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**THE DOE
INDUSTRIAL ENERGY
CONSERVATION PROGRAM**

**RESEARCH AND
DEVELOPMENT IN
THE TEXTILE INDUSTRY**

JUNE 1987

U.S. Department of Energy
Assistant Secretary, Conservation
and Renewable Energy
Office of Industrial Programs
Washington, DC 20585

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OVERVIEW

The U.S. industrial sector is both the world's largest and one of the world's most competitive industrial sectors. The strength of research and development (R&D) in this country is one among many contributing factors in achieving this distinction. R&D activities have been a major factor in continuing change for increased productivity in industrial practices.

Historically, R&D activities have been carried out by both private and public sectors. Federal funding has been made available to develop and promote new technical and scientific advancements in various disciplines. As a part of this effort, the U.S. Department of Energy, Office of Industrial Programs (IP) has managed numerous high-risk and potentially high pay-off R&D efforts to help improve U.S. industry's efficiency and competitive position relative to other competing countries.

Since its inception, IP has supported over two hundred R&D projects covering a wide range of industrial production processes. These projects have addressed both generic, wide-application technologies and technologies that are applicable to a particular industry. Many of these activities have successfully resolved existing technical problems and/or addressed previously unknown or unaddressed opportunities in industrial energy conservation.

Included in the portfolio of IP's projects are the R&D activities for several advanced technologies targeted at the textile industry, one of the top ten energy intensive industries in the country. These R&D projects have primarily been aimed at improving the energy efficiency and productivity of textile production processes. Many projects in this area have been successfully completed, and some have resulted in the development and implementation of new technologies (e.g., foam processing) for various process steps. Other projects have produced technical results that have later been utilized by the industry in other capacities (e.g., hyperfiltration). Several projects at various stages of development are currently underway.

This brochure describes the Office of Industrial Programs' R&D activities relevant to the textile industry. It is designed to serve as a tool in aiding the transfer of R&D results to those private sector parties interested in federal industrial energy conservation activities, specifically for the textile industry. The brochure is comprised of the following sections.

Industry Update. Presents a concise summary of the present status of the textile industry.

Energy Consumption in the Textile Industry. Provides an overview of the textile industry's energy consumption in 1985.

Potential Energy Savings in the Textile Industry. Discusses recent energy conservation gains and potential for future energy conservation by the industry through the use of advanced technologies.

Office of Industrial Programs, R&D Efforts. Describes some of the R&D projects conducted by the Office of Industrial Programs that address the needs of the textile industry.

R&D Data Base. Contains names of the contractor, the principal investigator, and the contractor location for each textile-related R&D effort sponsored by IP.

INDUSTRY UPDATE

Textile industry process steps consist of activities that transform raw materials such as cotton, wool, and synthetic fibers into yarn and finished fabrics. Primary products of textile mills are the fabrics that other industries convert into apparel or household products, the most notable being floor coverings (carpets and rugs), or into commercial or industrial products. Exhibit 1 depicts the major process steps in the textile industry, from fiber production through the final stage, consumer end use.

EXHIBIT 1. MAJOR PROCESS STEPS IN THE TEXTILE INDUSTRY

The United States' textile industry is primarily centered in the Southeast, and consists of both large, fully-integrated companies and small (often family owned) plants that perform only a few process operations. Many textile mills are the primary employers in their communities. Facilities are scattered, and many of the plants were built during the development of the industry in the early 1900's.

Textile manufacturing consists of numerous production steps, making the industry highly labor-intensive. In the United States, this industry accounts for one out of every eight manufacturing jobs and is the largest industrial employer. However, over the past decade, new market developments such as increasing imports and adoption of technical innovations have impacted the industry significantly. For example, the share of imports in the total value of shipments doubled between 1974 and 1986. Technical innovations have increased productivity on the average by nearly 4 percent per year between 1976 and 1985, enabling the industry to reduce employment by 23 percent. Exhibit 2 presents selected industry data for the years 1974 through 1986.

EXHIBIT 2. SELECTED TEXTILE INDUSTRY DATA

	<u>Total Shipments</u>	<u>Imports</u>	<u>New Capital Expenditures</u> (millions of dollars)	<u>Employment</u> (thousands)	<u>Productivity Index</u> (1977 = 100)
1974	32,791	1,752	1,060	965	78.3
1975	31,065	1,336	860	868	82.5
1976	36,387	1,791	980	919	87.8
1977	40,558	1,939	1,180	910	100.0
1978	42,324	2,400	1,310	899	102.4
1979	45,141	2,399	1,420	885	105.8
1980	47,280	2,676	1,540	848	106.8
1981	50,275	3,250	1,660	823	110.3
1982	47,159	3,000	1,460	749	121.9
1983	52,203	3,460	1,550	741	125.3
1984	55,054	4,874	1,920	746	128.0
1985	52,617	5,274	1,840	704	129.1
1986	54,528	6,151	1,630	709	n.a.

Source: ATMI Hi-Lites, December 1985

n.a.: not available

Recently, the U.S. textile industry has been modernizing its production equipment in response to increasing international competition. Over the past decade, new capital expenditures have been climbing fairly steadily. Between the years 1975 and 1985, the ratio of new capital expenditures to the total value of shipments increased from 2.7 percent to 3.5 percent. Exhibit 2 highlights recent information on the new capital expenditures and productivity of the U.S. textile industry.

Total mill fiber consumption, an approximate indicator of actual production, did not grow by any appreciable amount during the last decade (See Exhibit 3). This has occurred during a period of growing market demand and indicates a shrinking role for the U.S. textile industry. Furthermore, the weak growth of total mill fiber consumption is indicative of net losses in the U.S. textile industry's market share in both the domestic and world textile markets. The shifts and changes in the share of the three major fiber types (cotton, wool, synthetic) shown in Exhibit 3 are primarily attributed to market demand and consumer preference.

Source: ATMI Hi-Lites, December 1985

EXHIBIT 3. CHANGES IN THE SHARE OF FIBER TYPES USED BY THE INDUSTRY

Numerous changes in technology have been implemented in the U.S. textile industry over the past several decades, changes that have influenced production parameters such as employment levels, productivity, and trade patterns. More specifically, new technology has increased production efficiency and enabled textile manufacturers to produce new and more sophisticated products. Furthermore, the technological changes have encouraged the competitiveness of innovative firms and in general have helped the textile industry to improve product quality and reduce labor requirements. Other changes in textile industry practices have been attributed to a major strategy change in the production pattern recently instituted by several large producers in the industry. These producers have decided to operate with fewer product lines and are specializing in fewer products. This strategy was accomplished by selling off the peripheral production or less profitable lines.

INDUSTRY ENERGY CONSUMPTION

The textile industry (SIC 22) is among the top ten energy consuming industries in the U.S. Its 1985 energy consumption was 0.43 quads (1 quad = 10^{15} Btu), just under 2 percent of the total energy consumed by all U.S. manufacturing industries. However, energy consumption and management are more critical for the textile industry because energy costs are a higher percentage of total costs than is the case for many other industries. Energy costs average approximately 8 percent of the value added in textile manufacturing and can be as high as 25 percent of total production costs for the textile mills. Exhibit 4 illustrates the percentages of the major fuel types used by the industry in 1985. The category "others" includes wood and process waste.

TOTAL ENERGY CONSUMPTION = 431.1×10^{12} BTU

Source: EIA, Annual Energy Outlook 1986

EXHIBIT 4. MAJOR ENERGY SOURCES USED BY THE TEXTILE INDUSTRY IN 1985

POTENTIAL ENERGY SAVINGS IN THE TEXTILE INDUSTRY

The total energy consumption profile for the U.S. textile industry from 1974 to 1985 is illustrated in Exhibit 5. Also presented in this exhibit are the specific energy requirements for a pound of processed fiber. The data in this exhibit illustrate the great strides that have been made by the industry in reducing energy consumption requirements in the last decade. Total energy consumption continued downward and by the end of the decade reached about 82 percent of the energy required in 1974. Similarly, the specific energy consumption per pound of fiber consumed decreased by 20 percent during the same period.

Much of the industry's conservation achievement is attributed to better housekeeping practices implemented during the last decade. The impact of these better housekeeping practices has in reality been greater than would be expected from examining Exhibit 5, because some portion of the gains has been negated by increased use of more modern equipment with higher energy requirements i.e., air-jet looms.

EXHIBIT 5. ENERGY CONSUMPTION PROFILE OF U.S. TEXTILE INDUSTRY

A recent IP study (The U.S. Textile Industry: An Energy Prospective, 1986) exploring the potential for further energy savings associated with present textile industry production practices estimated that using alternative state-of-the-art technology could conserve one-third of the current energy consumed by the textile industry overall. Approximately 32 percent of the current dry process (e.g., spinning and weaving) energy and about 36 percent of the current wet process (e.g., washing, dyeing) energy would be conserved. Similarly, the study concluded that an estimated potential energy savings of up to 53 percent of the energy consumption associated with current production practices could be achieved from use of advanced technologies, e.g., solid-on-solid processing. Exhibit 6 presents the potential energy conservation for the two cases.

EXHIBIT 6. ESTIMATED SAVINGS ASSOCIATED WITH IMPLEMENTATION OF STATE-OF-THE-ART AND ADVANCED TECHNOLOGIES

OFFICE OF INDUSTRIAL PROGRAMS' RESEARCH AND DEVELOPMENT EFFORTS IN THE TEXTILE INDUSTRY

The Office of Industrial Programs (IP) has initiated a number of research and development projects aimed at improving energy consumption efficiency and increasing productivity within the textile industry. These projects include various technologies specific to the textile industry as well as generic technologies applicable to many industries. Research has been conducted at various stages of development, from basic research to demonstration. Exhibit 7 provides a summary of each project covered in this report. Information gathered in this report does not reflect all the efforts by IP that may be applicable to improving energy consumption efficiency in the textile industry. Rather, this report is a compilation of information on those projects which have the greatest potential for energy savings. The projects are described below and are organized according to their applicability to textile production processes.

TEXTILE PRINTING, FINISHING AND DYEING

Foam Processing

In conventional wet processing of textiles, fabrics are treated in aqueous baths of desizing, bleaching, dyeing, and finishing agents. Between some of the baths, the fabric must be dried to a certain moisture content or cured to fix the finishes. Converting unfinished cloth to a finished state can require four to six wetting and drying cycles. The function of water in these processing operations is to uniformly distribute the dye, pigment, or chemical agent throughout the fabric. If less water is used as a carrier for these agents, then less energy is required to heat the ovens and dry the fabric.

From 1977 to 1981, IP funded United Merchants Research Center to develop an energy-conserving method known as foam processing of textiles. In this processing method, shown in Exhibit 8, foam replaces water as the carrier for the particular treating agent. The foam, similar in consistency to shaving cream, typically contains 3 to 20 parts of air to each part of liquid. The wet pick-up of the fabric during foam processing is 50 to 70 percent less than the wet pickup during conventional wet processing. An energy audit at one site where foam finishing was first demonstrated - the Health-Tex, Inc., mill in Cumberland, Rhode Island, confirmed a 47 percent decrease in energy consumption for finishing and a 60 percent increase in the production rate on the finishing lines (from 25 yd/min to 40 yd/min). The technology is currently used by a number of plants throughout the industry. The potential energy saving associated with this technology is estimated at 4.9×10^{12} Btu/yr.

EXHIBIT 7
OFFICE OF INDUSTRIAL PROGRAMS
RESEARCH AND DEVELOPMENT ACTIVITIES
APPLICABLE TO THE TEXTILE INDUSTRY

Project Title	Contractor	Research Types			Status*
		Basic/Lab	Pilot Plant	Field Test	
Foam Processing	United Merchants	o	o	o	Completed
Beck Dyeing Modifications					
Bump-and-Run	Georgia Tech.	o	o	o	Completed
Dye-Bath Reuse	Georgia Tech	o	o	o	Completed
Hot Pull	Georgia Tech	o	o	o	Completed
Solid-on-Solid Processing	Georgia Tech	o			On-going
Machnozzle	Georgia Tech/ J.P. Stevens	o	o	o	Completed
Microcomputer Control of Textile Dryers	Clemson Univ.	o	o	o	Completed
Heat Flux Hygrometer	Trans-Met Engineering, Inc.	o			On-going
Optical Humidity Sensor	Spectral Sciences, Inc.	o	o		On-going
Coal-Fired High-Back-Pressure Clean System	Riegel Textile Corporation	o	o	o	Completed
Hyperfiltration	Carre, Inc.	o	o	o	Completed
Industrial Heat Pump R&D Program	---	o	o	o	On-going

*Completed designation indicates that no further IP funding is planned for the project.

EXHIBIT 8. FOAM PROCESSING OF TEXTILES

Beck Dyeing Modifications

A large amount of carpet and other textile material is bath dyed in stainless-steel tubs, known as becks, which are vented to the atmosphere. The conventional beck dyeing process heats the beck by steam injection. The boil is held for 30 minutes, after which the dye solution is checked for the proper shade. If the shade is correct, the material is boiled for another 30 minutes. If the shade is incorrect, additional dye is added, and the boiling cycle is repeated. Once the boiling cycle is satisfactorily completed, the used dye-bath solution is discharged as waste and the beck is refilled with water to rinse the material. After a rinse period of 5 minutes, the used water is discharged and the beck is cleaned and prepared for the next batch of material. About 49 percent of the energy supplied by the steam input is lost to the atmosphere through evaporation; 49 percent is lost in the heated, discharged solution; and 2 percent is lost through radiation and convection losses.

In 1979, IP funded the Georgia Institute of Technology, which subcontracted with Salem Carpet Company, to develop and demonstrate three energy-conserving modifications for the beck dyeing process. These modifications are bump-and-run, dye-bath reuse, and hot pull.

The bump-and-run modification eliminates much of the conventional energy loss by reducing the demand for steam in the dyeing process. In this method, the dye bath is brought to a boil in the usual manner, but only for 5 minutes (the *bump*), after which the beck doors and dampers are closed and the exhaust fan is turned off. These actions, in effect, turn the beck into a closed kettle for the remaining 25 minutes of the first part of the dyeing cycle (the *run*). The temperature drop during the run is limited to about 25°F. The bump-and-run method is also applied to the second 30-minute component of the dyeing cycle. The rest of the cycle remains unchanged. This method is presently widely used by the textile industry.

Dye-bath reuse reduces chemical, water, and energy consumption by recycling the spent dye bath after it is reconstituted. The spent dye bath is analyzed to determine the amount of dye remaining and additional dye is added to replace those lost in the dyeing process.

Hot pull increases the attractiveness of dye-bath reuse by eliminating the final rinse step in conventional processing, thus minimizing handling of the spent dye bath and saving the water used by the final rinse. It involves removing the hot carpet immediately after the end of the dyeing hold cycle. The final rinse step is then accomplished in the wet-out box used in conventional drying. This step is necessary to ensure a uniform moisture content in the carpet to prevent dyeing imperfections when the carpet is thermally shocked upon entering the dryer.

Solid-on-Solid Processing

Use of low wet pick-up techniques such as foams and process modifications such as bump-and-run and dye-bath reuse have considerably reduced the energy-intensity of wet textile processing. Concluding that water volumes had been reduced to a technically limiting level, researchers at the Georgia Institute of Technology, funded by IP, are developing a new concept in textile processing which eliminates solvents in application of colorants, finishes and sizes. Known as solid-on-solid (SOS) processing, the techniques developed by Georgia Tech researchers use chemical powders and electrostatic deposition. Yarn slashing, finishing of nonwovens and carpets, chemical binding of nonwovens, coloration and xerography printing studies (see Exhibit 9) have been the subjects of research to date.

Besides energy savings, the SOS technology offers several concomitant advantages, including elimination of water supply needs, elimination of steam generation needs, elimination of waste water effluent and the potential for dramatically increased process speeds. The latter derives from the low heat capacities of dry polymeric powders and fibers, leading to rapid heat transfer in curing ovens. The result is reduced dwell times for SOS-processed fabrics over those from comparative wet processes, since the energy-intensive slow process of water heat-up/evaporation is avoided (a limiting line speed factor). Greater productivity and reduced cost factors are projected for SOS textile processes, which should ultimately improve the industry's standing by reducing foreign imports.

Bench-scale development has been completed for several SOS textile processes.

- o Clear, well-defined color prints were achieved on prepared polyester/cotton sheeting fabric using a Haloid batch xerography copier and paper toner/carrier systems. This effort has also led to identification of E.I. duPont's Elvax 410, a poly (82% ethylene-co-18% vinyl acetate), as the primary print binder candidate for fabric xerography.
- o A spun laced polyester nonwoven material servicing the mattress pad cover market was successfully bound with two resins via powder spray gun deposition.
- o Fluoropolymer powder finishing of a polypropylene nonwoven material with the spray gun technology also proved feasible.
- o Two main-component sized candidates (Eastman WD and Carozet 525) for ring-spun polyester/cotton yarns were evaluated. Optimum sized-yarn properties (high abrasion resistance, low degree of "hairiness") were achieved on the electrostatic fluidized bed SOS application system with a blend of 60:40 weight ratio.
- o Preliminary research was conducted to identify 100% solid/liquid resin candidates for solid shade coloration of fabric.

With the help of a blue-ribbon industrial working group, the Georgia Tech researchers are driving toward large-scale demonstrations of the SOS technologies.

EXHIBIT 9. LABORATORY EQUIPMENT FOR SOLID-ON-SOLID TEXTILE PRINTING

TEXTILE DRYING

Machnozzle

Conventional drying processes, which rely heavily on thermal energy to remove water, are energy inefficient because a large portion of the thermal energy is lost to the surrounding environment. Drying methods that combine mechanical and thermal means of moisture removal have the potential to reduce overall energy consumption. One such method uses a Machnozzle, a device that accelerates high-pressure steam to the speed of sound by passing it through a narrow slot (Exhibit 10). The Machnozzle application was developed in a joint effort by IP, the Georgia Institute of Technology, and J.P. Stevens and Company, Incorporated.

When the Machnozzle is used, the fabric is passed across the slot exit where the high-velocity steam flow creates a large pressure differential across the fabric. This pressure differential literally blows the water out of the fabric. The steam loses little of its thermal energy as it passes through the fabric and can therefore be mixed with cold water to yield hot water for the plant. Studies on the demonstration device installed in the J.P. Stevens plant illustrated that the Machnozzle required less energy for drying than conventional steam cans (exterior-surface drum dryers). Fabric samples were tested and were examined microscopically for color, air permeability, and pilling. Tests of fabric samples indicated that the properties of fabrics dried by the Machnozzle did not differ from those of conventionally dried fabrics. A commercial-scale Machnozzle has been successfully demonstrated.

EXHIBIT 10. CROSS SECTION OF THE MACHNOZZLE

Microcomputer Control of Dryers

As wet fabric passes through a typical tenter frame continuous dryer, blowers in each section force hot air through high-velocity jets onto both sides of the fabric. Generally, the air is heated using natural gas as the fuel. Tenter-frame-dryer operating conditions in many mills are determined by trial and error because many operating variables are difficult and costly to measure. Cost-effective and convenient methods of estimating optimal control parameters for a range of dryer operating conditions could save significant amounts of energy in the textile industry. Near-optimal operation of tenter frame dryers is usually obtained when exhaust air rates are as low as possible and fabric velocity is as high as possible, while maintaining fabric quality.

IP contracted with Clemson University's Department of Chemical Engineering to develop a method for presenting advanced, complex techniques of dryer analysis in a simplified form that could be used by plant operating personnel in a production environment. This study of tenter-frame operations included an overall dryer analysis and a fabric temperature analysis. The overall dryer analysis quantitatively determined the effect of process variables -- such as exhaust-gas rate, exhaust-gas humidity, and fabric velocity -- on natural gas consumption. For the fabric temperature analysis, a method was developed that quantitatively determines the effects of process variables on the fabric surface temperature and the fabric drying rate, so that optimal operating conditions can be determined. A computer program was developed that can be run on a microcomputer and includes models of the energy and mass balances of the dryer processes involved. The program is designed to be used by plant personnel to determine optimal operating conditions for tenter frame dryers.

SENSORS

Heat Flux Hygrometer

In convective heat air dryers, heat is lost through the exhaust gas, through the walls and by means of the product itself. The addition of new control systems which accurately and continuously monitor the exhaust gas humidity and temperature for the purpose of maintaining the practical optimal exhaust gas conditions have achieved significant energy savings in many industrial processes. However, the existing humidity sensors are inadequate for many of the more common drying processes, since the high temperatures and contaminant-filled environment encountered in these processes damage the measuring instruments or alter the absorption properties of hygroscopic salts and ceramics and cloud reflectivities, rendering the sensors unreliable and inaccurate. With the funding from IP, Trans-Met Engineering, Inc., has developed a measuring instrument which senses the heat flux resulting from the release of latent heat of condensation when the sensing surface is cooled to the dew-point temperature. The prototype sensor is insensitive to grease and grime contamination, insensitive to vibration and prolonged exposure to 500° F air, and does not require a dust filter or a sweep gas. A prototype measured the dew-point to within 4.5 percent for both clean and contaminated theoretical conditions. This effort is still continuing with a plan for the prototype unit evaluation.

Optical Humidity Sensor

Hygrometers capable of measuring high temperature and humidity while remaining operational in a severely contaminating or particle-laden environment are currently unavailable. Conventional hygrometers measure humidity by using the properties of the surface that is in contact with and is directly influenced by the bulk medium containing the water vapor. The commercial availability of a reliable and accurate hygrometer for the industrial drying chambers could significantly reduce the overall energy used by industrial drying processes.

Spectral Sciences, Inc., in a cost-sharing program with IP, is developing an ultraviolet absorption hygrometer which uses the differential absorption of light by water vapor (Exhibit 11). Since the ultraviolet radiation absorption is a property of water vapor in the bulk medium, the surfaces do not come in direct contact with the contaminating or particle-laden flow medium. A breadboard version of the proposed sensor was successfully designed, fabricated and tested. On-going work involves the installation of the prototype in an industrial environment for verification of laboratory results and further experimentation.

GENERIC

Coal-Fired High-Back-Pressure Steam System

In industrial electricity generation, steam produced by fossil fuel-fired boilers drives a turbine; after the steam passes through the turbine, its energy quality is usually too low for process use. As a result, the energy content of the steam is generally rejected to the atmosphere as waste heat. To take advantage of this waste heat, cogeneration systems have been developed that produce both electrical and thermal energy. However, the present cogeneration systems using boilers with steam turbines are not practical for some industrial operations because of space limitations or because of the low energy content of the turbine exhaust.

EXHIBIT 11. BLOCK DIAGRAM OF THE OPTICAL HUMIDITY SENSOR

In September 1979, Riegel Textile Corporation signed a cooperative cost-sharing agreement with the IP to design, purchase, install, and operate a newly developed cogeneration system in its weaving, dyeing, and finishing plant in Ware Shoals, South Carolina. The system, which began operation in November 1981, is a coal-fired, high-back-pressure steam cogeneration system. The system boiler has been modified to a special design that solves current retrofitting space problems. The boiler generates 850-psig, 825°F steam that powers a steam turbine to produce electricity. The turbine exhaust steam (225 psig, 570°F) can be used for process heat requirements and for space heating. The high-pressure system has replaced two less efficient, low-pressure boilers in the plant and is generating 23.4 million kWh/yr.

Hyperfiltration

Conventional textile industry practices of scouring, bleaching, dyeing and rinsing of fabrics require use of hot water and chemicals on a once-through basis. Consequently, heated water and dyeing materials are discharged from process machinery into the plant waste stream. Hyperfiltration systems that separate the hot water, dyes, and other chemicals for reuse can effect substantial reductions in energy consumption for heating, in pollution-control needs, and in materials requirements. Hyperfiltration is a pressure-driven membrane separation technique that has been used effectively to desalinate sea water. Membranes that have been successful in desalination, however, are not applicable to the textile industry, because of temperature requirements and type of solids to be separated.

With cost-sharing support from DOE, the U.S. Environmental Protection Agency, and the U.S. Department of the Interior, Carre, Inc., developed a hyperfiltration system for textile processes. The hyperfiltration unit consists of zirconium oxide polyacrylate membranes dynamically formed on the interior of sintered stainless-steel support tubes. The unit was designed to recycle 90 percent of the dye wash water and to remove 97 percent of the color from a continuous dye range at a process temperature of 185°F. This hyperfiltration unit (Exhibit 12) was installed in LaFrance facilities in April 1981; its performance, recycling efficiency, economics, and the associated range-product quality were monitored for a year. By September 1982, the unit was being used routinely for full-scale reclaiming and recycling of hot rinse waters (permeate). Further work is being directed toward removing foulant from the membranes and development of additional techniques for reusing the concentrates.

EXHIBIT 12. MEMBRANE HYPERFILTRATION FOR TEXTILE DYE WASTES

Industrial Heat Pump R&D Program

One of the major programs conducted by the IP with potential for significant implication in the textile industry has been the Industrial Heat Pump Program. The goal of the Industrial Heat Pump Program is to advance the technology available for designing, fabricating, and using heat pumps to increase the energy use efficiency in industry. This generally does not involve space heating. It involves using heat pumps in a role of both increasing the process efficiencies and recovering and reusing waste energy emitted by the process.

In pursuit of this goal, the Industrial Heat Pump Program has funded studies and research for the development of new hardware. In one case, the Brayton Cycle Solvent Recovery System, development has successfully proceeded through design, hardware development, and prototype testing. Presently, efforts in the Program are divided between identifying promising applications for the heat pump in industry and developing chemical heat pump technologies.

Research and Development Data Base

Project Title	Contractor	Principal Contact	Address
Foam Processing	United Merchants	Chet Namboidri	United Merchants & Manufacturing 1407 Broadway New York, NY 10018
Beck Dyeing Modifications Bump-and-Run Dye-Bath Reuse Hot Pull	Georgia Tech	Dr. Fred Cook	Georgia Institute of Technology Atlanta, Ga 30332
Solid-on-Solid Processing	Georgia Tech	Dr. Fred Cook	Georgia Institute of Technology Atlanta, GA 30332
Machnozzle	Georgia Tech/ J.P. Stevens	Dr. Chuck Carr	Georgia Institute of Technology Atlanta, GA 30332
Microcomputer Control of Textile Dryers	Clemson Univ.	N.J. Beard	Clemson University Clemson, SC 29631
Heat Flux Hygrometer	TransMet Engineering, Inc.	Dieter Rall	Trans-Met Engineering, Inc. 1640 S. St. Claire Ave. Anaheim, CA 92806
Optical Humidity Sensor	Spectral Sciences, Inc.	Michael Gersh	Spectral Sciences, Inc. 111 South Bedford Street Burlington, MA 01803
Coal-Fired High Back- Pressure Steam System	Riegel Textile Corporation	J.L. Burnett/ M.J. Smith	Riegel Textile Corporation Ware Shoals, SC
Hyperfiltration	Carre, Inc.	Dr. Craig Brandon	Carre, Inc. 109 Debra Street Seneca, SC 29678
Industrial Heat Pump R&D Program	----	Scott Richlon	U.S. Department of Energy OIP, Washington, DC 20585

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