 M D-$160 M D-$100 M	R- 75% D- 75% D- 50%	63
Optimization of Drying Techniques	High	2.5×10^6 BOE/yr	R-1 yr D-1 yr D-1 yr	R- $75 M D- $75 M D- $75 M	D- 95% D- 95% D- 95%	63
Metering Techniques for Finishing Agents	High	2.25×10^6 BOE/yr	R-1 yr D-2 yrs D-1 yr	R- $80 M D-$400 M D-$100 M	R- 75% D- 75% D- 50%	63

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Exhaust Incineration	High	1.2×10^6 BOE/yr	R-1 yr D-1 yr D-2 yrs	R-$500 M D-$500 M D-$500 M	R-100% D- 75% D- 50%	64
Effluent Neutralization Via Flue Gases	Medium	0.4×10^6 BOE/yr	R-2 yrs D-2 yrs D-2 yrs	R-$500 M D-$500 M D-$1.5 MM	R-100% D- 75% D- 50%	64
New Size Development	Medium	1200-1600 Btu/lb	R-3 yrs D-1 to 2 yrs			65
Study of the Machnozzle	Medium	2.5×10^6 BOE/yr	R-1 yr D-1 yr D-1 yr	R- $50 M D- $25 M D- $25 M	R-100% D-100% D- 50%	65
Radiation Curing	Medium	9×10^6 BOE/yr	R-2 yrs D-1 yr D-1 yr	R-$170 M D-$800 M D-$800 M	R- 80% D- 65% D- 55%	65
Systems Analysis of a Finishing Plant	Medium			R-$100 M		66
New Bleaching Technology	Medium	0.46×10^6 BOE/yr	R-1 yr D-1 yr D-1 yr	R-$150 M D-$100 M D-$100 M	R- 70% D- 60% D- 50%	66
Alternate Fuels for Finishing	Medium					66
Microwave or Dielectric Heating	Low					67

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Modification of Steam Can Technology	Low					67
Flame Curing Finishes	Very Low					67

Opening Presentations

John Rossmeissl	Department of Energy
Richard Wright	Georgia Tech
David Brookstein	Georgia Tech
Wayne Tincher	Georgia Tech
John Beard	Clemson University
R. S. Gregorian	United Merchants & Manufacturers

Opening Remarks

John Rossmeissl
Department of Energy

First, let me thank you all for coming. This is one of a series of workshops that we have held to help define the research, development and demonstration programs that the Division of Industrial Energy Conservation should pursue. Industrial participation through these workshops ensures a relevancy in our planning by informing us of industrial needs, resources and limitations in the area of energy conservation. This workshop will enable top people, like yourselves, who represent the textile industry, equipment manufacturers, and academic institutions, to provide an input into our future projects within the industry. Hopefully, you will be able to take back with you as much, if not more information, than you will individually provide for us today. A brief description of the operative structure of the Division may give you a better idea of how your work here today interfaces with our overall efforts.

The formation of the Department of Energy on October 1, 1977 has brought rapid changes in the Federal energy establishment. What was formerly ERDA, along with other agencies such as the Federal Energy Administration and the Federal Power Commission, have been assimilated into the new Department of Energy. ERDA's role, in its three years of existence, was to assist industry in the development of new technology that would conserve energy and to develop the technology needed for the use of alternate fuels. With the advent of the Department of Energy, the former Office of Conservation of ERDA, which included the Industrial Division, is now divided between two of the Department of Energy's Assistant Secretariats. The Division of Industrial Energy Conservation, the Division of Buildings and Community Systems and the Division of Transportation will be part of the new Assistant Secretariat for Conservation and Solar Applications. The former ERDA divisions for Conservation Research and Technology, Energy Storage and Electric Energy Systems will be incorporated in the Assistant Secretariat for Energy Technology. The functions that previously existed within FEA will also be incorporated into the Assistant Secretariat for Conservation. The functions that were formerly exercised by the Department of Commerce, which were largely associated with technology transfer and the collation of data used throughout the industrial sector, will also be incorporated into the new Department. The energy reporting which many of your companies do through the ATMI, which was formerly done through FEA, will now come under the auspices of the Department of Energy. Thus there is a single, overall consolidation of industry programs into a single office function.

ERDA's efforts in research, development and demonstration will be continued and will be distinguished from any regulatory functions that previously existed within FEA. This delineation is apparently one of the organizational strictures placed upon the new Department. The other subject of importance to all of you is that we have finally achieved a degree of recognition within the Federal establishment indicating that our budgets are going to be significantly improved. During fiscal year 1977, which ended October 1 of last year, we had a $15.5 million budget for the whole industrial conservation section. Quite honestly, this figure is relatively small. The fiscal 1978 budget will be $29.2 million; essentially doubling our prior year's budget. It is clear that the Federal government is and will continue to exert a significant effort to assist all of industry in the development of energy conservation technologies.

The budget of our Division is distributed among a number of different areas. The focus of our program is on the most energy intensive industries: steel, petroleum refining, chemicals, paper, food production, aluminum, cement, textiles, and glass. We have examined the individual process streams in each of these industries and established the major sources of energy loss. The R&D work focuses on improving the efficiencies of components and processes that could cost-effectively replace conventional systems. We have identified a great number of conservation opportunities. The programs are predominantly cost-shared with industry. Several of the programs are done in conjunction with university research centers; these are primarily of a software nature. We also have several ongoing projects in national laboratories that are essentially generic in nature, such as high temperature materials development. We allow industry to maintain a proprietary position providing that if technology is developed as a result of the program, the industry must be willing to license it at a reasonable royalty to the industry at large. However, the definition of a reasonable royalty is somewhat ambiguous, so a standard accepted by most industries has been developed through the court systems.

The textile industry is one of the top energy consumers in the nation. Natural gas is the highest energy form consumed, and coal, our most abundunt fuel, the lowest. During the time span of 1972-1974, data indicates an increased use of natural gas and fuel oil and a decrease in coal usage. We have completed a detailed second law thermodynamic analysis of the individual processes in the textile industry. The total annual energy loss in quads for key processes i.e. preparation, dyeing, drying and finishing is .368 quads. If we compare the total consumption level of .5 quads, we can infer that there are gains to be made in waste heat recovery and in improved process efficiency. The programs we have underway which overlap with the key process areas are: Textile Process Modification, Hyperfiltration, Foam Dyeing and Finishing. Later this morning, some of the principal investigators of these projects will provide you with an overview of each of their research work.

Very shortly, our Division will be requesting proposals from the textile industry, as well as other energy intensive industries, on co-generation. We define co-generation as a simultaneous generation of electrical or shaft power and process heat which may be hot air or steam. We are hoping to get a good response from the textile manufacturers on the Program Opportunity Notice in order to get some programs on co-generation in the textile industry.

The four working groups of today's workshop are designed to unite the forces of the technologists with knowledge of equipment, processes and energy management systems in order to examine the textile industry for potential energy conservation ideas. Your efforts will help us define specific areas that are suitable for government participation in research and development. You will be asked to participate in project definitions that describe the process concerned and the R&D program that you think is required. The Division will examine these projects in comparision with our internal program and modify that program to compliment the energy conservation priorities of the textile industrial sector. Almost all of our good ideas come from people like yourselves. We are delighted to have them. Once again, I thank all of you for being here.

Energy Conservation in the Textile Industry
Project Overview

Richard Wright
Georgia Tech

I am the project director for the Textile Industry Energy Conservation Research Project at Georgia Tech. Our program is a joint effort between the Textile Engineering School and the Engineering Experiment Station. The first phase of this project was a study of the potential for energy conservation in various processes in the industry. A report on that phase is at the Department of Energy. The activities of the second phase of this project will cover four areas. One effort involves the evaluation of modifications to an atmospheric dye beck. We are working with a carpet manufacturer to document the use of steam in the dye beck and then evaluating the effects of various mechanical modifications. A second effort involves the evaluation changes in fabric preparation to reduce the number of baths and intermediate drying steps required. Our third area of effort is examining mechanical predrying. The emphasis of this project is on improved vacuum extraction techniques and the application of the Machnozzle. Finally, from the baseline data we developed during the first phase of this project, we are in the process of documenting costs and benefits of energy conserving modifications currently being implemented in the textile industry.

We are proposing research for a third phase of this project which would involve in-plant demonstration of dyebath reuse in hosiery dyeing. Several other areas of future research include the potential application of waste wood gasification and cogeneration to textile processes.

Dr. David Brookstein and Dr. Wayne Tincher will discuss the details of their work and findings in areas of predrying and dyebath reuse for you.

Mechanical Predrying

David Brookstein
Georgia Tech

The work being done in drying at Georgia Tech is examining methods of moisture removal in the most energy efficient manner. Our work is primarily emphasizing thermo-mechanical techniques. One such area is the utilization of a vacuum or reduced pressure and subsequent thermal treatment to increase the mass transport mechanism and reduce the amount of energy necessary for moisture removal in predrying.

We are also looking at what I would call hot water cans. We have found that fabrics can be dryed by using steam cans which contain hot water at about 160° - 180°F. Of course the residence time necessary for drying a fabric would increase. Our investigations have been examining the residence time required for different temperatures and fabrics and to determine if this is economically viable. An analysis is being conducted now on a stack of four steam cans where the first two stacks contain hot water and the latter two contain steam. Many of the people we have talked to in industry are concerned that they are overdrying with steam cans. If we can adjust the residence time and thermal treatments to the correct level of drying, energy can be saved. Finishing systems are being examined as a source of 160° - 180°F waste water for these hot water cans. Since this water does contain contaminents this waste water may have to be filtered or purified in some manner.

Another drying technique we are looking at is the Machnozzle. The Machnozzle, as some of you know was invented in Holland by the Brugmann Company. There are several companies in the U.S. which have the Machnozzle although its application is in the infancy stage. There have been papers published on the Machnozzle's effectiveness in Holland, but there is no direct experience on the Machnozzle and within a month we should have it running. Once on-line we will double check the European data and investigate methods of predrying with it. Our direct experience with the Machnozzle should help us make recommendations as to the most effective means of using it. We will also be looking at using the low pressure waste steam from the Machnozzle and routing back to the hot water can which I discussed earlier.

As a footnote, I would like to say that we are operating an Industrial Energy Conservation Service through the State of Georgia that we will be using as an avenue of technology transfer to at least the Georgia textile industry and hopefully this work will pass through to the entire textile industry.

Dyebath Reuse

Wayne Tincher
Georgia Tech

Most of the work at the Engineering Experiment Station and the School of Textile Engineering is in the wet processing of textiles. We are looking at processes which come under the heading of preparation, dyeing, finishing, and drying operations. Based on our early work, we concluded that one of the most energy intensive types of processes in textile processing is batch dyeing. Our work has been directed toward low capital cost modifications of batch dyeing procedures which are more energy efficient.

A typical batch dyeing operation, once finished, will have appreciable quantities of auxiliary chemicals, a small quantity of dye stuff, and a large amount of hot water in the dye bath which is flushed down the drain. In some cases, a small part of the energy is routed through various types of heat exchangers, but in general, approximately half of the energy that is lost in batch dyeing processes is dumped down the drain. Our approach in examining this problem is to analyze the dye concentration and raise it back up to the concentration level which is required for subsequent dyeing in order to reuse the whole bath.

Our study began with carpet dyeing because this is an area where color matching is not nearly as critical as it is in other textile operations. Also a relatively limited range of dyestuffs are used in carpet dyeing. In the laboratory we have been able to dye carpets five times in the same shade from the same dye bath using dispersed dyes. We have also been able to dye nylon carpet to ten different shades using dispersed dyes and reusing the dye bath for those ten dyes. Following our work with dispersed dyes, we have subsequently been working with acid dyes on nylon which is a more difficult proposition. This work has also lead us to different textile product areas. We found that hosiery dyeing bears a very close similarity to carpet dyeing. As a result, we are now dyeing hosiery on a batch basis; reusing the dye bath up to thirteen times. This work is now ready for in-plant demonstrations. Later on this year, we hope to go into a hosiery manufacturing plant and modify the hosiery dyeing machines. We will dye at least ten loads of hosiery in the same water before it is finally discharged. Other areas of dyeing we have studied include package dyeing of polyster yarns and reactive dyeing of cotton and cotton/polyester blends.

In the area of preparation, we have been examining the possibilty of combining operations to do de-sizing, scouring, and bleaching in a single bath. This way the number of washing operations can be reduced and energy can be conserved.

Optimization of Energy Usage in Textile Operations

Dr. John N. Beard, Jr.
Department of Chemical Engineering
Clemson University

The Department of Chemical Engineering at Clemson University has a contract to study tenter frame dryers and to develop guidelines for the optimal operation and design of the dryers. First, I would like to talk about the benefits obtained by operating a tenter frame at optimal conditions. In actual plant tests we found it is often possible to decrease the natural gas consumption by 25 to 50% and simultaneously increase the tenter frame capacity by 50 to 75% by analyzing the variables and optimizing them without doing large scale modifications On an industry-wide basis, these modifications amount to mor than $20,000,000 a year in savings.

Let's examine some of the things that make the analysis of tenter frame dryers difficult. First, there are many configurations: the penthouse style, low profile dryers. There are different types of nozzle design such as the perforated plate, the slot, and the new jet tube. Finally, there is the number, size, and speed of the circulating and exhaust fans. These variables are the tenter frame variables.

The second category of variables are the operating conditions. These variables include the fabric composition, style, weight, velocity, and inlet moisture content. These variables also include the tenter frame air temperature, and air humidity.

Finally, there is a third category of variables which are difficult to measure in a tenter frame. The exhaust gas humidity is very useful to know, but it is difficult to measure in the 350° - 400°F temperature range. Natural gas consumption rate is difficult to measure because most tenter frames do not have gas meters on them. Determining moisture content levels are difficult because you cannot stop the fabric to grab a sample. Fabric temperature profiles can be measured if you have the right type of pyrometer and if you have some openings so that you can see the fabric. Even if you do have the equipment and know what you want to do to get a good set of measurements, it still takes about a half a day. Thus, we have a number of problems, variables, and most of all, difficulties.

For a number of years the petroleum and chemical industries have used mathematical modeling and optimization techniques to study their processes on equipment which is more complex than a fabric dryer. In order to study a tenter dryer, we developed a mathematical model of it which will accurately predict the fabric temperature and moisture profile as the fabric moves down the dryer (figure 2). We have another output from a model, the fabric moisture content (figure 3). The model consists of three ordinary differential equations which describe the drying process (figure 1). These equations are solved simultaneously, using a digital computer, to accurately predict the profiles. This version of the model can be used to study many tenter frame process variables such as: fabric weight, fabric velocity, fabric inlet moisture content, and tenter air humidity. However, at present it is necessary to first experimentally determine three parameters for each tenter frame-fabric combination. These parameters, h, h_1, and B are determined by curve fitting the model to experimental fabric temperature profile data. Once these parameters have been determined, then process variable studies can be run on the computer.

Several textile firms have been using the model to study their processes, but it is still difficult to use because of the experimental data required. Our current efforts are aimed at trying to separate the effects of tenter variables from the operating conditions.

If we can do this it would: simplify the job of analyzing the tenter frame, enable us to predict the performance of any fabric in any tenter frame, and allow us to conduct studies of all of the fabric variables in the laboratory.

If you are interested in the work we are doing, our findings are reported in the annual summary reports to the Department of Energy.

$$\frac{dT_E}{dL} = \frac{h}{V\rho} \left[\frac{T_A - T_E - \frac{h_1}{h}(T_E - T_I)}{C_{PF}} \right] \qquad (1)$$

$$\frac{dT_I}{dL} = \frac{h_1}{V\rho} \left[\frac{T_E - T_I - \lambda\left(\frac{Y_2 \frac{X}{X_c} - Y_1}{B}\right) X}{C_{PF} + C_{PW} X} \right] \qquad (2)$$

$$\frac{dX}{dL} = \frac{h_1}{BV\rho} \left[Y_2 \frac{X}{X_c} - Y_1 \right] X \qquad (3)$$

B	Experimentally determined constant
C_{PF}	Specific heat of dry fabric, BTU/#°F
C_{PW}	Specific heat of water, BTU/#°F
h	Heat transfer coefficient between air and dry layer
h_1	Heat transfer coefficient between wet and dry layers
L	Distance from tenter entrance, Ft.
T_A	Tenter air temperature, °F
T_E	Fabric surface temperature, °F
T_I	Fabric interior temperature, °F
V	Fabric velocity, ypm
X	Fabric moisture content, lb. water/lb. dry fabric
X_C	Critical fabric moisture content, lb. water/lb. dry fabric
Y_1	Tenter air humidity, lb. water/lb. dry air
Y_2	Humidity at the air-moisture interface, lb. water/lb. dry air
ρ	Density of fabric, lb./ft.^{2} of surface
λ	Latent heat of vaporization of water, BTU/lb.

FIGURE 1. EQUATIONS USED IN MATHEMATICAL MODEL OF TENTER FRAME DRYER.

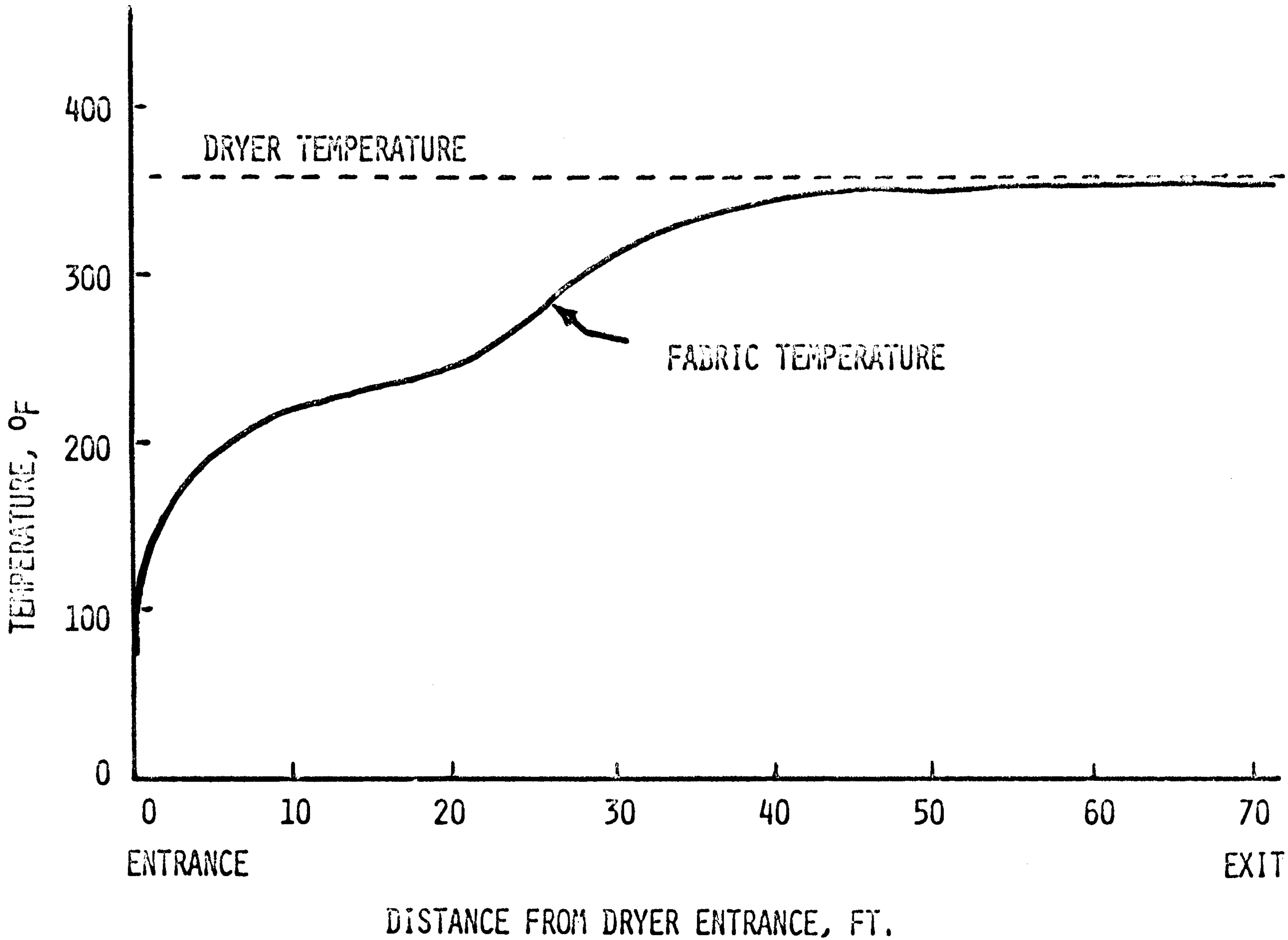


FIGURE 2 - FABRIC TEMPERATURE PROFILE IN A TENTER FRAME DRYER

FABRIC MOISTURE PROFILE

IN A TENTER DRYER

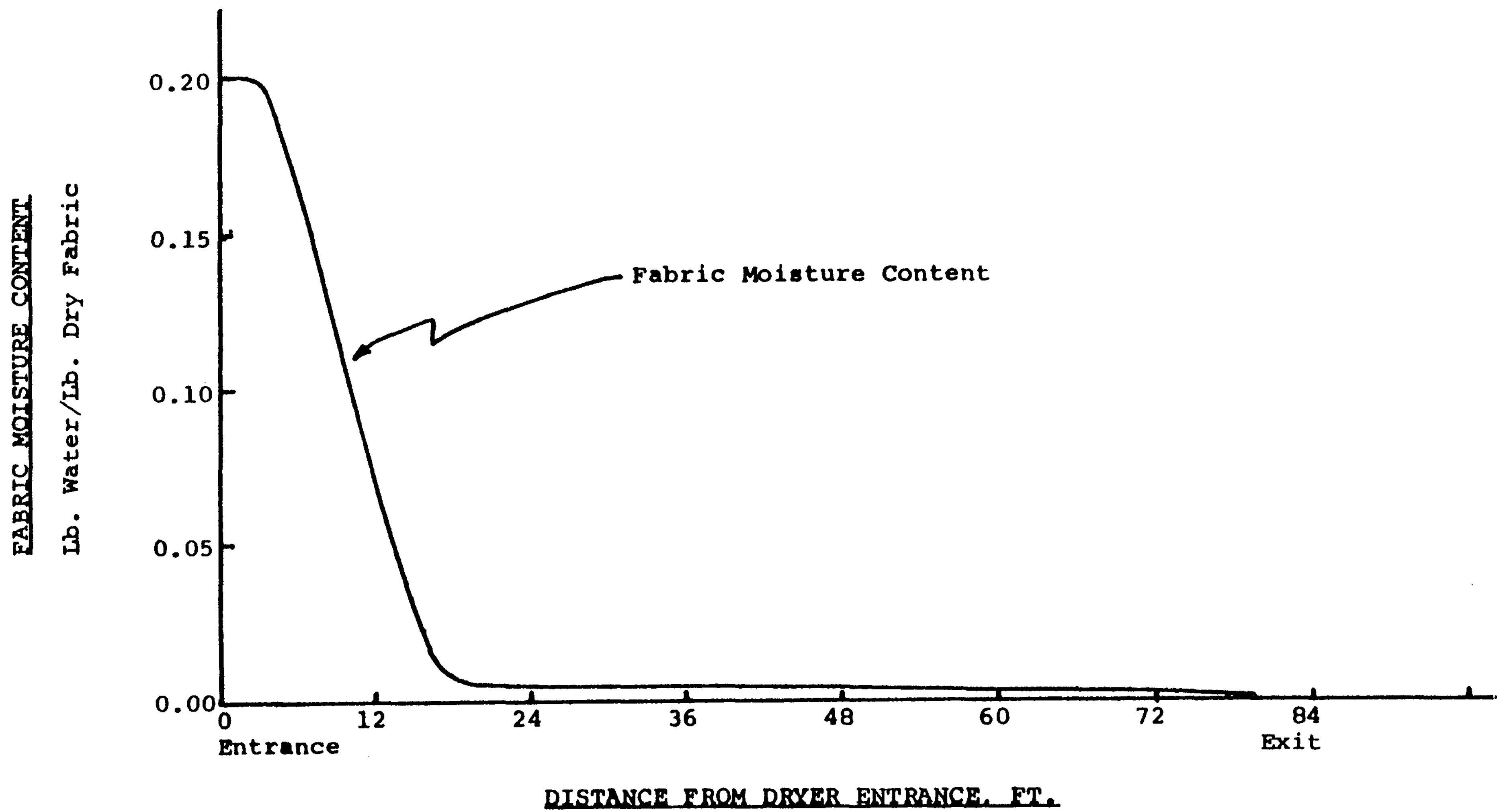


FIGURE 3

Foam Finishing and Dyeing Project

Dr. R. S. Gregorian
Director of Research
United Merchants Research Center

According to a recent article in Textile Industries, the textile industry will consume the energy equivalent of 50 million barrels of oil in 1980. The wet processing industry, including bleaching, dyeing, printing and finishing, will consume about 55-60% of this total energy. This energy is used almost exclusively to heat and evaporate water.

With a readily available supply of water and low cost energy, there was little incentive to significantly modify the manufacture, preparation, and finishing of textiles. However, the decreasing availability of first quality water, the environmental problems relating to the disposal and up-grading of the aqueous effluent from textile plants, and most important, the high cost and the probable unavailability of sufficient natural gas makes it incumbent that the traditional methods of textile operation be profoundly changed.

However, this same Textile Industries article points out that most of the energy conservation projects currently underway in the textile industry revolve around improving the efficiency of the conventional wet processes as, for example, improved boiler room efficiencies, heat reclamation, high extraction pads and higher fabric to liquor ratios in dye baths. Other projects such as solvent dyeing and solar heating will involve considerable capital expenditures.

We, at United Merchants have developed a new approach to the wet processing of fabrics which not only results in major reductions in the energy requirements for dyeing or printing and finishing, but cuts water consumption per pound of fabric by at least 50% and for some operations by 80 to 90% and virtually eliminates aqueous effluents.

The process involves little or no capital expenditure in that the required equipment is already in place in most textile and carpet finishing plants.

The necessary equipment to accomplish foam finishing of fabric could be retrofitted to all pad/dry/cure finishing ranges used in the textile industry. Continuous dye ranges could also be retrofitted. However, beck dye ranges could not be retrofitted.

The foam finishing process is potentially applicable in all pad/dry/cure finishing ranges and all continuous dye ranges in the textile industry. There are approximately 3,100 finishing ranges and 300 continuous dyeing ranges in the U. S. textile industry. It is estimated that by 1980, 10% of the ranges would be equipped for foam finishing. By 1985, 25% should be equipped and 50% by 1990.

The research staff of United Merchants began, over four years ago, to investigate alternative methods for the processing of textiles with the major objective of reducing the energy content of textiles.

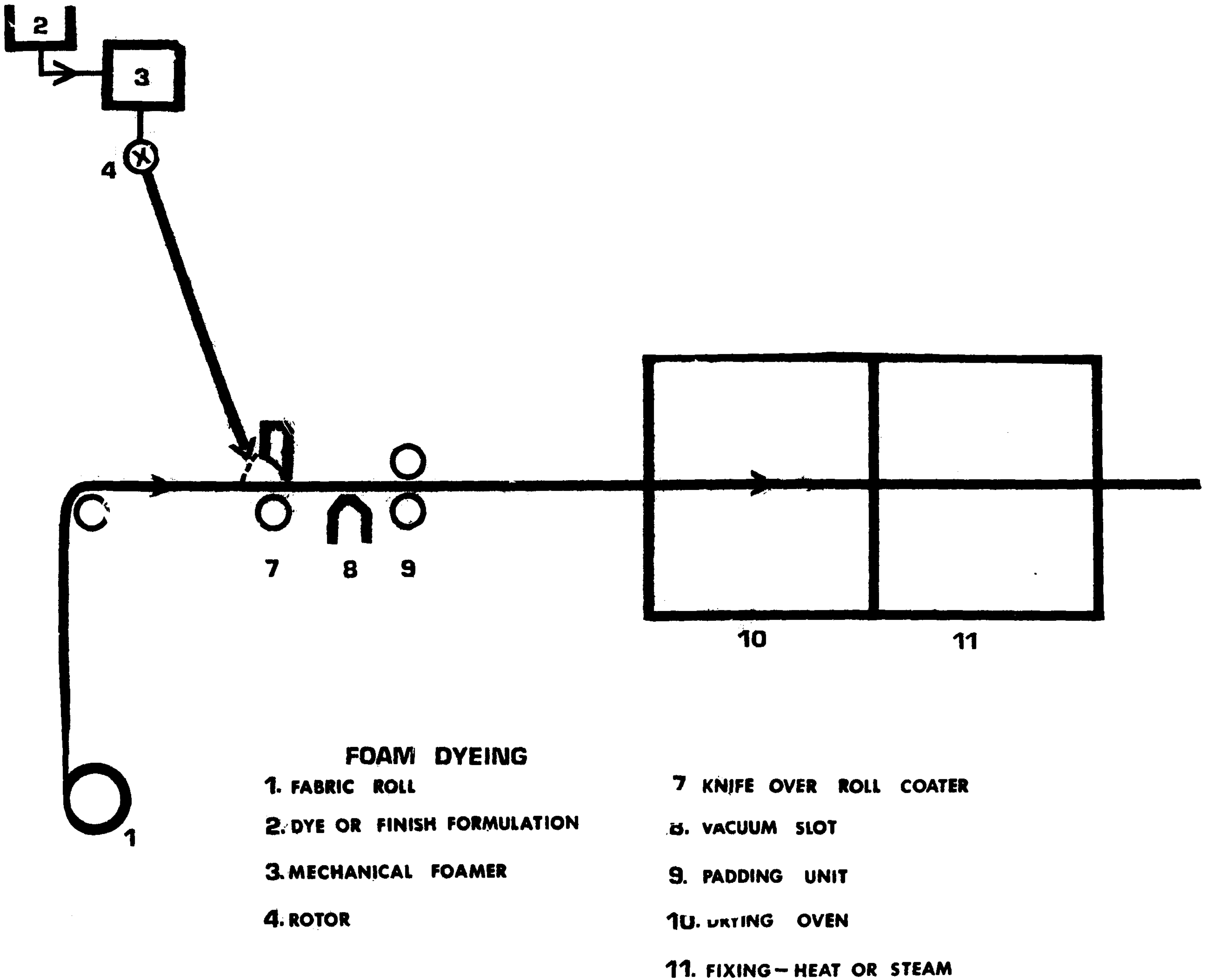
Water's primary role in textile processing is as a medium for uniformly applying chemicals to the fabric. The objective then was to find a low cost medium having a low heat of vaporization, low toxicity and with no disposal problems. A medium meeting these requirements is air and since under the conditions of use it is already gaseous, there is no heat required for vaporization.

Various techniques for using air as the medium were considered, as for example, powder or liquid sprays, however the method that would require least capital expenditure and least modification of in-place textile processing equipment is the use of foams where up to 75% of the water is replaced by air. Thus, depending on the particular processing step, by removing 75% of the water one simultaneously removes up to 75% of the energy content of the process.

The foam process, in essence, consists of preparing a concentrated solution (or dispersion) of the chemical or chemicals as, for example, a dyestuff in water (other dispersing media could also be used) and incorporation into the concentrate of suitable foaming aids. The concentrate is then mechanically foamed, the foam applied to a moving textile web by means of, for example, a knife over roll coater. The foam is then caused to collapse and flow over the fibers. This can be accomplished by passing the foam coated fabric through a pad mangle or through the use of a heat-sensitive foam which collapses when heated. The thus coated fabric is passed through a conventional oven to remove the small amount of water used in the concentrate and to fix the dye or finish on the fabric (see figure 1).

The main advantage of the process lies in the fact that the wet pickup by foam finishing and dyeing is usually less than half of that obtained by a traditional padding operation.

At United Merchants Research Center, present work is being partially funded under a contract with the U. S. Department of Energy.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FOAM DYEING
1. FABRIC ROLL
2. DYE OR FINISH FORMULATION
3. MECHANICAL FOAMER
4. ROTOR
7 KNIFE OVER ROLL COATER
8. VACUUM SLOT
9. PADDING UNIT
10. DRYING OVEN
11. FIXING – HEAT OR STEAM

Figure 1

Foam wet processing methods are currently being used by United Merchants plants for the application of various finishing agents such as resins and softeners to a variety of fabrics. The Valchem chemical division of United Merchants has introduced a group of finishing reagents which has been evaluated successfully at several plants. In all cases, reduction in energy consumption on the order of 30-50% has been reported.

In cases where the ability to drive off water was the rate-determining step, two-to-three-fold increases in production rates have been achieved when a foam finishing system was substituted for the traditional pad/dry/cure finishing system. The higher production rates naturally result in a significant reduction in the processing cost of the fabric.

We have had a number of in plant trials comparing foam finishing against the traditional pad/dry/cure finshings system. Below are some of the results of these trials.

<u>Dryer Data</u>

100% Cotton Flannel (4.2 oz/yd^2)
Softener only
One pass - Dry only

	Wet Pad	Foam
Finish %	68.4%	25%
Temperature F	345°/380°	260°/265°
Speed yds/min	60	107
% delta speed		78.3%
Btu/yd	423	92
Gas ft^3/yd	.409	.089
Gas Savings %		78.2%

50/50 Polyester/Cotton (6.6 oz/yd^2)
Shrinkage Control (less than 3%)
(Same finish as before)
Pad-Dry-Cure

	Wet Pad	Foam
Finish %	60%	30%
Temperature F	350°	250°
Speed yds/min	57	110
Cure	Same	Same
% delta Speed		92.9%
Btu/yd	2339	326
Gas Savings %		81.2%

50/50 Polyester Cotton (4.0 oz/yd^2)
DP/Shrinkage Control
Dry-Tenter Frame
Cure-Roller Cure Box
2 Component, In Series, One Step

	Wet Pad	Foam
Finish %	60%	30%
Temperature F	320°/350°/360°	320°/ 350°/360°
Speed yds/min	46	94.6
% delta Speed		105%
Btu/yd	1231	752
Gas Savings		39%

We have also had trials with durable press, water repellents, soil release, and flame retardent finishes on a number of fabrics.

The use of foams in other continuous wet processing operations, such as dyeing has also been evaluated. Acid, disperse, reactive, direct, vat, sulfur, pigment, and special effect dyes have all been applied via the foam technique.

For 39 oz/yd^2 carpeting, foam dyeing leads to a 60% energy savings over conventional dyeing. In the majority of cases, good to adequate crock fastness is obtained without an after-wash. An attendant benefit to foam dyeing over beck dyeing is the absence of spent dye liquor and after-wash liquor which must be disposed of in an enviromentally acceptable manner. Waste treatment facilities also consume energy in their operation, thus making the energy savings of foam dyeing even greater.

The utility of foam in dyeing fabric has been demonstrated on our pilot range with a variety of textile substrates. Particularly noteworthy is the ability to dye acrylic sliver knits by the foam process and yet retain the fur-like appearance. Normal wet processing completely wrecks the aesthetics of acrylic sliver knit fabric.

Foams have been used to dye cellulosic fabrics with direct reactive, naphthol, vat and sulfur dyes. In each case, good dyeings were achieved with wet pickups which range from 20% to 50%. In the case of direct dyes, good fastness was obtained without an afterwash.

The use of foams in printing has been intensively studied over the last couple of years. In commerical printing, the rheology of the print paste is primarily controlled by the nature and the amount of thickener used in the print pastes. In foam printing on the other hand, virtually no thickener is used in the system. Instead, the rheology of the print paste is controlled by the volume of air that is whipped into the print formulation and the size of the air bubbles in the foamed mix.

On a pilot plant scale, it has been demonstrated that foam print compositions can be printed on roller printers, rotary screen, and flat bed screens. In all cases, good print definitions were obtained even with fairly intricate patterns with pigment on commercial scale equipment with the results to date proving to be most gratifying.

Summary Reports & Project Recommendations

Textile Energy Management Systems	
Clarence Ressler	C. H. Masland & Sons
Preparation & Dyeing	
Doug Chambers	Springs Mills, Inc.
Textile Yarn & Fabric	
Ted Meyer	Riegel Textile Corp.
Finishing	
R. S. Gregorian	United Merchants & Manufacturers

Textile Energy Management Systems

Clarence Ressler
C. H. Masland and Sons

During our deliberations, our group covered five subjects. In some cases we may have overlapped with some of the other group's recommendations, but because of the importance of these subjects the group felt that they should be mentioned, figuring that duplication sometimes leads to attention.

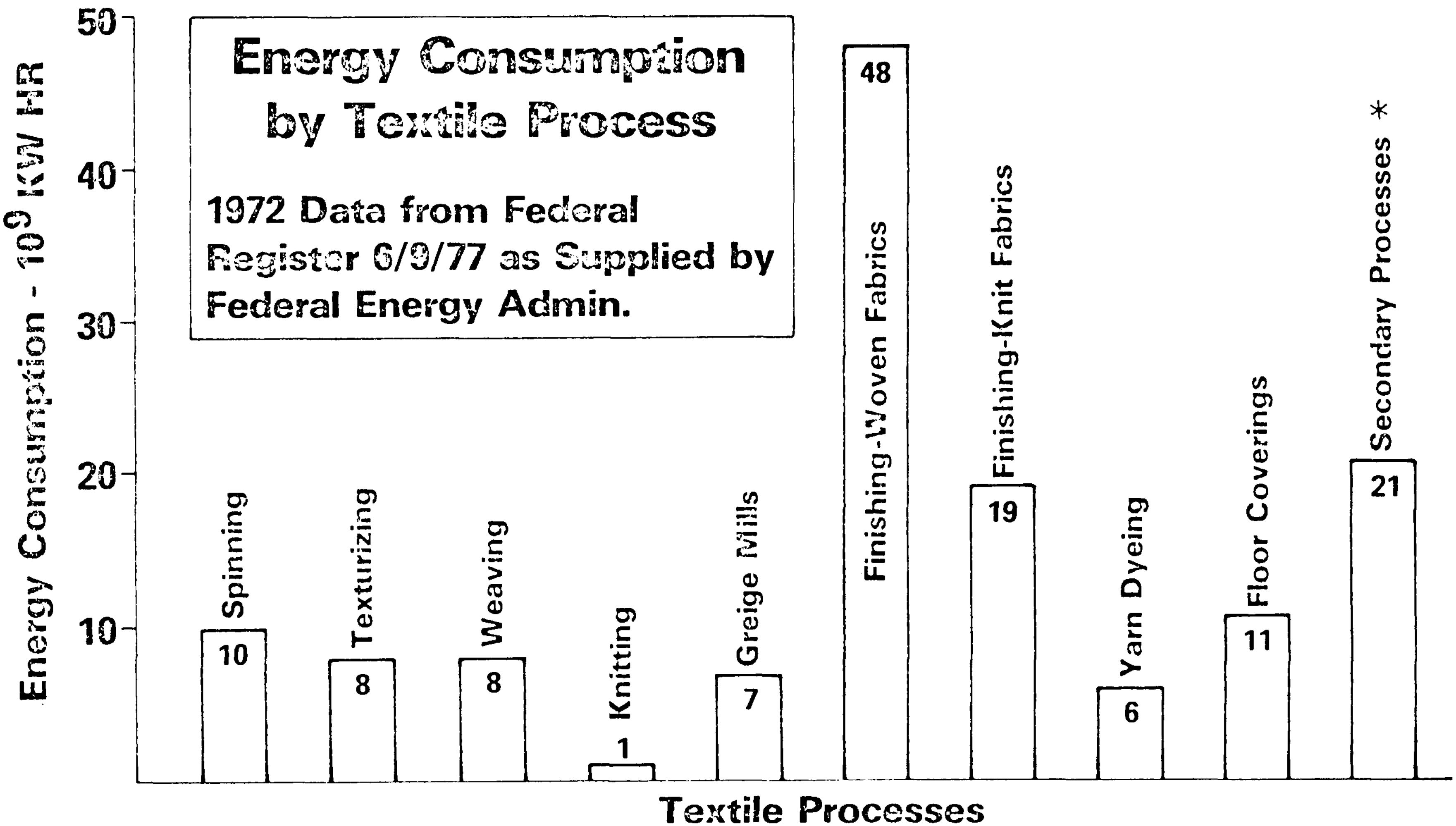
Since heat reclamation is an important subject in any discussion of energy management systems, the first project we considered was the development of an economical filtration system to maintain the efficiency of heat recovery units. This filtration system would be designed to filter contaminants and corrosives found in a textile mill. I am certain that most of you have heat recovery units in your mills and so you know the problems associated with maintaining them at maximum efficiency. The next project considered by the group was the development of co-generation systems to produce electricity and steam in the mill. Our third project concerned an energy analysis of all textile processes. The purpose of this project was to profile each process to identify poor efficiencies and to recommend solutions. We also submitted a project recommendation on the development of a package type coal burning boiler which would be economical. The boiler would operate in the range of 5,000 to 100,000 lbs. per hour. Since there is a possibility that coal is going to become our main boiler fuel, we felt that this is going to require a technical updating of this equipment. Our final project recommendation was on the improvement of drying technology. Drying is probably the biggest load on the energy consumption rate in the textile industry, thus we felt it deserves another look. I am sure that some of the other groups submitted similar project recommendations.

Our group had three other concerns which were not on our project forms, but which I would like to discuss. The first of these concerns dealt with two of the hand-outs (see pages 35 and 36). The members of the group felt that the data on energy consumption and energy losses is not correct. Several members, who had explicit knowledge in that field, felt that the hand-outs were completely in error. We hope that the information will not mislead the people at the Department of Energy into placing emphasis on the wrong projects.

Another problem which we discussed concerns the management of energy. The group felt that there was no reason to put forth a project on energy management via a computer since the hardware for controlling energy (electrical, steam or otherwise) is available on the market.

Further, each plant is different and therefore the equipment has to be designed to fit the needs of each plant. One project could not take care of everything.

Finally, the big item which we always get back to in energy management or control is the cost of the equipment. Today it is still hard for an engineer to get appropriations on equipment which does not have a 2 1/2 to 3 year payoff. I am certain that most of you will or have found that when you analyze energy control, your payoffs are in many cases much longer than that 2 1/2 to 3 year payoff period. We do not know how this can be done, but there has to be an education program for upper level management.



* Misc Woolen Fabric & Yarn, Felt Goods, Lace Goods, Womens Hosiery, Misc Knit Goods Not Included in Category Shown, Tire Cord & Fabric, Non Woven Fabrics, Cordage and Twine.

Textiles

Energy Consumption/Year .5 Quad

Key Processes:	Spinning Knitting Weaving	Preparation	Dyeing	Drying and Finishing	Total
Annual Energy Losses (Quads)		.192	.134	.042	.368

Key Programs Underway or Planned

- Textile Process Modifications
- Textile Drying Modifications
- Hyperfiltration Recovery of Hot Water, Dyes and Salts
- Foam Preparation Dyeing and Finishing

78-1370M/3-3

RECOMMENDATIONS - TEXTILE ENERGY MANAGEMENT SYSTEMS

Project 1. Heat Recovery System for Contaminated Exhaust

The objectives of this project are:

1. Develop an economical method of filtration of vapors and particulates from heat source to improve heat exchanger performance and to make them practical.

2. The filtration system should be cost effective.

3. The filtration system should aid in the recovery of reusable materials.

4. Cleaning the filtering device of condensed liquids and solids should be accomplished easily and with a minimum of downtime.

Project priority: high
Estimated energy conserved: 25% of the energy consumed by a dryer
Chance for industry implementation: good
Time frame for research: 2 yrs.; development: 1 yr.; demonstration: 1 yr.
Federal role for research: 100%; development: 75%; demonstration: 50%
Barriers to commercialization: practicability and cost

Project 2. Development of an Economical Co-Generation System

The objectives of this project are:

1. Develop economic and sizing guidelines for a system which would generate steam at 600 psig, generate electricity, and back pressure off the turbine at between 12[illegible] psig to 30 psig.

2. The system would operate at 150°F superheat.

3. There would be no condensing equipment for the system.

4. The system would generate 1500kw or 50,000 lbs/hr. of steam.

5. The equipment would have to be designed for cost effectiveness and compactness.

6. The system would have a price target of $100/kw (1977 dollars).

Project priority: high
Estimated energy conserved: 30% of the electric energy consumed by a textile mill
Chance for industry implementation: good
Time frame for development: 2 yrs.; demonstration: 2 yrs.
Cost of development: $1,000,000; demonstration: $500,000
Federal role in development: 50%; demonstration: 50%
Barriers to commercialization: system cost

Project 3. Energy Analysis of Textile Processes

This project would involve:

1. The identification of those areas in a textile mill which have high energy consumption levels.

2. Formulating energy profiles of those high energy use areas and analyze the application of the principles of the 2nd Law of Thermodynamics in terms of total mill efficiency.

3. Recommend approaches to achieving energy reduction.

Project priority: high
Chance for industry implementation: good if savings are appreciable
Time frame for research: 3-5 yrs.
Cost of research: 3 man years/yr.
Federal role: 100%

Project 4. Development of an Economical Coal Burning Boiler

The unit to be developed should have the following characteristics:

1. Package unit
2. Steam generation range: 5,000 to 100,000 lbs/hr.
3. Generate pressures ranging from 125 psig to 600 psig
4. Unit must meet EPA pollution requirements

A fresh look should be taken at technical design and cost data so that a system which is both cost effective and up to the current state-of the-art is designed.

Project priority: high
Estimated energy conserved: not applicable
Chance for industry implementation: good

Time frame for research: 1 yr.; development: 2 yrs.;
demonstration: 2 yrs.
Cost of research: 2 man yrs.; development: 10 man yrs./yr.;
demonstration: $3,500,000
Federal role for research: 100%; development: 100%;
demonstration: 75%
Barriers to commercialization: capital and operating costs

Project 5. Improvement of Drying Technology

This project would involve:

1. The optimization of dryer designs considering parameters of circulated air volume, temperature, exhaust volume, nozzle design, etc.

2. A survey of the state-of-the-art in sensing dew-point for exhaust control.

3. Design and develop a moisture content analyzer which would be able to function effectively in the operating environment of a textile mill.

Project priority: high
Estimated energy conserved: 20% of the energy consumed
in drying
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 2 yrs.;
demonstration: 1 yr.
Cost of research: 4 man yrs.; development: $250,000;
demonstration: $150,000
Federal role for research: 100%; development: 75%;
demonstration: 75%
Barriers to commercialization: reliability & maintenance

Preparation and Dyeing

Doug Chambers
Springs Mills, Inc.

During our deliberations, our group developed ten projects which were ranked in an order from 1 to 9 (we had two projects with a nine priority rating). In almost all of the projects, we are talking about new machinery which will enable us to scour, bleach, and dye more cost efficiently with concurrent savings in energy. Thus, capital costs are going to be a barrier which in some cases will be very difficult to overcome.

The project which we gave the highest priority to was on the development of low cost instrumentation to measure the moisture and humidity in a tenter frame. This type of device would enable the industry to make adjustments to equipment already installed to conserve energy. Our second project was on the development and demonstration of an exhaust gas incineration system for dryer and curer emissions. In this project, exhaust gases from dryers and curers would be piped to the boiler for incineration. The third project recommended by our group was on the development of Pad/Batch preparation and dyeing for synthetic and blend fabrics. Since Pad/Batch dyeing has already been demonstrated as an energy efficient dyeing method for cellulosic fabrics, we would like to see an extension of this method to other fabric types. Our fourth project was on a study to analyze and evaluate various scouring techniques to determine their efficiency and energy utilization. Other projects dealt with energy efficient moisture removal systems, cleaning exhaust emissions for heat recovery, direct application of process chemicals to fabrics, continuous dye systems, and sludge disposal.

Finally, I would like to say that we are encouraged at times by the efforts of the Department of Energy, but just as soon as we are encouraged, something happens in Washington to discourage us. Federal government decisions seem to be analogous to a prairie gopher in that it moves forward and backward with equal speed.

RECOMMENDATIONS - PREPARATION AND DYEING

Project 1. Development of Low Cost Instrumentation for Measurement of Moisture and Humidity

Based on current technology, there is a lack of accurate measurement and recording instrumentation for determining residual moisture content in fabrics following continuous drying processes. Consequently, fabrics are frequently overdryed, wasting valuable thermal energy. Previous studies have indicated a potential energy savings of at least 6% of the total drying energy consumed.

In addition, technology and necessary instrumentation are not available to measure humidity content in exhaust gases at high temperatures. The lack of this instrumentation results in large heat losses because of excessive flow of exhaust air.

Project priority: 1
Estimated energy conserved: .0025 quad
Chance for industry implementation: good
Time frame for research: 2 yrs.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $180,000; development: $90,000; demonstration: $90,000
Federal role for research: 85%; development: 85%; demonstration: 0%
Barriers to commercialization: limited potential market may be insufficient to offset development costs

Project 2. Exhaust Gas Incineration of Dryer and Curer Emissions

A feasibility study should be conducted and an evaluation made of the possible incineration of exhaust stack emissions from tenters, curers, and dryers via the plant boiler. The energy conserved is that amount over what is thought to be available under present techniques.

Project priority: 2
Estimated energy conserved: 1.1×10^{13} Btu's
Chance for industry implementation: good
Time frame for demonstration: 1 yr. (other phases not calculated)
Cost of demonstration: $250,000 (other phases not calculated)
Federal role for research: 100%; development: 100%; demonstration: 20%
Barriers to commercialization: possible boiler control performance

Project 3. Pad/Batch Preparation and Dyeing

The objective of this study is to markedly reduce the energy consumed in preparation and dyeing. The pad/batch method allows low temperature treatment and a more energy efficient means of preparing and dyeing fabric than do conventional processes. Feasibility of the concept has been demonstrated on cellulosics with energy savings up to 60% and water savings up to 90% reported over conventional cellulosic batch dyeing processes. This process, or a modification thereof, needs to be extended to synthetics and blends.

Project priority: 3
Estimated energy conserved: 10% of the annual energy loss in preparation and dyeing (.0326 quads)
Chance for industry implementation: fair
Time frame for research: 2 yrs.; development: 2 yrs.; demonstration: 1 yr.
Cost of research: $250,000; development: $250,000; demonstration: $500,000
Federal role for research: 80%; development: 60%; demonstration: 50%
Barriers to commercialization: the heavy capital investment already in place which would be displaced

Project 4. Energy Optimization in Textile Scouring

The object of this study is to evaluate the efficiency and energy utilization of various scouring processes. The study would include analyses of continuous, batch, counterflow, spray, foam and other innovative scouring techniques. The analysis would evaluate mechanical and chemical systems for scouring and determine methods for identifying the optimum end point for scouring. This would be a multi-phase project. Current technology on some phases could be demonstrated immediately. Other phases will require more research and development.

Project priority: 4
Estimated energy conserved: .0576 quad
Chance for industry implementation: good
Time frame for research: 2 yrs.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $500,000; development: $500,000; demonstration: $1,000,000
Federal role for research: 100%; development: 80%; demonstration: 60%

Project 5. Energy Efficient Moisture Removal Systems

A study should be made of all possible processes and combinations of processes by which moisture can be removed from materials at low or ambient temperatures. The moisture removal objectives for the following processes are:

Wet-on-wet processing	30% moisture content for 100% cotton 15% moisture content for polyester-cotton blends
Predrying operations	60% moisture content for 100% cotton 30% moisture content for polyester-cotton blends
Drying operations	10% moisture content for 100% cotton 5% moisture content for polyester-cotton blends

Some new or improved technologies which should be considered include: Machnozzels, microwave technology, ultrasonic technology, moisture removing rolls and felts (including new developments in moisture absorbing fiber systems i.e. "super slurppers").

Efficiencies of moisture removal over various ranges of moisture content should be evaluated. Combinations of technologies may be necessary to achieve stated objectives at a given moisture level. Systems for moisture removal must be compatible with current industry production rates and must take into account migration problems during predrying.

It is estimated that 25 to 35% of all energy demands in the textile industry are required for moisture removal operations.

Project priority: 5
Estimated energy conserved: 10% to 25% of the energy required for moisture removal (8.6×10^6 BOE)
Chance for industry implementation: good
Time frame for research: 2 yrs.; development 1 yr.; demonstration: 1 yr.
Cost of research: $200,000; development: $100,000; demonstration: $200,000
Federal role for research: 100%; development: 90%; demonstration: 50%
Barriers to commercialization: capital equipment costs

Project 6. Cleaning Exhaust Emissions from Dryers, Curers, Tenters for Optimum Heat Recovery

A study should be conducted to determine the most efficient as well as cost effective means of cleaning exhaust gas emissions from tenters, dryers, and curers in order to realize optimum heat recovery from such emissions.

Project priority: 6
Estimated energy conserved: 7.1×10^{12} Btu's
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $50,000; development: $50,000; demonstration: $200,000
Federal role for research: 100%; development: 100%; demonstration: 50%

Project 7. Direct Application of Process Chemicals to Fibers and Fabrics

Techniques should be developed for application of process chemicals to textile products with minimum use of liquid media. Such techniques would reduce or eliminate intermediate washing and drying steps (permit wet-on-wet processing) and would minimize energy requirements in final drying.

The following techniques may be promising:

1. Electrostatic deposition of dyes
2. Gaseous reactants in preparation (ozone, singlet oxygen, etc.)
3. Vapor phase reactants
4. Spray application of reactants
5. Machine development to reduce wet pick-up

These techniques must be capable of treating fiber and fabrics uniformly or in a controlled pattern to be adopted by the textile industry.

Project priority: 7
Estimated energy conserved: 10% of the total energy consumed in dyeing and finishing (4×10^{6} BOE)
Chance for industry implementation: fair
Time frame for research: 4 yrs.; development: 2 yrs.; demonstration: 1 yr.
Cost of research: $400,000; development: $200,000; demonstration: $200,000
Federal role for research: 100%; development: 80%; demonstration: 50%
Barriers to commercialization: capital equipment costs

Project 8. Development of Low-Energy Continuous Dye Systems

It has been documented that continuous dyeing requires less energy than batch dyeing processes (e.g. continuous dyeing of cellulose requires 20% of the energy required for batch dyeing). Presently, continuous dyeing is limited by the economic requirement that extremely long yardage of the same shade is necessary. Continuous dyeing can be made more universal if systems are developed for economical continuous dyeing of short yardages. Utilization of computer color measurement systems, which are already on-line, will optimize color control and substantially reduce the risk of failure on short runs. Development of computer color measurement systems for short yardages would be a part of this project.

Project priority: 8
Estimated energy conserved: 20% of the estimated energy losses in dyeing (.134 quads)
Chance for industry implementation: good
Time frame for research: 2 yrs.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $500,000; development: $500,000; demonstration: $1,000,000
Federal role for research: 80%; development: 65%; demonstration: 50%
Barriers to commercialization: capital investment for new equipment

Project 9. Disposal of Sludge from a Waste Treatment Plant via Incineration

An evaluation should be made of the disposal of sludge and mill wastes by incineration. A waste heat boiler would be utilized in this scheme to produce steam for process heat.

Project priority: 9
Estimated energy conserved: 1.4 x 10^{12} Btu's
Chance for industry implementation: fair
Time frame for development: 2 yrs.; demonstration: not calculated
Federal role for development: 100%; demonstration: 20%
Barriers to commercialization: initial cost, handling, and municipal laws

Project 10. Disposal of Sludge from a Waste Treatment Plant by Anerobic Digestion

An evaluation should be conducted of the generation of methane from waste and sludge outputs of textile mills. Pelletizing solid fuel from the remaining waste products would be examined.

Project priority: 9
Estimated energy conserved: 1.5 x 10^{12} Btu's
Chance for industry implementation: fair
Time frame for development: 2 yrs.; demonstration: not calculated
Cost of development: not calculated; demonstration: $500,000
Federal role for development: 100%; demonstration: 100%
Barriers to commercialization: initial cost, handling, and municipal laws

Textile Yarn and Fabric

Ted Meyer
Riegel Textile Corporation

Our discussions were oriented around yarn processing. As you know the Department of Energy does not have research and development projects in this area. But when you take processes such as yarn spinning, preparation and weaving all together, there is a tremendous amount of energy being consumed. When you examine this sector of the textile industry, you find that there is a great deal of equipment that is in the mill which has been there for quite some time. The design and purchase criteria for this equipment was "how little can you spend and how fast will it run". This, of course, was back in the days when you paid a half a mill for the last kilowatt hour. Now the last kilowatt hour is three times that price. Thus, we feel that there is a great need to look at the machinery we have in the mill.

I would like to briefly discuss some of the projects our group developed. One of the first things we thought ought to be addressed was a state-of-the-art review of the literature on energy consumption and conservation in textile manufacturing. When we started discussing various pieces of equipment one of the questions we asked was what amount of energy it consumed. Incidentally, in this area you are really only talking about electrical energy with the exception of slashing. We think there is quite a bit of literature which is available which many of us are not aware of. Thus, we would like to see a state-of-the-art review done.

A second project which we feel is a high priority item is the development of instrumentation and techniques for measuring the performance of various pieces of equipment (i.e. looms, etc.). Studies are also needed on energy conservation in weaving, texturizing, yarn forming and preparation. The objective of these projects would be to identify the main energy consuming mechanism in each process. Once the major energy sinks are identified the focus of the project would be switched to increasing energy efficiency.

Our group also suggested projects in low energy sizing, which would include studies of foam and dry sizing, a training program for mechanics and fixers to be more energy conscious and energy oriented.

Other projects include: electrostatic waste removal, development of a computer model of energy requirements, a study of the possibility of saving energy via improved lubricants and better lubrication techniques, and optimizing power requirements for air-conditioning in Greige mills. Regarding this latter project, we figured that at least 25-30% of all energy consumed in a Greige mill is consumed in air-conditioning and air handling. We feel that this is an area which needs further study.

Our final recommendations were two projects which have implications in the long range: tuft-to-yarn manufacturing and electrostatic spinning. Based on all of these recommendations we formulated a program outline which we suggest the Department of Energy follow in an R&D program on yarn and fabric processing (see below).

Finally, I would like to express my appreciation to the members of the group. It was a privilege working with them.

Suggested Structure for research projects proposed by the Textile Yarn and Fabric group:

I. State-of-the-art literature review

II. Characterize energy components of textile machinery

- A. Identify parameters to be monitored
- B. Develop measuring techniques and instrumentation

III. Conduct research in energy consumption and conservation in textile manufacturing and engineering

- A. Manufacturing
    1. Texturing
    2. Spinning
    3. Preparation
    4. Weaving
    5. Knitting
    6. Non-woven mfg.
    7. Tufting

- B. Engineering
    1. Evaluate and improve drive train efficiency
    2. Evaluate machine lubrication effectiveness
    3. Optimize machinery for energy efficiency
    4. Evaluate textile machinery motor efficiency

IV. Train Maintenace and operating personnel in energy effectiveness

V. Evaluate and optimize air-conditioning and handling requirements

- A. Level out demand

VI. Develop interactive computer model

VII. Develop energy-effective process innovations

A. Tuft-to-yarn mfg.
B. Electrostatic processing
C. Low-energy sizing methods
D. Electrostatic dust, waste and trash removal

RECOMMENDATIONS - TEXTILE YARN AND FABRIC

Project 1. State-of-the-Art Review of the Literature on Energy Consumption and Conservation in Textile Manufacturing

A comprehensive review should be conducted of the international literature on the consumption and conservation of energy in the manufacture of all textile products. The review will establish a data base, identify technology which can be implemented, and will indicate areas where research can be applied in a cost-effective manner.

Project priority: high
Estimated energy conserved: 10% of 25 x 10^9kWh
Chance for industry implementation: good
Time frame: 1 yr.
Federal role: 100%
Possible barriers to commercialization: the review needs to be prepared in a form which will be meaningful to persons on the operational level

Project 2. Development of Accurate Power Measurement Techniques and Equipment

Industry's efforts to measure the energy consumed by various operations, so that conservation steps can be taken, have met with the realization that the techniques and instrumentation needed to make these measurements is not available "off the shelf". All conservation projects will need appropriate instrumentation in order to be able to measure and document consumption and conservation.

An example of an instrument which is needed for loom studies is one which can measure electrical consumption of a 550 volt, 3 ϕ motor to an accuracy of $\pm$ 1%. The load is known to cycle between, for example, one and three kiloWatts some 5 to 10 times per second. The instrument would have to be able to operate in the dirty, vibrating atmosphere of a weave room.

Also, industry would like to be able to continuously monitor some energy-related property on equipment so that "bad actors" could be identified and corrected. This equipment would have to be relatively simple and inexpensive.

Objectives of the Project:

1. Determine the best methods for the textile industry to determine the energy, especially electrical energy, consumed by the various pieces of processing equipment.

2. Develop the necessary equipment and instrumentation for making these determinations accurately.

3. Provide industry with instructional information on how to: use the instrumentation, conduct surveys, analyze data, and take appropriate steps toward energy conservation.

Project priority: medium
Estimated energy conserved: no energy conserved directly, but completion of this project would enable other projects to be successful
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $50,000; development: $150,000; demonstration: $50,000
Federal role for research: 100%; development: 100%; demonstration: 100%
Barriers to commercialization: instrumentation cost

Project 3. Energy Consumption and Conservation in Weaving

Objectives of the Project:

1. Develop techniques for measuring and monitoring the energy consumption and instantaneous power input to loom motors.

2. Determine the main areas of energy dissipation for various types of looms and relate this to loom conditions such as setting and maintenance. Preliminary investigations showed that loom timing, frequency of lubrication and type of grease are very important factors affecting power consumption. Emphasis will also be on comparing shuttle and shuttleless looms.

3. Optimize the loom timing for minimum energy consumption.

4. Recommend modifications leading to a reduction in energy consumption in specific types of looms.

5. Determine the effects of changes in fabric construction on energy consumption to enable better estimations of the cost of energy per square yard of fabric.

Instrumentation for separating out the energy requirements for each of the loom motions should be provided. This will then serve as a base for determining the effect of mechanical modification of the loom design and the effect of interactions between the various loom motions on total energy requirements.

Project priority: medium
Estimated energy conserved: 0.8 x 10^9 kWh/yr.
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 1 yr
Cost of research: $60,000; development: $60,000; demonstration: $60,000
Federal role for research: 100%; development: 100%; demonstration: 100%

Project 4. Energy Conservation in Texturing

The main objective of this program is to investigate energy saving techniques applicable to texturing. A survey should be first made of what are considered to be the major energy sinks in the texturing process to determine the areas for rigorous analysis and investigation. Once the best targets for improvement are identified, the emphasis would be switched to increasing energy efficiency through machine redesign and determining optimum operating conditions.

Project priority: medium
Estimated energy conserved: 1.8 x 10^9 kWh/yr.
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $50,000; development: $80,000; demonstration: $80,000
Federal role for research: 100%; development: 100%; demonstration: 100%

Project 5. Energy Conservation in Spun Yarn Forming and Yarn Preparation

The objective of this project is to identify the main energy consuming mechanisms in each process in spun yarn forming systems and in yarn preparation. Once the major energy sinks are identified efforts should be switched to increasing energy efficiency through optimizing operating conditions and machine redesign. Processes to be investigated should include: opening and picking, carding, drawing, roving, ring spinning, open end spinning, winding, twisting, and warping.

Project priority: high
Estimated energy conserved: 2×10^9 kWh/yr.
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $60,000; development: $70,000; demonstration: $100,000
Federal role for research: 100%; development: 100%; demonstration: 90%

Project 6. Low Energy Sizing

A method of sizing warp yarn in preparation for weaving which does not require a large amount of energy for drying should be identified, developed and evaluated. This process would have to produce results which are at least equal to the quality of the state-of-the-art method of applying sizing materials.

Project priority: high
Estimated energy conserved: 4×10^9 kWh/yr.
Chance for industry implementation: good
Time frame for research: 2 yrs.; development: 3 yrs.; demonstration: 2 yrs.
Cost of research: $250,000; development: $500,000; demonstration: $300,000
Federal role for research: 100%; development: 100%; demonstration: 80%
Possible barriers to commercialization: process acceptability

Project 7. Development of a Curriculum for the Training of Fixers and Changers which is Fabric Style Oriented

Based on the assumption that energy requirements for a loom increase as loom settings change with wear, the objective of this project is to produce a curriculum for instructors and trainees (fixers and changers) sufficient for a base of 300,000 on a cooperative basis. This type of project could be handled by an industry trade association or a state education department.

Project priority: high
Chance for industry implementation: good
Time frame for development: 2 yrs; demonstration: 1 yr.
Cost of development: $100,000; demonstration: $537,000
Federal role for development: 100%; demonstration: 80%

Project 8. Electrostatic Waste Removal

An electrostatic method for cleaning the dust and trash from under the carding machine should be developed, demonstrated, and evaluated. Electrostatic waste removal could replace the present energy consuming method of air cleaning. Once developed, this technique could be extended to other areas presently cleaned by suction and air jets.

Project priority: high
Cost of development: $85,000; demonstration: $15,000

Project 9. Development of an Interactive Computer Model of Energy Requirements for Manufacturing Textile Products

A computer based model of energy requirements of various textile processes should be developed that could be easily adapted to each company's needs and computing facilities. This would provide immediate information on energy requirements and allow comparisons between alternate manufacturing methods. It would allow the company to identify the true energy requirements of its products and use this information in costing, industrial engineering, etc.

Project priority: medium
Estimated energy conserved: 10^7 kWh/yr.
Chance for industry implementation: good
Time frame for research: 1/2 yr.; development: 1 yr.; demonstration: 1/2 yr.
Cost of research: $25,000; developmemt: $50,000; demonstration: $25,000
Federal role: 100% all phases

Project 10. Optimization of Power Requirements for Air-Conditioning in Greige Mills

Greige mills consume approximately 18 x 10^9kWh annually. Approximately 25% of this or 4.5 x 10^9kWh annually is required for air-conditioning. New standards for clean air and work required to meet existing standards and comfort requirements will necessitate additional power demands. Many existing systems were designed and installed when power costs were lower and did not involve peak pricing schemes. It is proposed that a demonstration project be initiated to study the power demand to air-condition an existing mill as it is built and operated today versus the power required to air-condition the plant under optimum conditions. That is, properly maintained equipment, minimum air movement for the level of plant operations, properly sized motors, properly sized and maintained filters, and any other appropriate parameters. A 5% reduction in power is not unlikely. The parameters to be included in the study are: enthalpy controls, low leakage dampers, automatic chiller tube cleaning, optimum cooling tower operations, and optimum refrigerants.

Project priority: high
Estimated energy conserved: 675 x 10^6kWh/yr.
Chance for industry implementation: good
Time frame for demonstration: 1 yr.
Cost of demonstration: $250,000
Federal role: 75%
Barriers to commercialization: the dissemination of information

Project 11. Determination of the Contribution of Lubricants to Energy Conservation

In the textile industry, lubricants are usually purchased at the whim of the individual plant management with little thought being given to cost, wear protection, and salesman pressure. Little thought, if any, is ever given to how a lubricant choice can affect energy consumption. Lubricant suppliers are generally unable to recommend products which will minimize power consumption.

Laboratory test methods are needed which would simulate actual textile equipment so that lubricants could be evaluated accurately. Finally, a list of products which are found to be preferred in respect to energy conservation could be made and circulated.

Objectives of the project:

1. Develop methods for evaluating the effects of various lubricants on energy consumption levels of textile equipment.

2. Determine the lubricant properties which relate most to energy consumption.

3. Recommend the best lubricants for the various textile processes with the goal of energy conservation in mind.

Project priority: medium
Estimated energy conserved: 5% of the energy consumed by the textile industry
Chance for industry implementation: fair
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 1 yr.

Cost of research: $50,000; development: $100,000; demonstration: $50,000
Federal role for research: 100%; development: 100%; demonstration: 80%
Barriers to commericalization: resistance of industry to change from known to unknown product for the purpose of saving energy

Project 12. SRRC - Tuft to Yarn System

Research and development should be conducted into the tuft to yarn system developed by the Southern Regional Research Center as an alternate yarn producing system which is highly energy conservative. The present experimental mode for energy consumption as compared to present open end spinning systems should be evaluated. An engineering prototype should be developed to demonstrate the system and its potential as a viable candidate for commercialization.

Project priority: high
Time frame for research: 3 yrs.; development: 2 yrs.; demonstration: 1 yr.
Barriers to commercialization: overall system would be a revolutionary change in yarn production. Phases of the system could be introduced into present processing lines.

Project 13. SRRC - Electrostatic Spinning

The SRRC electrostatic spinner should be developed and demonstrated as a low energy method for the production of yarn. At present the concept of electrostatic spinning has been proven and experimental units should be developed and evaluated with a special emphasis on energy requirements. Development would be directed to the adaptation of electrostatic spinners to present feed systems for yarn production.

Project priority: medium
Estimated energy conserved: 30% of the energy consumed by present spinning equipment
Chance for industry implementation: good
Time frame for research: 3 yrs.; development: 2 yrs.; demonstration: 1 yr.
Barriers to commercialization: life or present spinning equipment

Finishing

R. S. Gregorian
United Merchants and Manufacturers

I would like to begin by thanking all the panel members for a very productive session. I would like to particularly thank David Brookstein from the School of Textile Engineering at Georgia Tech for his contribution. We recommended 14 projects which were categorized into four priority ratings. Four projects received a high rating, seven received a medium priority rating, two received a low rating and one received a very low rating.

First, I would like to discuss those projects which received our top priority rating. One of these projects is on low temperature curing. The project concept is to examine and develop systems which would reduce the curing temperature requirements in tenter frames. Our second project is on the optimization of drying techniques for existing equipment and is really an extension of the Department of Energy's project at Clemson University. Work on this project should be extended to include evaluation of other pieces of equipment besides tenter frame dryers. The third project with a high project priority rating is the development of metering techniques for finishes. This is an extension of the foam dyeing project which we are carrying out in conjunction with the Department of Energy. The objective of this project would be the development of methods for metering the amounts of finish applied to a fabric substrate. By limiting the amount of water that is initially applied, we reduce the quantity of water to be evaporated at the end of the process. Our fourth project, having a high priority rating, was on improved techniques for pollutant incineration. This project is in anticipation of a need rather than a current problem and focuses on the problem of "blue haze", particulate matter in the exhaust gases from the frames. In order to eliminate "blue haze" emissions, it is felt that enormous amounts of energy would have to be utilized for incineration. It is proposed that techniques be devised to recover this heat and put it to effective use in the mill.

In our projects given medium priority, I would like to discuss several which are of interest. First, there is a project recommendation on the utilization of flue gas which A. C. Edwards of Cone Mills will discuss.

Mr. Edwards: This proposal on flue gas utilization is based on the fact that nobody has ever done anything with flue gases except to use economizers. About 10% of the energy from boilers and burners goes up the stack and is not utilized because of its corrosive content. A design is being worked on to utilize the stack gas from a textile finishing plant. This flue gas has a pH of about 11-12. Some of the effluents include: H_2O_2, C_2, SO_2, H_2SO_4, etc. This flue gas can be utilized to neutralize the acidic waste effluents from the factory. At the same time, the heat reclaimed from the flue gas can be used to heat or pre-heat process water for the finishing plant. Thus, with this approach you are looking towards the solution of two sets of problems.

Dr. Gregorian: The next project concerned the development of sizes which would minimize the "blue haze" incineration problem. We also felt that aspects in new size development would include the removal of sizes at lower temperatures, and possibly the development of permanent sizes which would not have to be removed after weaving and could possibly contribute something toward the end product. Another area which we discussed was the use of the Machnozzel. Dr. Brookstein with Georgia Tech will elaborate on that subject.

Dr. Brookstein: The Machnozzel has all the prospects of being a remarkable low energy means to achieve a low moisture content in a piece of fabric for the final drying stages. Georgia Tech has now received a laboratory scale Machnozzel. We think that work should be done to examine the uses of the Machnozzel, optimizing those uses and determining what energy savings will result.

Dr. Gregorian: One final item which I would like to mention is radiation curing. We recognize that the development of this concept would probably translate into very expensive capital equipment. But in terms of energy savings it is, perhaps, the ultimate in low temperature curing operations and energy efficiency.

RECOMMENDATIONS - FINISHING

Project 1. Low Temperature Curing

The feasibility of curing at low temperatures without affecting production speeds should be investigated. Initial feasibility studies should investigate: hot catalyst curing, microwave curing, curing via chemical reactants, radiation curing, etc. Development and demonstration should be conducted on those techniques which show the most promise.

Project priority: high
Estimated energy conserved: 0.6 - 0.8 x 10^6 BOE/yr.
Chance for industry implementation: good
Time frame for research: 2 yrs.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $320,000; development: $160,000; demonstration: $100,000
Federal role for research: 75%; development: 75%; demonstration: 50%

Project 2. Optimization of Drying Techniques

The purpose of this project is to develop optimization techniques for textile drying equipment which is already in place in textile mills. Variables such as fabric type, production speed, fabric density, temperature levels, exhaust rates, etc. would all be evaluated and analyzed. This project would be an extension of the optimization work being done on tenter frames by Clemson University for the Department of Energy.

Project priority: high
Estimated energy conserved: 2.5 - 5 x 10^6 BOE/yr.
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $75,000; development: $75,000; demonstration: $75,000
Federal role for research: 95%; development: 95%; demonstration: 95%

Project 3. Application of Metering Techniques for Finishing Agents

Methods and techniques should be developed for metering the application of concentrated finishing agents so as to minimize the wet pick-up of the carrying agent. Development of a technique would reduce the energy requirements for removal of the carrying agent. Metering methods which might be developed include: foaming, spraying, kiss rolls, engraved rolls, and transfer rollers.

Project priority: high
Estimated energy conserved: 2.25 - 3 x 10^6 BOE/yr.
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 2 yrs.; demonstration: 1 yr.
Cost of research: $80,000; development: $400,000; demonstration: $100,000
Federal role for research: 75%; development: 75%; demonstration: 50%

Project 4. Development of Improved Techniques for Exhaust Incineration from Drying and Curing Operations

Current techniques of heat recovery and exhaust gas incineration from tenter frames, curers and finishing ranges are unsatisfactory. Heat exchangers are ineffective because of resin build-up from the exhaust gas, and incineration of the exhaust gas reduces hydrocarbon emissions but is not energy efficient. Improved techniques should be developed so that energy losses as well as hydrocarbon emissions can be minimized.

Project priority: high
Estimated energy conserved: 1.2 x 10^6 BOE/yr.
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 2 yrs.
Cost of research: $500,000; development: $500,000; demonstration: $500,000
Federal role for research: 100%; development: 75%; demonstration: 50%
Barriers to commericalization: capital cost

Project 5. Effluent Neutralization via Use of Flue Gases

An investigation should be initiated into the use of flue gases from the boiler and burners to neutralize acidic effluents from a textile finishing plant. The thermal energy of the flue gases would be transferred via a heat exchanger to the effluent stream. Both the system and the concept are not available at this time.

Project priority: medium
Estimated energy conserved: 0.4 x 10^6 BOE/yr.
Chance for industry implementation: good
Time frame for research: 2 yrs.; development: 2 yrs.; demonstration: 2 yrs.

Cost of research: $500,000; development: $500,000;
demonstration: $1,500,000
Federal role for research: 100%; development: 75%;
demonstration: 50%
Barriers to commercialization: capital costs, materials,
and maintenance

Project 6. New Size Development

Research and development into sizing should look into the following areas:

1) The development of sizes not requiring blue haze incineration.

2) Removal of sizes at lower temperatures or with alkalies.

3) Permanent size development (i.e. to be kept on the fiber throughout processing).

Project priority: medium
Estimated energy conserved: 1200-1600 Btu/lb.
Chance for industry implementation: good
Time frame for research: 3 yrs.; development: 1-2 yrs.

Project 7. Comparative Study of the Machnozzle

This study would compare the performance of the Machnozzle to other methods of mechanical moisture removal in the preparation and finishing of fabrics. Determination would be made as to the flexibility of using the Machnozzle in finishing operations and would compare the Machnozzle to other drying methods.

Project priority: medium
Estimated energy conserved: $2.5 - 3.5 \times 10^6$ BOE/yr.
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.;
demonstration: 1 yr.
Cost of research: $50,000; development: $25,000;
demonstration: $25,000
Federal role for research: 100%; development: 100%;
demonstration: 50%

Project 8. Radiation Curing

Research and development into methods for radiation curing should be initiated. The objective of this project would be the development and application of radiation curing systems for the textile industry. This project would examine various radiation processes as well as radiation curable chemicals.

Project priority: medium
Estimated energy conserved: 9×10^6 BOE/yr.
Chance for industry implementation: good
Time frame for research: 2 yrs.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $170,000; development: $800,000; demonstration: $800,000
Federal role for research: 80%; development: 65%; demonstration: 55%
Barriers to commercialization: capital cost

Project 9. Systems Analysis of a Finishing Plant

The purpose of this project is to identify unnecessary processing steps in a finishing plant. It is also expected that this study would also assist in making better use of heat recovery using closed-loop systems. The methodology of the project would be to utilize a systems approach to analyze the various processing steps in a finishing plant.

Project priority: medium
Chance for industry implementation: good
Cost of research: $100,000

Project 10. Development of New Bleaching Technology

A study should be instituted to examine a non-peroxide approach to bleaching which would enable fabrics to be bleached without the requirement of hot water or steam. An important criterion to the successful adoption of non-peroxide bleaching would be the ability to maintain operation speeds used in peroxide bleaching.

Project priority: medium
Estimated energy conserved: 0.46×10^6 BOE/yr.
Chance for industry implementation: good
Time frame for research: 1 yr.; development: 1 yr.; demonstration: 1 yr.
Cost of research: $150,000; development: $100,000; demonstration: $100,000
Federal role for research: 70%; development: 60%; demonstration: 50%

Project 11. Use of Alternative Fuels in Finishing

A study should be begun to examine the feasibility of using alternate fuels for the finishing process. This study would look into the use of fluidized bed combustors, direct heating using filters to screen off impurities from combustion, etc. Evaluations would be made as to the effect of the combustion gases on the quality of various fabrics.

Project priority: medium

Project 12. Microwave and Dielectric Heating

The feasibility of coupling microwave or dielectric heating with metered finishes should be investigated if development and demonstration of metering techniques is successful.

Project priority: low

Project 13. Modification of Steam Can Technology

An investigation should be made into the use of hot, clean waste water from rinsing operations to predry fabrics via a water can prior to steam can drying.

Project priority: low

Project 14. Flame Curing Finishes

An investigation should be made into the use of flammable carriers of finishes which have flame temperatures which are lower than the softening temperature of substrate but have flame temperatures high enough to cure.

Project priority: very low

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