



BAR CODE IMPLEMENTATION GUIDELINES AND TUTORIAL

PART I: IMPLEMENTATION GUIDELINES

by

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A Report to
The Construction Industry Institute
The University of Texas at Austin

Under the Guidance of the
CII Electronic Data Management Task Force

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PART I: GUIDELINES

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I. INTRODUCTION

In February 1988 the Construction Industry Institute issued a source document titled "Bar Code Applications in Construction". This source document summarized a research project that was conducted at Auburn University in 1987 under the direction of the CII Materials Management Task Force and a CII Bar Code Advisory Committee. The objective of the research was to examine the status of bar coding and other related automatic identification technologies in construction and other industries. The research also examined bar code related hardware and software components, and documented existing applications and resulting benefits of bar coding in construction.

In response to a growing interest in bar coding within CII member firms, a second research project was initiated in January 1988 to develop specific bar code implementation tools and guidelines. This second research project, the results of which are contained herein, was conducted at Auburn University under the direction of the CII Materials Management Task Force until its sunset date in August, 1988, at which time it was transferred to the newly created Electronic Data Management Task Force.

Bar code technology is at present being successfully utilized by seven CII member firms. Many others are in various stages of the implementation planning process.

Bar coding is a simple concept. The technology has been adopted on an almost routine basis in other industries. Furthermore, bar coding can easily be integrated into existing computer systems. A brief overview of the technology is presented in Chapter II.

A number of specific construction related bar code applications were presented in the previously issued CII source document report. Discussions of what the authors believe to be the applications that show the greatest potential for immediate implementation are described in Chapter III.

The implementation of bar code technology is a relatively straightforward process. Contained in Chapter IV are recommended sources of educational materials and guidelines for selecting hardware, software, and label vendors.

As part of this current research effort, four case study site visits were conducted. The systems selected and the resulting costs and benefits associated with the case studies are discussed in Chapter V.

Bar coding is essentially a means of providing rapid, error free data entry into a computer system. When the system is implemented using a portable programmable data terminal, additional benefits in the form of error free data entry at locations remote from the host computer result. In an effort to demonstrate basic bar code concepts and illustrate suggested applications, a working bar code tutorial was developed as part of this research. The tutorial, which consists of six menu driven programs and corresponding data files, is distributed on

two IBM PC compatible diskettes. The use of the tutorial and its bar coded data entry forms is described in a user's manual that is contained in Part II of this report.

The research described herein was conducted for the purpose of providing guidelines and educational materials for persons with little or no experience with bar code technology. This report will hopefully stimulate discussions between a wide range of potential system users, and subsequently lead to the implementation of cost saving data processing applications.

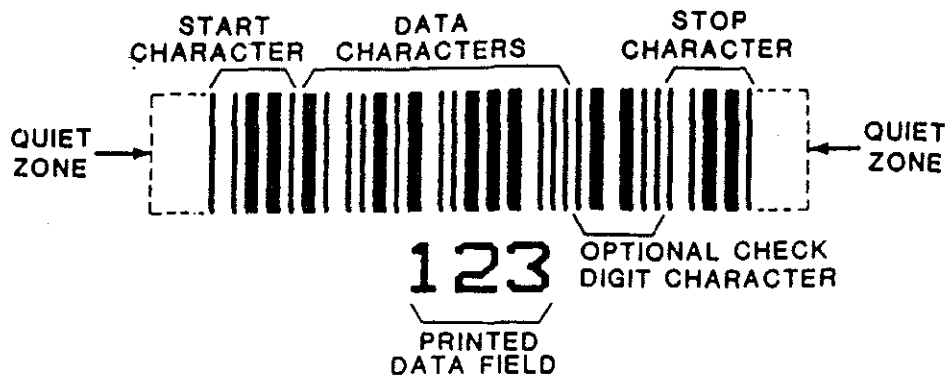
II. BAR CODE TECHNOLOGY

Benefits.

A bar code is a graphical representation of data in a machine readable format. The coded data may correspond to a database entity such as a drawing or purchase order number, or it may be a set of numbers or characters coded in any way that will speed computer keyboard data entry. Bar codes utilize combinations of wide and narrow bars and spaces to achieve the coded representation of the data. A typical bar code and the the corresponding bars and spaces that represent data characters are shown in Figure 2-1.

The construction industry has complex and comprehensive requirements for data gathering and data entry. It is estimated that thirty percent of the cost of a typical data processing operation can be attributed to data gathering and data entry [10]. In the construction industry, typical computer data processing applications include those related to controlling material status and associated paperwork, project cost and schedule, time and attendance, drawings, tools and equipment, and installed capital assets. Data gathering and keyboard entry responsibilities for these applications are frequently assigned to design engineers, cost estimators, purchasing agents, and other costly professional personnel.

The costs associated with data gathering and entry, including those associated with data entry errors, are



CHAR	PATTERN	BARS	SPACES	CHAR	PATTERN	BARS	SPACES
1		10001	0100	M		11000	0001
2		01001	0100	N		00101	0001
3		11000	0100	O		10100	0001
4		00101	0100	P		01100	0001
5		10100	0100	Q		00011	0001
6		01100	0100	R		10010	0001
7		00011	0100	S		01010	0001
8		10010	0100	T		00110	0001
9		01010	0100	U		10001	0001
0		00110	0100	V		01001	0001
A		10001	0010	W		11000	0001
B		01001	0010	X		00101	0001
C		11000	0010	Y		10100	0001
D		00101	0010	Z		01100	0001
E		10100	0010	-		00011	0001
F		01100	0010	.		10010	0001
G		00011	0010	SPACE		01010	0001
H		10010	0010	START/STOP		00110	0001
I		01010	0010	\$		00000	0111
J		00110	0010	%		00000	0111
K		10001	0001	^		00000	0111
L		01001	0001	_		00000	0111

Figure 2-1. Bar Code Symbol in Code 39 Symbolology

significant. These costs can, however, be reduced considerably through the use of bar code technology. Case studies documenting cost reductions and improvements in data accuracy in construction and other industries are contained in Reference [6], and noted for specific case studies in Chapter V of this report. Very briefly, the benefits associated with the use of bar codes can be summarized as follows:

- Bar coding provides a means of rapid data entry. A skilled data entry clerk can enter data at the rate of 2 to 5 characters per second. Bar coded data can be entered at the rate of up to 30 characters per second by unskilled personnel [10].
- Data entered from bar codes is essentially error free, as compared to manual keyboard data entry which produces on the average one keystroke error for every 300 characters entered [10].
- Bar coding, when combined with the use of portable data terminals, facilitates remote data collection, thereby eliminating intermediate manual recording and permitting the collection of accurate data that might otherwise be too cumbersome. It is estimated that portable data terminals reduce data gathering time by 30 to 60 percent [10].
- Bar coding consolidates the activities of data collection and data entry into a single operation. As data are being read from the bar coded source, it is concurrently being formatted for direct computer entry.
- Bar code hardware and related software is readily available, inexpensive, reliable, and compatible with existing data processing systems.

Hardware.

A wide range of scanning devices and related hardware components are used to capture data in a bar coded format. The simplest device for entering bar coded data is the "wedge". A wedge is a box like component that serves as a splice, or

wedge, in the computer keyboard cable. It permits data to be entered alternately from either the computer keyboard or a bar code scanner. The scanning of the bar code is accomplished by connecting either a contact light pen or a laser gun to the wedge. Data entry consists of passing the light pen across the bar code, or, focusing the laser gun briefly on the bar code without the need for physical contact.

Whereas the wedge is appropriate for entering bar coded data at the computer terminal, a portable data terminal (PDT) permits capturing data at a remote location. Again, either a light pen or a laser gun is attached directly to the PDT. The PDT is programmable and is capable of storing a significant amount of data that can be batch loaded to a host computer system at the conclusion of the field operation. Data can be entered by scanning bar codes with the attached scanner or through the use of the PDT keyboard. Also, PDT units can be purchased with RF data transmission capability that provides on-line interaction with the host computer system. A typical PDT with laser gun attached is shown in Figure 2-2.

Consider, for example, the simple task of executing an inventory of all construction materials stored at a given warehouse site. The PDT could be programmed to accept data in any desired sequence. Responding to prompts on the PDT display, the user would perhaps scan a bar coded part number, then key in the quantity on hand, and then scan a bar coded label denoting shelf or bin location, repeating the sequence until the inventory was completed. The inventory data would



Figure 2-2. Portable Data Terminal (PDT) with Laser Gun Attached

then be entered into the host computer system by connecting the PDT to the communications port of the host computer, and/or transmitted via modem to a home office mainframe system. Error checking routines are usually built into both the PDT (the part number is the correct number of digits) and the program that accepts and edits the data in the host computer system (the part number corresponds to a material catalog entry).

Labels.

Depending on the application at hand, bar code labels can be purchased in a preprinted format from third party vendors, or, printed by the user from inexpensive software packages that are compatible with existing computer files and programs. Preprinted labels, which are capable of withstanding most any project environment, can be used for tagging received materials, vendor submittals, tools, and installed capital equipment. Bar codes can also be easily added to existing purchase orders, drawings, receiving reports, and other paperwork using simple programs that utilize data and source programs stored in the user's computer system. Although dedicated bar code label printers can be purchased, acceptable quality bar codes can, for most applications, be printed using inexpensive microcomputer printers. Label vendor and label software selection are discussed in more detail in Chapter IV.

Symbology and standards.

The term "symbology" refers to the structural characteristics of the bar code symbol. In recent years, various symbologies (Two of Five, UPC Symbol, Code 39, and

others), with their respective advantages and disadvantages, have been proposed and adopted by different industries. At present, the Code 39 symbology (also known as Code 3 of 9), which permits the coding of both numeric and alphabetic data, has evolved as the standard in the automotive, defense, and manufacturing industries. Although there is no formal standard in the construction industry, all bar code applications developed by CII member firms thus far have utilized the Code 39 symbology.

To enhance quality and promote consistency throughout their industries, the automotive, health, fabric, retail grocery, and defense industries have developed comprehensive bar code standards. These standards define not only the symbology to be used, but also requirements for bar code printing (print dimensions and tolerances, print density, reflectivity), readability requirements, shipping label layout, label data content, and label size. Some industries have also set standards pertaining to data identifiers, which are symbols inserted into the bar code to tell the computer what type of information follows the symbol. For example, if the letter P is coded within the overall symbol, the number following the P is a part number.

A CII funded research project, conducted in parallel with the research described herein, was conducted at Texas A&M University for the purpose of investigating the need for bar code standards in construction. A good discussion of bar code standards in construction is presented in Reference [13].

III. CONSTRUCTION APPLICATIONS

Introduction.

Most any data processing activity that involves routine data gathering and keyboard data entry will be an excellent candidate for bar coding. Bar code applications in construction can be implemented in one of two ways. Preprinted bar code labels or tags can be applied to materials, equipment, employee badges, drawings, containers, bins and shelves, and/or to the paperwork that controls the status of labor, materials and equipment. For example, a tool issue application would involve scanning a bar coded label on the tool and the bar code on the employee's badge. As an alternative, it is possible to generate lists of bar codes on paper, a so called menu tablet, using inexpensive software packages that can be integrated into existing computer programs. A tool issue and tracking system could optionally be implemented with bar codes on the tools, and employee numbers coded on a menu tablet in the tool room.

Construction related bar code applications in the following areas are described in a previously issued CII source document report, Reference [6]:

- field material control;
- quantity takeoff;
- warehouse inventory and maintenance;
- tool and consumable material issue;
- timekeeping and cost engineering;
- purchasing and accounting;
- scheduling;
- document control;
- office operations.

As part of the narrative descriptions in Reference [6], samples of bar coded forms and labels used for the applications listed above are also illustrated.

Four specific bar code applications adopted by CII member firms since the above referenced source document was issued are discussed as case studies in Chapter V of this report. In addition, six typical bar code applications are illustrated as part of a working database tutorial that is described in Part II of this report. In the sections below, applications that hold the greatest potential for immediate implementation are briefly discussed.

Field material receiving, control and inventory.

Vendors supplying major material items can either be supplied with bar code labels, or they can be required by purchase order terms and conditions to obtain labels from third party vendors, and then apply the labels to the materials and associated paperwork before shipping. Scanning the bar codes on the received materials and paperwork facilitates the receiving process. The status of materials on hand can easily be determined by performing routine inventory counts using a portable data terminal. In addition, if the engineered equipment items are shipped with permanent bar code labels attached, the basis for an owner capital asset inventory and maintenance tracking system is established during the construction process. The efficiency of the field material control application could be improved through the use of industry wide bar code standards. This application is

discussed in more detail as a case study in Chapter V and as a tutorial module in Part II of this report.

Tool and equipment issue and tracking.

A relatively simple computer system can be used to track the status of tools and consumable materials issued from a tool room, and the status of safety equipment, welders, radios, and other apparatus that may be assigned to various site personnel. Bar codes facilitate the issue, return, and inventory activities associated with these items. Systems of this type also help reduce lost and destroyed tools, and reduce expendable tool consumption. Commercial computer programs for tool issue and tracking are available. This application is also discussed in more detail in Chapter V and Part II of this report.

Capital asset and office equipment inventory.

This is perhaps the simplest of bar code applications. Installed capital equipment, office equipment such as computers and peripherals, and other items can be periodically inventoried with a PDT, and resulting status reports generated. This application is discussed as a case study in Chapter V.

Drawing and document issue and control.

When bar codes are printed as part of a construction drawing title block, the status of the drawing is quickly and accurately determined by scanning the bar code to access related status information in a computer file. Similarly, bar codes that have been applied to vendor submittals are quickly scanned, and the status or required action information accessed

in a computer file. If a central drawing or document file is maintained at a site or home office location, drawings and documents can be issued and tracked in a manner similar to that used for tools and equipment. A drawing issue and control application is included as a tutorial module in Part II of this report.

Quantity takeoff.

Quantity takeoff is one of many data processing applications that involve a substantial, repeated keyboard data entry effort. Many contractors use computer aided systems that require the manual keyboard entry of short codes to designate common material entities. These short codes are tied to complete material descriptions and specifications in a computer file. The time required to enter takeoff related data, and the resulting accuracy of the entered data, can be significantly improved when short codes and other information are entered by scanning bar codes on a menu tablet. A bar code menu tablet and a properly structured takeoff computer program will eliminate the need for handwritten lists, and the subsequent manual keyboard entry, of material takeoff data. This application is illustrated as a case study in Chapter V and a tutorial module in Part II of this report.

Schedule updating, time and progress reporting, and field inspection.

Many data processing requirements in construction involve data gathering at locations remote from a computer terminal. The time required to gather the data, and the resulting

accuracy of the data, is improved when field data gathering operations utilize portable programmable data terminals. Bar coded forms and/or menu tablets can be used to facilitate PDT data entry. At the conclusion of the field data gathering effort, information stored in the PDT is easily batch loaded into a host computer for use in the appropriate project control computer system.

IV. IMPLEMENTATION GUIDELINES

Implementation planning.

When planning to implement one or more of the bar code applications discussed in this report, the status of existing computer systems should be carefully examined. In many cases it is a relatively straightforward effort to integrate bar coding into an existing computer system. For example, if tool issues are being tracked through a computer terminal in the tool room, applying bar codes to the tools and issuing bar coded employee badges will essentially complete the bar code implementation process. If a manual data entry quantity takeoff computer system is in place, an inexpensive software package can be purchased to create a menu tablet for the implementation of bar coded data entry.

When the computer system that will be tied to the bar coded data entry does not already exist, the effort to develop the associated system must be carefully estimated, and evaluated in light of the resulting benefits. A tool issue and tracking computer program, similar to the one illustrated as a tutorial module in Chapter VI, can be written using a microcomputer database management software package (dBASE III or dBASE IV) with minimal effort. On the other hand, the development of a computer assisted quantity takeoff program that utilizes specifications and catalog data for tens of thousands of bulk material items will require a substantial effort.

Bar code implementation planning activities include those associated with evaluating potential applications and selecting a pilot project, evaluating and selecting hardware, software and label vendors, and perhaps most important, convincing top management to fund the pilot project. These activities, and the follow-up evaluation of the pilot project, will best be accomplished through a planning committee that has a broad base of company representation. It is recommended that a single pilot project application be put in place and evaluated before expanding bar code applications in a more ambitious manner.

Education and sources of information.

Although bar code technology is not complex, members of the in house committee, and persons using the recommended system, will need a fundamental understanding of the technology. A number of background texts have been published, the best of which in the authors' opinion is the following, cited as Reference [10] in Appendix 1:

Reading Between the Lines: An Introduction to
Bar Code Technology
By Craig K. Harmon and Russ Adams
Helmers Publishing, Inc.
174 Concord St.
Dept FM98/P.O. Box 874
Peterborough, NH 03458-0874
Tel: 603/924-9631
300 pp, 1984, \$19.95

An essential source of general educational information is the monthly magazine, ID Systems. The magazine has not only useful articles and reports, but also comprehensive advertising by leading hardware, software, and label vendors. Subscriptions are normally granted on a complimentary basis to

qualified individuals by writing to:

ID Systems
174 Concord St., POB 874
Peterborough, NH 03458-0874

The Automatic Identification Manufacturers, Inc. (AIM) is an organization whose members comprise the major manufacturers of bar code hardware, software, labels, and related services. AIM sponsors an annual SCAN-TECH Show and Seminar and provides technical literature on every aspect of bar code technology. AIM publications can be obtained at reasonable cost, and a publications order form and AIM Membership Directory (86 member firms and their products and services are listed in the October 1986 Directory) can be obtained free of charge from:

AIM, Inc.
1326 Freeport Rd.
Pittsburgh, PA 15238
Tel: 412/963-8588

The Automotive Industry Action Group (AIAG) was formed in 1981 as a non-profit association by volunteer representatives from the major U.S. auto companies and suppliers. The AIAG has successfully implemented bar code standards and vendor compliance throughout the auto industry. Educational materials distributed by the AIAG include a comprehensive set of video tapes that can be purchased for approximately \$500:

Automotive Industry Action Group
North Park Plaza Building - Suite 830
17117 W. Nine Mile Road
Southfield, MI 48075
Tel: 313/569-6262

An outline of the six tape set sold by the AIAG appears in an appendix of the previously issued CII source document, Reference [6].

Hardware selection.

Although many hardware devices are available for bar code data input, it is recommended that initial applications be structured to utilize some combination of hand held light pens and laser guns attached to either a wedge or a portable data terminal (PDT). For most applications bar coded data will be first entered directly into a microcomputer (PC) data file for error checking. The data can then either be placed into a file that will be accessed by a PC application program, or transmitted by modem or other communications device to another system. The wedge or PDT selected must therefore be compatible with the PC that is receiving the data. Most any PC that has a detachable keyboard cable can be connected to a wedge device. Portable data terminals are equipped with RS-232 ports for data transfer to the serial input port on the PC, but additional communications software packages are usually required to convert the data into the editing application program format.

A wedge and light pen scanner can be purchased for about \$700 or less. A software package that prints bar codes from existing programs and data files can be purchased for about \$100. Because bar codes can be printed using most any available PC printer (a laser printer is preferred), a very basic bar coding capability can be established at a cost of about \$800. This basic system would serve to give potential users an immediate "hands on" learning capability while planning a more sophisticated pilot project application.

A hand held wand is a pencil like device that emits a visible light beam. The tip on the wand is kept in contact over the entire length of the bar coded surface while it is moved to read the message. Most wands have a jewel tip, the purpose of which is to minimize wear on both the tip and the message surface. The wand aperture, or diameter of the light tip opening, (say 6 mils or 0.006 in) controls the amount of light emitted. If the aperture is too large and the bar code width too narrow, the reader will not recognize the bars and spaces. If, on the other hand, the aperture is too small, a print flaw may be recognized as a bar or space during the scanning process. Some light pens are therefore marketed with different aperture openings. General purpose "medium and low density" wands are used for most applications whereas "high density" wands are used for scanning small compactly printed bar codes, which are usually printed with either laser printers or special bar code printers.

As an alternative, a laser gun can be attached to the wedge. A wedge, laser gun, and laser gun battery charger will cost approximately \$2000. Since the laser beam emitted from the gun actually scans the bar code (at a rate of about 36 scans/sec), a physical scanning of the bar code is not required. The code can, therefore, be read in about one second, or the time required to aim the gun (physical contact is not required) and activate the gun trigger. An additional advantage of the the laser gun is its ability to read bar codes that are out of reach (labels on bin shelves) and bar codes applied to

irregular or curved surfaces.

As noted in the previous chapter, a portable data terminal (PDT) is a small hand held battery powered computer that can be used for entering data from either a keyboard or, with wand or laser gun attached, by scanning a bar coded symbol. Collected data are stored in RAM memory for subsequent batch loading to a host computer system, printer, or communications device.

Whereas the selection of wedge, wand, and laser gun hardware components is relatively straightforward, the evaluation of PDT characteristics requires a more serious effort. The reader is encouraged to solicit input from potential hardware vendors, with particular attention given to the following:

Physical characteristics. Ideally, the unit should be lightweight and capable of resisting shock, temperature extremes, dust, moisture, and other environmental factors. The unit should have sufficient rechargeable battery capacity to operate continuously for at least 8 hours, or longer, depending on anticipated applications.

Display. The LCD display (typically from 4 to 16 lines) should be clearly visible in both indoor and outdoor applications.

Memory. Most units are sold with expandable RAM (random access memory) options which typically range from 64K to one megabyte. ROM (read only memory) and EPROM (erasable programmable read only memory) capabilities are also available for storing application programs that can be exchanged between users.

Programming and communications. The ease with which the PDT can be programmed is a characteristic that warrants close attention. Most units have their own internal proprietary programming language that, while not particularly difficult, may frustrate persons not accustomed to computer programming. Some units are capable of accepting programs written on a host PC, in languages very similar to BASIC, dBASE III Plus, and C. The data files created from these units are also easier to transfer to and from the host computer system in a format that can be used by host system software. The ease with which the data files can be transferred to the

host, and the additional software required to accomplish data transfers, should also be closely examined.

Other features. Other features available on many PDT units include an internal calendar and clock, automatic battery shut off (after say 10 minutes of inactivity), symbology autodiscrimination (ability to internally detect the bar code symbology), low battery power indicator, and memory protection.

The cost of the PDT will vary with its capabilities, but in general purchase prices range from \$1500 to \$3000 each.

Again, users of bar code hardware components are encouraged to establish contacts with local vendor sales offices. A good list of vendors that provide both hardware components and consulting services is contained in the the AIM Membership Directory, Reference [2]. Advertisements in most any issue of the magazine ID Systems should also be consulted.

The authors' experience indicates, and this has been substantiated through discussions with others, that the quality of technical support varies widely between hardware vendors, and also between local sales offices of a given vendor. An evaluation of hardware capabilities and vendor support is, of course, beyond the scope of this research. It can be stated, however, that CII member firms have developed generally successful bar code applications utilizing the products of the following major vendors:

Telxon Corporation
3330 W. Market St.
Akron, Ohio 44313-3352
Tel: 216/867-3700

Intermec Corporation
4405 Russell Road
P.O. Box 360602
Lynwood, Washington 98406-9702
Tel: 206/348-2600.

CMT Inc.
895 N.W. Grant Ave.
Corvallis, Oregon 97330
Tel: 503/752-5456

Label and tag selection.

Preprinted bar code labels and tags can be purchased from third party vendors and applied to tools, storage bins, received materials, and installed equipment. As a result of experience gained in other industries, label vendors are now capable of supplying products that can meet the requirements of most any construction application.

Label selection depends on the application surface material and a variety of environmental factors that include potential exposure to temperature variations, chemicals, moisture, paint, vibration, abrasion and sunlight. Depending on the selected application, labels can be supplied that consist of a wide range of base materials, laminates, and adhesives. Base materials and laminates include paper, plastic coated cloth, polyester, vinyl, aluminum, stainless steel, and fiberglass. Adhesives can be either pressure sensitive or solvent activated. For installed equipment maintenance and inventory applications, metal or fiberglass encased tags can be attached to the equipment with mechanical fasteners.

The cost of labels and tags depends on the type of base material, laminate, and adhesive, label size, extent of custom descriptive printing, print density, and quantity ordered. In general, good quality preprinted self adhering labels that can be applied to tools, storage bins, and installed equipment will

cost from about \$0.40 to \$1.00 each. Very durable bar coded tags encased in fiberglass will cost about \$2.50 each.

The following general guidelines apply to label and label vendor selection:

- Major label vendors are capable of matching individual requirements to their product line. Many vendors maintain in house testing capabilities to insure conformance to standards developed in other industries.

- Bar code labels need not contain an exhaustive amount of descriptive information. A bin shelf, tool, material component, or unit of equipment need only be marked with some unique identification number, or perhaps an identification number preceded with a data identifier (T101 to denote tool 101) for access to a data file that contains the descriptive information. Many items can therefore be labeled using a roll of preprinted sequential bar coded numbers.

- Self adhering vinyl or polyester labels are adequate for most applications. Labels installed on motors or other units that will experience temperature variations may warrant special considerations.

- Labels should be placed on tools, materials, and equipment in locations that will minimize the potential for inadvertent destruction.

- Label replacement problems can be avoided by maintaining flexibility in the host computer database system. For example, when the label on tool 101 is replaced, the database should be restructured such that the tool is renumbered as tool 807, or whatever sequence number is available from the unused portion of a roll of bar coded labels.

- When printing labels in house, label verification hardware (discussed in References [1], [6], [10]) should be used to make certain the printed labels meet symbology printing specifications.

As stated above, no attempt has been made as part of this research to judge the merits of product vendors. However, the following bar code label vendors have supplied products and services to a number of CII member organizations:

Electromark Co.
Box 25
Wolcott, New York 14590

Tel: 315/594-8085

W.H. Brady Co.
Signmark Division
727 W. Glendale Avenue
P.O. Box 571
Milwaukee, Wisconsin 53201
Tel: 414/961-2233

Additional bar code label vendors are listed in Appendix 2 of this report.

Label printing hardware and software selection.

Many of the bar code applications cited in the previous chapter use bar codes that are printed on drawings, vendor submittals, purchase orders, receiving reports, time cards, inspection forms, and user designed menu tablets. Inexpensive software packages are available that print bar codes from existing computer data files and programs. For example, the menu tablets that are used as part of the tutorial in Part II of this report were printed using the software package dBARCODE, which, when used with dBASE III Plus, will print a bar code symbol corresponding to any data entity stored in a dBASE III Plus file. Users having access to a Hewlett Packard LaserJet printer can purchase a font cartridge (cost approximately \$250) that will produce Code 39 bar codes in both 4.6 and 8.1 pitch. A list of vendors that market bar code printing software is included as part of Appendix 2 of this report.

Most bar code hardware vendors also market complete hardware systems for printing bar code symbols. These systems are essential for applications that involve printing large volumes of custom designed bar code labels and forms, and applications

that require small and compact printed symbols. The systems are relatively expensive, but they do, of course, generate bar codes with exceptional print quality. The alternative to purchasing a dedicated bar code printing system is to use existing microcomputer (PC) printers. Early versions of PC dot matrix printers probably did not have sufficient print quality to produce reliable bar code symbols. Present day PC laser printers do, however, produce bar code symbols of excellent quality. Although a laser printer is preferred, near letter quality dot matrix printers can be used for printing low density symbols on an interim basis. The bar code menu tablets that are used as part of the tutorial, Part II of this report, were printed using a 24 pin Epson near letter quality printer.

V. CASE STUDIES

Field material control.

In early 1987 a CII owner firm conducted an internal feasibility to investigate potential bar code applications related to materials management. The feasibility study concluded that the owner's field construction operations could be significantly improved through the use of a bar coded assisted PC based system for receiving, warehousing and inventory of owner purchased materials. Comprehensive educational efforts were undertaken, including a company wide conference for 85 employees that included presentations from hardware vendors.

A bar code steering committee was later established, a pilot project was selected, and pilot project funding was approved. The selected pilot project was a 12 month, \$40 million facility expansion that included \$22 million in owner purchased major equipment items (valves, pumps, tanks, etc.). Approximately 3000 major materials items would be purchased from some 150 different vendors. It was decided that approximately 2000 installed materials items would eventually be tagged with permanent bar code labels to facilitate the implementation of a capital equipment inventory system. The fact that the pilot project would create the basis for establishing a capital asset inventory system influenced management's decision to fund the pilot project.

A consultant was retained to develop a PC database field materials management system with field receiving, location status, and inventory capabilities. The PC system was tied to a home office mainframe computer purchasing system for the purpose of downloading purchase order information to the PC and uploading materials status information to the home office. A standard PC modem (Hayes) and PC software communications software package (Crosstalk) were used for data communications. Portable data terminals (PDT) were used by field personnel to record material receipts, changes in materials locations or status, and perform periodic materials inventories. PDT data were then batch loaded into the site PC system for editing and processing. The PC system software (written in PRO-IV) and PDT program modules were developed by the consultant in a six month time period at a cost of approximately \$30,000.

The field material control system utilized simple temporary bar code labels (vinyl file labels attached to aluminum tags) that were printed by the owner on site using a PC laser (HP Laser Jet) printer. Labels were forwarded to the vendor for attachment to the items prior to shipping. Because some purchasing efforts were undertaken before the pilot project was initiated, field receiving personnel were required to attach the labels to some items at the time of material receipt. The temporary bar coded tag utilized a numbering system (PO number combined with an item number) that resulted in a unique number being assigned to each major material item. This number served as a key to retrieve information stored in the PC data file