FINAL REPORT
PROJECT A–2969

ENERGY CONSERVATION IN THE TEXTILE INDUSTRY

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GEORGIA INSTITUTE OF TECHNOLOGY
A Unit of the University System of Georgia
Engineering Experiment Station
Atlanta, Georgia 30332
ENERGY CONSERVATION IN THE TEXTILE INDUSTRY

FINAL REPORT

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I. INTRODUCTION

Battelle, Pacific Northwest Laboratories (PNL) in Richland, Washington, has supported the Office of Industrial Programs (OIP) of the Department of Energy in various conservation programs. The Office of Industrial Programs has set forth as a goal the evaluation of new energy efficient technologies in selected industries and the assessment of the impact of OIP funding on the energy conservation activities of specific users. The Engineering Experiment Station of the Georgia Institute of Technology was chosen to assist Battelle PNL in the evaluation of activities in the textile industry. The preparation of case histories documenting energy conservation opportunities implemented by the textile industry was designated as the method of presentation of the results of the evaluation. These case histories document energy and cost savings resulting from the energy conserving technologies implemented, as well as information on the fundamentals of the technologies and ancillary benefits.

This project was conducted by the Technology Applications Laboratory of the Georgia Tech Engineering Experiment Station. The work was directed by the laboratory's Technology Transfer Branch with assistance from the School of Textile Engineering.

The program involved the selection of 15 energy conserving technologies that had been implemented by the textile industry. Of these 15 technologies, 10 were selected by Battelle PNL for further study. A visit was made to each industrial firm to survey plant operations and to study the technology implemented. A case history report was then prepared, summarizing the fundamentals of the technology and the resulting energy and cost savings.

This report summarizes the objectives, activities, and findings of the program. Copies of the individual case studies are included as appendices.
II. PROGRAM OBJECTIVES AND TASKS

The Energy Conservation in the Textile Industry project has been a multi-purpose program. The major objectives include the following:

- Identify energy conservation opportunities that have been implemented by the textile industry.
- Determine the energy and cost savings resulting from the implementation of these technologies.
- Highlight ancillary benefits of the energy conservation opportunities implemented.
- Determine the criteria by which industry evaluates energy conservation investments.

These objectives have been addressed through direct contact with engineering and managerial personnel at a number of textile firms throughout the country. The general methods utilized were specified in the project contract and were separated into three program tasks.

Task 1. Selection of Candidate Firms

Georgia Tech project team members contacted 35 textile companies that had implemented energy conserving technologies. The preliminary selection was based on factors including type of technology, energy and cost savings, ease of industry-wide commercialization, economics, DOE sponsorship, and liaison with Georgia Tech. Of these companies, 14 textile firms, which had implemented 16 energy conserving technologies, agreed to give full disclosure of all technical information. From these 16 candidate technologies, Battelle PNL selected 10 for detailed study.

Task 2. Plant Visits

Each of the plants selected by Battelle PNL was visited by a member of the Georgia Tech project team. The purpose of the visit was to gather information about plant operations, energy consumption and costs, specifics of the energy conservation opportunity implemented, and criteria for investment decision making.
**Task 3. Case Study Reports**

A comprehensive case history report was prepared for each energy conservation opportunity that was implemented. The report documented the information that was gathered during the plant visit. These reports were sent to the plant contact, the Battelle PNL technical monitor, and the DOE technical monitor for approval.
III. SELECTION OF CANDIDATE PLANTS

Under the contract requirements, 15 candidate technologies were to be selected for submission to Battelle PNL. Georgia Tech project team members from the Engineering Experiment Station and the School of Textile Engineering met and compiled a list of energy conserving technologies that had been implemented by the textile industry. They used their extensive background of industry contacts, as well as their association with trade organizations, to compile the initial list of plants to be contacted. The list consisted of 38 energy conserving technologies that had been implemented by textile firms throughout the United States, which produced a wide variety of different textile products. Some of the technologies were developed and demonstrated through funding from the Department of Energy. Table 1 summarizes the technologies considered for study, DOE sponsored projects, and major product and location of the companies contacted.

Each of these plants was contacted concerning participation in the project. The purpose of the project, the scope of work, and the requirements for participation were explained to each plant contact. Fourteen firms agreed to participate in the program, with two of these firms having implemented two different energy conservation opportunities.

The major reasons given by firms choosing not to participate in the program were unwillingness to disclose information and insufficient time available to handle telephone responses to the published reports. Appendix K gives a brief summary of some of the energy conserving technologies originally considered that were not studied because the companies chose not to participate in this project. These summaries include background information on the technologies and the application and need of the technology in the textile industry.

The 16 energy conserving technologies submitted to Battelle PNL as candidates for case studies are shown in Table 2, along with estimated impact on the textile industry. The industry impact was estimated based on the investigator's knowledge of the textile industry, using as a guideline the process production data found in the final report for Phase I of the Energy Conservation in the Textile Industry project, directed by Dr. F. L. Cook of Georgia Tech and completed in January 1978.
Table 1
LIST OF TECHNOLOGIES IMPLEMENTED
BY THE TEXTILE INDUSTRY

<table>
<thead>
<tr>
<th>Technology</th>
<th>Sponsored</th>
<th>Major Product</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Melt Slashing</td>
<td>DOE</td>
<td>Yarn</td>
<td>GA</td>
</tr>
<tr>
<td>Combined Preparation</td>
<td>DOE</td>
<td>Towels</td>
<td>AL</td>
</tr>
<tr>
<td>Tandem Preparation Line</td>
<td>DOE</td>
<td>Hosiery</td>
<td>AL</td>
</tr>
<tr>
<td>Caustic Recovery</td>
<td>DOE</td>
<td>Sheeting</td>
<td>AL</td>
</tr>
<tr>
<td>Beck Modifications</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Indirect Beck Heating</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Dyebath Reuse</td>
<td>DOE</td>
<td>Hosiery</td>
<td>NC</td>
</tr>
<tr>
<td>Dyebath Reuse</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Bump-and-Run</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Low Temperature Dyeing</td>
<td>DOE</td>
<td>Carpet</td>
<td>CA</td>
</tr>
<tr>
<td>Foam Dyeing</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Polyester/Cotton Dyeing</td>
<td>DOE</td>
<td>Sheeting</td>
<td>GA</td>
</tr>
<tr>
<td>Remaflam</td>
<td>DOE</td>
<td>Apparel Fabric</td>
<td>GA</td>
</tr>
<tr>
<td>Triatex MA</td>
<td>DOE</td>
<td>Upholstery Fabric</td>
<td>GA</td>
</tr>
<tr>
<td>Low Temperature Curing</td>
<td>DOE</td>
<td>Apparel Fabric</td>
<td>NC</td>
</tr>
<tr>
<td>Foam Finishing</td>
<td>DOE</td>
<td>Corduroy</td>
<td>SC</td>
</tr>
<tr>
<td>Foam Finishing</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Steamer Control</td>
<td>DOE</td>
<td>Apparel Fabric</td>
<td>GA</td>
</tr>
<tr>
<td>Wastewater Heat Recovery</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Wastewater Heat Recovery</td>
<td>DOE</td>
<td>Apparel Fabric</td>
<td>GA</td>
</tr>
<tr>
<td>Water Reuse</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Wastewater Chlorination</td>
<td>DOE</td>
<td>Upholstery Fabric</td>
<td>SC</td>
</tr>
<tr>
<td>Hyperfiltration</td>
<td>DOE</td>
<td>Sheeting</td>
<td>SC</td>
</tr>
<tr>
<td>Machnozzle</td>
<td>DOE</td>
<td>Upholstery Fabric</td>
<td>SC</td>
</tr>
<tr>
<td>Dryer Controls</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Dryer Controls</td>
<td>DOE</td>
<td>Apparel Fabric</td>
<td>VA</td>
</tr>
<tr>
<td>Dryer Counterflow</td>
<td>DOE</td>
<td>Apparel Fabric</td>
<td>SC</td>
</tr>
<tr>
<td>Dryer Heat Recovery</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Waste-Fired Dryer</td>
<td>DOE</td>
<td>Towels</td>
<td>GA</td>
</tr>
<tr>
<td>Ion Control</td>
<td>DOE</td>
<td>Yarn</td>
<td>VA</td>
</tr>
<tr>
<td>Carpet Backing</td>
<td>DOE</td>
<td>Yarn</td>
<td>GA</td>
</tr>
<tr>
<td>Boiler Economizer</td>
<td>DOE</td>
<td>Upholstery Fabric</td>
<td>NC</td>
</tr>
<tr>
<td>Wood-Fired Boiler</td>
<td>DOE</td>
<td>Carpet Yarn</td>
<td>GA</td>
</tr>
<tr>
<td>Wood-Fired Boiler</td>
<td>DOE</td>
<td>Carpet</td>
<td>GA</td>
</tr>
<tr>
<td>Trifuel Boiler</td>
<td>DOE</td>
<td>Apparel Fabric</td>
<td>NC</td>
</tr>
<tr>
<td>Solar Process Steam</td>
<td>DOE</td>
<td>Gauze</td>
<td>TX</td>
</tr>
<tr>
<td>Technology</td>
<td>Major Product</td>
<td>Location</td>
<td>Impact</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>---------------</td>
<td>----------</td>
<td>--------</td>
</tr>
<tr>
<td>Tandem Preparation Line</td>
<td>Hosiery</td>
<td>AL</td>
<td>15%</td>
</tr>
<tr>
<td>Dyebath Reuse</td>
<td>Carpet</td>
<td>GA</td>
<td>30%</td>
</tr>
<tr>
<td>Bump-and-Run</td>
<td>Carpet</td>
<td>GA</td>
<td>30%</td>
</tr>
<tr>
<td>Foam Finishing</td>
<td>Apparel</td>
<td>NC</td>
<td>40%</td>
</tr>
<tr>
<td>Wastewater Heat Recovery</td>
<td>Apparel</td>
<td>GA</td>
<td>50%</td>
</tr>
<tr>
<td>Wastewater Heat Recovery</td>
<td>Carpet</td>
<td>CA</td>
<td>50%</td>
</tr>
<tr>
<td>Wastewater Chlorination</td>
<td>Carpet</td>
<td>GA</td>
<td>20%</td>
</tr>
<tr>
<td>Hyperfiltration</td>
<td>Upholstery</td>
<td>SC</td>
<td>30%</td>
</tr>
<tr>
<td>Water Reuse</td>
<td>Apparel</td>
<td>GA</td>
<td>20%</td>
</tr>
<tr>
<td>Dryer Controls</td>
<td>Upholstery</td>
<td>SC</td>
<td>50%</td>
</tr>
<tr>
<td>Dryer Counterflow</td>
<td>Apparel</td>
<td>VA</td>
<td>50%</td>
</tr>
<tr>
<td>Waste-Fired Dryer</td>
<td>Towels</td>
<td>GA</td>
<td>40%</td>
</tr>
<tr>
<td>Boiler Economizer</td>
<td>Upholstery</td>
<td>NC</td>
<td>70%</td>
</tr>
<tr>
<td>Wood-Fired Boiler</td>
<td>Carpet Yarn</td>
<td>GA</td>
<td>70%</td>
</tr>
<tr>
<td>Trifuel Boiler</td>
<td>Apparel</td>
<td>NC</td>
<td>70%</td>
</tr>
<tr>
<td>Solar Process Steam</td>
<td>Gauze</td>
<td>TX</td>
<td>50%</td>
</tr>
</tbody>
</table>
Of these 16 technologies, 10 were chosen by Battelle PNL to be evaluated for case studies. The criteria for selection were as follows:

- DOE sponsored projects
- Location
- Industry impact
- Energy and cost savings
- Low implementation cost
- Ancillary benefits
  - Reduced usage of fossil fuels
  - Reduced water usage
  - Reduced wastewater discharge
  - Improved process efficiency

The technologies selected were chosen for two or more of the above criteria. A mix of DOE and internally funded projects was desired. It was also desired to study textile firms in as many geographic locations as possible. Energy conserving technologies chosen also had institutional and environmental benefits as well as energy savings. Based on these factors, the technologies listed in Table 3 were chosen for further study.
**Table 3**

**LIST OF CASE STUDY PLANTS**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Plant Details</th>
<th>Industry Impact</th>
<th>Benefits</th>
<th>Energy Savings</th>
</tr>
</thead>
</table>
| Tandem Preparation Line           | Niota Textile Mill, Fort Payne, AL | 15%             | - Reduced water usage  
- Reduced wastewater discharge  
- Reduced chemical usage  
- Estimated 30% energy savings |                |
| Dyebath Reuse                     | E & B Carpets, Dalton, GA          | 30%             | - Dye and chemical savings  
- Reduced water usage  
- Reduced wastewater discharge  
- Increased process efficiency  
- Estimated 30% energy savings |                |
| Bump-and-Run                      | Salem Carpets, Chickamauga, GA     | 30%             | - Increased process efficiency  
- Estimated 20% energy savings |                |
| Foam Finishing                    | United Merchants, Old Fort, NC     | 35%             | - Reduced wastewater discharge  
- Reduced water usage  
- Estimated 35% energy savings |                |
| Wastewater Heat Recovery          | Tuftex La Mirada Dye Plant, Los Angeles, CA | 50%            | - Increased process efficiency  
- Estimated 35% energy savings |                |
| Water Chlorination and Reuse      | Salem Carpets, Chickamauga, GA     | 20%             | - Reduced water usage  
- Reduced wastewater discharge  
- Increased process efficiency  
- Estimated 30% energy savings |                |
| Dryer Counterflow                 | Dan River, Danville, VA            | 50%             | - Increased process efficiency  
- Estimated 30% energy savings |                |
| Boiler Economizer                  | Collins and Aikman, Albemarle, NC  | 70%             | - Increased process efficiency  
- Estimated 20% energy savings |                |
| Wood-Fired Boiler                  | Integrated Products, Rome, GA      | 50%             | - Reduced fossil fuel dependence |                |
| Solar Industrial Process Heat     | Johnson and Johnson, Sherman, TX   | 50%             | - Reduced fossil fuel dependence |                |

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IV. PLANT VISIT STRATEGY

In order to prepare the highest quality reports, members of the Georgia Tech project team visited each of the textile firms participating in the program. Interviews with plant engineering and management personnel were conducted to obtain background information on plant operations and management strategy. Initial information on the energy conserving technology that had been implemented was also obtained. Project team members then observed the installation and collected operating data for the energy conserving technology. The following information was obtained during the plant visit:

- Plant employee contact
- Description of products
- Energy consumption in years before and after the energy conserving technology was implemented
- Energy costs in years before and after the energy conserving technology was implemented
- Energy savings since the energy conserving technology was implemented
- Description of investment decision-making processes
- Description of any institutional and environmental considerations

This information was used as a basis for the case study reports, and a summary sheet outlining these items was included in each case study.
V. CASE STUDY SUMMARY

Georgia Tech project team members prepared case study reports for ten energy conserving technologies that had been implemented by the textile industry. The technologies studied are representative of a wide variety of technologies implemented by the industry, and are applicable to most types of textile plants.

Saving energy is the goal of all of the technologies. Some result in an immediate reduction in plant energy consumption; while others save energy by reducing or eliminating the plant's dependence on fossil fuels. However, all of the technologies have ancillary benefits ranging from reduced water usage to improved process efficiency. Implementation of the technologies studied resulted in a total energy savings of 136,742 MMBTU annually and an energy cost savings of $635,089 for the ten plants. The majority of the textile companies that participated in this study evaluate investments based on payback period. Most firms contacted required a payback of two years or less; however, some would consider a payback of three to five years as acceptable.

Several of the technologies implemented were funded by Department of Energy grants. Other technologies studied were implemented by the companies based on the results of demonstration programs sponsored by DOE. The DOE sponsored projects have helped the textile industry determine which new energy conserving technologies work successfully and provide a good economic return. Technologies to reduce the industry's future dependence on fossil fuels have also been demonstrated through DOE sponsored programs.

A summary of the case history data is shown in Table 4. Annual energy consumption for the process or system to which the energy conserving technology was applied is given before and after implementation, as are energy costs. Annual energy savings are thus shown based on the consumption figures. Annual energy cost savings are calculated based on annual energy savings and current energy costs.
<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>COMPANY</th>
<th>MAJOR PRODUCT</th>
<th>ANNUAL ENERGY CONSUMPTION IN MMBTU Before</th>
<th>ANNUAL ENERGY CONSUMPTION IN MMBTU After</th>
<th>ENERGY COSTS PER MMBTU Before</th>
<th>ENERGY COSTS PER MMBTU After</th>
<th>ANNUAL ENERGY SAVINGS</th>
<th>ANNUAL ENERGY COST SAVINGS</th>
<th>INVESTMENT DECISION CRITERION</th>
<th>AUXILLARY BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tandem Preparation Line</td>
<td>Niota Textiles</td>
<td>Athletics Socks</td>
<td>4,580</td>
<td>1,286</td>
<td>Gas $3.30</td>
<td>$3.85</td>
<td>3,295</td>
<td>$19,275</td>
<td>Fast Payback</td>
<td>Reduced Water and Chemical Use and Wastewater Discharge</td>
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<tr>
<td>Dyebath Reuse</td>
<td>E &amp; B Carpets</td>
<td>Carpet</td>
<td>78,618</td>
<td>74,367</td>
<td>Gas $2.79</td>
<td>$3.41</td>
<td>4,251</td>
<td>$17,135</td>
<td>Two Year Discounted Payback</td>
<td>Reduced Water and Chemical Use and Wastewater Discharge</td>
</tr>
<tr>
<td>Bump-and-Run</td>
<td>Salem Carpets</td>
<td>Carpet</td>
<td>75,570</td>
<td>55,410</td>
<td>Gas $2.36</td>
<td>$3.43</td>
<td>20,160</td>
<td>$63,500</td>
<td>DOE Sponsored Project</td>
<td>Improved Economics of Dyebath Reuse</td>
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<td>Foam Finishing</td>
<td>United Merchants</td>
<td>Apparel Fabrics</td>
<td>23,100</td>
<td>10,109</td>
<td>Propane $2.61</td>
<td>$5.01</td>
<td>13,000</td>
<td>$65,150</td>
<td>Six Month Payback</td>
<td>Improved Process Efficiency</td>
</tr>
<tr>
<td>Wastewater Heat Recovery</td>
<td>Tuftex Carpets</td>
<td>Carpet</td>
<td>---</td>
<td>297,865</td>
<td>---</td>
<td>$3.87</td>
<td>21,749</td>
<td>$121,806</td>
<td>Included in Initial Cost of Plant</td>
<td>Improved Process Efficiency</td>
</tr>
<tr>
<td>Wastewater Chlorination and Reuse</td>
<td>Salem Carpets</td>
<td>Carpet</td>
<td>300,000</td>
<td>265,000</td>
<td>Gas $0.85</td>
<td>$1.27</td>
<td>35,875</td>
<td>$123,800</td>
<td>Reduced Fossil Fuel Usage</td>
<td>Reduced Wastewater Discharge</td>
</tr>
<tr>
<td>Oven Exhaust Air Counterflow</td>
<td>Dan River</td>
<td>Apparel Fabric</td>
<td>70,157</td>
<td>45,907</td>
<td>Gas $1.94</td>
<td>$3.60</td>
<td>24,250</td>
<td>$87,302</td>
<td>Up to 5 Year Payback Accepted</td>
<td>Improved Process Efficiency</td>
</tr>
<tr>
<td>Boiler Economizer</td>
<td>Collins and Aikman</td>
<td>Upholstery Fabric</td>
<td>624,725</td>
<td>315,765</td>
<td>0.11</td>
<td>$2.20</td>
<td>14,057</td>
<td>$74,971</td>
<td>Three Year Payback</td>
<td>Improved Process Efficiency</td>
</tr>
<tr>
<td>Wood-Fired Boiler</td>
<td>Integrated Products</td>
<td>Carpet Yarn</td>
<td>59,419</td>
<td>35,415</td>
<td>Gas $3.00</td>
<td>$6.14</td>
<td>59,419</td>
<td>$80,000</td>
<td>DOE Funding Reduced Payback to 3 Years</td>
<td>Reduced Fossil Fuel Usage</td>
</tr>
<tr>
<td>Solar Industrial Process Heat</td>
<td>Johnson and Johnson</td>
<td>Gauze</td>
<td>---</td>
<td>---</td>
<td>Gas $3.00</td>
<td>---</td>
<td>632</td>
<td>$2,350</td>
<td>DOE Sponsored Project</td>
<td>Reduced Fossil Fuel Usage</td>
</tr>
</tbody>
</table>

Table 4
Case Study Summary
Appendix A

CASE STUDY REPORT
TANDEM PREPARATION LINE
TEXTILE ENERGY CONSERVATION CASE STUDY:
TANDEM PREPARATION LINE

-performed by
Engineering Experiment Station
Georgia Institute of Technology

-sponsored by
Battelle, Pacific Northwest Laboratories

by
Rachel L. Moore

August 28, 1981
Niota Textile Mill, Inc.
Rt. 3
Ft. Payne, Alabama 35967

Mr. Bill Chestnut, Jr.
President
615-568-2191

Niota Textiles produces cotton and acrylic socks.

Niota Textiles has installed in a tandem configuration two of the paddle machines normally used to prepare and dye hosiery. The tandem configuration allows the goods to be bleached or scoured in the first machine and rinsed and softened in the second machine without losing either bath. Thus, one load can be processed immediately after another, taking advantage of the water that is already hot and already has most of the chemicals necessary to process the next load. Substantial energy, water, and chemical savings result from the use of this system.

Before Niota Textiles installed the tandem preparation line, which is now used to process all acrylic goods, the energy required to scour acrylic socks was 4,580 MMBTU per year. In the six months that the tandem preparation line has been in use, 643 MMBTU has been required to process acrylic goods.

Prior to the installation of the tandem preparation line, natural gas costs averaged $3.90 per MMBTU. Average plant steam costs were estimated to be $4.88 per MMBTU. Since the tandem preparation line has been in use, natural gas costs have averaged $4.85 per MMBTU. Average plant steam costs were estimated to be $6.05 per MMBTU.

In the six months that the tandem line has been in use, Niota Textiles has saved 1647 MMBTU in the preparation of acrylic goods, which projects to an annual savings of 3295 MMBTU and $19,275.

The tandem preparation line provides many other benefits besides energy savings. Since the bath does not have to be dropped between loads, wastewater discharge and water consumption are substantially reduced. The chemicals that remain in the bath after scouring are also reused.
TANDEM PREPARATION LINE

Introduction

The textile industry is faced with many problems such as increasing energy costs, air and water pollution, increasing dye and chemical costs, and the shortage of water that, if not solved, could limit or halt the existence of the industry in the United States. Thus, the push to make all preparation, dyeing, and finishing operations continuous rather than batch has resulted. Great strides toward this goal have been made in the carpet and fabric segments of the textile industry. However, certain other segments have had difficulty in adapting to continuous processing. Two notable segments are the hosiery and small rug producers, which both process small individual items rather than one continuous length of goods. An innovative new concept is being introduced into the hosiery industry for bleaching and scouring, using in a tandem operation the same paddle machines now utilized to prepare and dye hosiery and small rugs. This concept has the potential to be expanded for use in other operations such as dyeing, thus leading to even greater energy savings.

Traditional Operation

Niota Textile Mill, located in Ft. Payne, Alabama, produces cotton and acrylic athletic tube socks. The socks are knitted at other locations and shipped to the plant in boxes. The socks are bleached or scoured, dried, boarded, folded, and packaged for shipping. The cotton goods are bleached and the acrylic goods are scoured. The plant operates two 10 hour shifts per day, 5 days per week, 50 weeks per year.

Before the installation of the tandem preparation line, all of the goods processed were either bleached or scoured in one of three large paddle machines. All of the cotton goods are still bleached in the large machines, but the acrylic goods are now scoured on the new tandem line. Each large machine holds 650 pounds of goods in 1200 gallons of water. The scouring procedure that was used for the acrylic goods when the large machines were used was as follows:
- Fill machine with cold water
- Add hosiery
- Add scouring chemicals
- Heat bath to 140°F
- Hold 10 minutes
- Drain bath
- Fill again with cold water
- Add softening chemicals
- Heat bath to 100°F
- Hold 5 minutes
- Drain bath

Thus, both times the bath was discharged to the sewer, all of the heat in the water and all of the chemicals were lost. However, these losses can be eliminated when the tandem line is used.

Process Modifications

The tandem preparation line, shown in Figure 1, is a modification of the paddle machine used to prepare and dye hosiery and small rugs. Both machines in the tandem line at Niota Textile Mill process 400 pounds of acrylic in 750 gallons of water. Although the capacity of these machines is less than the large single machines, the same amount of goods or more can be processed in a day due to the time and personnel savings.

The first machine is used to scour the socks and the second to soften. For the first run, the water is added to the first machine, the goods and scouring chemicals entered, the bath heated to 140°F and held for 10 minutes. At the end of the cycle, the goods are transferred to the second machine by means of a perforated basket that fits inside the machine and raises out to move the goods and leave the bath in place. The socks are added to the second bath, the softening chemicals added, the bath raised to 100°F and held for five minutes. The goods are removed from the second machine and placed in a bag to be dried.

Once the goods have been removed from the first machine, a new load can be placed in the bath that is still hot and contains most of the chemicals
Figure 1. Tandem Preparation Line at Niota Textiles
necessary for processing. Every third load, the full amount of chemicals is added back to the bath. Both the scouring and softening baths can be used for an entire day without replacement, and steam is only added intermittently to keep the baths at the correct temperature. Thus energy, water, and chemical savings result when the tandem machine configuration is used rather than the single machines. Fewer operators are required to run the tandem line. Time is saved by not draining the machine after each run and also by not having to heat the bath each time.

Savings

When comparing machines of the same capacity as the machines in the tandem line, the savings shown in Table I result when using the tandem line rather than one single large machine.

<table>
<thead>
<tr>
<th>Annual Volume Savings</th>
<th>Annual Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>3,295 MMBTU</td>
</tr>
<tr>
<td>Chemicals</td>
<td>58,500 pounds</td>
</tr>
<tr>
<td>Water/Sewer</td>
<td>7,125,000 gallons</td>
</tr>
<tr>
<td><strong>TOTAL SAVINGS</strong></td>
<td></td>
</tr>
</tbody>
</table>

These savings are based on an average annual production rate of two million pounds of acrylic.

The system at Niota Textile Mill required a capital investment of $17,275. This cost was slightly more than half of the cost of a new system,
since one of the paddle machines was already installed in the mill and was used as a part of this system. The new machine that was added was constructed from 316 stainless steel so as to be able to withstand bleaching and scouring chemicals and also had a special high lift basket. Thus, the cost was slightly higher than a regular machine.

At present energy, water/sewer, and chemical costs the payback period before taxes is 4 months. The system has been installed for 6 months, and has thus paid for itself. Plant personnel wanted the system for its resulting water, chemical, and energy savings and knew that it would have a very short payback.

Summary

Niota Textile Mill has installed a new preparation machine using in a tandem configuration two of the paddle machines used for the preparation and dyeing of hosiery. This new line allows the preparation bath to be saved after each use thus conserving energy, water, and chemicals. This system has the potential to be expanded into other areas, such as small rug processing and dyebath reuse, which will result in further energy savings.

—for further information contact

Bill Chestnut, Jr.
President
Niota Textile Mill, Inc.
Niota, Tennessee
Appendix B

CASE STUDY REPORT
DYE BATH REUSE
TEXTILE ENERGY CONSERVATION CASE STUDY:

DYEBATH REUSE

-performed by
Engineering Experiment Station
Georgia Institute of Technology

-sponsored by
Battelle, Pacific Northwest Laboratories

by
Rachel L. Moore

August 14, 1981
E & B Carpets, Inc. produces nylon and polyester carpet.

E & B Carpets has implemented a dyeing procedural modification called dyebath reuse, in which spent dyebaths are analyzed and reused. The bath can be analyzed and reconstituted quickly so the bath temperature does not drop substantially. Thus energy, water, dyes, and chemicals are all reused resulting in substantial cost savings. E & B has installed a special pumping and control system linking several dye becks to facilitate the movement of the dyebaths.

Before the first set of becks was converted, polyester dyeing required 78,618 MMBTU annually. Since 25% of the polyester is now being dyed using dyebath reuse, the dyeing of polyester consumes 74,387 MMBTU annually.

From July 1979 to June 1980, the year before dyebath reuse was implemented, natural gas averaged $2.79 per MMBTU and No. 6 fuel oil averaged $3.41 per MMBTU. An average plant steam cost was estimated to be $3.60 per MMBTU.

From July 1980 to June 1981, the year that dyebath reuse was used to dye 25% of the polyester production, natural gas costs averaged $2.57 per MMBTU and No. 6 fuel oil averaged $4.99 per million BTU. An average plant steam cost was estimated to be $4.05 per MMBTU.

E & B Carpets has saved 4,231 MMBTU and $17,135 in energy costs in the year since dyebath reuse was implemented.

E & B Carpets requires a 2 year or shorter discounted payback to make an investment, which dyebath reuse bettered in the initial analysis and met in the first year of operation.

Dyebath reuse has many other benefits besides energy savings. Since the dyebath is used many times, wastewater discharge from the plant is reduced. The expensive dyes and chemicals still in the bath at the end of the dyeing can now be used. The plant's water requirements are also substantially reduced.
DYEBATH REUSE

Introduction

Wet processing consumes 60% of the energy required to produce a finished textile product. Two different types of wet processing are used by the textile industry, batch dyeing and continuous dyeing. Because batch dyeing is much more energy intensive than continuous dyeing, more effort has been devoted to the development of energy conserving technologies that apply to batch dyeing. Dyebath reuse is one such technology.

Dyebath reuse is a procedural modification that can be applied to most types of batch dyeing. When implemented, dyebath reuse can result in energy, water, chemical, and dye savings as well as a reduced wastewater discharge. Successful laboratory and plant trials have been conducted for the atmospheric dyeing of nylon, carrier polyester, and carrierless polyester carpet as well as nylon hosiery. Dyebath reuse has also been developed for pressure dyeing of nomex fabric, polyester knit fabric, and polyester yarn. Experimentation is still in progress to determine the applicability of dyebath reuse to the dyeing of acrylic hosiery and polyester/cotton blend fabrics and yarn. The concept of dyebath reuse and most of the subsequent pilot and plant scale work was conducted under Department of Energy grants.

Traditional Operation

In a conventional batch dyeing process, the dyeing machine is filled with water, the goods are added, and the material is moved through the dyebath. Chemical auxiliaries and dyes are then added to the bath. The water is raised to the dyeing temperature and held for a specified length of time. When the dye cycle is completed, the goods are checked for shade. If the color is correct, the hot dyebath is discharged to the drain. A final rinse is normally performed that can be hot or cold and with or without the addition of chemicals.

The dyebath that is discharged to the drain is usually at a high temperature and contains all of the dyes and chemicals that were not exhausted onto the material during the dyeing. If these items can be reused in a subsequent dyeing, substantial cost savings will result.
Procedural Modifications

Dyebath reuse consists of reconstituting the dyebath between dyeing cycles. The amount of dye remaining in the spent dyebath can be analyzed spectrophotometrically and the exact amount needed to dye the next shade determined. The amount of chemical auxiliaries to be added does not need to be as exact as for the dyes, and can be estimated depending on whether the chemical is exhausted onto the fiber like a dye or remains in the bath. Some water will be lost to evaporation, and some will remain in the material when it is removed. The amount of water to be added each time can be easily determined if a site glass is installed on the dyeing machine.

There are several different methods of materials handling that can be incorporated when using dyebath reuse. Either the dyebath or the material can be moved after each dyeing. The simplest method of operation is to move the dyebath from one machine to another. However, a substantial capital investment must be made to provide for holding tanks and a pumping and piping system. The other method involves removing the material from one dyeing machine and placing it in another, or using some other means of rinsing before drying. This method does not require a capital investment, but poses a problem for the dyeing machine operator who has to handle hot goods. Several modifications have been made to these two initially proposed systems that have proven to be viable alternatives. A carpet dyeing and finishing company in north Georgia is using a modified materials handling procedure that involves pumping the dyebath from beck to beck instead of into holding tanks.

Plant Operations

E & B Carpets in Dalton, Georgia, is now dyeing 45% of their carrier polyester production using dyebath reuse. Two separate beck systems have been modified to accommodate the movement of dye baths. One system connects five large becks and the other system connects six smaller becks, as shown in Figure 1. Dyebaths can be transferred between any two becks in a system. The system with five becks has been in operation for one year, and the system with six becks has been on line for one month.
Figure 1. Beck System for Dyebath Reuse at E & B Carpets
A small microprocessor unit sequences the valves and pumps between any two of the becks in a system. Two control panels, one for each system, are located in the dyehouse lab and are used by the dyer to direct the dyebaths. The dyer controls which shades are dyed in each beck and decides where each dyebath will go once the dyeing is completed. He keys this information into the control panel. When the first dyeing is completed and the second beck empty, the microprocessor signals the proper valves and pump to transfer the dyebath and the operator activates the pump. The pumping procedure involves adding back enough water to bring the bath up to the proper level, transferring the bath to the next beck, and then rinsing the remaining carpet with cold water to cool it down.

At E & B if scheduling permits, the same shade is dyed each time with a reused dyebath. If this is not possible, the dyer chooses a sequence that goes from light shades to dark shades. According to plant management, the same shade can be scheduled about 90% of the time since each dyebath is used only three or four times. The presence of a surfactant in the bath used for scouring the goods limits dyebath use. After three or four dyeings, the dye no longer exhausts sufficiently onto the fiber to produce first quality goods and the dyebath must be discarded.

Trials were run in the plant to establish the dyebath reuse procedure. During these trials it was determined that the dyeings were sufficiently consistent to assume an addition of 90% of the dyes normally added, 50% of the carrier, and 25% to 50% of the leveling agent depending on the shade. This particular procedure has been successful at E & B, since only six dyes are used for all of the polyester shades. If more dyes were used, the dyebath chemical analysis procedure would be required before each reuse.

The major problem that E & B has faced while using dyebath reuse is scheduling the production so that several loads are dyed the same shade in a sequence, especially when business is slow. Dyebath reuse is suspected to be the cause of crockfastness problems. Crocking on dark shades has been linked to reuse, but there is still doubt as to whether it is the only cause. Both of these problems are minor, however, in comparison to the savings resulting from dyebath reuse; and the plant management is pleased with the overall results.
Savings

The system was justified at E & B by a full-scale trial run in the plant on a manual basis, testing 40,000 square yards of goods. The trial resulted in a projected energy savings of 4500 BTU per square yard. Chemical savings were projected to be from $0.045 to $0.060 per square yard of goods dyed. Thus, the resulting savings were estimated to be $250,000 for the first year of operation, based on dyeing all polyester production by dyebath reuse. For an initial capital investment of $125,000, a discounted payback of 10 months resulted. This payback was well within the required two years, and the project was implemented.

An evaluation of the five-beck system, which has been installed for approximately one year, was recently performed by plant engineers. The resulting energy, dye and chemical, and water savings are summarized in Table I.

Table I
SAVINGS RESULTING FROM DYEBATCH REUSE
WITH THE FIVE BECK SYSTEM

<table>
<thead>
<tr>
<th></th>
<th>Annual Volume Savings</th>
<th>Annual Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>4,231 MMBTU</td>
<td>$17,135</td>
</tr>
<tr>
<td>Dyes and Chemicals</td>
<td>---</td>
<td>$43,400</td>
</tr>
<tr>
<td>Water</td>
<td>6,750,000 gallons</td>
<td>$3,700</td>
</tr>
<tr>
<td>TOTAL SAVINGS</td>
<td></td>
<td>$64,235</td>
</tr>
</tbody>
</table>
Based on the first year actual savings, a two year simple payback was obtained. These savings resulted from approximately 25% of the polyester production being dyed by dyebath reuse.

Now that 11 becks have been set up for dyebath reuse work, approximately 45% of the polyester production is being dyed in this manner. The projected savings for the next year are summarized in Table II.

<table>
<thead>
<tr>
<th></th>
<th>Annual Volume Savings</th>
<th>Annual Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>7,616 MMBTU</td>
<td>$30,845</td>
</tr>
<tr>
<td><strong>Dyes and Chemicals</strong></td>
<td><strong>—</strong></td>
<td>$78,120</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>10,000,000 gallons</td>
<td>$5,500</td>
</tr>
<tr>
<td><strong>TOTAL SAVINGS</strong></td>
<td></td>
<td>$114,465</td>
</tr>
</tbody>
</table>

These savings are based on current energy, chemical, and water costs. Increasing prices will probably result in higher savings.

**Summary**

E & B Carpets has been using dyebath reuse in its regular production dyeings for over a year and has been very pleased with the results. No major problems have occurred, and first quality goods have been consistently produced. An acceptable payback resulted from the first
year's actual savings, even though only 25% of the polyester production was dyed using dyebath reuse. Plant personnel are especially pleased with the resulting dye and chemical savings, and feel that the system is justified on this savings alone. The wastewater discharge has also been substantially reduced, which will help E & B continue to meet future federal water quality standards.

—for further information contact

Mark E. Cawthon
Plant Project Engineer
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Dalton, Georgia
Appendix C

CASE STUDY REPORT
BUMP-AND-RUN
TEXTILE ENERGY CONSERVATION CASE STUDY:
BUMP-AND-RUN

-performed by
Engineering Experiment Station
Georgia Institute of Technology

-sponsored by
Battelle, Pacific Northwest Laboratories

by
Douglas M. Moore

August 11, 1981
BUMP-AND-RUN

- Salem Carpets, Inc.
P. O. Box 10
Ringgold, Georgia 30736

- Mr. Dave Dake
Engineering Projects Manager
404-935-2241

Salem Carpets produces nylon and polyester carpet.

Salem Carpets uses a dyeing procedural modification called bump-and-run.
The procedure involves heating the dyebath to the dyeing temperature and
then turning the steam off and allowing the bath temperature to drift.
If the dyeing machine is well sealed, the bath temperature will only drop
a small amount.

Before Salem Carpets implemented bump-and-run in nylon dyeing, annual
energy consumption averaged 75,570 MMBTU.
Since bump-and-run has been incorporated into the nylon dyeing
procedure, the annual energy consumption for nylon dyeing has been
reduced to 55,410 MMBTU.

From March 1979 to March 1980, the year before bump-and-run was imple-
mented, natural gas costs averaged $2.36 per million BTU and No. 6 fuel
oil averaged $3.43 per MMBTU. An average plant steam cost was estimated
to be $3.10 per MMBTU.
From March 1980 to March 1981, the year after bump-and-run was
implemented, natural gas averaged $2.82 per MMBTU and No. 6 fuel oil
averaged $4.82 per MMBTU. An average plant steam cost was estimated to
be $3.93 per MMBTU.

Salem Carpets has saved 20,160 MMBTU in energy usage and $63,500 in
energy costs in the year that bump-and-run has been utilized.

Bump-and-run was initially implemented as a part of a Department of
Energy project performed by researchers at Georgia Tech.

Aside from the resulting energy savings, the other major advantage of
bump-and-run is the improved economic analysis of dyebath reuse when the
two technologies are combined.
BUMP-AND-RUN

Introduction

Beck dyeing is a batch dyeing process in which the textile material is loaded into a large stainless steel container called a dye beck. The beck is then filled with water, to which various chemicals and dyes are added. The bath is heated to some predetermined temperature, usually at or near boiling, to set the dyes. A substantial amount of energy is required to heat the water in the beck to the dyeing temperature and to hold it during the dye cycle. An exhaust hood and fan are required to remove the large volume of water vapor and steam produced at the surface of the bath.

Experiments conducted by Georgia Tech researchers revealed that 45% to 60% of the total energy used in a dye beck is lost through the exhaust stack. The need to reduce this loss is clearly indicated. The technology of bump-and-run, in which the dyebath temperature is allowed to drift for the last 85% of the hold time instead of being maintained by active steam sparging, has been shown to cut stack losses by 75% with no detectable reduction in quality.

Traditional Operation

Salem Carpets, headquartered in Ringgold, Georgia, has proven the effectiveness of a modified carpet dyeing procedure for beck dyeing that can cut steam consumption during a conventional dye cycle by 38%. The procedure, tagged "bump-and-run" by its developers, was implemented at Salem's plant in Chickamauga, Georgia, under a demonstration grant from the Department of Energy. The plant was automated for bump-and-run by the addition of a simple timer, at a cost of only $50 per beck. The installation costs were paid back after just a few days of operation.

Salem Carpet's dyeing and finishing plant in Chickamauga houses both batch and continuous dyeing operations. Energy is supplied to the process equipment primarily in the form of medium pressure steam, produced by two 50,000 pound per hour boilers. These boilers use natural gas as a primary
fuel, with No. 6 fuel oil as standby. The plant currently has 14 dye becks and operates 24 hours per day, 7 days per week, with a two-day shutdown one weekend per month.

Before adopting the bump-and-run procedure, Salem followed a conventional dyeing procedure that called for at least one and sometimes more hold cycles, in which the dyebath was held at a rolling boil for 30 minutes. This resulted in tremendous energy loss through the stack, as indicated in Figure 1. Several traditional alternatives were considered to reduce these losses, and then rejected for various reasons. Automatic damper controls that limit exhaust air flow from the beck were evaluated. Capital costs for the system were high and the controllers were found to be high maintenance items. A second alternative considered was low temperature dyeing. In this process, special chemicals were added to the dyebath to open up the fiber and allow the dyes to set at temperatures near 140°F. Cost analyses revealed, however, that the additional chemical costs offset any energy cost savings that would accrue. Also, the low temperature was not adequate to fully develop the bulk of the carpet. This possibility, therefore, was also rejected.

Procedural Modifications

The concept of bump-and-run, first proposed by Mr. John J. Toon of the Piedmont Chemical Company, avoids many of the drawbacks of low temperature dyeing. Previous research had shown that about half of the energy used in a dye beck was lost out the stack, while radiation and convection losses accounted for only 2% of total energy consumption. The process of bump-and-run takes advantage of the fact that radiation losses are small, while minimizing stack losses at the boil (see Figure 1).

In this process, the dyebath is heated or "bumped" to boiling temperature and held there for 5 minutes. The steam injection then is halted, the exhaust fan is stopped, the exhaust damper is closed, and the beck doors are closed. At this point, the beck becomes like a closed kettle, and the temperature is allowed to drift for the next 25 minutes of the conventional 30 minute hold cycle (the "run" portion of the process). Experience has
Figure 1. Atmosphere Beck Flows

- **Ambient Water**
- **Ambient Air**
- **Steam 100%**
- **Heated Water 49%**
- **Heated Air Steam 49%**
- **Stack Losses**
- **Loss to Drain 40% to 55%**
  Proportional to Liquor Ratio
- **Other Losses 2%**
shown that a temperature drop of approximately $20^\circ F$ is to be expected during the run period. The remainder of the cycle is the same as with the conventional procedure.

Although this modification was initially implemented at no capital cost by simply changing operating procedures, it soon became apparent that the dyehouse operators were having to set the temperature controllers four times each cycle rather than two. To alleviate this situation, electronic automatic reset timers (Omron STP-MYH-AH) were installed at each temperature controller, energized by the wire that ran to the end-of-cycle lamp. This lamp was then wired through a normally open contact on the timer. With this setup, the dyehouse operator set the beck controller for a 5 minute hold at the boil in the usual manner. When the 5 minute hold was complete, current was routed to the auxiliary timer, that was preset for the 25 minute run portion of the cycle. At the end of this period, the end-of-cycle lamp was illuminated. The use of the timers allowed the operators to control the system in exactly the same manner as had been previously done.

The auxiliary timers were installed on all of the beck temperature controllers, at an average cost including installation of $50 each. The other necessary equipment including beck doors and stack fan dampers were already being used, resulting in an almost immediate payback on the company's investment. Salem currently uses bump-and-run for all of its nylon carpet production, which accounts for 30% of the total plant production. The process is not presently used on polyester because of crock-fastness problems.

**Savings**

Energy consumption for both conventional dyeing procedures and for dyeing cycles using bump-and-run was monitored by Georgia Tech engineers at Salem's Chickamauga plant under a grant from the Department of Energy. Steam consumption during the conventional process was monitored for ten cycles and a base line average obtained. Consumption for ten cycles using bump-and-run was also monitored resulting in an average savings of 38%, as summarized for a normalized dye cycle in Table I.
Bump-and-run was used for all nylon dyeing at Salem beginning in March 1980. After a full year of operation under this system, plant engineers reported a net yearly energy savings of 20,160 MMBTU and a cost savings of $63,500. Based on an installed cost of $50 per timer, the total cost to modify all 14 of the company's becks was $700, giving a simple payback of four days.

The above savings were achieved by using bump-and-run on the plant's nylon production only, which accounts for 30% of total production. There has been no loss of quality among the nylon goods. The procedure has not been successfully used with polyester fibers because crockfastness problems have been observed. Salem is studying this problem and hopes eventually to use bump-and-run with all of its production.

The potential for energy savings if bump-and-run could be expanded to Salem's entire product line is impressive. If the assumption is made that energy costs will increase by 15% during the next twelve-month period, the potential for annual energy cost savings using bump-and-run plantwide amounts to over $240,000.

Bump-and-run also makes the technology of dyebath reuse easier and less costly to implement. At the end of the final hold cycle for a dyebath
reuse/bump-and-run dyeing, the carpet was checked for color level. By this time, the temperature of the dyebath had dropped to 170°F, allowing the carpet to be easily removed while leaving the dyebath in the machine. Since dyebath reuse was being utilized the spent dyebath was then analyzed, reconstituted, and reused for a number of subsequent dyeings. Bump-and-run thus eliminated the need for holding tanks and pumping systems normally associated with dyebath reuse to facilitate the movement of hot goods. Final rinsing of the carpet was completed in the wet-out box preceding the dryer.

Summary

Bump-and-run is an excellent example of the somewhat rare variety of energy conservation opportunity that offers substantial energy savings at an insignificant initial cost. The ability to discover opportunities of this type depends on the willingness of plant managers and plant personnel to analyze carefully their current operating procedures and evaluate each step of each process. An open mind is essential, as established practices must be scrutinized. Cooperation of plant personnel must be willingly offered in order to obtain the results anticipated. This requires excellent communication between management and labor, and a general awareness of the importance of energy conservation within the plant. These qualities are key elements of any successful energy conservation program.

In the case of bump-and-run, plant operations were hardly disturbed at all: the dyer used the same chemicals as in the conventional process, management had to provide negligible capital, and even the beck operator was satisfied. Savings to the plant were substantial, and neither the quality control engineers nor the dyers identified any dyeing problems.

—for further information contact

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C-8
Appendix D

CASE STUDY REPORT
FOAM FINISHING
TEXTILE ENERGY CONSERVATION CASE STUDY:
FOAM FINISHING

-performed by
Engineering Experiment Station
Georgia Institute of Technology

-sponsored by
Battelle, Pacific Northwest Laboratories

by
LuAnn T. Rockett
and
Fred L. Cook

October 1, 1981
United Merchants and Manufacturers
Old Fort Finishing Plant
Old Fort, North Carolina 28762

Mr. Floyd Parker
Plant Manager
704-668-7611

United Merchants produces cotton/polyester apparel fabrics.
United Merchants has retrofitted a conventional finishing range with a foam finishing system. The foam reduces the wet pick-up of the fabric to 25% to 35%, thus reducing drying time and chemical usage, and increasing line production.

Before foam finishing was introduced, the plant consumed 23,100 MMBTU per year in the finishing operation. Since foam finishing has been used, the plant has averaged 10,100 MMBTU per year in the finishing operation.

For the year prior to the installation of the foam system, propane averaged $2.61 per MMBTU. In 1980, propane has averaged $5.01 per MMBTU.

Since the foam system was installed, United Merchants has had an average weekly total savings of $5,203 and energy savings of $1,303.

Since the system promised a payback period of less than six months, United Merchants decided to invest in the procedure.

The major benefit realized from installing the foam system was a substantial increase in production capacity using existing finishing lines.
Introduction

Foam finishing is a process whereby the finish is applied to the fabric in an air-blown foam, rather than a pure liquid state. This results in the following advantages over conventional aqueous systems:

- Reduction in energy consumption for drying and curing per pound of fabric,
- More efficient use of chemicals,
- Application to wet fabric without first drying, and
- Reduction in water content of the finish resulting in higher production rates, decreased dryer temperatures and decreased fuel consumption.

Foam finishes may include fluorocarbons, permanent press resins, softeners or water repellants. Foam has been successfully used on nylon and polyester/cotton fabrics in pile, woven, and knitted forms.

The foam process consists of preparing a concentrated solution (or dispersion) of the chemical or chemicals in water, and then incorporating suitable foaming aids. The concentrate is then mechanically foamed and is applied to the fabric by means of equipment such as a knife over a roll coater. The foam is then forced to collapse and flow over the fibers. This can be done by passing the foam-coated fabric through a pad mangle or by using a foam which collapses when heated. The coated fabric is then passed through a conventional oven to remove the small amount of water used in the concentrate and to cure the finish.

To date, foam finishing has gained wider acceptance than foam dyeing, mainly because of the wider latitude in uniformity allowed for colorless finishes than for dyes and pigments. Foam finishing can also result in the elimination of the washing and drying steps after curing, another example of the energy savings possible with foam finishings.

Traditional Operation

United Merchants and Manufacturers Old Fort Finishing Plant in Old Fort, North Carolina, has been successfully using foam finishing since 1977. The Old Fort plant produces apparel fabrics ranging from 1.2 to 4.0 yards per pound. The average fabric weight is 2.5 yards per pound. The
fabrics are generally 50% polyester/50% cotton blends, with polycellulosics accounting for 80% of the total production. All fabrics produced in the plant are finished with foam processing.

Until 1977, the plant operated with conventional finishing ranges. The ranges typically ran at 40 to 80 yards per minute, and generally consumed 32 yards per gallon of finishing mix. Drying and curing temperatures ranged from 350° to 375°F when performed in the same step. During this time, total plant gas consumption in the finishing area was 23,100 MMBTU at an average annual cost of $2.61 per MMBTU.

**Modifications**

In 1977, United Merchants retrofitted their conventional finishing ranges with foam systems at an average cost of $25,000 per range. The incentives to invest were two-fold -- projected energy savings and increased production.

The system is shown in Figure 1. Using this type of foam finishing technology, both sides of the fabric are finished at the same time. Production speeds have been increased to 70 to 110 yards per minute using foam finishing, and plant personnel project that with new drying equipment speeds of over 200 yards per minute can be achieved. Using foam, the wet pick-up has averaged 25% to 35%. The details of the foaming system itself are pictured in Figure 2. The frame dryer in the foam system can operate two ways, by drying and curing in the same step at 350° to 375°F or drying first and then roller curing at 250° to 300°F.

Foam finishing has led to a decrease in chemical usage of 10% to 20%. A typical finish can now be applied at 100 yards per gallon of mix. Energy consumption for finishing has been reduced to 10,100 MMBTU for 1980 at a cost of $5.01 per MMBTU.

Environmentally, the impact of foam finishing has been minimal. Chemical usage has decreased. In terms of water volume, there has not been a dramatic change since the conventional finishing system did not use an afterwash. However, there has been a percentage decrease in water usage of approximately 50%.
FIGURE 1. UNITED MERCHANTS AND MANUFACTURERS FOAM FINISHING SYSTEM
FIGURE 2. FOAMING SYSTEM
Savings

The initial $25,000 invested in the system was recovered in 25 weeks with $1000 per week in savings due to the decrease in energy consumption. Because the total payback period was so short, the investment was made without any consideration given to return on investment or other economic analyses. Total finishing energy consumption is shown in Table I.

<table>
<thead>
<tr>
<th></th>
<th>Propane Cost</th>
<th>Energy Usage</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>$0.249/gal</td>
<td>925 BTU/yd</td>
<td>$2.31 x 10^{10} BTU/yr</td>
</tr>
<tr>
<td>(1977)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foam</td>
<td>$0.479/gal</td>
<td>405 BTU/yd</td>
<td>$1.01 x 10^{10} BTU/yr</td>
</tr>
<tr>
<td>(1980)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAVINGS</td>
<td></td>
<td>520 BTU/yd</td>
<td>13,000 MMBTU/yr</td>
</tr>
</tbody>
</table>

Total savings dollars are based on labor, materials and overhead costs. Energy consumption is also included in this figure. Based on current plant figures, the average savings shown in Table II were compiled.

<table>
<thead>
<tr>
<th></th>
<th>Annual</th>
<th>Weekly Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENERGY SAVINGS</td>
<td>$65,150</td>
<td>$1,303</td>
</tr>
<tr>
<td>TOTAL SAVINGS</td>
<td>$260,150</td>
<td>$5,203</td>
</tr>
</tbody>
</table>
Summary

United Merchants feels that resistance to change is the major barrier confronting the textile industry with regard to conversion to foam finishing. With less than a 6 month payback to retrofit an existing finishing range, foam finishing quickly produces savings in labor, materials, energy, and overhead. Foam finishing is clearly both an economically and technologically attractive energy conservation alternative that is being used by an increasing number of plants.

-for further information contact

Mr. Floyd Parker
Plant Manager
United Merchants and Manufacturers
Old Fort, North Carolina
TEXTILE ENERGY CONSERVATION CASE STUDY:
WASTEWATER HEAT RECOVERY

-performed by
Engineering Experiment Station
Georgia Institute of Technology

-sponsored by
Battelle, Pacific Northwest Laboratories

by
Rachel L. Moore

September 28, 1981
WASTEWATER HEAT RECOVERY

- Tuftex Carpet Mills, Inc.
  La Mirada Dye Plant Division
  15228 Bona Vista
  Santa Fe Springs, California

- Mr. Robert Brissette
  Plant Engineer
  213-921-6791

- The La Mirada Dye Plant produces finished nylon carpets.

- The La Mirada Dye Plant of Tuftex Carpets was constructed to include a wastewater heat recovery system that uses hot wastewater from the dyehouse to preheat incoming water to the dyehouse and water for boiler feed.

- From August 1980 to July 1981, the La Mirada Dye Plant consumed 297,865 MMBTU at a total cost of $1,153,960.

- The wastewater heat recovery system has saved an estimated 21,149 MMBTU annually, or 63,447 MMBTU since the plant began operation in September 1978. At current fuel costs, this results in an annual cost savings of $121,606.

- The cost of the wastewater heat recovery unit was included in the initial construction cost of the plant, since management personnel knew that it would provide a quick payback and solutions to other potential problems.

- The use of the wastewater heat recovery system helped the plant meet county emissions standards for wastewater. No wastewater over 120°F could be discharged from the plant, and the wastewater exiting the heat exchangers is at an average temperature of 110°F. Dye cycle time was also reduced, since the incoming water was at 100°F instead of 68°F.
WASTEWATER HEAT RECOVERY

Introduction

The textile industry consumes over 125 billion gallons of water and 290 billion BTU each year in its wet processing operations. Increasing energy costs and shortages in energy and water supplies have stimulated the implementation of technologies that reduce energy and water consumption. A large portion of the energy and water consumed in wet processing is used in batch operations. Because batch operations are much more energy intensive than continuous operations, research work has been directed toward ways to conserve energy and water in batch dyeing. New batch dyeing procedures have been perfected, which can save as much as 50% of the energy consumed in conventional procedures. Some of these procedures also reduce the amount of hot wastewater that is discharged from the plant. However, some wastewater discharge will still occur and the heat in this water should be recovered. A carpet mill in California uses wastewater heat recovery to provide warm dyehouse water and boiler feedwater.

Plant Operation

Tuftex Carpets, located in Los Angeles, California, is a fully integrated carpet mill that produces finished nylon carpet. Beck dyeing, resist printing, drying, and finishing are the major plant operations at Tuftex’s La Mirada Dye Plant. The plant is operated 24 hours per day, 5 days per week, 52 weeks per year.

The La Mirada Dye Plant uses two heat exchangers to preheat boiler feedwater and beck fill water using the outgoing hot wastewater from the dye becks as shown in Figure 1. The dye becks are equipped with two separate drain systems, one that directs water of 120°F or less to the sewer and one that directs water above 120°F into a holding tank. From the holding tank, the hot wastewater at an average temperature of 155°F is pumped into one of the two heat exchangers, which are connected in parallel. The large four-tube heat exchanger heats water to 100°F, which goes either to the dyehouse or back through the small three-tube heat exchanger. The pipe leading to the small exchanger has a flow restriction that allows approximately 20% of
Fresh City Water (68°F) → Holding Tank (Pump) → Large Heat Exchanger → Small Heat Exchanger → Deaerator → Boiler (255°F) → Steam Condensate → Boiler Blowdown (350°F) → Wastewater Pit (220°F) → Water Softener (100°F) → Sewer (100°F) → Dyehouse (100°F)
the wastewater to flow through, with the remaining 80% flowing through the large heat exchanger. The wastewater exiting from the exchangers is at an average temperature of 110°F and is discharged to the sewer.

Part of the fresh water that exits from the large heat exchanger passes through a water softening operation and then through the small exchanger where the temperature is boosted to 135°F. The water is then sent through a tank where it is indirectly heated by continuous boiler blowdown to 160°F. The next step for the boiler feedwater is to be heated to 225°F in the deaerator tank by steam coils, and then the feedwater goes into the boiler. Thus, the dyehouse receives water at 100°F and the boiler feedwater is preheated to 160°F, rather than having water entering both operations at 68°F.

The plant uses 930,000 gallons of water per day. The boiler requires an average of 100,000 gallons per day of feedwater. Thus, the dyehouse uses an average of 830,000 gallons per day, producing a flow of 575 gallons per minute. Approximately 250 gallons per minute of this flow is used hot. Thus, the average wastewater flow into the heat exchangers is estimated to be 300 gallons per minute, and the fresh water flow into the large heat exchanger is approximately 270 gallons per minute. The system is designed to handle a peak flow of 1200 gallons per minute. The flow to the small exchanger and then to the boiler is 70 gallons per minute. Approximately 24 gallons per minute of surface blow off at 350°F enters the holding tank, heats the softened boiler water from 135°F to 160°F, and is discharged to the wastewater sump at 220°F.

Tuftex's La Mirada Dye Plant began its operations in September 1978. The plant, built with the heat exchanger systems as an original part of the plant, has used the system continuously since startup except when maintenance was being performed.

The plant management has been very pleased with the operation of the system. Maintenance is minimal; the system is back washed by flow reversal once per day for 15 minutes. Once every six months, a caustic solution is run through the system to eliminate any chemical buildup. Lint has not been a problem in the system because a lint screen is used before the water enters the holding tank and dual filters are used between the pumps and the heat exchangers.
Savings

For an average flow to the dyehouse of 200 gallons per minute of fresh water at 100°F instead of 68°F, the savings resulting from using the system based on current energy prices are shown in Table I.

<table>
<thead>
<tr>
<th>Table I</th>
<th>DYEHOUSE ENERGY SAVINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Energy Savings</td>
<td>19,215 MMBTU</td>
</tr>
<tr>
<td>Annual Cost Savings</td>
<td>$110,488</td>
</tr>
</tbody>
</table>

For an average flow of softened water to the boiler feedwater system of 70 gallons per minute at 160°F instead of 68°F, the savings resulting from using the system based on current energy costs are shown in Table II.

<table>
<thead>
<tr>
<th>Table II</th>
<th>BOILER SYSTEM ENERGY SAVINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Energy Savings</td>
<td>1,934 MMBTU</td>
</tr>
<tr>
<td>Annual Cost Savings</td>
<td>$11,118</td>
</tr>
</tbody>
</table>

Thus, the total savings resulting from the installation of the wastewater heat recovery system are shown in Table III.

<table>
<thead>
<tr>
<th>Table III</th>
<th>TOTAL SAVINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Energy Savings</td>
<td>21,149 MMBTU</td>
</tr>
<tr>
<td>Annual Cost Savings</td>
<td>$121,606</td>
</tr>
</tbody>
</table>
Summary

Tuftex's La Mirada Dye Plant designed a sophisticated wastewater heat recovery system to be a part of the original plant equipment. The plant management knew that substantial energy savings would result from the installation and also knew that the system could solve other potential problems. The county code stated that no water above 120° could be discharged to the sewer. With the heat recovery system, the wastewater discharged from the plant was reduced to 110°F. The availability of warm water would also allow the dye cycle times to be shorter since it would take at least 10 minutes to heat the dyebath from 68°F to 100°F.

-for further information contact

Mr. Robert Brissette
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La Mirada Dye Plant Division
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TEXTILE ENERGY CONSERVATION CASE STUDY:
WASTEWATER CHLORINATION AND REUSE

-performed by
Engineering Experiment Station
Georgia Institute of Technology

-sponsored by
Battelle, Pacific Northwest Laboratories

by
Douglas M. Moore

August 4, 1981
WASTEWATER CHLORINATION AND REUSE

- Salem Carpet Mills, Inc.
  P. O. Box 10
  Ringgold, Georgia 30736

- Mr. Dave Dake
  Engineering Projects Manager
  404-935-2241

- Salem Carpets produces nylon and polyester carpet.
- Salem Carpets has installed a system that chlorinates the wastewater that is discharged from the dyehouse. The addition of chlorine to the water renders it colorless, which allows the water to be reused in subsequent dyeings. The wastewater goes directly from the dye becks into the chlorination system, and contains a substantial amount of the heat that was added during the dye cycle.

- Before the water chlorination system was installed, the beck dyeing operation at Salem consumed 300,000 MMBTU per year. Since the water chlorination system has been in use, Salem's beck dyeing operation has averaged 265,000 MMBTU per year.

- For the year prior to the installation of the water chlorination system, natural gas costs averaged $0.85 per MMBTU and No. 6 fuel oil averaged $1.27 per MMBTU. For 1980, natural gas has averaged $5.32 per MMBTU and No. 6 fuel oil has averaged $4.82 per MMBTU.

- Since the water chlorination system was installed, Salem Carpets has had an average annual energy savings of 35,875 MMBTU and an average energy cost savings of $123,800 per year.

- Salem Carpets requires a one year or shorter payback on its capital investments. The chlorination system had a 1.8 year payback when all savings were taken into account. The company decided to invest despite the longer payback since the city was limiting their wastewater discharge and consequently reducing their production capacity.

- The other major benefit from the water chlorination system was the reduced wastewater discharge and subsequent reduction in water usage.
WASTEWATER CHLORINATION AND REUSE

Introduction

The textile industry consumes approximately 125 billion gallons of water per year. Most of this water is discharged from the plant and contains substantial quantities of organic and inorganic chemicals such as dyes, surfactants, auxiliaries, pH control agents, and lubricants. These chemicals require extensive treatment at the wastewater plant and contribute to pollution problems associated with textile processing. The pollution problem has, in the past, been met by the construction and expansion of wastewater treatment facilities. Each year water quality standards become more stringent, and this requires the investment of more capital to upgrade waste treatment plant equipment and processes. Many areas are restricting the quantities of wastewater that can be discharged into municipal treatment facilities as a result of these problems. The industrial facilities must then find ways to reduce their wastewater discharge or invest large sums of their own capital in non-income-producing wastewater treatment facilities.

In addition to the problems associated with water supply and pollution control, the increasing cost and decreasing supply of energy represents a major problem for the textile industry. Thus, technologies providing solutions for all of these problems are continually sought by the industry. One such solution that has been implemented by the textile industry is water chlorination and reuse.

Traditional Operation

Salem Carpets, headquartered in Ringgold, Georgia, operates a carpet dyeing and finishing plant in nearby Chickamauga, Georgia. This plant houses both batch and continuous and dyeing, two highly energy intensive processes. Energy is supplied to the process equipment primarily in the form of medium pressure steam produced by two 1600 HP boilers. These boilers use natural gas as a primary fuel, with No. 6 fuel oil as a standby. The plant uses 14 dye becks and one continuous line and operates 24 hours per day, 7 days per week, with a two-day weekend shutdown once per month.
Batch dyeing is more energy intensive and consumes much larger quantities of water than continuous dyeing. Beck dyeing is a batch process in which the carpet is loaded into a large stainless steel container called a dye beck. The beck is filled with water, normally 3000 to 5000 gallons per fill for carpet, and the dyes and chemicals are added. The dyebath is heated to the dyeing temperature (180°F to 212°F) to set the dyes. When the correct color is obtained, the dyeing water is discharged to the drain. The beck is filled again with fresh water, the carpet rinsed, and the rinse water also discharged to the drain.

A substantial amount of energy is required to heat the water to the dyeing temperature and hold it during the dye cycle. All of this energy is lost each time a dyebath is discharged to the drain. Tremendous quantities of water are also required by the beck operation. Water is supplied to Salem by the city and by a number of drilled wells on the plant property. Treatment of the wastewater has posed a problem as well, in terms of both the disposal cost and the limitations of the city's waste treatment facility.

Process Modifications

By the end of 1974, growth of industry and community had begun to tax the capability of the local water and sewer facilities. The city therefore imposed a limit on the maximum amount of effluent that could be discharged from the Salem plant. In order to continue to expand their operation, plant engineers were forced to find ways to reduce water consumption and the resulting effluent. Many alternatives were considered, but a water chlorination system showed the best overall results. The system, pictured in Figure 1, was chosen for its excellent cost-benefit ratio, which was greatly enhanced by the energy savings afforded by the system. Installation of the system was completed by July 1975 at a cost of $412,000, and provided a total cost savings of $215,500 during its first year of operation.

The system chosen by Salem uses chlorine gas to oxidize the remaining dye particles in the spent dyebath into colorless chemical fragments. Both dyeing and rinsing baths are pumped to one of four fiberglass treatment tanks where chlorine gas is bubbled through the water. The temperature of
Figure 1. Salem Carpets Water Chlorination System

From Wastewater Pit

Chemical Feed System

Control Center

Holding Tanks

Treatment Tanks

Filtration System

To Dye Becks
the water entering the system averages 125°F. The pH of the water is adjusted to neutral with a weak base, since the formation of hypochlorous acid occurs during the chlorine treatment and lowers the pH. The water, still at an elevated temperature and containing the chemical fragments, is then pumped into one of four fiberglass storage tanks. The temperature of the water returned to the process can be as high as 120°F. However, since the tanks are located outdoors and are not insulated, the returned water supply temperature averages 85°F on an annual basis. The energy savings provided by the system arise from the return of the water at an elevated temperature, thus eliminating the need to expend energy to heat incoming water from 60°F to 85°F.

Savings

Salem's water reclamation system has been in operation for six years and in that time has saved the company over $1.4 million in avoided energy, water, and sewer costs. Water usage and the resulting sewer discharge has been reduced from 1.2 million gallons per day to 440,000 gallons per day, thus allowing the plant to continue its normal operation. Energy is saved by returning water at 85°F instead of 60°F to the dyehouse. Based on an average steam plant efficiency of 75%, with 50% of the water used for beck dyeing being the recycled water, an energy savings of 35,875 MMBTU per year is possible. The resulting cost savings for the first year of operation (1975) are shown in Table I.

<table>
<thead>
<tr>
<th></th>
<th>Volume Savings</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>35,875 MMBTU</td>
<td>$89,700</td>
</tr>
<tr>
<td>Water</td>
<td>266 million gallons</td>
<td>$159,600</td>
</tr>
<tr>
<td>Sewer</td>
<td>266 million gallons</td>
<td>$39,900</td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL SAVINGS</strong></td>
<td></td>
<td><strong>$289,200</strong></td>
</tr>
</tbody>
</table>
The operating costs of the system for 1975 are summarized in Table II. At least two people are present at all times and are responsible for the system operation. These operators control the addition of chlorine gas, sulfite, soda ash, and other chemicals to control the water quality.

Table II
WATER CHLORINATION SYSTEM OPERATING COSTS FOR THE FIRST YEAR OF OPERATION

<table>
<thead>
<tr>
<th></th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>$46,700</td>
</tr>
<tr>
<td>Supervisor</td>
<td>$12,600</td>
</tr>
<tr>
<td>Operators (4)</td>
<td>$34,100</td>
</tr>
<tr>
<td>Chemicals</td>
<td>$21,200</td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL COSTS</strong></td>
<td><strong>$67,900</strong></td>
</tr>
</tbody>
</table>

As shown in Table III the labor and chemical costs are more than offset by the savings.

Table III
NET SAVINGS FOR THE FIRST YEAR OF OPERATION

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Savings</td>
<td>$289,200</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$67,900</td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL SAVINGS</strong></td>
<td><strong>$221,300</strong></td>
</tr>
</tbody>
</table>
Due to the tremendous increase in energy costs since 1975, the system savings are even greater for 1980, as shown in Table IV.

Table IV
SYSTEM SAVINGS FOR 1980

<table>
<thead>
<tr>
<th></th>
<th>1975 Unit Cost</th>
<th>1980 Unit Cost</th>
<th>Annual Cost Savings for 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>$2.50/MMBTU</td>
<td>$6.00/MMBTU</td>
<td>215,250</td>
</tr>
<tr>
<td>Water</td>
<td>$0.60/1000 gal</td>
<td>$0.60/1000 gal</td>
<td>155,000</td>
</tr>
<tr>
<td>Sewer</td>
<td>$0.15/1000 gal</td>
<td>$0.21/1000 gal</td>
<td>54,300</td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL SAVINGS</strong></td>
<td></td>
<td></td>
<td><strong>$424,550</strong></td>
</tr>
</tbody>
</table>

Although the savings from the system are substantial, there are several drawbacks that should be evaluated when considering the installation of a water chlorination and reuse system. The returned water contains chemical fragments of unknown composition that, although colorless, can contribute to dyeing problems that could be difficult to solve. Dyes and chemicals in the water are destroyed by the process, and therefore no chemical savings are possible. In addition, recent research has shown that under certain conditions polychlorinated biphenyls (PCB's) can be formed by bubbling chlorine gas through aqueous solutions containing biphenyl and related aromatic carriers commonly used in dyeing polyester.

Summary

In analyzing this investment, Salem's management chose the simple payback technique. At 1975 costs, the initial investment of the system was paid back in only 1.8 years. Although this payback period was longer than the normal one year payback sought by the company, the economics were
greatly enhanced by the fact that total plant production was constrained by the available water supply, and the effects of this potential lost revenue were taken into consideration.

From an overall viewpoint, Salem's water recycling system provides several benefits. From the standpoint of energy, it provides a facility that is more energy efficient than comparable operations, while allowing the plant to achieve otherwise unobtainable production levels. Another benefit offered by the system is the conservation of water, an increasingly scarce resource.

-for further information contact

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Ringgold, Georgia
Appendix G

CASE STUDY REPORT
OVEN EXHAUST AIR COUNTERFLOW
TEXTILE ENERGY CONSERVATION CASE STUDY:

OVEN EXHAUST AIR COUNTERFLOW

-performed by

Engineering Experiment Station
Georgia Institute of Technology

-sponsored by

Battelle, Pacific Northwest Laboratories

by

William B. Himes, Jr.

September 30, 1981
OVEN EXHAUST AIR COUNTERFLOW

- Dan River, Inc.
P.O. Box 261
Danville, Virginia 24541

- Mr. B.C. Haraway
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804-799-4961

- The primary product at Dan River is a shirting weight composed of a 65/35 blend of polyester and cotton.

- Dan River, Inc. has modified 10 tenter frame ovens and predryers with a system that ducts the predryer exhaust into the tenter and counterflows the tenter exhaust. These changes reduce the total exhaust from the predryer and tenter by approximately 47%.

- For the year prior to the installation the price of natural gas averaged $1.94 per MMBTU. For 1980, the natural gas cost averaged $3.60 per MMBTU.

- Since the modifications, Dan River has had an average annual energy savings of 24,250 MMBTU, and a cost savings of $87,302 based on 1980 natural gas prices.

- The average payback period of Dan River energy conservation projects is one year or less, however, programs with a payback period of five years or less are still considered.
OVEN EXHAUST AIR COUNTERFLOW

Introduction

One of the major energy consuming industries in the United States is the textile industry. In an effort to reduce the industry's energy requirement of over 67 million barrels of oil equivalent annually, much work is being done to determine ways to conserve energy in textiles. A major textile processing area that shows promise for energy conservation is the drying/curing/heat setting operation.

The major method for removing water from textile materials, curing finishes, and heat setting fabrics is convective drying using tenter frames and predryers. This operation consumes roughly 25% of the energy required to produce finished textile goods. Most of the ovens and dryers used in textile operations today were designed and built during the time when energy costs did not make a significant impact on the cost of finished goods. Consequently, from an energy standpoint, the efficiency of most textile ovens is low. The energy efficiency of older textile ovens can be improved through some relatively inexpensive modifications.

The thermal energy consumed in a convective heating operation arises from the following four requirements:

- Thermal energy is needed to heat water in the textile material to the evaporation temperature, evaporate it, and then raise the vaporized water from the vaporization temperature to the exhaust temperature.

- Thermal energy is required to raise the textile material from the entrance temperature to the exit temperature.

- Thermal energy is required to replace the heat lost by radiation and convection from the oven housing.

- Thermal energy is required to replace the heat lost when the hot air in the oven is exhausted.
Traditional Operation

Dan River Inc., in Danville, Virginia, has been successful in substantially reducing the quantity of gas consumed in the drying/curing/heat setting operation without significantly affecting product quality or production rates. Their primary product is a 65/35 percent blend of polyester and cotton in dress goods and shirting weight material. Polyester and cotton fiber is brought into the plant in bales. The fiber is processed into yarn, which is woven or knitted into fabric. Depending on the type of material, it is either prepared, dyed, or finished.

Before modifications were made to the tenter frames at Dan River, the drying/curing/heat setting process began in the gas fired infrared predryer (see Figure 1). Ten gas fired burners divided into three banks provided the initial drying, reducing the moisture content of the fabric to around 35%.

The tenter frame dryer was the next step in the process. The tenter frame was divided into three zones, each of which had exhaust ducts. Burners in each zone were separately controlled to vary the operating temperature in each zone. The first two zones were used for drying and curing, and the last zone was used for heatsetting.

Air was exhausted from the tenter frame to remove vaporized water, smoke, solvents, and particulate matter from the dryer housing. Prior to any modification, Dan River was only exhausting air from the first and third zones of the tenter. The exhaust air left the tenter housing at the average temperature inside each zone. Fresh make-up air, usually at room temperature, was taken into the tenter to replace the exhausted air and was heated to the tenter operating temperature. The energy required to heat this large volume of air constitutes approximately 50% of the energy used in the process.

Modification

It is in the area of hot air exhaust reduction that Dan River found the potential for significant savings. The modification implemented on the tenter frames involved the counterflow of the tenter exhaust air and the ducting of the predryer exhaust into the tenter housing instead of to the atmosphere (see Figure 2).
FIGURE 1.
TYPICAL UNMODIFIED CONVECTIVE DRYING ARRANGEMENT
FIGURE 2.
TYPICAL COUNTERFLOW CONVERSION
Prior to modification, the exhaust from the predryer averaged approximately 12,000 to 15,000 CFM at 360°F. This air had a low moisture content and was very clean and was thus able to be ducted into the tenter. After the change, the volume of air through the predryer was reduced to an average of 7,000 to 8,000 CFM and the entire exhaust was ducted into the tenter housing, with a portion entering each of the three tenter zones.

To counterflow the air inside the tenter, a duct with a fan inside was constructed on the side of the tenter housing. This duct carried air from the third zone back into the first and second zones.

The volume of air exhausted prior to conversion was equally divided between the first and third zones, and was approximately 10,000 CFM from each zone. After the changes, the exhaust from the first zone was reduced to 7,000 CFM and the exhaust from the third zone was reduced to 3,000 CFM. Table I shows the results of the first complete tenter modification, at a cost of $17,920.

<table>
<thead>
<tr>
<th>Table I</th>
</tr>
</thead>
<tbody>
<tr>
<td>EFFECTS OF COUNTERFLOW MODIFICATIONS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
<th>Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Volume</td>
<td>33,500 CFM</td>
<td>17,500 CFM</td>
</tr>
<tr>
<td>Natural Gas Consumption</td>
<td>1,575 CFH</td>
<td>1,080 CFH</td>
</tr>
</tbody>
</table>

Based on the reductions shown above, the decision was made to convert nine more tenter frames in early 1977 at a total cost of $150,061 or $16,673 per tenter.

Savings

The exact amount of exhaust reduction possible will vary from tenter to tenter based on initial operating conditions and several other factors,
such as the amount of oils and resins that are evaporated along with water that can cause smoke. Reducing the amount exhaust air increases the tendency of this smoke to blow out the entrance and exit slots. Insurance companies also have regulations that must be strictly adhered to when combustibles are being evaporated. Each of these factors has an effect on the amount of reduction possible. The results of Dan River's modification are shown for the first year of operation and for 1980 in Table II.

<table>
<thead>
<tr>
<th>Year</th>
<th>Natural Gas Cost</th>
<th>Energy Savings</th>
<th>Cost Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>$1.94/MMBTU</td>
<td>24,250 MMBTU</td>
<td>$47,046</td>
</tr>
<tr>
<td>1980</td>
<td>$3.60/MMBTU</td>
<td>24,250 MMBTU</td>
<td>$87,302</td>
</tr>
</tbody>
</table>

The payback period in 1977 was 3.6 years. However, at 1981 natural gas prices the conversions return their investment in less than two years.

Summary

Dan River's management is conservative in cost considerations, yet at the same time is imaginative and innovative and always seeking new opportunities to provide a better product at a competitive price. Each plant annually submits to corporate management an estimate of capital needs for energy improvements. The average return that is accepted is approximately one year or less; however, a five year return is still attractive.

—for further information contact

B.C. Haraway
Technical Superintendent, Finishing
Dan River, Inc.
Danville, Virginia
TEXTILE ENERGY CONSERVATION CASE STUDY:

BOILER ECONOMIZER

-performed by

Engineering Experiment Station
Georgia Institute of Technology

-sponsored by

Battelle, Pacific Northwest Laboratories

by

LuAnn T. Rockett

September 4, 1981
BOILER ECONOMIZER

- Collins and Aikman Corporation
  1803 North Main Street
  Roxboro, North Carolina 27573

- Mr. Ernest F. Godshall
  Environmental and Utilities Engineer
  704-596-8500

- Collins and Aikman produces woven and knitted pile upholstery and apparel fabric at its Roxboro plant.

- Collins and Aikman has installed an economizer on the exhaust stack of an 80,000 pound per hour boiler. The hot flue gases pass over a set of coils in the stack through which feedwater for the boiler is passed. The feedwater is preheated and the amount of energy used to produce steam is reduced.

- Before the economizer was installed, an average of 60,000 pounds per hour of steam was produced, and 624,725 MMBTU was consumed annually by the boiler.
  After the economizer was installed, an average of 32,600 pounds per hour of steam was produced, and 315,765 MMBTU was consumed annually by the boiler.

- Before the economizer was installed, No. 6 fuel oil costs averaged $2.20 per MMBTU.
  After the economizer was installed, No. 6 fuel oil costs averaged $5.30 per MMBTU.

- Based on the output of the boiler being 32,600 pounds per hour, an energy savings of 14,057 MMBTU and a cost savings of $74,971 resulted from the installation of the economizer.

- The decision to invest in the boiler economizer was based on pilot plant feasibility studies and a projected payback of 3 years. Collins and Aikman requires a payback of 3 years or less.
BOILER ECONOMIZER

Introduction

Faced with rising energy costs and the decreasing availability of fossil fuels, the textile industry has been forced to conserve energy in as many ways as are economically feasible. Because 80% of all energy consumed is in the form of fossil fuels and boilers consume more fuel to generate steam than any other process, many textile companies have concentrated a large energy conservation effort toward improving boiler and steam system efficiency.

Improvements in boiler efficiency result primarily from reductions in waste heat energy losses in the stack gases and expelled water. Maximum efficiency results when combustion of the fuel is complete and the heat losses are minimized. Excess air for combustion must be held to a minimum in order to optimize boiler efficiency. Because most boilers are designed to operate with more air flow than is needed for complete combustion, regular tune-ups must be made to ensure that the excess air level is optimized. Other boiler losses result from radiation and convection from equipment surfaces, and are especially critical in older, less well insulated systems.

On the average, for manufacturing facilities, boilers use from 50% to 70% of the total energy requirements of a plant. The savings potential for a steam system can be up to 50% with a good energy conservation program that focuses on steam line insulation, combustion efficiency tune-ups, condensate return, wastewater heat recovery, and proper feedwater treatment. The addition of a boiler economizer is an example where these savings can be increased even further.

Traditional Operation

Collins and Aikman Corporation is a large diversified textile, paper, and wallcovering manufacturer with 29 plants in North America. They are involved in all phases of textile manufacturing from spinning yarn to dyeing and finishing textile products. One of the largest divisions is located in Roxboro, North Carolina. The plant produces woven and knitted pile
upholstery and apparel such as velvets, velours, and artificial furs.

The boiler at the Collins and Aikman Roxboro plant is tuned up on a regular basis. The plant normally runs 24 hours a day, 7 days a week; however for calculation purposes, a 7000 hour per year operating schedule is assumed to be average. The boiler operation is detailed in Figure 1. The boiler has an 80,000 pound per hour steam capacity, and at an average projected load of 60,000 pounds per hour operates at an efficiency of 80.4%. The system presently burns No. 6 fuel oil and, without an economizer, burned 1.71 million gallons per year at a price of $0.33 per gallon.

Modifications

A boiler economizer is a heat exchanger located in the boiler stack which is designed to recover some of the waste heat from the products of combustion. A substantial amount of waste heat from a boiler can escape in exhaust gases. The economizer consists of a series of tubes through which feedwater flows on the way to the boiler. Water enters at one end of the economizer and is directed through a series of bends and headers before returning to the steam drum. The feedwater is thus preheated by waste heat and less oil is required to generate an equal amount of steam.

Collins and Aikman Corporation's Decorative Fabrics Division at Roxboro, North Carolina, successfully installed an economizer on their 80,000 pound per hour oil/gas boiler. The system was installed in May 1979 and has been operating without any problems since that time. The economizer at Roxboro was based on the successful implementation of another economizer at a pilot plant site in Albemarle, North Carolina.

The economizer was installed in a bypass arrangement with the boiler. This arrangement has three advantages:

- The feedwater flows upward, preventing recirculation and steaming in the feedwater line.
- The economizer can be shut down completely for general maintenance while the boiler remains in operation.
- Greater energy recovery is possible since the system may be "over designed" to absorb too much heat and the damper adjusted to optimize overall efficiency.
Boiler Operation Before Adding Economizer

Figure 1.

Boiler Operation After Adding Economizer

Figure 2.
Installation was based on the boiler operating at 60,000 pounds per hour for 7000 hours per year, and was designed to increase boiler efficiency from 80.4% to 86.4%. (See Figures 1 and 2.)

The only modifications made to the system involved operational criteria. Before the system was installed, the boiler operated at a steam load of 60,000 pounds per hour. During May 1979, while installation was accomplished, the boiler load was still 60,000 pounds per hour. Once the economizer was successfully running, a general slowdown in the economy affected plant production to a point that during 1980, the system averaged a steam load of 32,600 pounds per hour, well below the forecast load. The steam loads are summarized in Table I.

<table>
<thead>
<tr>
<th>Avg. Steam Load</th>
<th>Steam Generated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecast 60,000 pounds per hour</td>
<td>4.20 x 10^8 pounds</td>
</tr>
<tr>
<td>Actual 32,600 pounds per hour</td>
<td>2.28 x 10^8 pounds</td>
</tr>
</tbody>
</table>

Savings

Savings resulting from using the economizer at the forecast load of 60,000 pounds per hour are shown in Table II.

<table>
<thead>
<tr>
<th>Energy Savings MMBTU/yr</th>
<th>Fuel Savings gal/yr</th>
<th>Cost Savings $/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>33,998</td>
<td>226,573</td>
<td>74,769</td>
</tr>
</tbody>
</table>

1978 Fuel Cost 33¢/gal
Although the system only operated at an average load of 32,600 pounds per hour, significant savings were achieved in fuel cost and consumption. The decrease in system load is due to the fact that the recessed economy has led to an overall decline in goods produced. In spite of this decreased load, the dollar savings exceeded the original forecast. This was due, however, to the tremendous increase in fuel costs. No. 6 fuel oil increased in price from 33¢ per gallon to 80¢ per gallon during the time of the study. The savings are summarized in Table III.

Table III
ECONOMIZER SAVINGS
AT 32,600 PPH

<table>
<thead>
<tr>
<th>Energy Savings MMBTU/yr</th>
<th>Fuel Savings gal/yr</th>
<th>Cost Savings $/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,057</td>
<td>93,714</td>
<td>74,971</td>
</tr>
</tbody>
</table>

1980 Fuel Cost 80¢/gal

The Roxboro economizer has operated without any down-time due to problems of fouling. Regular cleaning and maintenance is performed, as are general tune-ups on the boiler. Down-time is defined as any period of time when the boiler is not operating due to anything other than regular maintenance. Down-time can occur due to any number of factors, including tube fouling or scaling.

Summary

The decision to invest in the economizer was based on:

- Feasibility studies based on the Albemarle pilot site.
- A projected payback of approximately 3.4 years.

The actual total cost of the system was $148,230 installed. Based on dollar savings of $74,971 per year, the system will have a payback of 1.98 years. Again, this savings is directly attributable to the ever increasing cost of No. 6 fuel oil.
Because of the success of the economizers at both Roxboro and Albemarle, the company is planning to install as many as three more at existing plant sites.

—for further information contact

Ernest F. Godshall
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Appendix I

CASE STUDY REPORT
WOOD-FIRED BOILER
TEXTILE ENERGY CONSERVATION CASE STUDY:

WOOD-FIRED BOILER

-performed by
Engineering Experiment Station
Georgia Institute of Technology

-sponsored by
Battelle, Pacific Northwest Laboratories

by
William B. Himes, Jr.

August 28, 1981
WOOD-FIRED BOILER

- Integrated Products, Inc.
P. O. Box 1791
Rome, Georgia 30161

- Mr. Mike Brown
Research Engineer
Georgia Tech
404-894-3636

- Integrated Products produces nylon carpet yarn.
- Integrated Products has installed a 400 HP boiler fired by wood fuel, which is capable of supporting all plant manufacturing operations and plant heating requirements.
- From May 1978 to April 1979, Integrated Products consumed 59,419 MMBTU of natural gas and No. 2 fuel oil to fire a 200 HP boiler and a 350 HP boiler.
  From February 1981 to July 1981, the wood-fired boiler has required 35,415 MMBTU of wood fuel to fire the 400 HP boiler.
- From May 1978 to April 1979, natural gas costs averaged $3.00 per million BTU and No. 2 fuel oil averaged $6.14 per MMBTU.
  From January 1981 to August 1981, wood fuel costs have averaged $1.00 per MMBTU. Integrated Products has not consumed any natural gas or fuel oil in this time period; however, current prices in the Rome area are $3.25 per MMBTU for natural gas and $6.38 per MMBTU for No. 2 fuel oil.
- The use of the wood-fired boiler at Integrated Products has virtually eliminated the need for fossil fuels, and resulted in a fuel cost savings of $60,000 per year even though it has not reduced the amount of energy needed to produce steam.
WOOD-FIRED BOILER

Introduction

The textile industry is one of the major fossil fuel consuming industries in the United States and is dependent upon petroleum products and natural gas for process energy. Total energy requirements for the industry are approximately 67 million barrels of oil equivalent annually. In an effort to reduce this fossil fuel demand, the conversion to renewable energy sources is being carefully considered by the textile industry.

One major application for the use of alternate energy sources is in the production of process steam. An average of 50% to 70% of the fossil fuel energy consumed by the textile industry goes into the production of steam. Thus using alternate energy sources such as wood or solar energy to produce steam can reduce the textile industry's heavy dependence on fossil fuels. As part of a state demonstration of wood energy utilization for nonforest products industries, the U.S. Department of Energy provided matching funds to install a wood-fired boiler at a textile plant in northern Georgia.

Traditional Operation

Integrated Products, located in Aragon, Georgia, is a textile manufacturing firm that produces nylon yarn for the carpet industry. The manufacturing process involves spinning nylon fibers into yarn. A twist in the yarn is heat set in large autoclaves using steam. The yarn is then dried in steam-heated dryers to complete the process. During the winter months steam is also used for space heating.

Prior to conversion to wood fuel, the plant operated one 350 HP boiler and one 200 HP boiler on natural gas or No. 2 fuel oil. Approximately 85% of the energy consumed was provided by natural gas and the remaining 15% was No. 2 fuel oil. The plant is operated 24 hours per day, 6 days per week, 50 weeks per year. Average annual consumption of each fuel is shown in Table I.
Table I
FOSSIL FUEL CONSUMPTION PRIOR TO WOOD CONVERSION
May 1978 - April 1979

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Quantity</th>
<th>MMBTU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>519,348 therms</td>
<td>51,934</td>
</tr>
<tr>
<td>No. 2 Fuel Oil</td>
<td>53,464 gallons</td>
<td>7,485</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>59,419</td>
</tr>
</tbody>
</table>

Modifications

In order to use wood fuel to produce steam, a completely new boiler system had to be designed. The new wood system was required to supply all of the process and space heating requirements. No backup by the fossil fuel boilers was to be employed except in emergencies.

Sizing of the boiler was based on the existing energy consumption, size and utilization of existing boilers, and plans for future expansion. Based on these considerations, a 400 HP boiler was installed to replace a 200 HP and a 350 HP gas/oil fired boiler.

The boiler chosen was a horizontal return tube firetube boiler designed to produce 13,200 pounds per hour of saturated steam at 130 psig from feedwater supplied to the unit at 220°F. Wood with a 50% moisture content (wet basis) such as sawdust, bark, and chips was to be burned as fuel.

After determining the boiler size, fuel requirements for the chosen boiler were used to determine the volume and area necessary to store an adequate fuel supply for reliable operation of the system. At rated capacity, a 400 HP boiler consumes fuel at the rates shown in Table II.
Table II
FUEL REQUIREMENTS FOR 400 HP SYSTEM

<table>
<thead>
<tr>
<th>Wood Consumption</th>
<th>100% Capacity</th>
<th>70% Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>tons/hr</td>
<td>2.6</td>
<td>1.8</td>
</tr>
<tr>
<td>ft$^3$/hr</td>
<td>221</td>
<td>155</td>
</tr>
<tr>
<td>truckloads/day</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>tons/year</td>
<td>19,100</td>
<td>13,300</td>
</tr>
</tbody>
</table>

A poured concrete silo, 48 feet high by 24 feet in diameter, is used to store fuel for the automatic fuel feeding system. The usable storage capacity of the silo is 14,464 cubic feet and is sufficient to store wood fuel for approximately 72 hours when the boiler is operating at 70% load. For long term storage, an open area with a 6,000 square foot concrete floor provides sufficient space to store wood for approximately 15 days.

A simple wood handling system is most economical for a plant of this size. Self-unloading trailers bring the wood chip fuel to the plant. They can unload the fuel in the open storage area or in the fuel staging area, located close to the storage silo. The wood fuel in the staging area is moved to the receiving hopper by means of a front-end loader. From the hopper, a screw conveyor delivers the fuel to a bucket elevator, which raises it into the storage silo. Screw conveyors transfer the fuel from the silo first to the metering bin and then to the air sweep feeders where it enters the combustion area. Figure 1 shows the layout of the system.

Results

The energy savings analysis shown below includes the operating cost associated with the new wood system and the old oil and gas system, the
Figure 1. Wood Fired Boiler System at Integrated Products
first year savings, and the simple payback period. The installed cost of the system was $460,000. First year federal tax credits of $92,000 resulted in an adjusted capital investment of $368,000. Based on the financial analysis, an annual cost savings of $59,071 should result. The simple payback calculated for this system before taxes was 6 years.

 SYSTEM FINANCIAL ANALYSIS

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Wood System</th>
<th>Existing System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Cost of Capital</td>
<td>$49,268</td>
<td>$0</td>
</tr>
<tr>
<td>Amortization</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(20 years @ 12%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$40,552</td>
<td>$20,744</td>
</tr>
<tr>
<td>Electricity, labor,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>front end loader,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insurance and Property</td>
<td>$4,500</td>
<td>$4,000</td>
</tr>
<tr>
<td>Tax</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood fuel @ $8/ton</td>
<td>$73,136</td>
<td>---</td>
</tr>
<tr>
<td>Gas @ $3/MCF</td>
<td></td>
<td>$155,804</td>
</tr>
<tr>
<td>Oil @ $0.86/gal</td>
<td></td>
<td>$45,979</td>
</tr>
<tr>
<td>Total Cost Per Year</td>
<td>$167,456</td>
<td>$226,527</td>
</tr>
<tr>
<td>SAVINGS</td>
<td>$59,071</td>
<td></td>
</tr>
</tbody>
</table>
Two additional factors have a bearing on the economic analysis and actual payback period of the system at Integrated Products. The first is a $146,000 United States Department of Energy demonstration grant that reduced the actual adjusted capital investment to $222,000 and the projected payback period to 2.8 years. The second factor was the slow economy in the first half of 1980 that forced the plant to operate at a greatly reduced capacity. This lengthened the payback period since the annual cost of capital, operating costs, insurance and property taxes remained relatively constant and the fuel savings decreased.

Overall operation of the new system has been nearly flawless. With the exception of a defective feedwater pump there have been no problems with the new system supplying steam for the plant. The existing boilers were retained for use as an emergency backup system; however, the wood-fired unit is so reliable the gas-fired system has been completely shut down since initial tests were completed on the wood system.

Operating labor is higher for the wood system than for the gas boilers since fuel must be manually loaded into the receiving hopper. Routine maintenance is also necessary for the materials handling equipment that makes up the automatic feed system. The additional labor cost is more than offset by the savings in the cost of fuel.

Summary

The demonstration grant from the United States Department of Energy was an important factor in the decision to invest in wood energy for Integrated Products; however, several other factors also made the conversion attractive. Adequate local supplies of waste fuel at economical prices, combined with a desire to move away from dependence on fossil fuels influenced the decision. Integrated Products also has a competent technical staff that was interested in designing and operating an innovative cost savings system.

Despite the reduced plant output, the new system is performing well and corporate management is very pleased. Exact cost savings are difficult to define because fuel is being inventoried and production is approximately 20% below capacity; however, the cost savings are still approximately $5,000 per month or $60,000 annually. With the grant taken into consideration, the simple payback period is less than 3 years.
The benefits of the project reach farther than just Integrated Products. The installation of the wood energy system at Aragon demonstrates the feasibility of using wood fuel in nonforest industries. Conversions to renewable energy systems also reduce dependence on foreign energy supplies.

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Appendix J

CASE STUDY REPORT
SOLAR INDUSTRIAL PROCESS HEAT
TEXTILE ENERGY CONSERVATION CASE STUDY:
SOLAR INDUSTRIAL PROCESS HEAT

-performed by
Engineering Experiment Station
Georgia Institute of Technology

-sponsored by
Battelle, Pacific Northwest Laboratories

by
James L. Clark

September 29, 1981
Johnson and Johnson produces a variety of sterile pharmaceutical products.

The U.S. Department of Energy has sponsored the installation at the Johnson and Johnson plant of a solar energy system to produce steam to augment that provided by conventional boilers. The system incorporates an 11,520 square foot array of tracking parabolic trough concentrators as the solar collector and a 5000 gallon flash boiler. Treated water is delivered from boiler feed pumps to the flash boiler. It is circulated at high pressure through the collectors where it is heated. The pressure is reduced as the water is throttled back to the boiler, and a portion is flashed to steam. As pressure builds in the boiler, steam is released into a 110 psig plant steam header for the process areas.

The solar energy system does not serve an individual process for which energy consumption, costs, and savings may be identified. The estimated total energy provided to the plant during the first year of the system's operation was 632 million BTU. This includes steam metered into the plant header plus steam leaked to the condensate line by faulty traps and later recovered. The current cost of conventional fuel is $3.00 per million BTU with future price increases already announced.

Johnson and Johnson's investment criteria include a required 15% after tax internal rate of return and a maximum simple payback period of eight years. An added benefit of the solar system was the plant's reduced dependence on fossil fuels.
SOLAR INDUSTRIAL PROCESS HEAT

Introduction

Most industrial energy conservation efforts are directed at procedures and equipment that will reduce total energy consumption. In recent years, however, there has been increased emphasis on the use of renewable energy resources rather than conventional fuels. Many devices have been designed to capture energy from the sun, the wind, ocean currents and tides, inland waterways, and biomass systems.

The suitability of some of these designs to provide industrial process heat from the sun has been investigated through a series of field tests sponsored by the U.S. Department of Energy. One of these tests was conducted at the Johnson and Johnson plant in Sherman, Texas. This test program has demonstrated the technical feasibility of providing a portion of a plant’s thermal energy needs with solar energy by means of a steam generating system interfaced with a conventional steam plant.

The economic viability of the technique is still under evaluation because of the high development costs associated with the system, the low current price for conventional fuel, and the current economic environment that stresses near-term benefits over future benefits. The company has developed plans for the expansion of the system, which will be implemented when financial investment criteria are met.

Conventional Operation

The Johnson and Johnson plant processes a variety of sanitary pharmaceutical products. The plant uses several processes requiring heat including gauze bleaching, cotton bleaching, sterilization, and space heating. These needs are served by a central steam plant that operates at 110 psig. The solar energy system interfaces with the central steam plant at a main steam header, rather than directly operating a manufacturing process. Thus, the manufacturing processes are not measurably affected by the source of the energy used.
Solar Energy System

The solar energy system installed at the Johnson and Johnson plant is illustrated in Figure 1. Pressurized water is circulated from a flash boiler, through an array of tracking parabolic trough solar collectors and back to the boiler. Water in the collector loop may reach a temperature of 395°F. A control valve in the return line maintains the water pressure in the collector at 165 psi higher than the pressure in the boiler. As the water is throttled back to the lower pressure in the boiler, a portion of the water is flashed to steam. As steam is produced and the pressure in the boiler increases above that in the plant steam main, a control valve releases the steam to the main to be used in the process areas.

The collector fluid is pure water, obtained from the existing treatment plant for boiler feedwater. Because the collector fluid is eventually flashed and used as process steam, no antifreeze additives are used. Make-up water is pumped into the flash boiler vessel by the plant's boiler feed pumps.

The solar collector array is composed of 192 modules of Acurex Model 3001 parabolic trough for a total collection area of 11,520 square feet. Each module has an aperture of 6 feet and a length of 10 feet. Each drive unit operates a section of eight modules, four on each side of the drive. Tracking of each section is controlled by a sensor located at the drive unit.

The array configuration is eight rows with three drive sections (24 modules) in each row. The array is divided into four parallel flow loops with six sections of troughs per loop. Performance of the collector array is slightly dependent on orientation. Rather than the desired north-south axis, the installation uses a northeast-southwest axis. This was chosen for aesthetic considerations related to the orientation of the plant building and the public visibility of the array site. This non-optimum orientation results in a minor performance deterioration.

Several design variations for the collector modules have been developed and marketed by Acurex. Reflective surfaces have included 3M FEK film, silvered glass, and polished metal. The array installed at the
Figure 1. Johnson and Johnson Solar Installation

Parabolic Trough
Concentrating Collectors
11,520 Square Feet

5,000 Gallon Flash Boiler

345°F Collector Pump

345°F Collector Pump

395°F Throttling Valve

5,000 Gallon Flash Boiler

Steam 345°F

Main Steam Header

Control Valve

Feedwater 200°F

Control Valve

Control Valve

200°F Feedwater Valve
Johnson and Johnson plant uses a polished aluminum reflector surface. The module design currently being marketed has an increased collection area with an aperture of 7 feet and a length of 20 feet. The larger area provides proportionately increased energy output with only a minor cost increase.

A central control system monitors solar insolation and determines when the array should begin tracking. In the event of high winds (above 35 mph) or a loss of sunlight for more than 20 minutes, the control system will return the collectors to their stowed (face down) position. The system also controls the operation of the circulation pump in both the operating and freeze protection modes.

The flash boiler is an ASME pressure vessel rated for 160 psig at 370°F; however, it is only required to operate at pressures less than 125 psig. Pressure in the steam main is 110 psig, and only a 5 psi differential pressure is required for release of steam from the flash boiler.

The boiler has a capacity of 5,000 gallons that provides a limited energy storage capability. In addition to offering a smoothing effect on energy output, the storage capacity provides the energy required for freeze protection. At times when the ambient temperature is below 35°F, the circulation pump operates at low speed even if there is inadequate solar insolation for the system to provide energy. By the circulation of hot water from the boiler through the collector array, freezing and damage to the collectors and piping are avoided.

The two-speed pump is driven by a 25 horsepower motor and operates at 3500 rpm (68 gpm) in the operating mode and 1120 rpm in the freeze protection mode.

System Performance

The solar energy system was installed during the latter half of 1979 and began operation in January 1980. Operation responsibilities were turned over to Johnson and Johnson from Acurex in April 1980. During the first year of operation, the system was available for operation 97% of the days and actually delivered energy 70% of the days. The remainder of the time there was either insufficient solar insolation or the plant was not operating.
The number of days the system operated does not give a good indication of its contribution to the plant's energy requirements. On many days the system delivered energy to the flash boiler without generating adequate pressure for steam to be released to the plant steam header.

During the first year 472,350 pounds of steam were delivered to the steam main. This figure is significantly below that expected, and analysis revealed that a substantial amount of energy was being released from the boiler to the condensate line by faulty steam traps. Since all condensate was recovered, most of the energy was eventually available to the plant, though at a lower temperature.

It was estimated that the total energy delivered to the plant during the first year of operation was 632 MMBtu. Delivery of solar energy to the boiler was at an average efficiency of 25.4%, while delivery of energy from the boiler to the plant (including the steam leaked to the condensate line) was estimated to be at 76% efficiency.

<table>
<thead>
<tr>
<th>Table I</th>
<th>PROCESS ENERGY SAVINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Steam Production</td>
<td>472,350 lb</td>
</tr>
<tr>
<td>Annual Energy Savings</td>
<td>562.6 MMBtu</td>
</tr>
<tr>
<td>Estimated Total Energy</td>
<td>632 MMBtu</td>
</tr>
<tr>
<td>Annual Cost Savings</td>
<td>$2,250</td>
</tr>
<tr>
<td>Estimated Total Cost</td>
<td>$2,530</td>
</tr>
</tbody>
</table>

Even by the initial design projections, the system provides only 2% of the plant's total energy needs. Thus, the system is mainly a field test of equipment rather than a major energy-producing installation. Nevertheless, the design provides for possible expansion of the collector array.
Johnson and Johnson has already been notified of a 33% increase in natural gas prices to take place in the next year. The opportunity for an investment in additional solar energy equipment will be evaluated in light of the anticipated financial environment and established corporate decision criteria.

Summary

A potential barrier to the implementation of solar energy technology exists in the disparity between actual and claimed performance levels of early systems. Nevertheless, the solar industrial process heat field test installation at the Johnson and Johnson plant has demonstrated the technical feasibility of providing process steam with solar energy and has identified several implementation problems which have since been addressed.

In order for such an installation to be economically attractive to the industrial sector, capital costs must be reduced substantially and/or conventional fuel prices must be significantly higher. As fuel prices escalate more rapidly than the general cost of manufactured goods and as solar energy system costs are reduced through mass production and modular design, such installations will become more viable as industrial alternatives.

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Appendix K

SUMMARY OF OTHER ENERGY CONSERVING TECHNOLOGIES IMPLEMENTED BY THE TEXTILE INDUSTRY
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SUMMARY OF OTHER ENERGY CONSERVING
TECHNOLOGIES IMPLEMENTED BY THE TEXTILE INDUSTRY

The following section includes a discussion on several energy conserving technologies that have been successfully implemented by the textile industry, but were not studied under this project because the companies chose not to participate. Further information on these technologies can be obtained from Georgia Tech project team members at the following address:

Technology Applications Laboratory
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

Mechanical Predrying

The removal of water by mechanical processes consumes up to 40% less energy than thermal processes. Therefore, whenever product construction or process conditions permit, mechanical water removal should always precede thermal drying in the interest of fuel economy. Not all the water contained in the textile material can be removed by mechanical means, therefore mechanical drying cannot be relied upon alone. Loose water, adherent water, and sometimes capillary water can be removed mechanically. Thermal drying is needed to remove the chemically bound swelling water.

The most common forms of mechanical drying are suction and mangling. Whenever conditions permit, squeeze rolls followed by a vacuum slot should be utilized before thermal drying. The major concern for squeeze rolls is the capital investment, because the operating cost is negligible as compared to other forms of mechanical drying. The energy consumption of a vacuum slot is approximately 300 BTU per pound of water removed, which is considerably less than thermal drying. Generally, the moisture content after mechanical predrying is from 30% to 70% of the dry weight of the material.

A new device known as the machnozzle uses sonic and supersonic steam flow (acoustic transport) to literally blow the water molecules from the cloth or other textile items. This device is presently being tested and should be evaluated fully in the near future.
Dryer Controls

Air is exhausted from a dryer to remove vaporized water and sometimes smoke, solvents, or particulate matter from the dryer housing. The exhaust air leaves the housing at the average temperature inside the dryer containing moisture and particulate matter. To replace the exhausted air, fresh make-up air, usually at room temperature, is taken into the dryer and heated to dryer temperature. The mass flow of the incoming air must equal the mass flow of the air exhausted in order to maintain steady operation. Therefore, a reduction in exhaust flow rate or dryer operating temperature will result in a net energy savings.

There are several means by which the exhaust rate can be reduced and dryer air humidity increased. A simple method of reducing exhaust air flow is to close the exhaust dampers back or reduce the speed of the exhaust fans. This can be performed manually but might prove troublesome due to the wide variety of product constructions with different entering moisture levels and drying characteristics. Therefore, the most effective means of control is to have the output of a product moisture monitor and an exhaust humidity monitor feed back to the exhaust dampers or fans and adjust the levels accordingly.

In theory there is no limit to the humidity level that can be tolerated while still maintaining efficient drying. However, a very important factor limiting the exhaust flow rate is safety and insurance regulations. In the drying of materials that might lead to the buildup of combustible particulate matter, explosive oils or solvents, or potentially toxic materials in the dryer housing, the insurance formula and safety considerations will always take precedence over any reduction in exhaust for the sake of energy savings.

As a result of studies on the drying of textile materials, the recommended humidity level for air leaving the dryer is from 0.08 to 0.12 pounds of water per pound of dry air. In-plant trials are necessary to determine the optimum level for each dryer based on the types of fabrics dried.

Dryer Heat Recovery

Recovery of heat from the dryer exhaust air should be considered when the exhaust air humidity has been adjusted to the maximum level, based on guidelines.
stated in the previous section. The heat that is recovered from the exhaust air can be used to preheat make-up air or process water.

Two major barriers to the implementation of heat recovery from textile ovens and dryers are the buildup of lint and the condensation of finishes inside the heat exchanger. These two factors can cause severe maintenance problems and can literally render the heat exchanger useless. Therefore, conventional fin-tube heat exchangers are not well suited for use in textile dryer applications. Maintenance problems have also been noted in other more conventional heat exchanger types.

There are, however, several new heat exchanger designs which offer solutions to these problems. One type utilizes glass rather than metal for the tube portion of the heat exchange surface. The smooth, nonporous surface is more effective in resisting finish and lint deposits. Another new type of heat exchanger uses regenerator units that attach to the dryer sides. Each regenerator unit consists of two heat storage sets through which flow alternately hot dryer exhaust and cool make-up air. The lint and finish problems are minimized because lint builds up at the hot end of the heat storage set but does not adhere to the surface because the finishes do not condense until they reach the cool end. Thus, the lint can be easily removed by blowing the units off with air.

**Batch Processing Equipment Modifications**

Control of direct sparge heating is usually achieved by temperature feedback to a pneumatically actuated proportional steam control valve. The different accuracies in temperature controllers require different command settings to control at a desired temperature. Obviously, the higher the command set point above the maximum signal for control, the greater the resulting error signal that determines how much steam is added to the bath. Since the sparge steam has been throttled from supply pressure to just above atmospheric pressure, it is superheated. Therefore, the steam has a tendency to pass through the bath without yielding its latent heat, remaining in a vapor phase that is exhausted to the atmosphere.
In many textile plants, the command is set much higher than the control temperature in order to satisfy the operators' subjective desire for "more" temperature and agitation. However, liquids boil at constant temperature if pressure is constant so that higher temperatures are in fact not achieved. If agitation is required above that provided with the machine, speeding up or changing the design of the mechanical agitation device is much less expensive than using live steam. Thus, the controller set point should be placed on the lowest possible setting to still obtain the desired operating temperature.

Sparging efficiency refers to the mixing efficiency of the sparge steam and processing liquor and is always an important energy consumption consideration for heating of liquids by live steam injection. The superheat in the sparge steam inhibits the tendency for the steam to mix with the processing liquor and give up latent heat. Steam sparge tubes in general are under-designed and usually consist of a tube with uniform holes drilled on a uniform spacing. The placement of the sparge tube in the processing equipment is usually such that live steam injection directly on the textile material is prevented. This placement usually results in the lowest level of steam-to-liquor mixing with a low pressure escape route provided directly above the sparging device. The mixing of sparge steam and processing liquor may be enhanced by any device that causes the break-up of sparge steam bubbles or results in longer retention time for the sparge steam within the processing bath. Devices of this type include sparge area covers, baffles or screens, and wire braid or screen fitted around the sparge tube.

It has been estimated that 50% or more of the energy used in typical batch processing is lost through evaporation. The reduction of evaporative losses is an easy problem to attack. Pressure equipment has been developed to reduce energy consumption by reducing evaporation losses. When modifying atmospheric batch processing equipment to reduce evaporative losses, it is desirable to approach as closely as possible the operation of pressure equipment without violating any pressure vessel codes. Therefore, changes should be made in atmospheric equipment to eliminate almost all of the vapor escape routes, such as using doors and reducing the use of large exhaust fans.
Indirect Steam Heating

Once the above modifications have been evaluated and implemented, if economically attractive, an alternative to improving steam sparging efficiency should be considered. The indirect steam heating of dye becks through heat transfer surfaces and coils is becoming economically feasible as energy costs rise.

The major advantages of indirect steam heating over direct sparging are the ability to return condensate to the boiler and the elimination of steam that passes through the dyebath without condensing. Since the condensate can be returned to the boiler, the temperature of the feedwater is increased thus improving the boiler efficiency. Chemical treatment of feedwater can be reduced since the returned condensate does not have to be retreated. Boiler capacity is freed for other uses due to the reduced steam demand from the dye becks. The condensed steam is not present to dilute the dyebath and increase the water volume.

An inherent characteristic of indirect heating is that the temperature control must be very precise in order to prevent overheating. If the set point of the controller is set above the dyeing temperature, especially when dyeing at the boil, steam will continue to be added even after the dyeing temperature is reached while trying to reach the set point temperature. This results in supplying unneeded steam to the beck at a high flow rate. The problem is not as critical for direct sparging since the heat transfer area is much smaller, and thus flows are lower. The problem can be solved by fine tuning of the controller mechanism and careful supervision of the set point temperature, as well as optimum placement of the temperature probe in the dye beck.

Differential Pressure Control of Steamers

The steaming process is commonly used as a part of continuous dyeing operations to set the dyes onto the material. The process requires that the material be subjected to elevated temperatures and an oxygen-free atmosphere. To assure that these conditions are met, the traditional practice is to provide a sufficient steam flow for a maximum production run. The steam flow rate is set by the operator who manually opens the steam valve or by a pneumatically operated
temperature controller that adjusts the steam valve to maintain a desired temperature. Neither method compensates the steam flow for changes in production rates, thus resulting in a very high steam flow into the steamer. This requires steam to be continuously exhausted from the steamer to prevent condensation.

An alternate means of controlling the steaming process is by maintaining a set pressure inside the steamer. The problem with the temperature controller is that the steam temperature may be the same no matter what the steam flow rate might be. A differential pressure controller, however, regulates the steam flow rate by maintaining a slight positive pressure inside the steamer. The pressure controller works in conjunction with a temperature controller to maintain the desired degree of superheat. The positive internal pressure prevents air from entering the steamer and is maintained by compensating for changes in atmospheric pressure in the process room or for changes in production rate. The differential pressure controller regulates the steam flow valve to allow only the amount of steam necessary to make up for losses of heat through the steamer walls and for losses due to condensation on the fabric. This reduces or eliminates the exhaust, thereby minimizing the stack losses. Measurements taken on a vertical steamer on a carpet dye range before and after a differential pressure controller had been added indicated that the steam flow could be halved by using the device.