ENERGY EFFICIENCY IN THE PRINTING AND PUBLISHING INDUSTRIES

Nancy G. Margolis, Energetics, Incorporated
Joan L. Pellegrino, Energetics, Incorporated

OVERVIEW

In 1994, Energetics, Incorporated examined electricity use in the printing industry for the Electric Power Research Institute (EPRI) Center for Materials Fabrication and the Association for Suppliers of Printing and Publishing Technologies. The objectives of the study were to quantify electricity use in the various segments of the industry (SIC 27), to identify emerging printing technologies and electrotechnologies and assess their potential impact on electricity use patterns, and to analyze the use and impacts of commercially available electrotechnologies. As part of the study, a survey of fifteen major printing industry segments was conducted to collect electricity use data as well as statistics on power quality problems, use of power protection equipment, use of state-of-the-art technologies and electrotechnologies, and factors considered in making equipment purchase decisions.

THE PRINTING INDUSTRY--CHANGES AND CHALLENGES

Over the last few decades the U.S. printing industry has undergone dramatic technological changes. Advances in electronics and computers have completely revolutionized printing processes, and will continue to do so in the future as computer capabilities expand and new digital technologies emerge. Practically all hand and machine composition has been replaced by photo and computer typesetting. Even more dramatic change is on the horizon--over the next twenty years printing processes are expected to move into a filmless era in which printing plates will be made digitally, without the use of conventional graphic arts film. Printers are fast becoming part of the "information superhighway", where links between computers, telephones, and customers are increasingly used to facilitate the production process. New information concepts like multimedia, CD-ROM, and computer network information systems are also forcing printers to stay versatile and consider the potential of paperless products.

Keeping up with the pace of technological change is a constant challenge for the printing industry. High capital costs, combined with the competitiveness of the market and changing customer demands, make equipment-purchasing decisions critical for printers. Complicating the investment decision is the growing cost of compliance with increasingly stringent environmental regulations. According to the Environmental Protection Agency, the printing and allied industries spent over $265 million on pollution abatement and control in 1991.[1]

The cost and availability of energy is another factor--in 1991, the industry as a whole spent over $1.6 billion for about 110 trillion Btus of purchased fuels and electricity.[2] While energy costs currently represent only 1-3% of the value of shipments from the printing industry, a reliable electricity supply is vital to the printing operation. As the industry moves increasingly toward computerization and the digital environment, electricity consumption as well as power quality will become more important. To stay competitive, printers will need to gain an understanding of how electricity can be used more efficiently, how to take advantage of emerging electric-based technologies (electrotechnologies) to improve productivity in the new digital environment, and how new technology adoption will impact products and markets in the longer term.

MAJOR PRINTING INDUSTRY SEGMENTS

The five most common printing processes are lithography (offset printing), letterpress, flexography, gravure, and screen printing. These processes account for about 97% of the value of shipments for SIC 27.[3,4] Printing processes are characterized by the method of image transfer and by the type of image carrier employed. In direct printing, the image is transferred directly from the image carrier (plate) to the substrate. Direct image processes include gravure, flexography, letterpress, and screen printing. During indirect, or offset printing, the image is first transferred from the image carrier to an intermediate blanket cylinder and then to a substrate. Lithography, which accounts for about half of the printed products in circulation today, is offset of indirect printing. In addition to the five major printing

processes, there are a number of plateless technologies in use, including electronic, electrostatic, magneto-graphic, thermographic ion-deposition, and ink-jet. While these processes currently represent a very small share of the printing market (about 3%), they are expected to gain widespread acceptance by 2010 and beyond.

The printing processes described above are used in many different ways throughout the printing and publishing industry to produce a variety of products. For example, a newspaper publisher might use lithography, letterpress, or flexography to print his product; magazines might be produced using flexography or lithography; and packaging could be produced with either gravure or flexographic processes. Printers have a variety of reasons for choosing specific printing processes. Sheetfed offset printing is cost-effective and in high demand for short-run publications like annual reports, menus, and magazine covers. Web offset presses are used mostly for long-run markets, like magazines, catalogs, and newspapers. Letterpress, which was the foundation of the printing industry for 500 years, has almost been completely replaced because of low productivity and high cost when compared with offset printing. Flexography is popular for packaging and paperbacks, and though a simpler process than lithography, does not produce the same quality, is slower, and uses more corrosive inks. Gravure is traditionally used for high-quality, very long-run markets, like consumer packaging, which is required in quantities beyond the capabilities of other printing processes.

THE SURVEY

A survey of major segments of the U.S. printing industry was conducted using a survey format developed through the cooperative efforts of the EPRI Center for Materials Fabrication, the Association for Suppliers of Printing and Publishing Technologies, Mason Consulting, Incorporated, and Energetics, Incorporated. The survey was designed to elicit responses concerning electricity use, deployment of advanced technology and electrotechnology, and power quality issues. Fifteen industry segments were included in the survey, including heatset and non-heatset web offset printers, gravure publication and packaging printers, other packaging printers/converters, sheetfed offset printers, newspaper printers, book printers, forms printers, quick printers, electronic printers, prepress trade shops, trade binderies, in-plant printers, and label printers. The sources for the names and addresses of printers included trade association directories and mailing lists, other business directories, publishing yearbooks, and mailing lists supplied by Mason Consulting.

For each segment, an n^{th}-name selection of names was done, with "n" determined for each segment according to the total number of names available and the desired number of printers to be surveyed. Phone surveys were also performed to increase the total number of responses. Overall, 171 of the 2,660 surveys mailed were returned, and 132 surveys were done by phone. However, only 181 surveys were deemed useable; others were deemed unusable because they were incomplete, the answers were way out of line with answers of similar printers, or the printer refused to give out certain information because of confidentiality or corporate policy.

In addition to performing the survey, two detailed case studies of printing operations were conducted to show specifically how the replacement of older equipment (particularly presses) with state-of-the-art equipment could affect an individual facility's energy use and productivity. The two operations studied were chosen from the survey respondents and represented the two largest segments of the printing industry, sheetfed offset printing and heatset web offset printing. Telephone interviews were conducted with the two participating respondents (the president of the first operation and the plant engineer of the second) to obtain more in-depth information on the facility's equipment, energy use and cost, consideration given to energy use/conservation, and major business and technical concerns. The information was then passed on to representatives of participating equipment manufacturers--Heidelberg USA for the sheetfed offset printer and Heidelberg-Harris for the heatset web offset printer--for estimations of how the two operations could be improved through the use of state-of-the-art equipment.

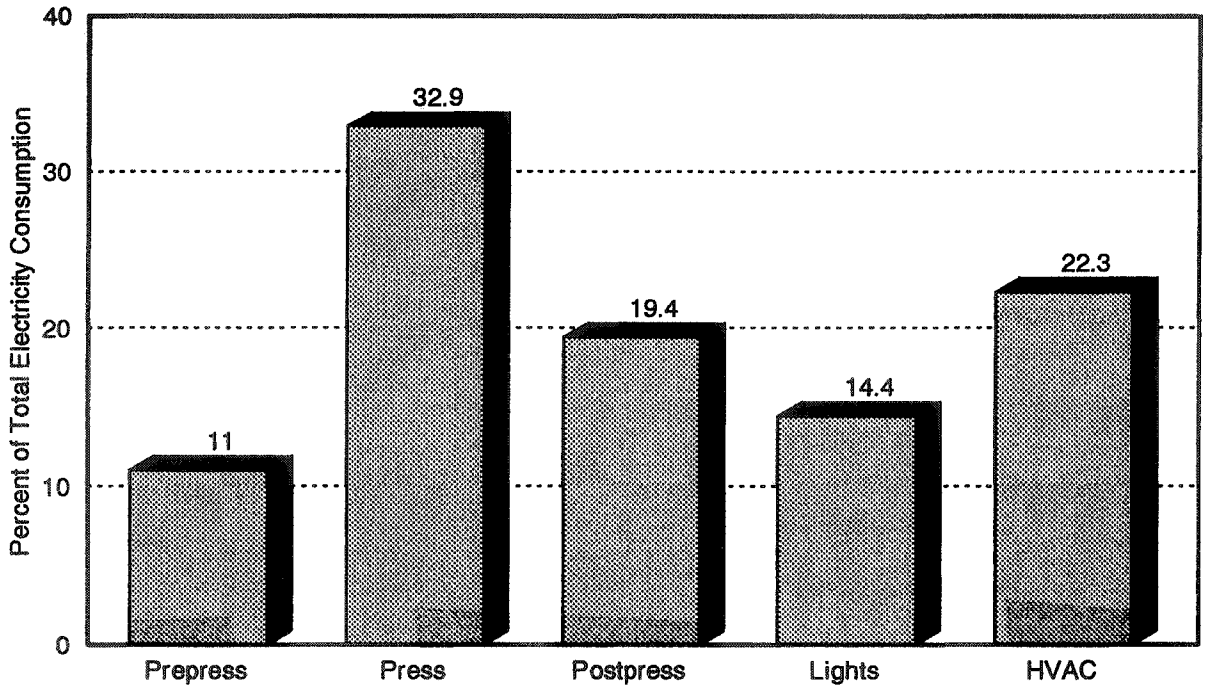
PRINTING PROCESS ENERGY USE

Most of the electricity (about 70%) used for printing and publishing is consumed during the operation of motor drives on presses, in finishing operations (binders, cutters, collators, trimmers, labeling and addressing machines), and for materials handling (conveyors, stackers, forklifts, etc.). Lighting, heating, cooling, and ventilation systems account for the rest of electricity use. Natural gas and other fuels are used primarily to operate drying and curing systems for inks and coatings.

Several of the major industry segments use dryers to set the inks on the product. These segments, which include heatset web printers, gravure publication printers, and label printers, are therefore more energy-intensive than the segments that do not require the use of dryers. While some dryers--mainly ultraviolet, infrared--use electricity, the largest dryers are gas-fired.

As part of this survey conducted during this study, printers were asked questions concerning level of electricity use. Based on the survey, it was found that for 98% of respondents, electricity costs averaged up to 3% of the total cost of annual sales; less than 2% used electricity in excess of 3% of annual sales. Survey results (based on estimates of respondents) also indicated that press operations are the most electricity-intensive, which is consistent with the application of motor drives on presses in printing equipment. Survey results for the median electricity consumption in different areas of the printing operation are shown in Figure 1. In all segments, press operations dominate electricity use.

Figure 1. Average Energy Use by Operation in Printing (Survey Results)



Estimates of energy-intensity, based on average energy consumption and annual sales data provided by the survey, indicate that the highest electricity users per dollar of sales are found in heatset web and large book publishing establishments (see Figure 2). These results are consistent with the type of equipment and operations performed within these printing segments. Heatset web printers, for example, use energy-intensive dryers and presses, as well as prepress equipment such as platemaking, where high-powered ultraviolet light is used to expose printing plates. In fact, all survey respondents from the heatset web segment indicated that their facilities maintained prepress, press, and postpress operations on-site. While newspaper and many book printers do not use dryers, nearly all respondents from these segments also indicated that their facilities included prepress, press, and postpress operations.

Based on survey results, average energy demand was found to increase with increasing sales and facility size for all industry segments (see Figure 3). Large packaging, book, and newspaper printers were found to have the greatest electricity demand. In fact, little information is available about the level and cost of electricity consumption of printing industry processes and equipment in practical applications.

Figure 2. Average Electricity Use per Dollar of Sales for All Sizes of Printing Establishments (Survey Results)

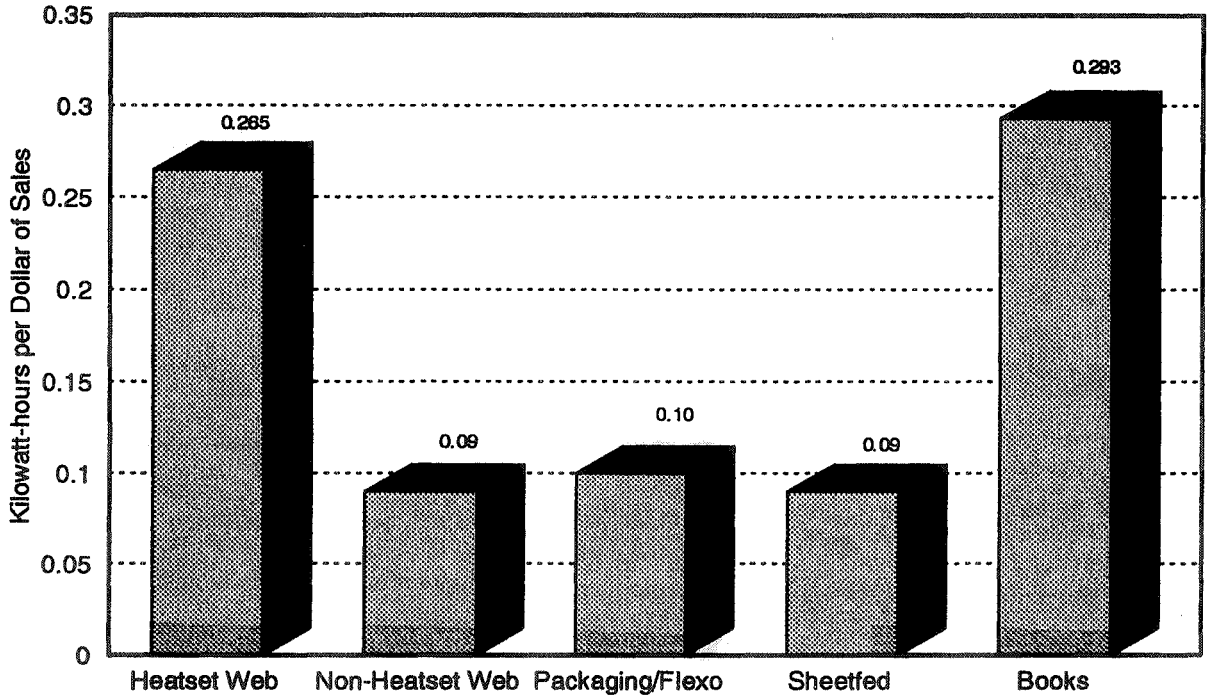
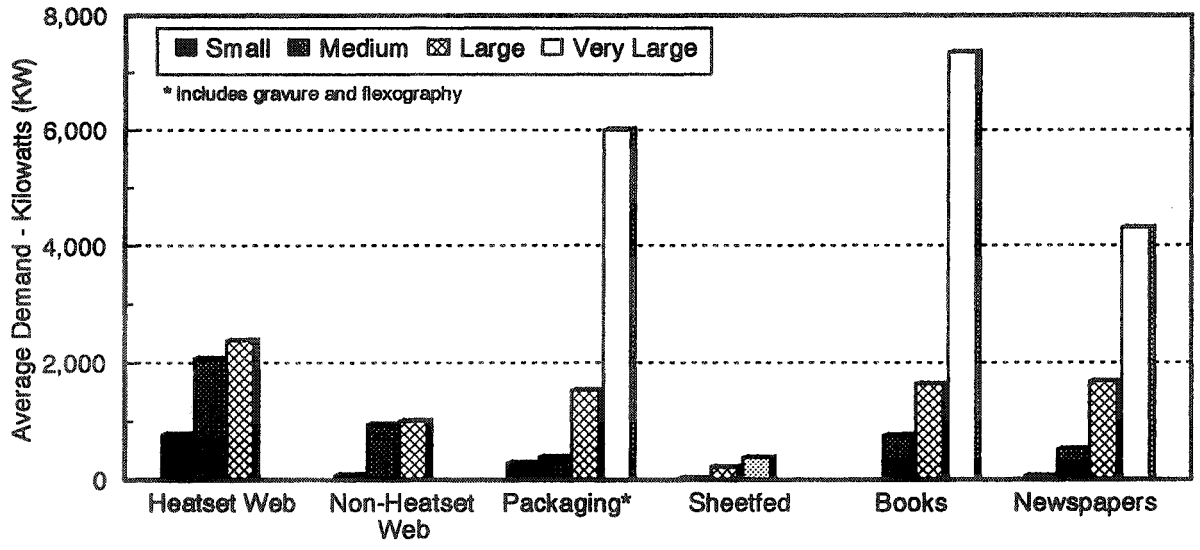


Figure 3. Average Energy Demand in Major Printing Segments (Survey Results)



How Electricity Costs Factor in Equipment Purchasing Decisions

In purchasing equipment for printing, most firms are more concerned with issues that have a large impact on profitability, such as customer demands, quality, productivity, and environmental compliance. Electricity costs have a low impact on profitability, and are thus often considered last when making equipment purchasing decisions. Based on survey results, it was found that 54% of all printers ranked electricity consumption as the least important factor considered when purchasing new equipment; another 36% ranked it as sixth or more out of nine possible factors. Specifically, out of the fifteen printing segments responding, ten ranked productivity, quality, and purchase price as the top three factors considered when purchasing new equipment. When asked what electricity cost savings would

be required to motivate printing firms to invest in equipment on the basis of saving electricity, 38% responded that electricity use was not considered at all when purchasing equipment; and about 38% stated that they would require cost savings of greater than 20%. The majority of respondents (about 72%) also indicated that life cycle and first costs (rather than just first costs) were considered equally in purchasing new equipment. While many printers who purchase more efficient, higher-productivity equipment do see improvements in their electric bills, it occurs after the fact and is not the primary motivation in purchasing equipment.

In conducting a case study on a small sheetfed offset printer in New Jersey, the president of the company indicated that his company does not consider electricity in any decision-making process. For this firm, electricity costs are part of doing business; all the competition is paying the same rate and costs are essentially passed on to the customer. In the second case study, conducted for a very large heatset web offset printer, the firm felt significant energy savings could be obtained only if two presses could be replaced with one faster press, with comparable dryer energy requirements. This firm was interested, however, with energy savings that might accrue through advanced dryer and chiller technology, and had already had the local electric utility and a private firm investigate various options for improving chiller efficiency.

STATE-OF-THE-ART PRINTING TECHNOLOGY

The widespread application of computerized electronic imaging and control techniques has caused many significant changes in conventional printing processes. The lines between once distinctly separated operations are slowly blurring; the new hierarchy in printing is to more closely integrate prepress, press, and postpress functions. New technology has brought faster presses, greater productivity, and more flexibility into the printing process. While these changes are driven mostly by customer demand, environmental regulation, and the desire to stay competitive, in some cases they provide additional benefits in the form of improved energy efficiency. With new technologies, energy-intensive manual steps and equipment are often eliminated, processes become automated and take less time, and the efficiency of the printing process increases. Over the last decade, more efficient technology has been introduced into all phases of the printing process, from prepress to postpress operations.

Today, personal computers permit printing customers to perform virtually all the tasks previously performed by printers or prepress trade shops. Typesetting can be done on a basic PC and output on a laser printer with a quality level appropriate for most printing. Scanners are available that permit the PC user to size, crop, and retouch photos to prepare them for printed pieces. Printers now are likely to receive a majority of their work on floppy disks or via modem. The implications of the personal computer phenomenon for the industry are great. Typesetting has been virtually eliminated, work formerly performed by color trade shops and printers is at least partially performed by users; designers and layout artists now work almost universally with keyboards and computer monitors rather than pencils and drafting boards.

Beyond the prepress area, the implications of the PC for printers also can be profound. For short run print jobs--typically fewer than 500 copies--a printing press may not even be used. Such work is often produced on a xerographic printer or a copier rather than a printing press. Sophisticated copiers accept floppy disks or operate on-line to personal computers on networks. Many simpler copiers either do so as well, or will in the near future. Newer, more sophisticated printing presses even accept digital information directly from the PC to produce quality color printing. Moreover, these new electronic presses--unlike conventional presses-have the ability to vary information from page to page. This feature means that conventional printing formerly done for the direct mail industry, for example, may migrate to these new presses because of their ability to tailor the message to individual recipients. This capability, coupled with the databases available today, could change many portions of the printing industry.

Prepress

Prepress operations consist of the steps required to transform the concept of a printed image into a printing plate or other image carrier. These include composition/typesetting, copy and art preparation, graphic arts photography, color preparations, image assembly and imposition, and platemaking. Many dramatic changes in efficiency and productivity have occurred through the introduction of digital processing into various parts of the prepress operation.

Traditional typesetting, copy preparation, photography and film assembly steps are complicated, time-consuming, and

expensive manual operations that require highly skilled craftspersons. Because these steps often create a bottleneck in production, many new developments in digital imaging have been directed at these areas. Major changes have come through the development of front-end platforms, which allow users to create, edit, and store text, graphic images, and entire documents before printing. Electronically performing these tasks greatly reduces the time, expense, and equipment needed to produce layouts for platemaking. Along with front-end platforms have come advances in color capabilities, screening, proofing, process photography, and linkage of peripherals.

Because of the trends in digital processing, the prepress operation is often completely electronic, from type to color photos. Totally electronic prepress will drive the development of more efficient direct-to-plate and direct-to-press technologies, where even more equipment- and labor-intensive steps are eliminated. Technologies that characterize the electronic state of the art in prepress include color electronic prepress systems (CEPS), PC workstations or desktop publishing systems, digital scanners, direct digital proofing, and electronic imaging, which is beginning to replace the use of process photography in printing.

Advances in platemaking include the ability to make plates directly from digital data using lasers, ultraviolet light, electrical impulses, or spark discharge. These technologies have made possible breakthrough technologies like direct-to-plate printing that will help revolutionize the printing industry over the next decade, as well as promote the filmless printing environment. Direct-to-plate technology permits the direct application of an image to a printing plate without the need for intermediate films. Plates can be imaged directly from computerized data using lasers or other non-light-sensitive techniques. Size limitations of machines, the shorter run lengths of plates, process color limitations of machines, and the limited availability of direct digital proofing systems all have hindered the acceptance of digital direct-to-plate systems in offset printing. These problems are being addressed by manufacturers, however, and direct image systems are expected to play a major role in offset processes by the late 1990s.[5,6,7,8]

Another promising development is waterless lithographic plates, which eliminates all of the disadvantages of ink-water balance systems yet retains the low plate costs, ease of makeready, high speed, and good print quality that characterize lithography. The p late is exposed by conventional UV light in a standard vacuum frame. Studies performed in Japan and the U.S. indicate as much as 35% higher productivity for the waterless system. Such systems are also environmentally friendly, as they eliminate the dampening process and the associated chemical solvents, most of which are hazardous.[5,6,9-14]

Press

Important developments in printing processes have occurred through automation and control of printing operations; faster, bigger, and more flexible presses; advances in waterless plates for lithography; and direct-to-press or plateless technologies. Throughout the industry, there is a major trend toward the automation and more sophisticated control of printing press operations. Microcomputer technology is increasingly being used for data collection and process control, as well as in-line monitoring and adjustment of high-speed presses. This enhances productivity through faster operations, reduced wastes, improved quality, and lower labor intensity. The use of in-process control techniques like Statistical Process Control is growing across the printing industry, and will necessitate the growing use of on-press scanning devices. These devices evaluate the printed page and record statistical information that can later be interpreted and related to production problems.[15-21]

High-productivity web presses now commercial are capable of operating at speeds of up to 3,000 feet per minute. Another more revolutionary development is the wide-web press format (50 inches or larger), generally designed for large-volume publication or catalog printers. These larger presses reduce the number of makereadies required, produce less waste, and provide greater operating flexibility.[5,6,15] Direct-to-press systems are now available for offset printing. This technology uses computer-controlled equipment to image plates directly on the press cylinder. Direct-to-press systems combine and automate most of the steps required in traditional prepress operations, including platemaking, resulting in considerable reductions in equipment use, plate preparation time, and press downtime. Images can be changed electronically, at full printing speed, even from page to page.[5,6,7,9,19-22] Another new development is press temperature controls that have the potential to correct and eliminate many of the variables causing deficiencies and inconsistencies in offset printing.[23]

Electronic printing is defined as the process of creating a hard copy original directly from a computer. Some

electronic printing processes are designed for use with presses, but most use copier or laser printer technology to output the printed product and subsequently less energy- and labor-intensive. Some are plateless, while others use reimageable plates or drums. Electronic printing and imaging technologies that are currently challenging traditional printing markets include:

- Advanced electronic printers[8]--high-speed, high-quality spot-color and full-color electronic printers are now available and are used extensively for short-run variable information printing and for on-demand book publishing. These printers have the capability to scan, manipulate, store, and print paper originals, as well as read electronic files from a disk of LAN.
- Color copiers[8]--with higher speeds, better resolution, and greater reliability are now available for making one or several copies of spot or process color subjects.
- Dry-Toner Electrophotography[6]--uses the reimageable plate or cylinder technology found in laser printers. New systems can print directly from a computer, in either monochrome or process color, in the perfecting mode (two sides in one pass), with automated in-line finishing features (e.g., collating, folding).
- Liquid-toner electrophotography[6,19-21]--is a plateless, direct-to-press electronic imaging technology that has been introduced for sheetfed presses.
- Continuous ink jet printing[6,24]--is a high-speed, direct-to-substrate technology used in direct mail and other high-volume, variable-data applications.

Postpress

While technological change in binding and other postpress operations has been relatively slow, a number of innovations have emerged, primarily because the role of the bindery is changing. Today's bindery does more than bind--it adds value to the printed product, producing finished products ready for use by consumers. Items such as books, catalogs, magazines, and newspapers are assembled, addressed or labeled, customized, packaged, sorted, and prepared for distribution. Major technological change is coming about in postpress operations primarily through increased automation and computer-controlled in-line finishing systems. Automation has considerably decreased the time and cost spent on materials handling, which is a major cost element in postpress operations. For example, in-line finishing systems directly link the press with postpress operations, and considerably reduce the time required to produce a finished product.

Equipment improvements, along with automation, have considerably increased postpress productivity. New multiple-signature saddlestitchers are now available that have an output of 40,000 bound magazines per hour, compared with the conventional 18,000 per hour for one-chain stitchers. With the advent of automated and more productive equipment, more commercial printers are considering installing postpress facilities rather than sending their finishing work to outside trade shops. With on-site binding operations, printers can effectively integrate the entire process from prepress to postpress, while ensuring a more consistent product, a higher net output, reduced waste, and lower cost.

POTENTIAL IMPACTS OF ELECTROTECHNOLOGIES ON PRINTING

Specific electrotechnologies that could impact the energy use, productivity, and product quality of printing processes include high-efficiency motors and motor drives; ultraviolet, electron beam, infrared, and radio frequency curing/drying technologies; and direct-to-plate technologies.

Motors and Motor Drives

Motor drives, which account for about 70% of electricity consumption in printing processes, are used throughout the printing industry in press operations, materials handling, and binding and finishing. A recent study indicates that in the printing industry, about 27% of motor drive is used in pumps, fans, and compressors; 34% is used for materials handling; and 39% is used in materials processing, primarily in the press area.[25] High efficiency motors and adjustable speed drives (ASDs) are electrotechnologies that can significantly reduce electricity consumption, and many opportunities exist for their application throughout the printing industry.

High efficiency motors use improved design and better quality materials to reduce electrical, magnetic, mechanical, and stray losses to achieve 84-96% technical efficiency (compared with 77-94% for standard motors). While high

efficiency motors typically cost 30% more than standard motors, the reduction in electricity consumption can offset the capital cost in a short time. High efficiency motors can be specified for new purchases of equipment packages that contain electric motors; when purchasing spares or replacing failed motors; instead of rewinding failed motors; to replace grossly oversized and underloaded motors; and as part of utility rebate or incentive programs.[26-29]

Adjustable speed drives are used to precisely control the speed of AC motors, eliminating the need for high-cost, low-efficiency mechanical or electromechanical controls. In addition to improving energy efficiency, ASDs reduce equipment wear and improve the operating performance of motor drive processes. ASDs can result in energy savings of from 15-40% in many cases, depending on the application. They can be specified any time a continuous range of motor speed control (rather than constant speed(is required, for example, in conveyors, presses, pumps, and fans.[26-29]

In 1990, about 14% of all motors in U.S. industry were driven by ASDs; in 1985, about 10% of sales of electric motors over 5HP were high or "premium" efficiency motors.[25,26] With the institution of the motors standards set forth in the Energy Policy Act of 1992, market penetration is expected to increase significantly. In conducting the survey for this study, respondents were asked several questions about high efficiency motors and motor drives. Of those surveyed, overall 63% said they would specify such equipment when purchasing new equipment or retrofitting existing equipment. Ninety-three percent of respondents indicated that they would pay the extra capital costs for a high-efficiency motor if they could recover the costs in electricity savings in four years or less. Eighty-two percent of those respondents stated they would prefer to recover costs in two years or less.

In talking with printing facility managers and engineers, those at large facilities appeared most knowledgeable about the use of more efficient motors and drives; those at smaller facilities were mostly uneducated about the benefits of more efficient motor drives. And a majority of managers in all printing segments said that they relied on equipment vendors to make decisions about which type of drives to install on equipment. For example, Sir Speedy (a quick printer franchise) offers a fully equipped and complete press package to new franchise owners that includes high efficiency motors and adjustable speed drives.

Based on survey results, it is difficult to predict the future rate of implementation of high efficiency motors and drives in the printing industry. While more than two-thirds of all printers surveyed indicated that they would specify high efficiency motors and drives in equipment purchases, many are not knowledgeable enough to do so, and have a poor understanding of the economic benefits to be gained. Increased dissemination of economic and technical information on the performance, reliability, and benefits of high efficiency motors and drives might serve to promote their use in the industry. Because many printing establishments rely on vendors to specify motors and drives when purchasing new equipment, these suppliers could be a possible source for providing this type of information. For example, a typical printing establishment with prepress, press, and postpress operations and an electricity bill of $12,000 per month could potentially reduce that bill by about $2,100 per month, or $25,200 per year through the use of ASDs and premium motors in all equipment.

To gain a perspective on adoption of these technologies, a linear regression of the historical electricity use attributed to motor drives in printing was used to project electricity usage for drives out to the year 2000. The results is shown in Figure 4. Assuming all new motor drive growth would be in the form of high efficiency technology (100% high efficiency on Figure 4), a 25% increase in efficiency would result from the combined utilization of ASDs and premium motors. This would result in an electricity savings of about 1,190 million kWh during the year 200 (based on the projection of historical energy use). If high efficiency technology is applied to only half of new motor drive growth (50% high efficiency on Figure 4), electricity savings of about 580 million kWh would be achieved.

Drying/Curing Technologies

About 50% of energy consumption in the printing industry is natural gas and other fuels used in drying and curing processes for inks and coatings. Electrotechnologies like ultraviolet, electron beam, infrared, and radio frequency curing can substantially lower the energy used for these processes, as many use less energy than conventional thermal drying processes. UV and EB drying use at least 50% less energy than their natural gas counterparts. Based on survey responses, many printing establishments use some combination of dryer types; none were using EB technology due to its high capital cost. The majority of survey respondents (43%) said they chose UV or other radiative-cured

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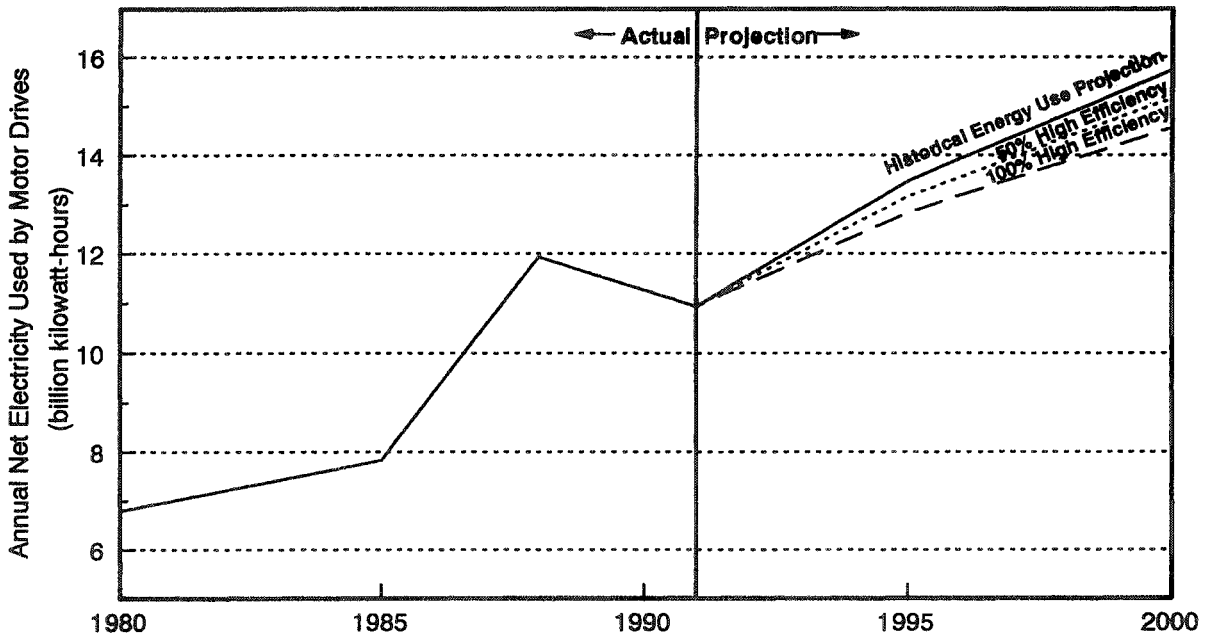
Figure 4. Potential Electricity Savings Possible Through Use of High-Efficiency Motors and Drives in Printing



inks because of customer requirements; other reasons were product quality (375) and environmental regulations(20%). When asked about future strategies for moving toward lower volatility inks and coatings (required by environmental regulations), about 70% said they would be looking for improved dryer technology, while 13% said they would install additional dryers.

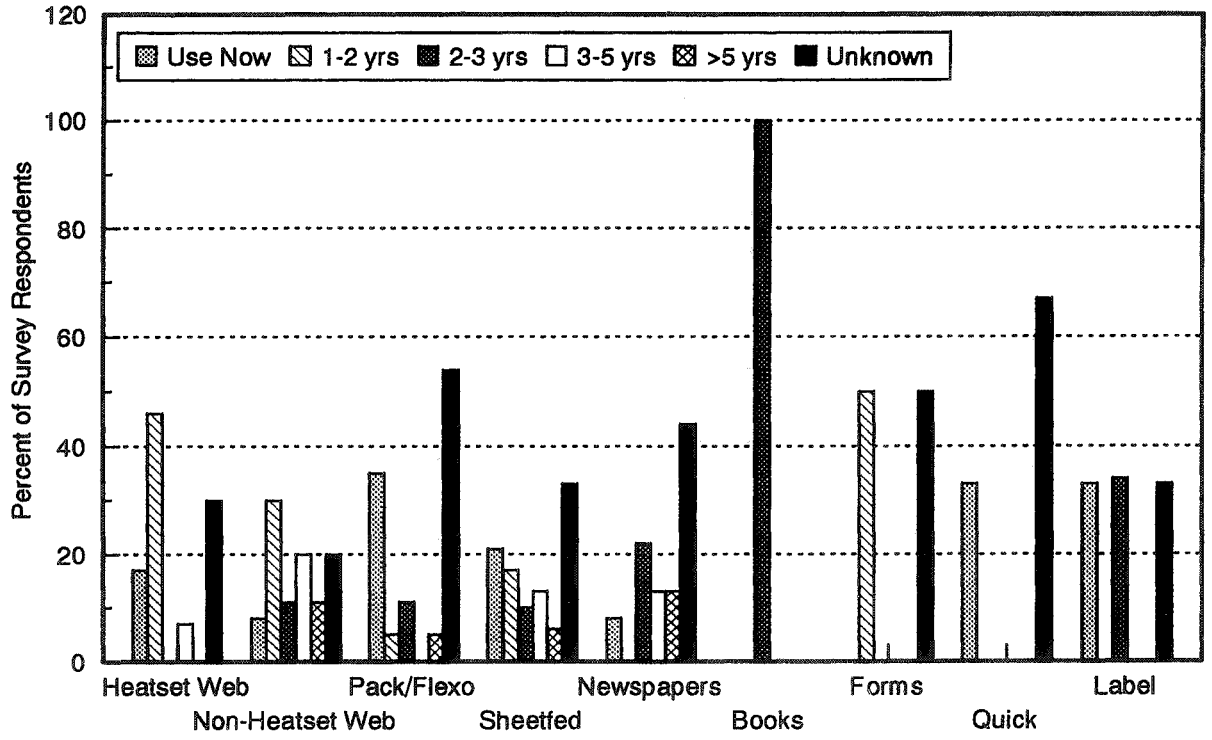
Direct-to-Plate Technology

According to survey responses, direct-to-plate technology has already been adopted in some offset printing operations, and many firms are at least considering implementation over the next five years (see Figure 5). Most printers questioned felt this technology would reduce electricity use, lower overall costs, and increase productivity. Those who have not yet aggressively pursued this technology are mostly concerned about the effect on work flow and related issues like job control, late changes, and proofing. About 50%of heatset and non-heatset web, sheetfed offset, newspaper, and label printers indicated that they were either using direct-to-plate technology or would implement it over the next five years.

POWER QUALITY AND THE PRINTING INDUSTRY

Power quality issues affect all manufacturing operations. They are of significant interest to the printing industry because of its heavy reliance on computer control and electronic data transmission. The survey revealed that most printers experience power interruptions and other quality problems at least several times a year, but the financial impact of these problems is less than $10,000 annually for the vast majority of printers. Most printers indicated that prepress and press equipment (particularly presses with computer controls) were most affected by power quality problems. The majority of respondents felt that they were doing a sufficient job of protecting their equipment as much as they possibly could (within a reasonable budget) from the effects of power quality problems. Most of the indicated widespread use of surge suppressors on all computer-controlled equipment, particularly prepress equipment. UPS systems were the next most common power protection equipment used in prepress operations, with voltage regulators and capacitors trailing in percentage use.

Figure 5. Survey Response Concerning Adoption of Direct-to-Plate Technology



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