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BAR CODE INSTRUMENTATION FOR NUCLEAR SAFEGUARDS

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I. Introduction

Bar codes are a family of methods for encoding letters, numbers, and special symbols in the form of alternating reflecting and non-reflecting (or light and dark) bars. They provide a relatively cheap and easy-to-implement way to encode information on machine-readable labels for direct transfer to a computer for processing. Implemented carefully, a bar-code labelling system can speed up data collection and reduce error rates significantly. Success in use of a bar code system, particularly in the relatively hostile environments often encountered in processing and handling nuclear materials, depends strongly both on the choice of the specific bar code hardware and labels used and on how bar-code based data are integrated into an overall information processing system. This paper presents a brief overview of the basic principles of bar codes and the equipment used to make and to read bar code labels, and a summary of some of the more important factors that need to be considered in integrating bar codes into an information system.

II. Bar Code Basics

Although all bar codes share the same basic characteristics, there are a number of different systems in use. These different bar code systems vary in ways such as the number of characters per inch of bar code, the use of uniform bar widths or varying widths, the characters that can be encoded, and the ability to incorporate self-checking features into the code.

The most commonly seen bar code is the Universal Product Code (UPC), used on virtually all items in grocery stores, but the UPC is unsuitable for safeguards use because of its relatively low number of characters per inch of code and because it can only encode numbers and a few special symbols. For safeguards use, the best code is probably the 3 of 9 code, which is also the standard used in the Department of Defense LOGMARS logistics system. This code can encode all letters and numbers and a number of punctuation marks, can be printed in very high densities (up to 11.4 characters per inch), and incorporates a limited amount of self-checking. Equipment for printing 3 of 9 code labels and for reading the labels is widely available.

Bar code labels may be produced in a number of ways. If the information to be put on the labels is known well in advance, and the number of labels to be used is fairly large, it is usually easiest to have the labels pre-printed. A number of firms around the U.S. provide this service, and the labels can be printed on a wide variety of materials, included laminated plastic and stainless steel.

If the number of labels to be used is relatively small, or if the information that will be put on the labels is not known in advance, labels can be printed at the facility. There are three main types of bar code printers: specialized bar code impact printers; dot-matrix impact printers; and dot-matrix thermal printers. All three types of printers are usually connected to and controlled by a computer, but there are a few stand-alone printers available (which normally are controlled via a dumb CRT terminal).

In cases where very high-quality or very dense (high number of characters per inch) labels are required, a specialized bar-code impact printer is the best choice. Such printers are fairly expensive (typically $5-10,000), but they can produce very high quality labels on a number of types and sizes of label stock, including plastic. Most bar-code impact printers can print one or more lines of text on the labels as well as the bar code. The main disadvantages of this type of printer are their expense and the fact that compared with other types of printers, they are relatively slow (typically about one label per second).

If the labels to be used need not have very high density, or where a lot of non-bar-code data must appear on the labels, a dot-matrix impact printer is a good choice. Such printers are basically the same as those commonly used with microcomputer systems. The difference lies mainly in the software used to drive the printer (although some of these printers use a denser than usual or overlapping dot matrix to get higher quality). Most common dot-matrix printers that have the capability to print dot-addressable graphics can be programmed to print bar code labels, and there are commercial software packages available for this purpose. Dot-matrix printers can usually handle a variety of label stocks, but not as wide a variety as a specialized bar code impact printer. Dot-matrix impact printers are typically somewhat faster and less expensive than specialized impact printers, however.

The least expensive bar code printers are thermal dot-matrix printers. While such printers are typically fairly fast, they have the disadvantages that they can only print on special heat-sensitive stock (which can fade or discolor from time or exposure to a hot environment) and that the print quality is not as high as that obtainable using an impact printer. A dot-matrix thermal printer would be a good choice where funds are limited or speed is a high priority, and the lower quality and relative fragility of thermally-printed labels can be tolerated.

In some cases, bar codes can be put directly onto the items to be labelled. It is possible to use a special laser system to etch a bar code directly into the surface of a metal object. This has the advantage that the bar code marking can't be removed and is very robust. Use of this technique might be appropriate in cases where the identification of an item (such as a UF_6 cylinder or a sealed source) never changes, or where the environment is very harsh. Laser-etched metal tags can also be made, for use in cases where the item itself can't be labelled.

No matter how a bar code is produced, it is read in basically the same way: the code is scanned by a light source, and a detector is used to sense the amount of light reflected from the light or dark portions of the code. The electrical signal from the detector is then processed into a clean digital signal and fed a to decoder (usually a dedicated microprocessor) and converted into a character string that can be fed to a computer.

There are two main types of bar code readers: contact readers, in which a wand or pen is passed in physical contact over the bar code; and non-contact readers, in which the bar code is illuminated from a distance (usually using a low-powered laser) and the reflected light is sensed. With a contact-type reader, either the wand or the bar code must be physically moved to scan the code, but non-contact readers typically incorporate a rotating mirror or some other mechanism to move the light source and detector field of view over the bar code.

In a contact reader, the wand or pen contains a low-power light source (typically an LED or semiconductor laser), a solid-state light detector (such as a photodiode or phototransistor), and a short focus optical system to concentrate and collimate the beam from the light source and the reflected signal. The wand or pen is connected using a multiconductor cable to an electronics package that does the signal processing and decoding and has the interface electronics necessary to communicate with a computer (usually via an RS232 serial interface).

Contact readers may use either visible light or infrared. Visible light gives the best performance when labels are printed using non-carbon-based inks such as those usually used in dot-matrix impact printers (or thermal printers). Infrared performs better with carbon-based inks such as those used by specialized bar-code impact printers.

Non-contact bar code readers typically use a low-power (less than 1 milliwatt) red laser as a light source. The actual scanning head (which can be either hand-held or permanently mounted) contains the laser, a detector, and the optical system for scanning the light source and the detector field of view across the label being read. Like contact readers, non-contact scanning heads are connected by wire to an electronics package that does the necessary signal processing and decoding. Typical commercial non-contact readers can be used at distances from 1 inch to two feet, depending upon the particular scanning optics used and the size and type of bar code being read. In many cases, the electronics package used with non-contact readers is the same as that for contact-type readers, and several manufacturers offer either type of reader as an option.

III. Integrating Bar Code into an Information System

Bar codes are not a cure-all for problems with information systems; they merely provide an easy way to collect data for such systems without keying or manual transcription of the data. In order for a bar-code-based information system to perform properly, it is necessary not only to choose the appropriate bar code hardware, but also to integrate bar code data collection into the overall system, including not only hardware, but also software and administrative procedures.

Most bar code readers are designed to be connected in series with the data communications line to a computer terminal, such that the data coming from the reader look to the host computer as if they had been typed on the keyboard of the terminal. A few readers are designed to be used as terminals by themselves, and incorporate some sort of display and keyboard. In either case, however, the software used on the host computer needs to be able to process the bar code data correctly. This requires an understanding of the exact format of the data, including such details as the way ends of records are indicated, the number of characters or records sent by the reader at one time, the number of data and stop bits used, the data rate and parity of the bar code data, any special codes that need to be sent to the reader to start or stop transmission, and any codes sent by the reader to indicate its status. Provision must be made in the software used to take care of all of these factors.

Bar code data may also need to be processed somewhat differently than manually entered data. Typically, bar code data have few errors due to the format of the data (since the rate of incorrectly read data is usually very

low), but errors due to duplicate data (for example, in cases where a particular label is read twice) or erroneous data (in cases where a label has been printed incorrectly) should be checked for. Thus the data editing and checking software used to process bar code data should be tailored specifically to the needs of bar code data.

In cases where bar code labels are printed locally, special software will probably be necessary to drive the bar code printer. Not only will the software requirements for the specific bar code printer used have to be well understood, but also the software should include provisions for checking the validity of the information to be printed on the labels and for elimination of duplicate labels (unless duplicates are necessary).

An information system is composed not only of computer hardware and software, but also of administrative procedures that determine how people interact with the system. A system that uses bar codes is no exception to this, so care should be taken to implement appropriate measures into the system. Among the topics that need to be considered in planning a bar code system are:

- How are the items to be labelled chosen?
- How are labels printed and distributed?
- How is it determined that the proper label is placed on each item?
- Who trains people to print bar code labels and to use bar code readers?
- If portable bar code readers are used, how are they distributed and what provisions are made to ensure that the data are transferred to the computer correctly once and only once?
- What provisions are made for collecting data in cases where the bar code label has been damaged or is missing?
- What provisions are made to ensure that bar code labels are read on all items and that no item's label is read more than once?

A bar-code-based information system must include well-thought-out and implemented administrative procedures as well as the appropriate hardware and software, since the administrative procedures are essentially what governs how people will use the system. A system is only as good as its worst part; care should be taken that all aspects of the system get the careful consideration they need for the system to perform as intended.

IV. Bar Code Equipment Considerations

Once a system has been designed, appropriate bar code hardware must be chosen. With the advent of the Department of Defense LOGMARS system, which requires bar code labels on all items, the amount and variety of commercially-available bar code equipment has increased enormously. Rather than discuss specific hardware, suggestions will be made concerning the factors that should be considered when choosing bar code equipment for safeguards use.

The first thing that must be decided is the format and content of the bar code labels themselves. This will to a large degree determine what type of bar

code printer must be used, and will affect the choice of bar code readers. Among the factors that should be considered are:

- How much information will be on each label?
- How much of the information will be in bar code, and how much in text?
- How big must the label be?
- How will the labels be attached or affixed?
- What kind of environment will the labels be exposed to, and for how long?
- How many times will the label be read?
- How many labels will be needed, and how often?
- Will the information on the labels be known in advance, or must labels be printed on demand?

These factors will determine the appropriate size and type of label stock and the adhesive (or other fastening) to be used to attach labels, which will in turn determine the type of printer to be used or the characteristics of the labels to be ordered from a commercial printing firm.

Similar considerations govern the choice of bar code reading equipment. This choice depends among other things on:

- whether fixed or portable readers are to be used;
- if portables are used, how much information must be stored in the reader;
- if fixed readers are used, how they will interface with the host computer and whether local data storage will be used or all data must be sent to the host as they are collected;
- whether or not bar code readers are to be incorporated into other pieces of equipment such as digital scales;
- what kind of environment will the readers be used in (in other words, must the electronics package be moisture-proof or the wand and its cable armored);
- whether contact or non-contact readers should be used (contact readers are less expensive, but non-contact readers may be advisable for reading labels on possibly contaminated items); and,
- whether visible light or infrared should be used (depending upon the type of label stock and the ink used to print the labels).

In some cases, there may also be considerations unique to the nuclear industry. For example, if electronics are to be used in a radiation area, must they be shielded or radiation-hardened? Is data security a consideration (if so, portable readers may not be permissible)? Should the bar code scanner be located somewhere other than where the electronics package is (for example,

if the items to be read are in a glovebox, should the electronics package be inside or outside of the glovebox)? Should each reader have independent local data storage (so it can be used even if the host computer is unavailable), or should all data be transmitted immediately to the host? Ideally, before any equipment is purchased, the entire system should be planned in considerable detail, so that all of these considerations can be taken into account.

V. Conclusion

In sum, it should be emphasized that a bar-code based information system is really no different from any other information system: it will only work well if <u>all</u> of the elements of the system (hardware, software, and administrative procedures) are carefully planned and considered in the context of the system as a whole.