A small-business guide

Apparel Manufacturers

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ORDERING INFORMATION

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REPORT SUMMARY

Many of the challenges faced by small business owners can be addressed through efficient use of electric technology. Each volume in the Small Business Guide describes the current state of a business type and details new or alternative electric equipment that can help it meet its characteristic problems.

Background

Members of the small-business community historically have had little contact with their energy providers. These guides were developed to facilitate communication between electric utilities and the small businesses in their communities.

Objective

To provide utility personnel and small business owners and operators with information on the key electrotechnologies that can help these businesses compete effectively.

Approach

The project team researched small business energy, productivity, and environmental concerns and the electrotechnologies that can meet these needs. Telephone surveys, published reports, directories, buyers guides, and technical journals provided information on technology availability, suppliers, information sources and trade associations.

Results

The Small-Business Guide series covers a range of industries:

Volume 1: Wholesale Bakeries

Volume 2: Auto Body Shops

Volume 3: Lodging

Volume 4: Medical Clinics

Volume 5: Drycleaners and Launderers

Volume 6: Metal Finishers

Volume 7: Shopping Centers

Volume 8: Convenience and Grocery Stores

Volume 9: Printers

Volume 10: Office Buildings

Volume 11: Electronic Components

Volume 12: Wood Preservers

Volume 13: Plastics Products

Volume 14: Wood Furniture

Volume 15: Apparel Manufacturers

Each guide is based on extensive and ongoing research and contains the latest information available at the time of publication. The guides have been organized as a reference document for use on an as-needed basis. Selection tabs are included to facilitate quick access to topics of interest; and each volume concludes with lists of equipment suppliers, EPRI information resources, and trade organizations.

EPRI Perspective

The EPRI Small Businesses target is dedicated to research, development, and dissemination of information on electrotechnologies that address the energy, productivity, and environmental concerns of small business owners and operators. Future volumes in the Small Business series will cover

- Photofinishers

TR-106676, Volume 15
Interest Categories

Commercial building systems and analysis tools

Commercial appliances

Product and service design

Marketing

Keywords

Electrotechnologies

Load building

Marketing

Customer needs

Commercial buildings

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Wayne Krill manages the Small Businesses Target at EPRI and directed development of this *Guide*.

ABOUT THIS GUIDE

Members of the small-business community historically have had little contact with their energy providers. This guide was developed to facilitate communication between electric utilities and the apparel manufacturers in their communities.

The *Apparel Manufacturers* guide is intended to familiarize readers with the business of apparel production by providing a historical overview, descriptions of basic processes and practices, and summaries of the key challenges faced by domestic apparel manufacturers. It focuses on delineating how electric equipment can address the needs and interests of businesses involved in apparel production.

This business guide is one of a series of publications produced by EPRI about small businesses. The *Apparel Manufacturing* guide is based on extensive and ongoing research and contains the latest information available at the time of publication. Nevertheless, it is a work in progress rather than a definitive and final document. The information and resources presented offer the reader a solid perspective from which to develop electricity-based solutions to energy and business needs.

This guide is organized as a reference document for use on an as-needed basis. Section tabs are included to facilitate quick access to topics of interest; icons representing energy end uses are also provided to help with locating complete information on electrotechnology solutions.

Clothing is a basic human need, and for a large part of U.S. history, it was homemade. Today, approximately 15,000 companies are involved in apparel production and employ a total of roughly 757,000 people; the industry's revenues were over $53 billion in 1993.

Human attention to detail is essential to the production of quality apparel. Nevertheless, apparel manufacturers have embraced automation such that the industry is now relatively mechanized, but not necessarily high-tech. Opportunities exist for further automation with computer-linked technologies that would lend apparel manufacturers the ability to improve production time and flexibility, reduce labor hours, and use materials more efficiently. Each of these advantages is key to survival in a market increasingly influenced by comparatively low-cost imports.

To maintain a healthy domestic apparel industry, manufacturers must produce marketable goods in a minimum amount of time and at minimum cost, and address worker comfort and health concerns. The accompanying table identifies electrotechnologies that can meet these business needs. These electrotechnologies and other high-efficiency electric technologies are described in the *Apparel Manufacturers* guide (EPRI TR-106676-V15), copies of which are available from the EPRI Distribution Center. To order this publication or other guides in this series, call the Center at (510) 934-4212.

Electrotechnologies for Apparel Manufacturers

	Computer-Assisted Design and Pattern Making	Computer-Assisted Marking and Cutting	Unit Production System	Manufacturing Control System	Outdoor Lighting	Electric Infrared Drying and Curing	Ultraviolet Curing
Description	Uses specialized hardware and software in stand-alone PC or client-server networks; systems can be assembled for multi-user and multi-task applications.	Accepts fabric from a manual feed or spreading machine and layers the material, holds it down, and moves a cutting head across it according to instructions provided by an operator or a data file.	Uses an automated, motorized system to carry single production items from one workstation to the next, and presents pieces to workers in positions that are ergonomically favorable.	A software algorithm uses information on necessary tasks, task sequence, and task time to work backward from a delivery date to schedule production and account for labor and material needs.	Six types of lighting technologies are available. Each offers different characteristics in wattage, brightness, light tone, efficiency, and life span; they can be combined to meet site-specific needs.	Quartz lamps and reflectors direct infrared (IR) radiation at an inked surface; heat is generated within the ink, providing extremely quick, non-blister drying.	Ultraviolet (UV) light emitted from a bank of lamps triggers a reaction that nearly instantly dries radiation-curable inks.
Apparel Manufacturer Need	Manufacturers need technologies that improve communications with retailers and speed up the design-to-manufacture process.	Manufacturers need methods for cutting fabric that are less labor-intensive and more flexible.	Manufacturers need cost-effective alternatives to the conventional practice of shifting bundles of partially completed pieces among production workers.	Manufacturers need production methodologies that support on-time delivery of products—at maximum quality and minimum cost.	Lighting improves the visibility and attractiveness of a facility, reduces the potential for crime, and increases employee safety.	Manufacturers that perform decorative printing on garments seek technologies that will allow them to improve the ink drying process.	Manufacturers that perform decorative printing on garments seek technologies that will allow them to improve the ink drying process.
Application	Used to draft designs, display designs for evaluation, scale patterns, create pattern templates, and determine pattern layout to conserve fabric.	Used in conjunction with cut-optimization software and digitized computer-assisted-design files that supply pattern information electronically.	Unit production systems involve multiple workstations and are applied as a complete reconfiguration of a plant's production system.	Control systems are typically sold in modules and configured to meet site-specific needs; for example, inventory control only, or scheduling of an entire production process.	Signs on or near the facility; general lighting in parking lots, walkways, delivery areas; facade and landscape lighting.	IR drying is used in conjunction with silk-screening equipment to dry decorations applied to garments such as T-shirts and sweatshirts.	UV light can dry UV-curable inks on all types of substrates, including tightly woven fabrics that have minimal ink seepage.

	Computer-Assisted Design and Pattern Making	Computer-Assisted Marking and Cutting	Unit Production System	Manufacturing Control System	Outdoor Lighting	Electric Infrared Drying and Curing	Ultraviolet Curing
Benefits	Allows quick design and redesign, facilitates multi-party review of designs, speeds incorporation of design changes, and translates designs into data files for automated production.	Improves productivity by cutting fabric more quickly and consistently; reduces costs for labor and fabric.	Workers spend more time on direct production activities, less inventory is tied up as work in process, the production process is more flexible, and work quality is improved.	More accurate scheduling of deliveries, lower inventory costs, improved quality control, and opportunity for coordination with retailers to determine production needs.	Increased public perception of quality, goodwill, and success from lighting on signs and the building facade; reduced potential for accidents, injuries, and crime from area lighting.	IR drying ovens are quicker than conventional convection ovens, require less labor, use less energy, and take up less floor space.	UV curing equipment is more compact than conventional ink-drying equipment and cures inks quickly, thereby allowing manufacturers to conserve floor space and maintain productivity.
Cost	Basic systems cost $10,000–$40,000; advanced systems serving several users cost $70,000–$80,000.	System costs vary, depending on specific application needs. Each workstation costs $80,000–$250,000; annual electricity costs are $9500–$16,200.	System costs vary, depending on specific application needs. Each workstation costs approximately $4000–$8000.	Manufacturing and control systems cost $10,000–$100,000; one-third of the cost is for hardware (network server, workstation, bar code scanning device).	Systems are custom-designed to meet a facility's needs and budget.	A small panel heater costs $1000–$2500; a large, custom-designed oven costs $10,000–$250,000. Units use 8–15 kW/sq ft.	A typical small system costs $1000–$5500 and consumes 120–160 W/in. of process line; a fully automatic system costs $8000–$60,000 and consumes 200–800 W/in.

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INTRODUCTION TO THE APPAREL INDUSTRY

As people migrated from farms to factories, and as immigrants flooded the cities in the early 1800s, demand arose for low-cost, ready-to-wear apparel. Until then, clothing had been made by hand at home, or made by a tailor. Supported by a well-established domestic textile industry, and with labor readily available, an apparel manufacturing industry was born. Over the next 40–50 years, the invention and mass production of the sewing machine; demand for uniforms for the Civil War; improvements in cutting machines, pressers, and buttonholers; the creation of U.S. protectionist trade policies; and the adoption of mass production methods helped to establish a robust garment industry.

Business Overview

The industry was relatively stable until World War II. Then, the development of synthetic and man-made fibers, spurred by the need for inexpensive fabric to replace scarce silk for military parachutes, transformed industry practices. These fibers produced wrinkle-resistant fabric that maintained its shape after washing and required little, if any, ironing. This fabric was incorporated in a variety of garments and reduced the need for pressing on the manufacturing floor. When the women's movement began in the 1970s, the industry was propelled forward again. As greater numbers of women attended college, entered the work force in professional capacities, and became active in politics, they had less time to make clothing at home, and had a new need for wardrobes of professional clothing.

Today, the most important influence on the industry is low-cost imports. As a result of open U.S. trade policies, imported apparel from low-wage countries in Southeast Asia, Latin America, and the Caribbean has flooded the U.S. market. Finding a way to compete—through reduced costs, increased productivity, and improved flexibility—is the biggest challenge facing domestic apparel manufacturers. The Apparel and Other Finished Products industry (Standard Industrial Classification [SIC] code 23) manufactures clothing and other products by cutting and sewing purchased woven or knit fabrics and materials such as leather, rubberized fabrics, and furs. The industry typically is divided into two categories: apparel or garment manufacturing (SIC 231–238), and fabricated textile products manufacturing (SIC 239). Fabricated textile products include home furnishings, canvas products, and automotive trimmings. This guide focuses only on the apparel, or garment, portion of the industry.

The 23 four-digit SIC codes that make up the apparel industry can be divided into four broad categories, based on the type of product manufactured (see Table 1). The products range from bras and belts to suits and sweatshirts. Custom tailors and dressmakers are classified within SIC 5699 (Miscellaneous Apparel and Accessory Stores) and are not considered in this guide.

According to the Department of Commerce, there were more than 15,200 establishments in the apparel industry in 1993; these companies employed a total of over 757,000 people and generated annual revenues exceeding $53 billion (see Table 2).

Apparel manufacturing facilities range from small, family-owned factories to huge, multi-million-dollar, publicly owned manufacturing plants. Many firms are highly specialized, producing a single generic product or a narrow product line. As a result, more than 76% of apparel manufacturing establishments have fewer than 50 employees, and 87% have fewer than 100 employees (see Table 3). For example, according to the Garment Industry Development Corporation, the average apparel production shop in New York City—a mecca for apparel manufacturing—has 30–35 employees.

From a historical perspective, the apparel industry is rooted in New York City. In the industry's infancy, manufacturers in New York were well situated to take advantage of the city's plentiful and inexpensive immigrant labor. Also, as a port city, New York was linked to textile mills in New England and the South. By the turn of the century, apparel manufacturers had firmly established themselves on Seventh Avenue, the area now known as the "garment district." The labor intensity of the apparel manufacturing industry evinced a constant need for cheap sources of labor. This, along with the increased congestion and expense of New York City, forced many manufacturers to move South and West in the early to mid-1900s.

Table 1-1
Apparel Industry Categories and Typical Products

Key Categories	Typical Products
Men's and Boys' Apparel (SICs 231 and 232)	Suits, Coats, Vests, Shirts, T-shirts, Sweatshirts, Underwear, Pajamas, Neckties, Jeans, Pants, Trousers, Uniforms, and Work Clothing
Women's and Misses' Outerwear (SIC 233)	Blouses, Shirts, T-shirts, Sweatshirts, Dresses, Pantsuits, Coats, Jackets, Vests, Bathing Suits, and Uniforms
Women's and Children's Underwear, Headwear, and Children's Outerwear (SICs 234, 235, and 236)	Bras, Slips, Underwear, Lingerie, Hats; and Children's and Infant's Blouses, Dresses, Shirts, Pants, Rompers, and Coats
Misc. Apparel and Accessories (SICs 237 and 238)	Fur Coats, Gloves, Robes, Raincoats, Leather Clothing, Belts, and Costumes

Table 1-2
Profile of the Apparel Industry (1993)

Segment by SIC Code	No. of Establishments	No. of Employees	Value of Shipments ($ millions)
Men's and Boys' Suits and Coats (SIC 231)	294	41,862	2,463
Men's and Boys' Furnishings (SIC 232)	2,353	264,630	17,771
Women's and Misses' Outerwear (SIC 233)	9,864	295,224	22,706
Women's and Children's Undergarments (SIC 234)	457	48,725	3,943
Hats, Caps, and Millinery (SIC 235)	363	19,355	1,055
Girls' and Children's Outwear (SIC 236)	779	51,795	3,221
Fur Goods (SIC 237)	182	788	154
Misc. Apparel and Accessories (SIC 238)	997	34,734	2,432
TOTAL	15,289	757,113	53,745

Source: U.S. Department of Commerce, Bureau of the Census, *County Business Patterns 1992 & 1993—United States, (CBP-92/93), and 1992 Census of Manufacturers* (CD-EC92-1H), 1996.

Table 1-3
Distribution of Apparel Establishments by Size (1993)

Segment by SIC Code	Number of Employees						
	Small (0-49)		Medium (50-99)		Large (100+)		
	No.	% of Total	No.	% of Total	No.	% of Total	Total
Men's and Boys' Suits and Coats (SIC 231)	146	50	36	12	112	38	294
Men's and Boys' Furnishings (SIC 232)	1,174	50	369	16	810	34	2,353
Women's and Misses' Outerwear (SIC 233)	8,333	84	891	9	640	6	9,864
Women's and Children's Undergarments (SIC 234)	51	81	18	144	32	232	457
Hats, Caps, and Millinery (SIC 235)	269	74	40	11	54	15	363
Girls' and Children's Outerwear (SIC 236)	476	61	152	20	151	20	779
Fur Goods (SIC 237)	181	99	1	1	0	0	182
Misc. Apparel and Accessories (SIC 238)	818	82	99	10	80	8	997
TOTAL	11,629	76	1,669	11	1,991	13	15,289

Source: U.S. Department of Commerce, Bureau of the Census, *County Business Patterns 1992 & 1993—United States,* (CBP-92/93), 1996.

States	Facilities
CA	4414
NY	3785
PA	827
FL	722
NJ	664
TX	594
NC	480
TN	393
GA	368
MA	237

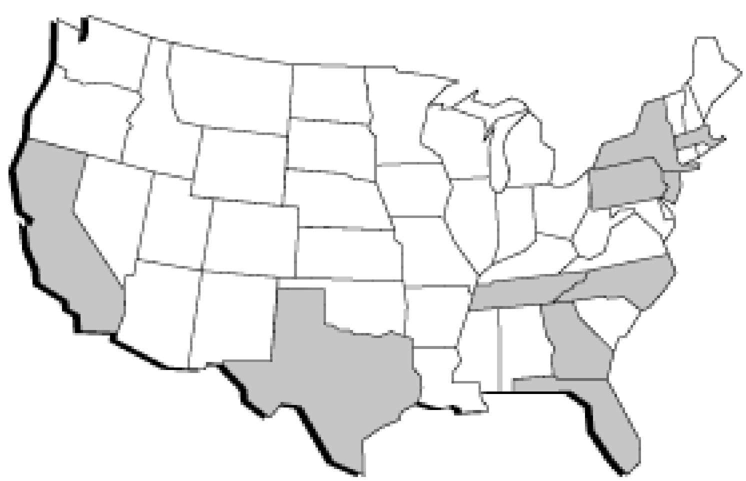

Figure 1-1
Top 10 States for Apparel Manufacturing (1993)

Although apparel manufacturers are located in every state, today's apparel industry has three main commercial centers—New York, Los Angeles, and Atlanta—each located in a different region of the country. The three port cities serve as centers of apparel activity: designing, manufacturing, retailing, importing, and exporting. Each of these cities is home to an apparel mart—a large marketplace that houses company/designer showrooms and sells apparel to the retail sector. By congregating around these three cities, the apparel industry facilitates communication between buyers and sellers, increases the speed with which new innovations are adopted, and helps build a supportive business environment for apparel manufacturers.

In 1993, California had the largest concentration of apparel industry establishments, with more than 4400 garment manufacturing facilities. The state of New York followed, with 3785 establishments. Pennsylvania, Florida, and New Jersey round out the top garment manufacturing states. Other states with a significant number of apparel manufacturing facilities include Texas, North Carolina, Tennessee, Georgia, and Massachusetts (see Figure 1).

Since the mid-1980s, the apparel manufacturing industry has experienced downsizing and consolidation. This trend results from a number of growth-retarding forces, including stiff domestic and international competition, the weak economy of the late 1980s and early 1990s, changes in consumer buying patterns, and other demographic factors.

- Domestic Competition**.** Apparel producers, especially small producers, face intense domestic competition. This results in a slower rise in apparel prices than in the economy as a whole. As the number of manufacturers declines, reflecting lower profit margins and a more difficult market, the surviving facilities tend to be larger and more efficient, producing more garments per unit of labor. The intensity of the competition exerts pressure on manufacturers to improve the cost-effectiveness of their operations.

- Imports and Outsourcing**.** The apparel industry has faced tough competition since the 1960s from countries with lower wages. Many manufacturers have turned to outsourcing their production to these same low-wage countries to address the issue of competition. This has resulted in a relatively large (35%) drop in industry employment over the last 10 years.

- Recession**.** The apparel industry is extremely sensitive to changes in domestic economic conditions. As a result, the recession that began in 1989 put an end to the spending "binge" of the 1980s. Although the economy recovered in the mid-1990s, domestic and international competition has kept prices low, forcing many small manufacturers out of business.

- More Casual Office Dress**.** The trend toward more casual, comfortable office wear is currently reshaping demand in the industry. Sales of traditional tailored suits have decreased while sales of sweaters and sport coats have increased.
- Demographic Factors**.** Two demographic changes have made an impact on the apparel industry: women entering the work force and the aging of the baby boom population. Baby boomers are now in their 40s and 50s and are less concerned with fashion and more concerned with paying mortgages and saving for retirement and their children's education. As a result, apparel expenses now represent a smaller portion of their total expenditures. Baby boomers have led a trend toward frugality, thereby increasing the popularity of sensible and basic apparel in moderately priced brands.

Although the apparel industry in general is in a period of decline, overall shipments have remained fairly steady since the late 1980s, rising slightly from $48.5 billion in 1987 to an estimated $53.7 billion in 1993. These figures include garments cut in this country and sent abroad for sewing and other processing. However, the number of establishments and workers employed by the industry has fallen since 1982. The Department of Commerce projects moderate growth in the apparel industry's value of shipments through the late-1990s, based on a favorable long-term outlook for consumer spending.

Types of Apparel Establishments

Three types of establishments make up the apparel industry: manufacturers, jobbers, and contractors.

Manufacturers. Manufacturers perform the usual manufacturing functions. They buy raw materials, design and prepare samples, and cut and sew garments at their facilities.

Jobbers. Apparel jobbers perform the entrepreneurial functions of a manufacturing company, but specialize in cutting fabric, which they then supply to contractors for sewing. Jobbers are usually design and marketing businesses hired to perform special functions such as purchasing materials, designing patterns, creating samples, cutting material, and hiring contractors to manufacture the products.

Contractors. Contractors specialize in sewing garments from pieces provided to them, typically by jobbers; in other words, they manufacture apparel from materials owned by others. Contractors are generally small, family-run businesses faced with stiff competition from low-cost imports. Outside contractors are often hired by a manufacturer when demand for an item exceeds the manufacturer's capacity or ability to meet a deadline. Many firms, regardless of size, contract out cutting and sewing, as well as embroidery, quilting, and pleating (which uses specialized machinery).

Contractors are especially useful during seasonal production peaks. Rather than make risky investments in the equipment to handle busy times, jobbers send some or all of their work to contractors.

Jobbing and contracting companies are growing because they allow manufacturers to expand their production without a lot of overhead. This reduces the need for large capital investments and the cost of unused capacity for the manufacturer. For example, Liz Claiborne, Inc., a major women's clothing manufacturer, owns no factories. Instead, it produces its products through a network of contractors in nearly 30 countries. Both manufacturers and jobbers sell to retailers.

The Apparel Manufacturing Process

The "bundle" or "batch" system of apparel manufacturing was developed in the 1890s. In this system, bundles of garments are moved from one worker, or group of workers, to another; each worker/group performs a single operation on a repetitive basis until the task is completed for all garments in the bundle. This method of production is still widely used throughout the apparel industry.

For the average garment, the manufacturing process, from design to sale, takes 6–8 months. Initially, a designer's sketch becomes a pattern. Fabric is then selected, and a cost sheet is developed that details expenses; the wholesale price is determined from the cost sheet. The pattern is then graded, and the fabric is cut to accommodate the needed size ranges; in some cases, the manufacturer also dyes and/or prints a design on the fabric before cutting. The materials are then sewn, finished, pressed, and packaged or hung for shipment to the retail customer (see Figure 2).

With modern production methods, it takes approximately 40 distinct operations to make a shirt, 20 of which are "critical path" operations. Critical path operations are operations that must be performed sequentially to construct a garment. For the non-critical path operations, most manufacturers use a progressive bundle system, where various operations are performed simultaneously.

Shirts, for example, typically are processed or manufactured in batches of 1500 pieces. Once the fabric has been cut, the production process involves three major phases: detailed operations on various small parts, assembly, and packaging. In the detailed operations phase, the five basic shirt components—collar, back, front, cuffs, and sleeves—are sewn individually and prepared for assembly. During the assembly phase, all of the individual pieces are combined to form a garment, and any finishing operations, such as creating buttonholes and sewing on buttons, are performed. This is a complete set of operations (i.e., results in a completed garment), and is difficult to automate. The final production phase involves packaging—either packing or hanging—prior to shipment.

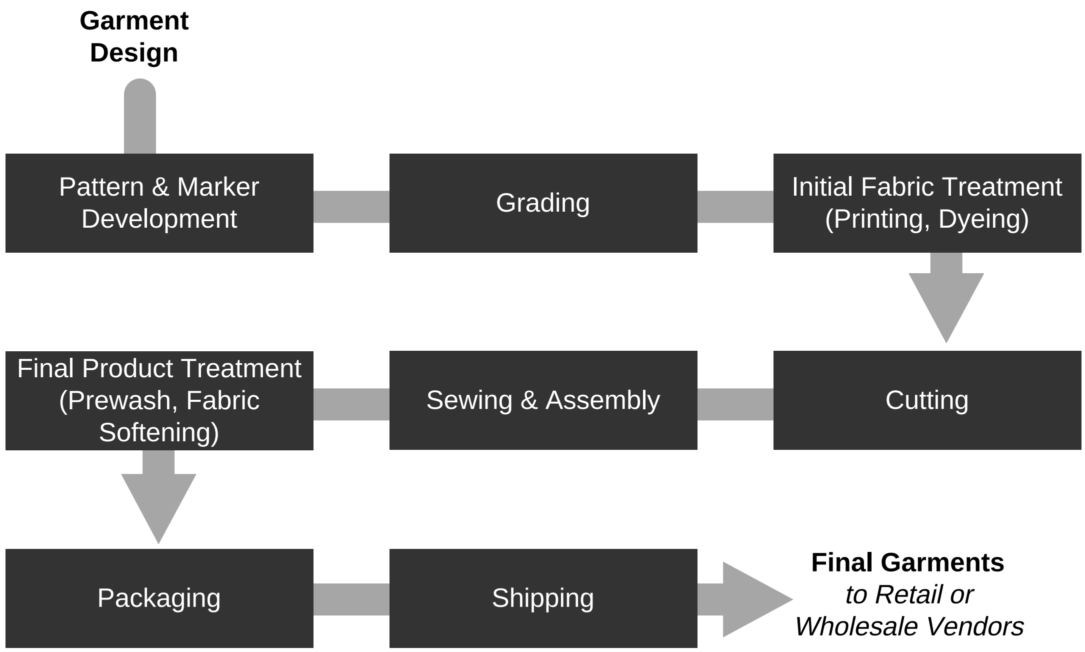

Figure 1-2
The Apparel Manufacturing Process

Garment manufacturers assess the complexity of a product on the basis of the number of operations performed and production time required to produce one unit. A shirt may take 12 standard allowed minutes (SAM). Manufacturers strive to reduce the large number of sewing, assembly, and packaging operations necessary, thereby reducing the amount of time it takes to produce each unit. Alternative assembly operations have been designed, such as the unit production system (UPS).

A UPS uses robotics to move garments from one operation to the next. In shirt manufacturing, a UPS reduces the number of operations from 40 to 27 and the SAM from 12 to 9. A UPS also reduces the number of critical path operations from 20 to 14. While the UPS has benefited other industries by reducing throughput time by 80% and increasing productivity by 25%, the system has not yet been widely adopted by the apparel industry due to its relatively high initial cost.

Energy Use

According to the U.S. Department of Energy, the apparel and related textile products industry (SIC 23) consumed a total of 44 trillion Btu of energy in 1992. This energy use was evenly split between electricity (43%) and natural gas (43%), with fuel oil making up the remaining 14%.

Approximately 65% of the 5.6 billion kWh of electricity consumed by the industry in 1992 was used in the manufacturing process. The largest percentage of electricity (41%) was consumed by machine drives (see Figure 3). Miscellaneous technologies used during the manufacturing process accounted for 21% of electricity use; process heating, 3%. Important non-process electricity uses include heating, ventilation, and air conditioning (HVAC) operations (20%) and lighting (15%).

Apparel industry electricity usage appears to be declining; the 1992 consumption level of slightly over 5.6 billion kWh is a drop from 6.7 billion kWh used in 1988. In 1993, approximately 70% of electricity use, or 3.9 billion kWh, was consumed by the apparel portion of the industry (SICs 231–238) that is the focus of this guide.

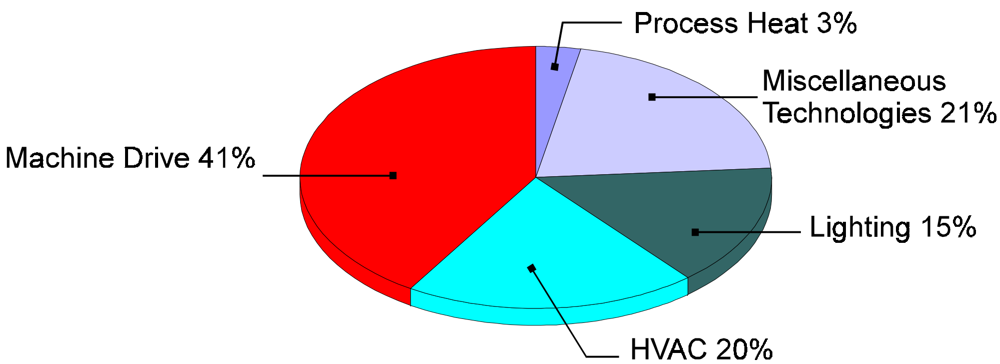

Figure 1-3
Typical Electricity Use in Apparel Manufacturing

2

BUSINESS CHALLENGES AND NEEDS

The U.S. apparel industry is struggling to maintain a strong position domestically in an increasingly global market. Apparel manufacturers are applying a variety of business strategies to achieve this goal. Some have downsized to focus domestic efforts on apparel design and now send precut fabric overseas for sewing. Others have chosen to consolidate operations, seeking the economies of scale. Still others are designing and producing very limited product lines that serve carefully studied niche markets, thereby minimizing the number and variety of operations performed. In the 1990s, efficiency is the industry watchword.

Competition

The primary challenge facing any U.S. apparel business is competition from other domestic manufacturers and foreign producers. To succeed in this competitive environment, domestic manufacturers must reduce operating costs, increase productivity, and/or improve the flexibility of their operations. These three goals are closely related and can be achieved by investing in new technologies that increase automation and allow a company to respond quickly to market changes. Improving employee comfort and safety can also make a manufacturer more competitive by supporting worker productivity.

In 1993, electricity represented only a little more than 1% of total material costs. As a result, the opportunity for energy savings is not a high motivation for technology adoption. Instead, the ability of a technology to help a manufacturer stay competitive by reducing other operating costs, improving productivity, and/or increasing flexibility is likely to be of strong interest.

Need

Reduce Operating Costs

In the United States, apparel manufacturing costs are 10–35% higher than those reported by apparel manufacturers abroad. Apparel manufacturing is labor-intensive, with labor accounting for more than 20% of the total manufacturing cost of a garment.

Decreasing the cost of labor is therefore a key to cost control in garment manufacturing. Stiff international competition in the 1980s forced the industry to make investments in computer-controlled machinery that would sustain or increase productivity and further decrease labor costs per unit. Large companies implemented both labor- and cost-saving technologies, widening the cost differential with smaller companies.

One area of potentially significant operating cost savings is fabric cost. Computer-assisted technologies for apparel design, pattern development and placement, and cutting can help reduce the amount of material that is wasted. Manufacturers of computer-assisted design technologies estimate that their systems can reduce material use by 3%, translating to sizable fabric cost savings. For example, if fabric costs represent 10% of total costs for a manufacturer with $10 million in annual sales, a 3% reduction in fabric waste would save $30,000 per year.

Technology Solutions

A number of technologies can reduce both labor and fabric costs through automation. These technologies include

- computer-assisted pattern makers;
- computer-assisted cloth marking and cutting processes;
- networked computer systems used for pattern making, grading, and fabric utilization;
- programmable sewing units that use microprocessors; and
- automatic conveyor systems using robotics.

All of these technologies are relatively expensive. Larger firms with access to internal capital are better positioned to implement these technological advances.

Technologies that increase the energy efficiency of the manufacturing line or facility—servo motors, energy-efficient motors, adjustable speed drives (ASDs), and energy-efficient HVAC and lighting technologies—can reduce the energy portion of a plant's operating costs. Infrared (IR) drying and curing and ultraviolet (UV) curing can also reduce labor and energy costs at plants that require drying or curing of inks, depending on the technology currently being used.

See pages 3-2, 3-3, 3-4, 3-5, 3-12, 3-13, 3-14, 3-15

Need

Increase Productivity and Flexibility

High labor intensity also restricts productivity. Productivity is the ratio of the value of a production item to the cost of the labor and material required to produce it. Since the value of a product is determined by the market, and the costs of component materials are difficult to control, manufacturers attempt to improve productivity by adjusting the one input they can affect the most: labor. Reducing the time required to produce a single unit, known as “cycle time,” can raise productivity. Cycle-time reductions often involve updating the production machinery to allow workers to perform tasks more quickly. Investing in materials handling systems and, where possible, automating the manufacturing process are effective ways to lower cycle time and decrease the amount of labor associated with each unit of production.

Technology Solutions

Automating the production process reduces unit labor costs, improves flexibility, and standardizes quality. Since it is nearly impossible for U.S. manufacturers to compete on the basis of wage rates, a technological edge is essential to compete in the world market. By installing automated technologies for garment construction and materials handling in existing manufacturing facilities, garment producers can achieve key competitive advantages and thus defend against market share losses to plants in countries where wages are lower.

New information technologies such as “quick response” and manufacturing control systems can help improve manufacturer flexibility. By using bar codes to track items selling well, quick-response systems allow a greater responsiveness to consumer tastes and preferences. “Hot selling” items can be replaced quickly and precisely, shortening the production cycle and minimizing the inventory cost. Manufacturing control systems schedule the production process to meet delivery dates, minimize work in process, and control inventory.

Other technologies, such as energy-efficient electric motors and ASDs, improve productivity by increasing the responsiveness of motor-driven systems and decreasing downtime for maintenance. Servo motors and energy-efficient HVAC and indoor lighting technologies indirectly improve productivity by improving employee comfort and safety. Technologies such as IR drying and curing and UV curing can improve the speed of the ink drying or curing process, thereby improving productivity in the apparel finishing process, depending on the technology currently being used.

See pages 3-5, 3-6, 3-8, 3-10, 3-11, 3-12, 3-13, 3-14, 3-15

Need

Improve Employee Comfort and Safety

The apparel industry has a reputation of providing poor working conditions for employees, giving rise to the term "sweatshop." In recent years, revelations of low pay, long hours, and objectionable working conditions in apparel manufacturing plants—both abroad and here in the United States—have resulted in public outcry.

Apparel manufacturers claim the situation is the result of consumer pressure for low-priced clothing. While consumers want the opportunity to purchase inexpensive clothing, clothing is often manufactured under sweatshop conditions to achieve a low price. Although it is unclear what percentage of concerned consumers are willing (or able) to pay more for clothing manufactured by higher-paid employees working under better conditions, some manufacturers may be interested in improving shop conditions to improve employee productivity and/or company public relations.

Technology Solutions

Employee comfort can be affected, often dramatically, with improved indoor lighting and HVAC systems, which often lead to productivity improvements as well. Better ventilation and air filtration also can contribute to employee health and safety. Finally, adding extra lighting outside the plant, around walkways, parking areas, and along driveways, can create safer conditions that may help prevent accidents or crime. In addition, many of the newer technologies that automate the manufacturing process are more ergonomic, quieter, and easier to operate, potentially reducing physical stress for employees.

See pages 3-11, 3-12, 3-13, 3-14, 3-15

3

TECHNOLOGY SOLUTIONS

This section describes each of the technology solutions identified in the previous section. Each technology is summarized, linked by end-use application to a business need, and categorized as an "electrotechnology" or "efficiency technology." Electrotechnologies are new or alternative electric equipment options. In many apparel manufacturing applications, the electrotechnologies can reduce operating costs, increase productivity, and/or enhance employee comfort or safety. Efficiency technologies offer opportunities to decrease energy use, but typically have little or no direct impact on production.

Also discussed are "emerging electrotechnologies," electrotechnologies that are not currently used in the industry, but have the potential to meet business needs in the future. Each technology is more completely described in Section 4, Electrotechnology Profiles. Vendors of these electrotechnologies, sources of information on efficiency technologies, and trade associations are listed in Section 5, Resources.

In this section, technologies are grouped and discussed by end use, beginning with "Motors and Drives," the end use that represents the greatest percentage of total electricity use in the apparel industry. Table 3-1 summarizes the technology solutions.

Table 3-1
Technology Solutions to Apparel Industry Needs

End use	Solution Type	Technology Type	Business Needs: Reduce Operating Costs	Business Needs: Increase Productivity/ Flexibility	Business Needs: Increase Employee Comfort & Safety
Motors and Drives	Efficiency Technology	Servo Motors	■	■	■
Motors and Drives	Efficiency Technology	Energy-Efficient Electric Motors	■	■	
Motors and Drives	Efficiency Technology	Adjustable Speed Drives	■	■	
Misc. Process	Electrotechnology	Computer-Assisted Design and Pattern Making	■	■	
Misc. Process	Electrotechnology	Computer-Assisted Making and Cutting	■	■	
Misc. Process	Electrotechnology	Automated Sewing	■	■	
Misc. Process	Electrotechnology	Unit Production Systems	■	■	
Misc. Process	Electrotechnology	Manufacturing Control Systems	■	■	
HVAC	Efficiency Technology	Air-to-Air Heat Pump	■	■	■
HVAC	Efficiency Technology	Closed-Loop Water-Source Heat Pump	■	■	■
HVAC	Efficiency Technology	High-Efficiency Electric Chiller	■	■	■
Lighting	Efficiency Technology	Energy- Efficient Indoor Lighting	■	■	■
Lighting	Electrotechnology	Energy- Efficient Indoor Lighting	■		■
Process Heating	Electrotechnology	Electric Infrared Drying and Curing	■	■	
Process Heating	Electrotechnology	Ultraviolet Curing	■	■	
Process Heating	Emerging Electrotechnology	Radio-Frequency Drying	■	■	

Motors and Drives

More than 40% of the electricity used in the apparel industry operates motors that drive sewing machines and other equipment. The significance of machine drive in manufacturing warrants attention to opportunities to improve the efficiency and performance of existing machinery. In addition, domestic garment manufacturers can improve worker efficiency and the cost-effectiveness of their facilities by increasing the level of automation of machine-driven processes. Automating tasks such as materials handling and sewing reduces labor costs, which constitute a large portion of an apparel manufacturer’s operating expense. Most importantly, automation provides a necessary manufacturing cost advantage in an increasingly competitive market.

Improving power factor makes motor-driven systems more energy-efficient. Power factor refers to the “phase” of current and voltage in ac electrical distribution systems; in other words, the relationship between actual power being used and the power drawn from the distribution system. When power factor is 100%, current and voltage are in phase. In practice, a fully loaded motor typically has a power factor of 80%, while a lightly loaded motor may have a power factor of 40% or less.

Power factor is important to the apparel industry because of the large number of motors used. The effects of poor power factor include increased current flow, greater power losses, and motors that run less efficiently. These effects can result in higher demand charges and power factor penalties (if these are included in the utility rate schedule). Power factor correction can reduce current flow and power losses and improve voltage regulation, thereby lowering energy costs.

For a garment manufacturer, poor power factor is most likely caused by underloaded or idling motors and can be corrected by changing the way the equipment is operated. Motors that are continuously underloaded should be replaced with smaller motors, and motors that regularly idle for more than a few minutes should be equipped with controllers to stop them when they are not in use. A more costly method to improve power factor is to increase the use of synchronous motors; these motors have power factors of 100% or higher and are more efficient than induction motors. Synchronous motors are well-suited for high-torque, low-speed applications. Alternatively, capacitors can be installed at the equipment level, in a bank servicing a group of equipment, or at the utility point of delivery (in a bank with an automatic switching system).

Efficiency Technology Solution
Servo Motors

A recent trend in equipment selection in garment manufacturing is the increased use of servo motor drives in lieu of clutch-operated machinery. Garment production inherently requires frequent engagement and disengagement of process machines as workers handle and align fabric pieces. Approximately 30% of sewing machine operating time is spent sewing; the remaining time, the machine is on standby as the operator aligns fabric or prepares for a new piece. Since electric motors do not respond well to frequent starts and stops, clutch-controlled machinery is necessary. Servo motors eliminate unnecessary electricity consumption by allowing the operator to control motor speed directly rather than simply disengage a spinning motor from the driven equipment. Thus, servo motors can lower both operating and maintenance costs. Servo motors also generate less heat and operate more quietly, which improves workplace conditions and lessens worker fatigue, potentially improving worker productivity.

Efficiency Technology Solution
Energy-Efficient Electric Motors

Energy-efficient electric motors (also known as high- or premium-efficiency motors) are typically 2–6% more efficient than their standard counterparts, and cost 15–30% more than standard motors. Over a typical 10-year operating life, a motor can consume electricity valued at over 50 times the initial cost of the motor. As a result, energy-efficient motors are extremely cost-effective, with simple payback on investment of less than 2 years when compared to a standard-efficiency motor. The payback is generally attractive unless electricity prices are very low or a motor is operated infrequently.

Energy-efficient motors offer more than just reduced electricity consumption. They typically are manufactured to closer tolerances, use better materials, and offer more robust construction than standard motors. This higher quality translates into quieter operation, improved reliability, and fewer maintenance requirements. Workers respond positively to equipment improvements; quieter operation results in less fatigue, and improved machinery responsiveness can increase the production rate, decrease quality problems, and lower the scrap rate. Energy-efficient motors are available for most garment manufacturing operations requiring motor services over 1 horsepower.

Efficiency Technology Solution
Adjustable Speed Drives

ASDs, also known as variable speed drives, should be considered for motors of more than 5 horsepower. ASDs utilize electronic control of the motor current frequency to raise and lower the speed of a motor in accordance with the demands of the load. Reducing the frequency of the current to a motor below 60 hertz slows the motor, thereby eliminating energy use that otherwise would be wasted. In conventional motors, the motor speed remains constant when the load decreases, causing power factor to drop and the motor to run inefficiently.

Historically, motor systems requiring variable output have been controlled with dampers or valves that apply back pressure on the system. Unfortunately, in many applications, such as ventilation fans, this form of load control is relatively ineffective. Fans typically respond to system pressure changes with corrections in flow; consequently, bypass and recirculation lines are used to handle excess flow, which results in wasteful energy consumption. In contrast, ASDs manipulate the electrical supply such that motor speed, rather than back pressure, reacts to the system requirements. In general, controlling motor speed provides higher motor efficiencies and power factors over a range of system operating conditions.

Miscellaneous Process Technologies

Two key characteristics of the apparel industry are reliance on relatively simple technology and large amounts of labor. The sewing machine—the industry's primary tool—has remained essentially the same over the last century. During the post-World War II period, however, several major technological breakthroughs occurred, including the development of portable rotary and reciprocating electric knives (the forerunner of modern portable electric cutting tools), motor-driven cloth spreading machines, and the gas-fired steam iron (which replaced hand-held irons heated over a gas- or coal-fired flame). Other innovations eliminated the need to hand sew buttonholes, pockets, belt loops, and lapels. In addition, improvements in textile industry technologies increased the quantity and quality of the fabric available. In the late 1960s, automation eliminated much of the manual labor involved in handling and positioning garments as they pass from one operator to the next. Although this increased productivity and reduced labor costs, opportunities for further automation remained. In the late 1970s and early 1980s, computer-controlled spreading, marking, and cutting systems were introduced. To date, these advanced technologies for fabric spreading, marking, and cutting, and specialized stitching operations have been implemented only by high-volume manufacturers.

Process Technologies

A number of advances in electric-based apparel manufacturing technologies are available to help manufacturers reduce the time and labor involved in making a single garment. These include computer-assisted apparel design, pattern making, and marking and cutting technologies; automated sewing; unit production systems; and automated handling systems. According to the Department of Commerce, only 60% of the industry has adopted these new technologies; the larger, specialized companies are making the greatest use of technological advances. The new computerized equipment reduces or eliminates reliance on operator skill, thereby increasing quality and reducing downtime. The computer-based technologies are particularly appropriate for small-volume establishments because they allow manufacturers to quickly produce low-cost, small-scale batch runs.

Electrotechnology Solution
Computer-Assisted Design and Pattern Making

Computer-assisted design (CAD) is used in many industries and is expanding into the apparel industry. Used to design apparel and generate patterns and markers (marks that show placement of buttons, pockets, etc.), CAD streamlines the product-development process in many ways. However, the most significant benefit is the reduction in the quantity of scrap fabric. System vendors claim fabric savings of 3% over manual design methods, resulting in a payback period of less than 2 years (for manufacturers with annual sales of at least $10 million).

The garment-design advantages provided by this technology are equally attractive. CAD allows the quick exchange of ideas and design specifications among design team members and between designers and retail store buyers. Garment designs can be graphically shown to customers for immediate feedback, and changes in proportion, dimension, and color can be quickly incorporated. Once a design is established, a CAD data file can be digitized and sent to a plotter for pattern cutting and marker layout. The close interface between design and pattern making increases a manufacturer’s responsiveness to fashion trends and customer feedback. As retailers become increasingly demanding of manufacturer performance, CAD systems offer an opportunity to improve both customer relations and design-to-manufacture flexibility.

Electrotechnology Solution
Computer-Assisted Marking and Cutting

Computer-assisted pattern layout, marking, and cutting are now technologically feasible due to the advent of powerful (and inexpensive) microelectronic information processors. While many manufacturers presently use systems that cut multiple layers of fabric to form bundles, these systems can eventually be replaced or augmented by systems that allow continuous cutting of fabric, one layer at a time, for faster, more accurate production.

Current cutting technologies include the reciprocating knife, jet cutter, and laser cutter. While these technologies are major advances over hand cutting, all have drawbacks. Such systems need the ability to cut multiple plies more reliably than currently possible and/or to cut single layers quickly with immediate transfer to assembly stations. The reciprocating knife is limited in speed and flexibility and is thought to be a weak link in modern cutting systems. Jet cutters suffer severe energy losses if too many layers are presented to them, and laser cutters tend to fuse fabrics that are cut in more than one layer. Computer-assisted technology can be applied to operate any one of these cutting systems. An ideal cutting system would apply to all fabric types, have a small cutting blade, would be operated by computer, and would be able to enter a fabric at the center as well as at the edges.

One important issue in laying out patterns and cutting fabric is materials utilization, as fabric cost represents 30–50% of garment cost. Wasted fabric, which ranges from 8% for well-placed, computer-generated marks on unpatterned material to 25% for patterned fabrics, is a major loss to manufacturers. Computer-controlled cutting can reduce material losses by 2–3%, reduce planning by 1–2 weeks, and reduce the number of fabric parts that are cut simultaneously by 30–50% (nonsimultaneous cutting allows better quality control).

Electrotechnology Solution Unit Production Systems

Unit production systems (UPS) provide significant reductions in throughput times while increasing the quality level and flexibility of a production line. Some manufacturing systems have reported conventional processing times of 4–6 weeks dropping to 1–2 days after changing to a UPS. A UPS uses a batch size of one to provide high levels of control, quality assurance, and flexibility. Since production items are immediately transferred away from a workstation upon completion of a task, bundles do not accumulate, thus minimizing work in process. Single-unit batches also allow maximum flexibility in a production line; design corrections and process modifications can be readily incorporated, and multiple products can be produced on the same line.

UPS are characterized by automated materials handling systems that move production items from station to station. By exploiting the strengths of a materials handling system while maintaining single-unit batch sizes, a UPS can achieve significant increases in throughput by lessening the time required for a garment to move through a production line. A garment can be cut, sewn, and packaged in several hours, rather than in days or weeks, making quick response to retailer needs possible. Automatic conveyor systems for handling in-process goods are currently used in many plants, and industry experience with this technology is relatively mature.

The competitive strengths offered by a UPS range from cost-effective operation to increased responsiveness to retailer demands. Production advantages are evident in the throughput and lower inventory costs, while improved customer service is realized in more accurate delivery schedules and better apparel quality. While the flexibility of a UPS expedites production of special orders, because it generally improves control over the production process, it allows more precise planning of all delivery dates. Apparel quality is enhanced because an automated handling system improves the visibility of the production line, such that inspection of in-process garment pieces can be made in between workstations or at designated checkpoints. The single-unit batch size facilitates both the identification of defects and their point of origin.

Automated Sewing

Isaac M. Singer introduced the sewing machine in 1850, providing a key ingredient in the development of the apparel industry. The sewing machine dramatically reduced the amount of labor needed per garment, thereby reducing the cost to manufacture clothing. The sewing machine also changed the structure of the work place by increasing job specialization.

The apparel industry still utilizes handwork and sewing machines, although automatic sewing machines are used in some locations. The Textile/Clothing Technology Corporation—a government/industry research and development collaborative—is spearheading the U.S. effort to introduce automated sewing. In this system, cut fabric is fed into an automated machine that uses a computer-aided vision system and robot to sew, turn, and fold the fabric to produce garment parts. The collaboration has succeeded in developing robotics for the production of sleeves for men's suits, representing a major technological breakthrough that promises to significantly reduce production time, labor costs, and work in process (bundles of sewn parts awaiting the next stage of manufacture). Until recently, automated manufacturing was only possible with rigid materials such as metals because robots lacked the dexterity to handle cloth.

The use of automated sewing in the apparel industry is currently limited. The human ability to predict fabric reaction, recognize seam problems, and react to fabric creases or subtle misalignments is difficult to replace. Although optical recognition technology has advanced sufficiently such that machines can identify fabric patterns and can set pockets and other features appropriately within those patterns, direct human oversight is still essential. The control required to sew garments with the necessary consistency, quality, and flexibility is not yet commercially feasible with automated machinery. Human capabilities are especially needed for the frequent and subtle adjustments that characterize the sewing of garment seams.

However, programmable sewing machines enjoy widespread use in applications such as embroidery, and belt loop and pocket attachment. Embroidery patterns can be programmed into an automated sewing machine and subsequently applied to flat garment surfaces at relatively high speeds. Similarly, automated machines that attach belt loops and pockets to clothing are common in the industry.

Essentially, automated sewing equipment that performs specialized functions on simple fabric surfaces is commercially available and provides opportunities for manufacturers to automate portions of their production process or integrate operations that they currently outsource. Many producers contract out to keep labor costs low; automated equipment involves little labor and offers quick task times. Justifying the investment in automated sewing equipment requires assigning a value to increased turnaround time, tighter production control, and increased responsiveness to retailer demand, and subsequently balancing this benefit against the equipment cost and added maintenance burden.

Beyond these specialized tasks, the complexities of sewing seams in garments do not currently favor the application of automated sewing equipment. However, other forms of joining, such as gluing, fusing, and welding, which are currently used in certain applications, may be more amenable to automation than sewing. Incorporating joining techniques into the production process would require changing the design specifications for garments and, as such, demands input from retailers and designers as well as manufacturers. Although sewn seams will never be completely replaced, the labor effort associated with them may motivate a shift toward alternative joining methods.

Information Technologies

Information technology advances in the apparel manufacturing process enable manufacturers to increase their control over the production process, quickly respond to customer preferences, and enhance customer relations. Two key information technologies include manufacturing control systems and quick response systems.

Automated Handling Systems

In garment manufacturing, as in any manufacturing process, automating materials handling lowers labor costs and/or frees up human resources to perform work of higher value. Automated materials handling systems often accompany computer-assisted manufacturing technologies to ensure sufficient process control and to achieve productivity improvements. For example, computer-assisted marking and cutting machines often are equipped with automatic spreaders and automated hold-down features. These features improve the level of standardization among production units while increasing task speed. In fact, the production and quality benefits offered by automated materials handling machines frequently are significant factors in determining the economic feasibility of a computer-assisted equipment purchase.

Automated handling equipment is also a key component of other process improvements such as flexible manufacturing and UPS. In flexible manufacturing, workstation tasks are modified according to the needs of a particular product and/or to resolve production or quality problems. Automating the delivery and removal of production units from these workstations allows accurate control of production line speed. This prevents bottlenecks and maintains high process visibility, improving inspection and quality assurance efforts. Some flexible manufacturing plants use automated, guided vehicles to ensure the swift, continuous transfer of garment parts to downstream tasks.

Other plants, such as those with UPS, link workstations through a continuous product handling system. Many of the productivity gains that garment manufacturers achieve by adopting a UPS are attributable to improved materials handling. Similar quality and productivity benefits are available to facilities with more conventional production configurations by simply automating the materials handling tasks between workstations.

Electrotechnology Solution
Manufacturing Control Systems

Manufacturing control systems schedule the production of garment assemblies and sub-assemblies such that delivery dates are met, work in process is minimized, and inventory is well-controlled. An example of such a comprehensive system is the manufacturing resource planning system known as MRPII.

MRPII systems evolved out of the material requirements planning (MRP) systems that gained widespread acceptance in the 1970s. MRP programs were designed to improve the cost-effective operation of complex production systems by scheduling raw material order dates very precisely. The goal was to avoid the expense of large inventories and yet ensure the availability of enough material to support production. MRPII systems expand the MRP concept to include scheduling of production work. By identifying start times for production operations, MRPII systems control work such that garment assembly is continuous and work in process is minimized. This helps reduce cash-flow requirements and minimizes the floor space dedicated to storage. MRPII systems also improve labor resource planning and reduce missed delivery date occurrences. MRP and MRPII systems control a significant share of production activity and are relatively large investments.

Software programs that handle specific, limited aspects of the production process are also available. These less-comprehensive systems include

- time and attendance systems that monitor direct labor effort to improve the accuracy of cost accounting systems;

- inventory control systems that provide real-time status of raw material supply levels and can be enhanced to authorize restock purchases; and

- customer-order processing systems that receive and respond to customer resupply demands.

Quick Response Systems

In the late 1980s, some apparel manufacturers purchased state-of-the-art quick response (QR) communications systems to track consumer preferences. By utilizing computers and bar codes on apparel at the retail level, QR uses electronic data interchange (EDI) to provide an immediate transfer of information on sizes, styles, colors, and inventory levels. Retailers are encouraging suppliers to directly access this point-of-sale information through QR to produce the right garments and provide timely resupply. The QR system eliminates the need for retailers to inventory their stock and issue purchase orders. Since a QR system reduces a retailer's administrative costs, retailers are often amenable to entering into long-term QR-driven relationships with manufacturers.

The intense competition characterizing the apparel market is forcing manufacturers to invest in QR technology. To implement QR requires purchasing computer hardware and software for receiving and processing EDI information, training personnel, and modifying the production control system to react directly to customer input.

Although QR technology is initially a capital cost burden, it can provide a viable alternative to offshore production. Retailers value responsiveness, and domestic garment producers enjoy the advantage of proximity, making it easier to achieve short order-to-delivery times. In addition, the telecommunications networks available to domestic manufacturers are more sophisticated and reliable than those available to most offshore facilities, giving domestic producers another advantage over most offshore companies.

The number of retailers and manufacturers using QR has grown significantly in recent years. Although it requires a high degree of cooperation, QR can significantly reduce order cycle times. In one study, order processing time dropped from almost 18 days in 1985 to 12.5 days in 1990 to about 9 days in 1995.

Heating, Ventilation, and Air Conditioning

Approximately 20% of the electricity used in the apparel industry operates HVAC equipment. The extensive use of motors and physical labor in this industry creates large cooling loads. Ventilation and filtration of air to remove fabric fibers are also important functions of an HVAC system in an apparel manufacturing facility. Worker productivity levels in sweatshop environments tend to be lower than those in better-conditioned environments, and accidents and health problems due to fatigue and exposure to particle-laden air are more prone to occur. More comfortable workers are not only happier, but potentially more productive and accurate in their work.

Aside from facilities that perform adhesion and printing tasks, most apparel manufacturing plants lack special exhaust and makeup air equipment. Therefore, the volume of air exchange depends heavily on the tightness of the building envelope and the draw-through of open doors and windows. Often, outside air must be brought in by the primary HVAC system to ensure proper air quality. In response to studies documenting the health impacts of poor ventilation, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has increased the recommended quantities of outside air (the air exchange rate) for workers in a variety of activities, including those present in apparel manufacturing facilities. Increasing the quantity of outside air brought into a building can create a burden on a facility's HVAC system and may favor a system upgrade.

The HVAC loads in an apparel manufacturing facility are primarily caused by production workers and machine operation. The heat generated by people performing light machine work is roughly 200 watts per person; machines generate additional heat through friction and electrical losses. Some garment manufacturing processes also require process heating, which can add to a facility's cooling load.

Unfortunately, the intensely competitive nature of the apparel manufacturing industry is characterized by small profit margins. Therefore, any investment typically must result in a short payback period. Justifying HVAC system upgrades can be problematic due to the difficulty of quantifying increased productivity due to worker comfort. However, competitive pressures are prompting many domestic manufacturers to increase process automation in order to decrease labor expenditures. By placing additional machinery on a production line, more heat is added to the work environment. Recognizing that most equipment operates better under temperate conditions may justify enhancing the cooling services to support this environment.

The HVAC technologies that address the needs of garment manufacturers range from high-efficiency air-to-air heat pumps, appropriate for smaller facilities, to closed-loop water-source heat pumps and central chillers for larger facilities. Key factors in determining the economic feasibility of the various system options include the layout of the plant, the distribution of production workers and machines within the plant, and the degree of production process automation.

Efficiency Technology Solution
Air-to-Air Heat Pumps

Air-to-air heat pumps use the refrigeration cycle to transfer heat to or from a building to provide indoor heating or cooling, as required. In the cooling mode, a heat pump absorbs heat from the indoor air and rejects it outside; in the heating mode, energy is pulled from the outdoor air and transferred inside. These systems are efficient, simple, and inexpensive to install and operate.

Recent improvements in compressor technology enable air-to-air heat pumps to achieve high thermal efficiencies. The efficiency of a heat pump is measured by the coefficient of performance (COP), which is the amount of heat transferred divided by the energy used. Many air-to-air heat pumps have COPs exceeding 3, indicating that the amount of heat these systems add or remove from a building is 3 times the amount of energy that they use. This operating efficiency translates into low operating costs. Air-to-air heat pumps have been used for many years.

During cold weather extremes, the capacities of air-to-air heat pumps are limited by the amount of energy available in the outside air. These systems are often combined with electric resistance heating to supplement the heat pump's air delivery temperature.

Air-to-air heat pumps are available in packaged units that are expedient for retrofits. Expanded cooling or heating requirements can be met by adding these units directly to a room or a building area, thereby avoiding the need for expensive and space-consuming duct work.

Efficiency Technology Solution
Closed-Loop Water-Source Heat Pumps

Closed-loop water-source heat pumps are efficient and appropriate for facilities with a distributed, diverse set of heating and cooling needs. These systems place heat pumps throughout a facility, connecting a closed-loop water line to each unit to provide a common heat source/sink. This closed-loop water line is maintained at a temperature of 60–90°F such that each heat pump can efficiently absorb heat from it or reject heat to it. These systems are particularly appropriate for facilities that require simultaneous heating and cooling in different zones. In garment production facilities, the production areas often need cooling while the administrative areas require heating. A system of closed-loop water-source heat pumps effectively transfers the heat from one zone to the other.

Closed-loop water-source heat pump systems are highly efficient, reliable, and popular. Although these systems are costly for small buildings, they offer accurate and efficient temperature control for many garment production facilities.

Efficiency Technology Solution
High-Efficiency Electric Chiller

The high ceilings and large, open work areas common to the apparel manufacturing industry tend to discourage the use of piping and duct work due to high installation costs, additional structural requirements, and the lack of flexibility in reconfiguring floor operations. Roof top chiller units that supply cool air directly to a work environment without the use of piping or duct work are well-suited for apparel manufacturing plants. By installing multiple roof-top chilling units across a plant, cool air can be distributed to several areas of the work environment, and the failure of a single unit has a less significant impact on plant operations than the failure of a central system. Therefore, there is less maintenance effort and cost involved.

Lighting

Lighting accounts for approximately 15% of the apparel industry's total electricity consumption. Since most apparel manufacturing is done in warehouse-type facilities, the majority of the lighting systems are fluorescent tubes with magnetic ballasts. Fluorescent fixtures are available in a variety of shapes and sizes. The most common are 4-foot-long tubes used in two-, three-, or four-tube fixtures; 8-foot-long tubes are also used, particularly in larger manufacturing facilities. The basic components of the fluorescent lighting system are fixture, reflector, switch, tubes, ballast, and lens.

The second most common lighting source used in the apparel industry is the incandescent lamp. These fixtures are relatively inexpensive and easy to install. However, incandescent lighting is the least efficient lighting source available. Incandescent lights are most often used for common areas and hallways. They are also used for decorative lighting (e.g., on signs and displays) and for exit lights.

High-intensity discharge (HID) lamps are also used in larger warehouse-type facilities. The HID family of lamps includes mercury vapor, metal halide, and high-pressure sodium lamps. Mercury vapor lamps are the least efficient lighting source in this category and can be replaced with either metal halide or high-pressure sodium lamps with a relatively short payback. All of the HID lamps have significantly longer lives than incandescent lamps and many fluorescent lamps.

Efficiency Technology Solution
Energy-Efficient Indoor Lighting

Human responsiveness and flexibility are essential to apparel assembly. The ability to recognize a seam inconsistency, to anticipate changes in fabric properties, and/or to correct for subtle misalignments in fabric patterns are the principal reasons that automation lags in the garment industry. The need for human talent in apparel construction creates a corollary need to ensure that work conditions promote productivity, quality, and accuracy. Integral to favorable work conditions is adequate lighting; task lighting provides an opportunity to improve work conditions at a relatively low cost.

The sewing area requires much higher levels of lighting (1000 lumens per sq ft) than marking and cutting areas (70 lumens per sq ft); wrapping, packaging, labeling, and inspection areas (50 lumens per sq ft); or locker rooms and washrooms (20 lumens per sq ft).

Task lighting is typically provided by incandescent fixtures; these can be cost-effectively replaced with compact fluorescent lamps. In addition to offering higher lumens per watt, the longer life of fluorescent fixtures reduces the maintenance burden and lessens the risk of production slowdowns due to lamp failure.

Many production machines have built-in light fixtures. These lamps are sized and configured to directly support machine operation and, although considered task lighting, they do not necessarily illuminate the entire workstation. Materials handling and fabric setup and alignment are labor-intensive steps that precede machine operation and, as such, may require additional illumination beyond the equipment's own task lighting. A site-specific lighting survey to measure illumination levels at task stations can help identify problems that might restrict worker comfort and productivity.

Electrotechnology Solution
Energy-Efficient Outdoor Lighting

Although typically not a large portion of a manufacturer's energy bill, outdoor lighting can contribute to facility operating costs. Existing applications range from incandescent lights on a facility's sign, fluorescent security lights over walkways and entrance ways, and mercury vapor lights in the parking lot and driveway. These lighting systems normally represent only a small portion of the energy bill because they are on for limited periods of time and seldom contribute to a facility's peak electrical demand. This means that the cost for operation, in terms of cents per kilowatt-hour, is normally less than for other systems (e.g., cooling, heating, and indoor lighting), and that the potential savings from energy conservation projects may be smaller. However, important benefits can accrue if outdoor lighting levels reduce crime and increase employee safety.

Process Heating

Process heating—provided primarily by natural gas—accounts for 3% of electricity use in the apparel industry. Process heat is required for hand irons, iron table steamers, steam pressing machines, and some garment finishing equipment.

Opportunities to improve the efficiency of process heating exist primarily in the ink drying portion of the finishing process. Two technologies—IR drying and UV curing—are available for this application. IR drying is used both to dry and cure solvent-based inks; UV curing uses light to initiate a chemical reaction in special UV-curable inks. IR drying is an established technology that has been used in certain screenprinting applications for years. UV curing was developed primarily for non-fabric applications in printing and semiconductor manufacturing. Recent improvements in UV curing now make the technology feasible for the apparel industry. However, applications are limited to fabrics with tight weaves.

Electrotechnology Solution
Electric Infrared Drying and Curing

Apparel manufacturers typically use silk-screening equipment to apply designs to garments such as T-shirts and sweatshirts. The ink must be cured to affix the design to the garment. The curing is typically accomplished using natural gas convection ovens. These units are inefficient and may increase HVAC requirements by adding heat to the environment and allowing indoor air to escape with the exhaust.

Electric IR drying ovens provide less heat-intensive drying and curing than convection ovens. The IR process reduces curing time, energy consumption, and labor. In one case study, the addition of four electric IR panels to a silk-screening machine reduced energy consumption by 23% and resulted in an annual energy savings of $900. In addition, because the units are much more compact than a gas convection oven, they free up floor space.

Electrotechnology Solution
Ultraviolet Curing

UV curing is a process in which UV-curable inks are applied to a substrate and then exposed to UV light. Photoinitiators in the inks react to the light and cause resins and bonding elements to adhere to the substrate. This technology enjoys widespread use in the printing industry, but has been slow to penetrate the apparel market. Since UV-curable inks can hide in the weave of many fabrics, they may not receive sufficient exposure to the radiation, making their durability suspect. However, the technology is being improved, and advances in ink chemistry and UV light intensity should enable UV curing to find greater use for apparel screenprinting in the near future.

The appeal of UV curing rests primarily in the size of the equipment. In most manufacturing facilities, floor space is limited and a common reason for outsourcing most screenprinting services. UV curing equipment is relatively compact, and the curing process occurs rather quickly; it can make the large drying equipment associated with most screenprinting operations unnecessary.

Emerging Electrotechnology Solution
Radio-Frequency Drying

Radio-frequency (RF) drying currently is used on a limited basis in the apparel industry. Although it serves several applications in the textile industry, equipment expense and special production conditions have limited its use in garment manufacturing. RF drying requires electronic systems similar in complexity to microwave systems. Control of the RF energy is provided by a capacitance-inductance circuit which, for the larger equipment necessary for most industrial applications, is relatively expensive.

RF drying is practical under only a few garment production conditions. Material that has a uniform depth, such as a continuous sheet of fabric, reacts well to RF energy because heat concentration is not a problem. Unfortunately, apparel is not typically characterized by uniform thickness, making RF drying difficult.

The textile industry is a more attractive market since many of its moisture-removal tasks favor the energy characteristics of RF. RF drying is a dielectric heating process: Regions with high water content absorb more heat than drier regions, which results in a relatively uniform drying process. Consequently, RF drying can be considered for applications that involve the proper fabric conditions and have high enough volume to justify the expense of the equipment. The manufacture of raincoats and other waterproof garments (SIC 2385), which are relatively flat and can be made in large quantities, presents one specific, practical apparel application of RF technology.

4

ELECTROTECHNOLOGY PROFILES

This section provides profiles of the electrotechnologies identified in Sections 2 and 3. Each profile explains the technology, its advantages and disadvantages, commercial status, and costs. The profiles have been designed as stand-alone descriptions so they can be utilized separately from this guide. Turn to Section 5 for a list of equipment vendors that can provide further information as needed.

Computer-Assisted Design and Pattern Making

Basic Principle

Computer-assisted design (CAD) technology exploits the power of graphics software to facilitate the apparel design process and eliminate manual drafting of designs. Using CAD, a garment design can be viewed from all angles, dimensionally evaluated for fit and interference among design elements, and digitized for further analysis or prototype manufacture. The ability to examine a three-dimensional image of a design is helpful in evaluating its relative proportions. Flaws in the appearance of a part become obvious, and corrections can be made and reviewed for effectiveness. CAD also allows an apparel manufacturer to inexpensively show fashion ideas to clients. Moreover, CAD enables manufacturers to more rapidly incorporate subtle changes or entirely new designs into their garment lines in response to new trends.

A second area in which CAD aids manufacturers is in the transfer of information between design and production departments. CAD stores graphical images as digital data files that can be translated to instructional language for automated production machinery. CAD enhances the performance advantages offered by automated equipment by compressing the time required for a design concept to become a production item.

Speed and flexibility are essential attributes in an increasingly competitive industry. Domestic manufacturers cannot compete on cost alone, due to dependence on higher-wage labor; however, a quick design-to-manufacture cycle can provide a key competitive advantage. Domestic manufacturers have an inherent transportation advantage over offshore competition, and decreasing in-plant turnaround with CAD technology further reduces the amount of time between a retailer’s order and delivery of product. Since retailers value both cost and performance, CAD is becoming essential to success in domestic apparel manufacturing. In essence, CAD is recommended as a manufacturer's first step in increasing the level of automation in a production facility.

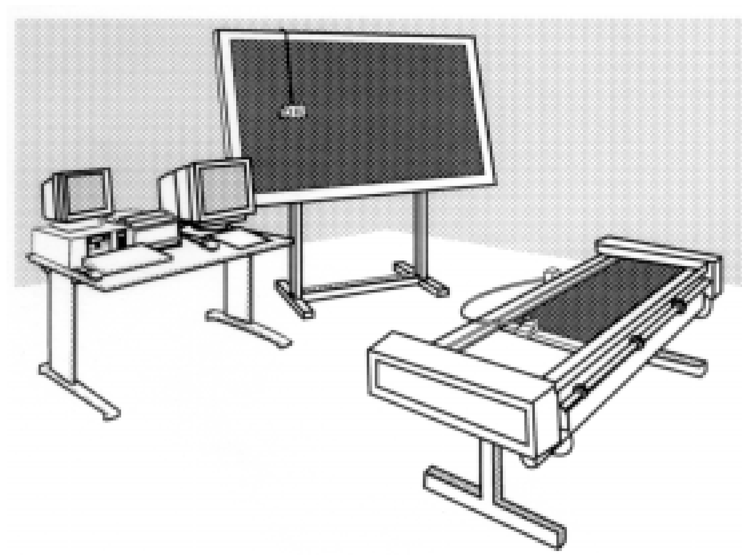

Figure 4-1
CAD Station with Plotter

System Description

CAD systems translate graphic designs into numerical data files. The translated designs are easy to scale to determine the dimensions of all necessary garment sizes. This scaling capability significantly reduces the amount of labor and time required for pattern development and grading. A CAD data file is superior to physical templates in that it can be corrected and updated more quickly.

A CAD system consists of hardware such as computers, monitors, pattern cutters, and software such as graphics programs. Available hardware ranges from self-contained PCs connected to a single pattern cutter to powerful workstations capable of supporting several pattern cutters. Graphics software allows the use of both mouse commands and keyboard entries to specify the dimensions, materials, and colors of a garment. These programs then translate the designs into numerical data files that can be used either to generate a physical drawing of the design or to drive a pattern cutter. A key advantage of these numerical data files is the ability to scale the garments to their appropriate sizes in a process known as "grading." Conventional grading is performed manually; however, by applying a series of multipliers to a CAD data file, grading is accomplished much more quickly.

Graphics software packages can include cost-accounting functions. The more sophisticated packages calculate a cost estimate for garment production by summing up the cutting and sewing tasks and then multiplying them by the corresponding labor and materials costs.

Advantages

- Quick design and redesign: Garment design modifications can be visually evaluated without the creation of a prototype. Changes to the colors, proportions, and dimensions of a garment can quickly be reviewed for effect.

- Effective presentation of fashion ideas: Apparel manufacturers can improve customer relations by readily translating client fashion ideas into graphical models.

- Swift upgrade of existing designs: Changes to a garment design based on retailer feedback are easy to incorporate into the model. CAD systems that tie into production equipment can quickly translate design upgrades into production changes.

- Improved productivity through numerical data files: By translating graphical models into digital files formatted to drive automatic marking and cutting machines, CAD compresses the design-to-manufacture cycle.

Disadvantages

- High initial cost: CAD systems require an investment in workstation hardware and software. Cost savings from decreases in fabric scrap typically pay back the investment in less than 2 years.

- High operating skill levels: CAD requires operators trained in both design work and computer use; therefore, system operators typically have higher labor rates than production workers.

Commercial Status

CAD is a mature technology that was originally developed for stress and flexibility calculations for automotive, aerospace, utility, and other industries. CAD's graphic abilities now provide attractive opportunities for improving the garment design process. CAD systems can be installed on either stand-alone PC or client-server networks, depending on particular system needs. Plotters that generate pattern templates can be included with the system.

Cost and Electrical Requirements

Since CAD systems can be assembled for multi-user and multi-tasking applications, systems span a range of costs. Basic systems with limited capabilities cost $10,000; more advanced systems that can accommodate several users cost $70,000–$80,000. Hardware costs represent 33–50% of these costs; the remainder is attributable to software, training, and maintenance services. The memory requirements of apparel-based CAD systems are less than CAD applications in other industries; consequently, garment manufacturers can upgrade their CAD systems relatively inexpensively. Training is typically included with the system purchase.

The electrical consumption of client-server CAD systems is comparable to other client-server computer systems. Depending on the capacity of the server, a rough estimate of the power rating for a complete CAD system is about 500 watts. Although CAD systems do not consume large amounts of electricity, they add to the cooling system load and may warrant providing cooling services to a previously unconditioned room.

Table 4-1
CAD System Characteristics

Power Rating	Approximately 500 watts per workstation
Energy Consumption	Approximately 1040 kWh annually*
Key Inputs	
Power	Electricity
Other	None
Costs	
Purchase, Setup, & Training	$10,000-$80,000

*Assuming 1 workstation used 8 h/d, 260 d/yr.

CAD systems typically decrease fabric costs by 3% compared to manual layout methods. CAD vendors generally claim that their systems pay for themselves based on fabric cost savings alone. Garment manufacturers typically expect fabric costs to represent 10% of sales. If a manufacturer with $10 million in annual sales invests in a CAD system that costs $40,000 ($20,000 for hardware and $20,000 for the graphics software and training), the material costs savings would run $30,000 per year. Payback, based solely on fabric savings, would be 16 months. The speed and flexibility afforded by a CAD-supported production line are additional benefits which, although not quantified and included in the cost justification, certainly enhance the attractiveness of the investment.

Computer-Assisted Marking and Cutting

Basic Principle

Subsequent to designing a garment, patterns and markers must be developed to guide the cutting of member pieces. While conventional cutting methods use physical templates and hand-guided cutting tools, computer-assisted marking and cutting equipment is increasingly providing these services.

A typical automatic marking or cutting machine accepts fabric from a manual feed or a spreading machine that layers the material to a certain height. Fabric is held flat on the marking or cutting surface by a vacuum. The marking or cutting piece travels over the material in a two-dimensional plane according to instructions provided directly by an operator or, depending on the equipment's capability, from a data file loaded into the machine. A cutting head cuts the fabric according to the pattern; a marking head marks the location of buttonholes, pockets, and other design features.

The use of computer-assisted marking and cutting machines shortens the design-to-manufacture process. Connecting computer-assisted design (CAD) files to production machines allows quick incorporation of design changes and corrections in the production run. This benefit increases the responsiveness to retail customer feedback. In addition, although these machines require relatively skilled operators, they generally reduce the labor hours associated with marking and cutting.

System Description

Automated marking and cutting machines receive pattern information either directly from operator-fed instructions or from CAD files. Although automated cutting and marking machines are considerably quicker than manual methods, the most significant advantages offered by this equipment are a compatibility with cut-optimization programs and digitized CAD files. Cut-optimization routines reduce the amount of fabric scrap by planning cut paths that maximize the geometric efficiency of a layout. In addition, the ability of an automatic cutting machine to be driven by a CAD file improves cutting accuracy and product quality. Sending a CAD file directly to an automatic cutting machine eliminates the need to manually transfer patterns to a fabric sheet. Manually generating patterns and markers is slow and labor-intensive, and introduces the possibility of error. Since computer-assisted cutting machines operate directly from design dimensions and consistently use the same cutting action from lot to lot, these machines perform multiple cutting operations with improved accuracy and precision.

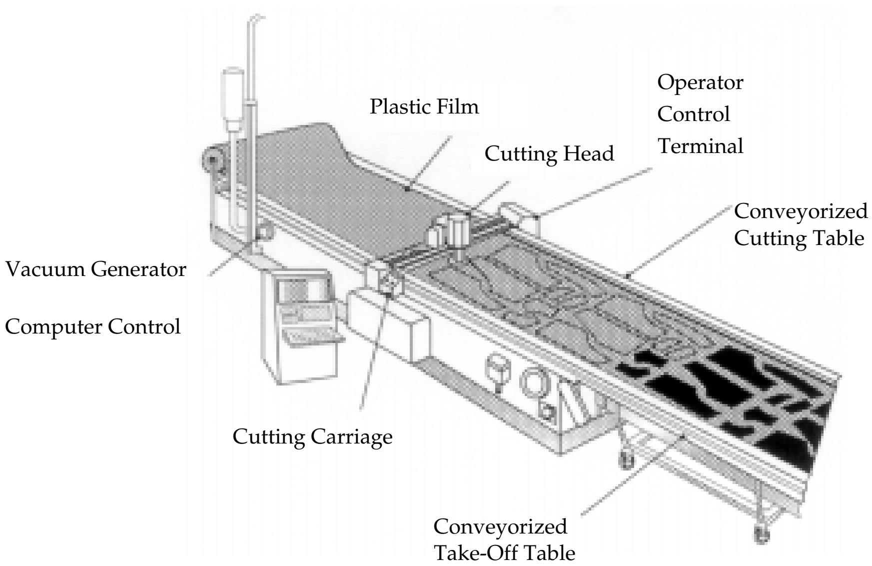

Figure 4-2
Computer-Assisted Cutting Machine on a Production Line

Advantages

- Quicker cutting and marking operation: Computer-assisted machines receive instructions and perform operations more quickly than manual processes. The shorter task time reduces overall production time and helps get product to the retailer sooner.
- Tighter design-to-manufacture process: Computer-assisted machines can be driven by information from CAD data files. This connection allows new designs and design changes to be quickly incorporated into the manufacturing process.
- Reduced labor costs: By replacing several manual steps, computer-assisted marking and cutting equipment allows a worker to generate more cut/marked material per unit of time, lowering the labor cost.
- Less fabric scrap: When driven by CAD-generated data files and cut-optimization routines, computer-assisted marking and cutting machines reduce fabric waste.

Disadvantages

- High initial cost: Computer-assisted marking and cutting machines are relatively expensive, costing $80,000–$250,000.
- Increased worker skill level: Machine operators and maintenance personnel must receive specific training.

Commercial Status

Computer-assisted marking and cutting machines are a mature technology. They were introduced on an experimental level in the early 1970s and generally have grown in capacity and decreased in cost in concert with computer technology. The industry trend is to integrate the machines more tightly into the design-to-manufacture process. One obstacle is lack of a standardized instruction language for CAD systems and production equipment. Such a language would make it possible to network equipment from different vendors. Domestic apparel manufacturers are increasingly identifying this automation technology as a necessary production tool.

Table 4-2
Computer-Assisted Marking and Cutting Equipment Characteristics

Dimensions	Length: 10-13′ Width: 6-8′ Height: 3′ for the cutting table; 8-12′ of vertical height needed to run vacuum piping
Power Rating	220 V or 440 V, 60 Hz, Single- or 3-phase controller: 8-15 kW Vacuum system: 30-50 kW
Key Inputs	
Power	Electricity
Costs	
Purchase, Setup, & Training Operating	$80,000-$250,000 $9500-$16,200 annually*

* Cost of electricity, assuming equipment is used 16 h/d, 5 d/wk (4160 h/yr.)

Cost and Electrical Requirements

The cost of computer-assisted marking and cutting machines varies widely. Fabric properties, the number of layers of fabric, cutting speed, and frequency of cutting tool reconfigurations determine the appropriate equipment size and features. Low-end automatic cutters typically cost less than $100,000, while more advanced machines cost well over $200,000. The vacuum system for holding fabric flat consumes most of the electricity in an automatic cutting machine, pulling upwards of 30 kW. Larger cutting surfaces with greater hold-down capabilities require larger vacuum systems, increased motor size, and increased cost. The control systems that drive the cutting head are less electricity-intensive and pull approximately 10 kW.

Unit Production System

Basic Principle

A unit production system (UPS) uses a batch size of one to increase both the flexibility and labor efficiency of a manufacturing line. In a single-unit batch system, production pieces are transferred from one workstation to the next as soon as a given task is completed. Apparel manufacturers typically combine a UPS with automated materials handling systems. Automated materials handling systems are designed to move production items between stations and to improve ergonomic conditions for line workers. In conventional apparel manufacturing processes, 80% of labor effort is applied to materials handling and the remaining 20% to cutting, sewing, packaging, etc. In a UPS, more of the materials handling responsibilities are automated, increasing labor efficiency and allowing workers to spend more time making the garments and less time moving them around. In addition, the ergonomic benefits of an automated handling system increase worker productivity and help safeguard worker health.

In conventional systems, bundles of production items accumulate at workstations and then are manually gathered and moved to the next station. These bundles act as buffers that ease variability in the production line, but also mask problems. For example, defects in garments remain undiscovered until the items arrive at an inspection station. Also, bundle transfer of production items means there is always a lot of work in process, rather than a constant stream of completed apparel.

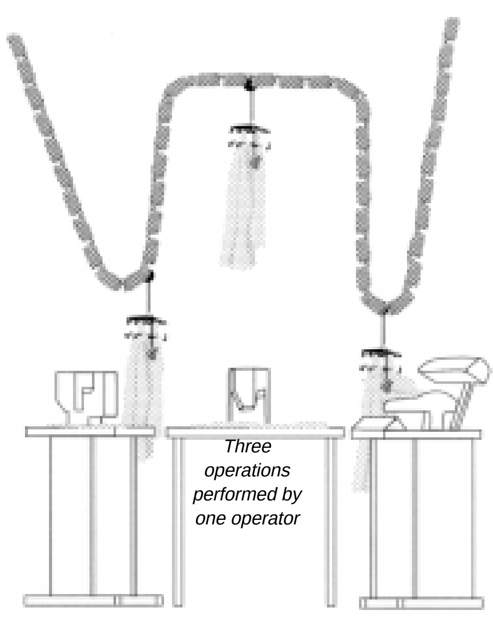

Figure 4-3
Unit Production System

Source: Sven G. Bodell, Corporate; Eton Systems, Inc.

With a UPS, production items continuously move along the manufacturing line. Bundles do not accumulate because completed items are immediately sent downstream. Unplanned bottlenecks are quickly identified and resolved by rebalancing the line or applying more workers to a problem area. A UPS also allows in-process inspections between worker stations and at designated checkpoints. Errors, assembly defects, and process problems can be identified and resolved prior to final batch inspection, reducing the scrap rate and late delivery of goods.

In addition, a UPS improves the flexibility of a production line. The single-unit batch size and minimal amount of work in process in the system allows quick implementation of changes. Design problems can be corrected in-process with minimal interruption and scrap. Multiple products can be concurrently produced on the same line, and lines can be balanced by shifting task responsibilities among the workstations.

System Description

A UPS is a production system that operates using a batch size of one and that ties the workstations together with an automated materials handling system. UPS systems use a moving line or chain to carry items from one workstation to the next; they also present work pieces to operators at ergonomically favorable positions. The fixtures that carry the work from station to station are often bar coded and can be scanned into a tracking system to provide real-time monitoring of production line operation. This feature and enhanced monitoring and control of production improves the accuracy of delivery schedules.

Single-unit batch sizes offer maximum flexibility in manufacturing garments; however, since line imbalances are corrected by redistributing workers or retasking workstations, workers must be sufficiently skilled to handle varying responsibilities. Instead of repeating the same task operations on multiple items within a batch, a worker must be able to perform one operation on one item and then perform a different operation on the next item. Although cross-training of workers is useful in many manufacturing environments, a UPS requires this workforce attribute.

Advantages

- Increased worker productivity: Since the automated materials handling system replaces manual transfer of production pieces, workers spend more time on direct production activities.

- Reduced work in process: Work in process is minimized, keeping inventory costs low and maximizing the availability of finished product.

- Decreased potential for worker injury: Shifting materials handling tasks to automated equipment and improving the ergonomics of workstations can lessen repetitive motion injuries. Also, workers who are less fatigued may have fewer accidents.

- Greater flexibility: Line imbalances can be identified and corrected more quickly, and multiple items can be concurrently produced on the same production line.

- Improved quality: A UPS allows quick recognition of problems with work quality at the workstation level.

Disadvantages

- High initial cost: A UPS reconfigures a plant's set of production and control processes and requires investment in structural additions and modifications to support the automated materials handling systems.

- Requires a skilled work force: The flexibility of a unit batch process requires a workforce that can quickly adjust to different responsibilities and tasks according to current production needs.

- Increased maintenance requirements: The motor-and-chain systems associated with automated handling add to a shop's maintenance.

Commercial Status

UPS is a mature technology. The value of this technology is recognized throughout the apparel manufacturing industry, where it has been used for almost 30 years. Several companies manufacture and install UPS. Although system and installation costs are high, depending on a UPS system's size and the manufacturer's current production costs, a UPS can provide a rate of return over 20%. UPS provides competitive strength to defend against market share losses to offshore plants.

Table 4-3
Unit Production System Characteristics

Power Rating	
Primary loop	3-phase, 440 V or 220 V electric motors, from 15—75 kW
Feeder loop	Single-phase, 120 V electric motors, from 0.38—7.6 kW
Computer-control system	Single-phase, 120 V, 500 W per terminal
Key Inputs	
Power	Electricity
Costs	
Purchase, Setup, & Training	$4000—$8000 per workstation

Costs and Electrical Requirements

Although system costs vary depending on specific application needs, an approximate cost of $4000–$8000 per workstation can be used for estimation. The number of workstations served by a UPS depends on product characteristics, production tasks, and the sequence in which these tasks are performed. Typically, the automated materials handling system consists of two separate systems: the primary loop, which transfers production items from station to station; and feeder loops, which take items off the primary loop, deliver them to a workstation, and return them to the primary loop when completed. A buttonholing station, for example, might be located on a feeder loop, since only some garments need buttonholes. Inspection and packaging stations, however, would be located on the primary loop, since these steps are necessary for all garments being manufactured. The electrical requirements of the primary loop vary according to the weight of the garment load; however, motor capacities ranging from 20 horsepower (15 kW) to 100 horsepower (75 kW) are common. The feeder loops require smaller motors ranging from 0.5 horsepower (0.38 kW) to 10 horsepower (7.6 kW).

Manufacturing Control System

Basic Principle

A manufacturing control system schedules the steps of a production process to optimize the use of labor and materials, and subsequently monitors the completion of these steps. This type of system improves the performance of a production facility, decreases operating costs, and increases planning accuracy. Control systems insert known production characteristics, such as the time required to complete a particular task and the order in which each task must be performed, into an algorithm that accounts for raw material supply schedules, delivery requirements, and available labor. The resulting output is a production schedule defining a start time, task time, and batch size for each production operation. Using this schedule to pace a production process minimizes work in process and allows for accurate forecasting of production batch completion. Recognizing that work in process drives the cash flow needs of many manufacturers, minimizing this quantity improves a plant's financial condition. In addition, the ability to accurately plan completion of a production run improves customer confidence and can lead to long-term supply contracts.

Manufacturing control systems also offer an opportunity to improve inventory control. Improved measurement of the production process increases the accuracy of estimates for when and how much material is needed to support production. Raw material purchases can then be made more intelligently, reducing the amount of cash tied up in inventory, decreasing storage space requirements, and allowing a more effective use of plant floor space.

System Description

A manufacturing control system is a computer-based system with software that essentially works backward from a required completion date to schedule the production of an item. Manufacturing resource planning systems (known as MRPII) are typical of such control systems. The data required for a typical system include a list of necessary tasks, their sequence, and their standard allowed minutes (SAM) allotment. The control system then determines batch sizes for the item and its subassemblies, and the start time for each task. For example, the manufacture of a shirt requires about 40 production steps, at least 20 of which must be performed sequentially. An MRPII system schedules both the sequential steps and those that can be performed in parallel such that shirt production flows smoothly. In addition, the system sizes batches and buffer capacities to maximize the production rate while minimizing the work in process.

The more advanced control systems include real-time monitoring of the production line. By applying bar codes to each production batch and scanning them into the system at each workstation, the status of garment pieces can be determined at any point in time. Accurate measurement of production line performance facilitates identification of bottlenecks and quality deficiencies and increases a floor manager's ability to resolve problems before the completion date is unalterably compromised. Also, improved measurement of worker performance increases the accuracy of cost accounting since the amount of labor spent on each task is known more precisely.

Inventory control is another benefit available from a well-controlled manufacturing process. Immediate feedback from the production line to the inventory system improves the accuracy of inventory records. It is also possible to extend the responsibility of the manufacturing control system to include inventory replenishment. For example, after a certain number of deductions from the inventory, the control system can automatically generate a purchase order to restock the spent item.

Table 4-4
Manufacturing Control System Characteristics

Power Rating	Approximately 500 watts per workstation
Energy Consumption	Approximately 1040 kWh annually*
Key Inputs	
Power	Electricity
Costs	
Purchase, Setup, & Training	$10,000—$100,000

* Assuming 1 workstation used 8 h/d, 5d/wk, 52 wk/yr.

Advantages

- More accurate planning of completion dates: Quantifying task times and production rates decreases errors in product delivery estimates.
- Lower inventory costs: Incorporating inventory resupply into the manufacturing system lessens the need to keep extra material on hand.
- Improved monitoring of quality levels: Problems in work quality can quickly be traced to the appropriate workstation.
- Enhanced coordination with quick response systems: Bar-code-driven sales information from retail customers can be used to determine production requirements.

Disadvantages

- Disruptive implementation: Installation of a manufacturing control system can be performed in modules; however, system implementation requires educating production planning personnel and retraining workers.
- Opposite of just-in-time (JIT) manufacturing: Manufacturing control systems are typically “push” systems in that production work is based on delivery dates and labor requirements. Conversely, JIT processes are “pull” systems in that work is paced by downstream needs rather than scheduled ahead of time.

Commercial Status

The manufacturing control system is a mature technology developed in the 1970s. The use of these systems has expanded as computer system capabilities have increased and costs have decreased. Control systems are software systems, typically sold in modules and configured to match the specific needs of the manufacturer. Some manufacturers only need inventory-control features while others perceive sufficient value in incorporating the entire production process into the control system. Control system vendors generally provide installation and preliminary training services with product packages.

Costs and Electrical Requirements

Manufacturing planning and control systems cost $10,000–$100,000, depending on the specific needs of the manufacturer. Approximately one-third of the system cost is for hardware; the remainder covers software and training. Typical system hardware includes a local network server, workstations, and bar code scanning devices. System software needs depend on the complexity of the expected production processes. Incorporating electronic data transfer capabilities to support a quick response relationship with a retailer obviously adds to the complexity and cost of the control system software. The electrical requirements of these systems are comparable to office equipment.

Outdoor Lighting

Basic Principle

Many small businesses benefit from enhanced outdoor lighting through reduced potential for crime, increased employee safety, and improved visibility and attractiveness of the facility.

These benefits are obtained for a relatively small operating cost because, in most cases, outdoor lighting does not contribute to a facility’s peak electrical demand. This means that the average energy cost for outdoor lighting (in terms of cents/kWh) is typically less than the energy cost of other improvements.

Table 4-5
Typical Outdoor Lighting Applications

Type of Light	Exterior Signage	Parking Garages	Parking Lots/ Driveways	Walkways	Facade and Landscaping
Incandescent	ν			ν	ν
Compact Fluorescent		ν		ν	ν
Fluorescent	ν	ν		ν	ν
Metal Halide		ν	ν	ν	ν
High-Pressure Sodium			ν		
Mercury Vapor			ν		

Note: Additional applications are possible for each of the lighting types, but the chart identifies the most efficient applications for each of the light sources. Low-pressure sodium lamps are not normally used in small businesses because of their poor color quality.

There are three principal methods for using outdoor lighting in small businesses:

1. Signage on the exterior of the building or illuminated signs near the building to generate attention for the building or the small business

2. General lighting in parking lots, driveways, parking garages, and walkways

3. Facade lighting to increase the visibility of the structure and surrounding architectural features and landscaping

Different lighting technologies are typically used for different applications. Existing lighting systems can often be retrofitted or replaced by energy-efficient lighting systems. In addition, existing lighting systems can be supplemented with new lighting systems to increase safety, security, visibility, and name recognition.

System Description

Mercury vapor, high-pressure sodium (HPS), and metal halide lamps are referred to as high-intensity discharge (HID) lamps. Metal halide lamps and HPS lamps provide approximately 100 and 140 lumens per watt, respectively, while mercury vapor lamps provide up to 60 lumens per watt. Mercury vapor lamps emit a blue-green light, while HPS lamps emit a yellow-orange light. Metal halide lamps emit a predominately white light. Most HID lamps require a spacing-to-mounting height ratio of 1.0–1.9, which means that the spacing is roughly one to two times the pole height.

Each HID lamp requires a specific ballast to drive the lamp; however, some manufacturers offer metal halide and HPS lamps that can be operated by a mercury vapor lamp ballast. This allows easier conversion from inefficient mercury vapor lamps to higher-efficiency metal halide and HPS lamps. HID lamps are available in a variety of wattages from 35–1500. The HID ballast adds approximately 8–15% to the wattage of the lamp.

Fluorescent lamps are also used as outdoor lighting sources for small businesses. Conventional 4-foot and 8-foot tubes are used in many parking garages and covered walkways. Compact fluorescent lamps are also becoming popular as replacements to incandescent lamps in stairways. Newer T-8 lamps and electronic ballasts are approximately 30% more energy-efficient than older 40-watt T-12 lamps with magnetic ballasts.

Incandescent lamps are the least efficient form of outdoor lighting. However, incandescent lamps are still used as spotlights on signs and as floodlights on building facades and landscaping. The short lifetime of incandescent lamps often has a bigger impact on operating costs than does the additional energy use.

Common controls used for outdoor lighting systems include time clocks, photocells, and programmable controllers.

Advantages

Well-designed outdoor lighting systems can offer the following advantages:

- Increased perception of comfort and friendliness
- Increased security for customers and employees
- Reduced number of accidents in driveways, parking areas, and walkways
- Increased visibility for the facility and the small business

Disadvantages

Other than installation and operating costs, there are no overall disadvantages of outdoor lighting. However, specific lamps do have weaknesses:

- HID lamps require 2–7 minutes to warm up before reaching full output.
- Metal halide lamps require up to 15 minutes to cool before restrike.

- Special low-temperature fluorescent lamps are required in cold climates to maintain a relatively constant lumen output when temperatures are below freezing.

Table 4-6
Typical Lamp Characteristics for Outdoor Applications

Type of Lamp	Typical Wattages	Initial Lumens/Watt	Avg. Rated Life (h)
Incandescent	60—1,500	15—24	750—2,500
Compact Fluorescent	12—35	25—75	8,000—12,000
Fluorescent	20—215	50—100	9,000—20,000
Metal Halide	175—1,500	69—115	10,000—20,000
High-Pressure Sodium	35—1,000	51—140	7,500—24,000
Mercury Vapor	40—1,000	24—60	12,000—24,000

Note: Initial lumens/watt includes ballast losses.

Commercial Status

All of the lamps described above are readily available from a variety of manufacturers. However, mercury vapor and older T-12 fluorescent lamps are being phased out of production.

Gradual improvements have been made in the efficiency of outdoor lighting systems. In addition, color-corrected HPS lamps are available, as well as improved metal halide lamps that contain incandescent or fluorescent lamps that come on if the power is interrupted.

EPRI Information

Additional information on lighting technologies is available from the EPRI Lighting Information Office, (800) 525-8555.

Electric IR Drying & Curing

Basic Principle

Infrared (IR) is part of the electromagnetic spectrum, occurring between visible light and radio waves (0.75–1000 microns). Electric IR radiation is produced by heating an emitter of IR radiation. The radiation emitted is then absorbed by the substance at which it is directed, causing the molecules of the substance to vibrate and generate heat. The heat thus generated dries a coating from the inside out. IR systems require no special airflow for heat transfer because energy radiates directly to the coated surface without heating the air. By localizing the origin of the emissions, and allowing the use of reduced- or non-solvent paints, inks, and coatings, the technology enables facilities to significantly reduce or eliminate VOC emissions.

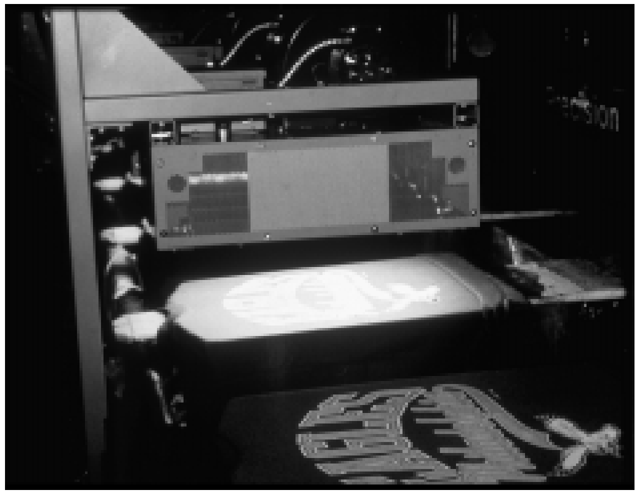

Figure 4-4
Panel IR Unit for Process Line Drying

IR wavelengths are separated into three ranges: short, medium, and long. Short-wave IR provides fast, intense bursts of energy and, depending on the material, can penetrate the deepest. Short-wave IR is most useful when short cycle times are required, such as in drying inks in the printing industry and curing powder coatings in the metal finishing industry. Medium-wave IR is less intense than short-wave; thus, it is more useful for heat-sensitive materials such as textiles. Medium-wave IR is also more readily absorbed by plastics and glass, and is typically used to dry water-based inks, coatings, and adhesives. Long-wave IR has the shallowest penetration and therefore heats more by convection; it is well-suited to slower, more even heating, such as is required for drying paper products and film. Long-wave IR is also less sensitive to color differences, making it the wavelength of choice for drying or curing multicolored products.

Many factors must be considered in selecting the appropriate type of IR equipment (i.e., short-, medium-, or long-wave emitters) for a given application. These factors include the absorption factor and color of the product as well as the depth of penetration and processing speed required. The absorption factor is determined by the temperature, humidity, thickness, color, and surface condition of the material being dried or cured. Each material best absorbs energy of a specific wavelength. Peak efficiencies are typically achieved by matching the wavelength of the IR emitter to the absorption wavelength of the product. For example, water has a maximum absorption of 2.6–3.2 microns, making medium-wave IR best for drying water-based materials.

System Description

A typical electric IR system includes quartz lamps and reflectors. Systems are typically configured as a tunnel or bank of lamps on a process line; smaller applications use moveable arch or portable arm-mounted lamps. An IR system reaches full power in less than 1 second and can be accurately regulated with simple controls. Electric IR systems are also highly energy-efficient, especially in comparison to gas IR systems. In an electric IR system, more than 85–90% of the energy used is converted to radiation, and 50–70% of the energy used is absorbed by the substance that needs drying. A gas IR system transfers only 20–25% of the energy used to the drying substance and produces emissions of its own.

Advantages

- Quick, effective drying or curing. Reduces process time 50–80% in comparison to convective drying ovens. Curing takes place almost instantly.
- Markedly increases production potential.
- Quick startup and shutdown eliminates costly preheating, thereby increasing overall efficiency.
- Relatively insensitive to changing conditions (i.e., temperature, humidity).
- Modular design and small size of IR panels allow flexibility; they are easily incorporated into existing production lines and require minimal floor space.
- Reduced need for air circulation since IR heats products directly.
- Long lifespan, minimal routine maintenance.
- Relatively short payback period, depending on the application.

Disadvantages

- Initial capital cost can be high.
- Has difficulty uniformly heating geometrically complex shapes.

Table 4-7
Electric IR Drying & Curing System Characteristics

Dimensions	Length: 6—90″ Width: 10—60″ Height: 10—90″
Power Rating	8—15 kW per square foot
Energy Consumption	4160 kWh annually*
Key Inputs	
Power	Electricity
Other	None
Key Outputs	
Solid Waste	None
Air Emissions	None
Water Effluent	None
Cost	
Purchase	Panel: $1000—$2500 Custom oven: $10,000—$250,000
Installation	10—20% of purchase cost
Other Supplies	None

* Assuming an 8-kW unit used 2 h/d, 5 d/wk, 52 wk /yr.

Commercial Status

Long- and medium-wave IR are well-known and have been used to dry materials and/or cure coatings since the 1930s. A variety of IR source systems are available from numerous vendors. Systems can be obtained with heating element temperatures of 600–4000°F, thereby producing radiation in the 1.0–6.0-micron wavelength. However, as the industry makes increased use of low- and non-solvent paints, inks, and coatings, short-wave technology (0.75–2.3-micron wavelength) is becoming more prevalent. As evidenced by the large number of IR equipment manufacturers active in this market, many manufacturing facilities are already using short-wave IR equipment.

Cost and Electrical Requirements

A basic electric IR spot heater or panel heater with two or three quartz emitters costs $1000–$2500. Custom-designed ovens or tunnels cost $10,000– $250,000.

Electric IR ovens typically cost 10–20% less than gas convection ovens for the same application and features. This is primarily because fewer control systems are required (e.g., air handling equipment and gas-related safety features).

Ultraviolet Curing

Basic Principle

Ultraviolet (UV) radiation has a wavelength range of 4–400 nanometers. UV radiation can be used to cure inks or coatings containing polymers that cross-link when subjected to radiation. The cross-linking transforms the coating from a liquid to a solid. Radiation-curable coatings provide a clear or pigmented finish that protects, decorates, and provides other functional properties.

Curing differs from drying in that drying is accomplished by driving off a solvent, usually through evaporation, leaving the pigment or coating material on the surface of the product. Only solvent-containing inks or coatings can be dried. Curing, on the other hand, changes the molecular structure of the coating material to solidify it. Radiation-curable coatings, therefore, do not need to contain organic solvents and eliminate the problem of volatile organic compound (VOC) emissions.

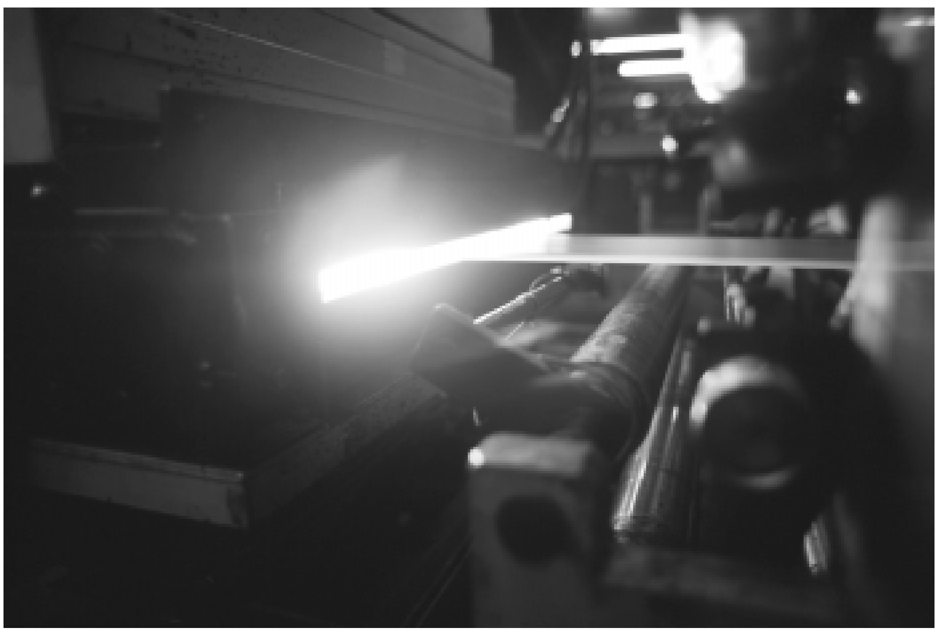

Figure 4-5
Ultraviolet Curing

System Description

Two basic types of lamps are commonly used to produce UV light: medium-pressure mercury vapor lamps (arc lamps) and medium-pressure mercury microwave-powered lamps (microwave-powered or electrodeless lamps). In both cases, the UV energy produced by the lamp bulb is focused by reflectors onto the coated materials as they move down a process line. The UV energy striking the materials causes a photoinitiator (a chemical in the coating) to trigger the cross-linking reaction, curing the coating. The UV light must be enclosed to prevent worker exposure.

Most UV systems are custom-made for use with conveyor-driven process lines. By using multiple lamps, the width of the treatment area can be extended as needed. Lamp length determines the number of lamps needed to achieve a specific treatment-area width. The system price varies with the type, number, and length of lamps; type of shielding; and cooling method. The capital cost of a conventional curing system such as a gas-fired curing oven can be nearly four times greater than that of an equivalent UV curing system. Also, although radiation-curable inks or coatings are twice as expensive per pound as conventional solvent-based coatings, less coating material is used per unit. The process is also easy to control; so there is less loss of product due to poor quality, and costs become comparable.

Advantages

- Radiation-curable inks and coatings dry quickly, thereby increasing the production rate.
- UV systems work with non-solvent coatings, thus eliminating VOC emission concerns.
- Since no VOC emissions occur, UV curing eliminates the need for VOC incinerators.
- UV curing equipment takes 10–50% less space than conventional fuel-fired curing ovens.
- Radiation-curable coatings are available in an array of colors and provide a high-gloss finish with improved wear- and scratch-resistance.

Disadvantages

- Ozone can form if the UV light reacts with available oxygen.
- Operating personnel must avoid the hazards of exposure to UV light.

Commercial Status

UV curing is currently used in a variety of industrial applications where a clean or very thin coating is required and where acceptable radiation-curable coatings are available. Examples include printing labels, decorating metal, hardening polymers on non-wax flooring materials, and coating printed circuit boards with protective insulation.

UV systems are readily available for a range of applications. Small systems with one or two lamps are frequently used in laboratories and in manufacturing plants for testing ink coatings and adhesives before application to film, foil, or paper substrates. Medium-sized systems with multiple lamps are used to cure finishes on metal, glass, and plastic products. Large multichambered ovens with rows of lamps are used to cure finishes on floor tiles and on textured coatings on large substrates such as paper, board, or glass. More complex UV systems are used in curing coatings on products that are not flat, such as wires, tubes, furniture, packaging, and electronic assemblies.

Table 4-8
Ultraviolet Curing System Characteristics

Dimensions	Length: 11—86″ Width: 9—55″ Height: 18—86″
Power Rating	120—800 watts per inch
Energy Consumption	9600—64,000 kWh per year*
Key Inputs	
Power	Electricity
Other	None
Key Outputs	
Solid Waste	None
Air Emissions	Ozone
Water Effluent	None
Cost	
Purchase	$1000—$60,000
Installation	Minimal
Other Supplies	None

*Assuming a system with four 10-inch lamps operated 2000 h/yr.

Cost and Electrical Requirements

The cost of UV curing systems varies significantly with size and system complexity. A single-lamp system may cost a few hundred dollars, while a complex multilamp system may cost hundreds of thousands of dollars. The majority of UV curing systems are custom-made multilamp systems; their price depends on the type and number of lamps, type of shielding, and cooling method.

An arm-mounted UV system for new installation or retrofit to an existing system usually costs $1000–$5500 and consumes 120–600 watts per inch, depending on the number of lamps and lamp length. A fully automatic UV lamp conveyor system costs $8000–$60,000 and consumes 200–800 watts per inch, depending on the complexity of controls and lamp lengths.

5

RESOURCES

This section contains three lists: 1) equipment suppliers for the electrotechnologies profiled in this guide; 2) EPRI information sources on efficiency technologies; and 3) apparel manufacturing trade associations. Information used to compile these lists was based on a combination of a telephone survey, published reports, directories, buyer's guides, and technical journals. This information was current at the time of publication and is expected to change over time.

Computer-Assisted Design and Pattern Making

Equipment Suppliers

Assyst, Inc.
P.O. Box 13581, Research Triangle Park, NC 27709
(919) 467-2211, fax: (919) 467-2297

Gerber Garment Technology
3567 Parkway Lane, Suite 100, Norcross, GA 30092
(770) 448-4448, fax: (770) 448-1233

Investronica, Inc.
5875 Peachtree Industrial Blvd., Suite 350, Norcross, GA 30092
(770) 242-0798, fax: (770) 242-1912

Lectra Systems, Inc.
844 Livingston Court, Marietta, GA 30067
(770) 422-8050, fax: (770) 422-1503

Computer-Assisted Marking and Cutting

Equipment Suppliers

Gerber Garment Technology
3567 Parkway Lane, Suite 100 Norcross, GA 30092
(770) 448-4448, fax: (770) 448-1233

Investronica, Inc.
5875 Peachtree Industrial Blvd., Suite 350, Norcross, GA 30092
(770) 242-0798, fax: (770) 242-1912

Lectra Systems, Inc.
844 Livingston Court, Marietta, GA 30067
(770) 422-8050, fax: (770) 422-1503

Unit Production System

Equipment Suppliers

Eton Systems, Inc.
4000 McGinnis Ferry Rd., Alpharetta, GA 30202
(770) 475-8022, fax: (770) 442-0216

Gerber Garment Technology
3567 Parkway Lane, Suite 100, Norcross, GA 30092
(770) 448-4448, fax: (770) 448-1233

Manufacturing Control System

Equipment Suppliers

Assyst, Inc.
P.O. Box 13581, Research Triangle Park, NC 27709
(919) 467-2211, fax: (919) 467-2297

Byte Systems, Inc.
317 Neely Ferry Road, Mauldin, SC 29662
(864) 288-7206, fax: (864) 288-4544

Gerber Garment Technology
3567 Parkway Lane, Suite 100, Norcross, GA 30092
(770) 448-4448, fax: (770) 448-1233

Investronica, Inc.
5875 Peachtree Industrial Blvd., Suite 350, Norcross, GA 30092
(770) 242-0798, fax: (770) 242-1912

Outdoor Lighting

Equipment Suppliers

Bairnco Corp.
2251 Lucien Way, No. 300, Maitland, FL 32751
(407) 875-2222, fax: (407) 875-3398

Bieber Lighting Corp.
970 W. Manchester Blvd., Inglewood, CA 90301
(213) 776-4744, fax: (310) 216-0333

Bulbtronic, Inc.
45 Banfi Plaza, Farmingdale, NY 11735
(800) 647-2852, (516) 249-2272, fax: (516) 249-6066

Carlon (Lanson & Sessions Co.)
25701 Science Park Dr., Cleveland, OH 44122
(216) 831-4000, fax: (216) 831-5579

Cooper Lighting Group
400 Busse Rd., Elk Grove Village, IL 60007-2195
(847) 956-8400, fax: (847) 956-1475

Crouse-Hinds Co.
Lighting Production Div., P.O. Box 4999, Syracuse, NY 13221
(315) 477-8185

Doane, L.C., Co.
55 Plains Rd., P.O. Box 975, Essex, CT 06428
(203) 767-8295, fax: (203) 767-1397

Duro-Test Corp.
9 Law Dr., Fairfield, NJ 07004
(201) 808-1800, fax: (201) 808-6622

Federal APD, Inc., Federal Signal Corp.
24700 Crestview Ct., Farmington Hills, MI 48335
(800) 521-9330, (810) 477-2700, fax: (810) 477-0742

Gardco Lighting
2661 Alvarado St., San Leandro, CA 94577
(510) 357-6900, fax: (510) 357-3088

G.E. Company
3135 Easton Turnpike, Fairfield, CT 06431
(800) 626-2004, fax: (518) 869-2828

Hapco Division of Kearney-National, Inc.
P.O. Box 547-KN, Abingdon, VA 24210
(540) 628-7171, fax: (540) 628-7707

Litetronics International
4101 W. 123rd St., Alsip, IL 60658
(708) 389-8000 ext 195, fax: (708) 371-0627

Mason, L.E., Co.
98 Business St., Boston, MA 02136
(617) 361-1710, fax: (617) 361-6876

Philips Lighting Co.
200 Franklin Sq. Dr., Somerset, NJ 08875
(908) 563-3000, (800) 631-1259, fax: (908) 563-3975

Rig-A-Light
P.O. Box 12942, Houston, TX 77217
(713) 943-0340, fax: (713) 943-8354

Sterner Lighting Systems
351 Lewis Ave., Winisted, MN 55395
(320) 485-2141, fax: (320) 485- 2899

Thomas and Betts
Corporate Headquarters, Memphis, TN 38119
(800) 888-0211, fax: (800) 888-1366

Unique Solution Division of Holophane Corp.
515 McKinley Ave., Newark, OH 43055
(614) 349-4194, fax: (800) 346-5923

Infrared Drying and Curing

Equipment Suppliers

Aitken Products, Inc.
P.O. Box 151, 566 North Eagle St., Geneva, OH 44041
(216) 466-5711, fax: (216) 466-5716

Americure, Inc.
2353 W. Lincoln Street, Phoenix, AZ 85009
(602) 253-3130, fax: (602) 495-1380

Argus International
424 Route 31 North , Irngoes, NJ 08551
(609) 466-1677, fax: (609) 466-4111

BGK
4131 Pheasent Ridge Dr., N.E., Minneapolis, MN 55449
(612) 784-0466, fax: (612) 784-1362

Cleveland Process Corporation
127 S.W. Fifth Avenue, Homestead, FL 33030
(800) 241-0412, fax: (305) 248-4371

Dry-Clime Corporation
P.O. Box 146, State Rd. 46W, Greensburg, IN 47240
(812) 663-4141, fax: (812) 633-4202

Eraser Company, Inc.
Olivia Drive, P.O. Box 4961, Syracuse, NY 13221
(315) 454-3237, fax: (315) 454-3090

Fostoria Industries, Inc.
1200 N. Main Street, Box 986, Fostoria, OH 44830
(419) 435-9201, fax: (419) 435-0842

Future Cure
29313 Clemins, Westlake, OH 44145
(800) 722-4664, fax: (216) 835-1578

Glenro, Inc.
39 McBride Avenue, Paterson, NJ 07501
(800) 922-0106, fax: (201) 279-9103

Infratech Corporation
1634 Industrial Park Street, Covina, VA 91722
(818) 331-9400, fax: (818) 858-1951

Infratrol Manufacturing Corporation
646 S. 29th Street, Milwaukee, WI 53234
(414) 671-7140, fax: (414) 671-5088

IRT Systems
89 Connie Crescent, Concord, Ontario, L4K IL3
(800) 387-3639, fax: (905) 669-1171

Prime Heat
1946 John Towers, El Cajon, CA 92020
(619) 449-6623, fax: (619) 449-9844

Process Thermal Dynamics
304 G 50th Avenue, Alexandria, MN 56308
(612) 762-2077, fax: (612) 762-1319

Radiant Energy Systems
458 Hamburg Turnpike, Wayne, NJ 07470
(201) 942-7767, fax: (201) 942-5581

Solaronics
704 Woodward, Rochester, MI 48307
(810) 651-5333, fax: (810) 651-0357

Tech Systems
1030 N. Lincoln Street, Greensburg, IN 47240
(812) 663-4720, fax: (812) 663-4799

Watlow Electric Manufacturing Company
12001 Lackland Road, St. Louis, MO 63146
(314) 878-4600, fax: (314) 878-6814

Ultraviolet Curing

Equipment Suppliers

Specialty Coating Systems
5705 W. Minnesota St., Indianapolis, IN 46241
(800) 356-8260, fax: (317) 240-2073

Ultraviolet Products, Inc.
2066 West 11th Street, Upland, CA 91786
(909) 946-3197, fax: (909) 946-3597

Information on Efficiency Technologies

This list provides EPRI resources on efficiency technologies identified in this guide. Copies of these publications can be ordered through the EPRI Distribution Center, (510) 934-4212.

Adjustable Speed Drives

Medium-Voltage Adjustable Speed Drives: A Basic Specification Guide, BR-104420, May 1995.

Adjustable Speed Drives: Application Guide, TR-101140, February 1993.

Environmental Benefits of Adjustable Speed Drive Applications, TR-100200, August 1992.

Adjustable Speed Drive Directory, Third Edition, CU-7544, January 1992.

Energy-Efficient HVAC and Heat Recovery

Space-Conditioning System Selection Guide, TR-103329, December 1993.

Additional information on HVAC can be obtained from the EPRI HVAC&R Center, (800) 858-3774.

Energy-Efficient Lighting

Proceedings—Efficient Lighting 1993: A Lighting Symposium for Electric Utility Lighting and DSM Professionals, TR-105963, January 1996.

Advanced Lighting Technologies Applications Guidelines: 1990, TR-101022-R1, May 1993.

Electronic Ballasts, BR-101886, May 1993.

High-Intensity Discharge Lighting, BR-101739, May 1993.

Lighting Fundamentals Handbook, TR-101710, March 1993.

Commercial Lighting Efficiency Resource Book, CU-7427, September 1991.

Additional information on lighting can be obtained from the EPRI Lighting Information Office, (800) 525-8555.

Energy-Efficient Motors

Assessment of Electric Motor Technology: Present Status, Future Trends, and R&D Needs, TR-101264, December 1992.

Electric Motors, TR-100423, June 1992.

Trade Associations

Affiliated Dress Manufacturers
500 Seventh Avenue, New York, NY 10018
(212) 819-1011

Members are 190 dress manufacturers, primarily located in New York City.

American Apparel Contractors Association
P.O. Box 720693, Atlanta, GA 30358
(404) 843-3171, fax: (404) 256-5380

This association was established for the purpose of domestic apparel sourcing in direct competition with imports. Members are apparel contracting companies.

American Apparel Manufacturers Association
2500 Wilson Blvd., Suite 301, Arlington, VA 22206
(800) 520-AAMA, fax: (703) 522-6741

This is the primary industry association, representing 70% of all apparel manufacturers.

Childrenswear Manufacturers Association
Two Greentree Centre, Suite 225, Marlton, NJ 08053
(609) 985-2878, fax: (609) 985-3238

Members are manufacturers of children's apparel.

Garment Industry Development Corporation
275 7th Avenue, 5th Floor, New York, NY 10001
(212) 366-6160, fax: (212) 366-6162

The GIDC has established training and educational programs aimed at upgrading worker skills. It also offers on-site assistance in re-engineering and quality control.

Greater Blouse, Skirt, and Undergarment Association
225 West 34th Street, New York, NY 10122
(212) 563-5052, fax: (212) 563-5373

Members are concentrated in the New York area.

Ladies Apparel Contractors Association and Sportswear Apparel Association
450 Seventh Ave., Suite 1009, New York, NY 10123
(212) 564-6161, fax: (212) 564-6166

Members are companies that manufacture women's apparel.