

Introduction to Bar Codes for the Automated Laboratory

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Keywords:

bar codes,
symbolologies,
data accuracy,
2D symbols,
bar code scanners,
printing methods

INTRODUCTION

Many labs will invest an extensive amount of time and capital on automated instruments to improve efficiency and increase productivity. What is often overlooked is the bar code that supports the automation process. An understanding of what a bar code is, how it functions, and how it brings advantages to laboratory applications will provide the foundation needed to leverage bar code technology effectively for achieving the objectives of the automation application while obtaining the highest data integrity possible.

SYMBOL OVERVIEW

The traditional bar code can best be described as a series of parallel bars and spaces, commonly referred to as elements. The bars, the dark elements of the bar code, absorb light. The white spaces reflect light. Predetermined width or height patterns defined by the symbology are used to encode the data in the symbol. A light source, typically the laser diode of a bar code scanner, is used to extract the data from the bar code. As the light moves across the bars and spaces of the bar code, the light is reflected back to a photo diode, which measures the light levels reflected by the bars and spaces. The data are then decoded by the scanner and output.

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JALA 2003;8:51–8

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1535-5535/2003/\$30.00 + 0

doi:10.1016/S1535-5535(03)00013-3

Because only the widths or the heights of the bars and spaces are important in decoding the symbol, single-row bar codes are considered one-dimensional codes.

Two-dimensional codes can be grouped into two different categories: stacked linear codes and matrix codes. Stacked codes are rows of width-modulated bar codes stacked directly on top of each other. Each row is the same length and resembles a single-line bar code. Matrix codes are a two-dimensional pattern of data cells in the shape of a square, circle, or polygon. Unlike linear and stacked bar codes, matrix codes must be read with an image-based reader. They cannot be decoded by a laser scanner.¹

Bar codes can either be width-modulated or height-modulated. Height-modulated bar codes are almost exclusively used in the document and mail-processing industry. Width-modulated, or traditional linear bar codes, are the most common type of bar code and are the focus of this tutorial (Figure 1).

PHYSICAL DIMENSIONS

The physical properties of an element in a linear bar code are commonly described in terms of height and width. The unit for the width dimension is expressed in mil (0.001 inch) or mm (millimeter). Typically, the widths of both bars and spaces are significant. The width of the narrowest element is often the only one quantified, as the width of the other elements can be expressed based on the narrow element width. The element width is nominally the same for the narrow bar and the narrow space. The width is also referred to as the narrow bar width, element width, mil size, or the X-dimension. The X-dimension of a bar code is the theoretical width of the narrowest element.

Width modulated**Height modulated**

Figure 1. Bar code symbologies can be divided into two distinctly different groups: width-modulated and height-modulated bar codes.

The length of the symbol is the measurement perpendicular to the length of the bars, regardless of orientation.

The height unit is often expressed in inches or millimeters. The height is measured along the length of the individual elements. If different heights are used within one symbol (height-modulated bar code), the smallest dimension is used. The element height is conceptually the same for bars and spaces. Unlike the width, this property is almost exclusively referred to as the bar height of the bar code. The taller the bar code, the more area the bar code reader has to scan the symbol. If part of the bar code is damaged, the scanner has a greater chance of still reading the symbol. Microscan recommends that the scanner receive a minimum of five looks at each symbol to achieve the optimal read performance possible from the bar code scanner.

TERMS AND ATTRIBUTES

To create a good bar code, one must first understand the attributes of a bar code and how they can affect the readability in an application.

Quiet Zone/Margin: The quiet zone is the space preceding the first bar and trailing the last bar. This is also sometimes referred to as the “no print” zone. Generally, the quiet zone must be a minimum of 10 times the width of the narrow bar. If text or a graphic encroaches into this space, the bar code scanner may not be able to read the bar code.

Quiet zone intrusions are the most frequent violations in bar code applications. Even in space-constrained applications such as labels on a microplate, the bar code scanner will not reliably read the bar code if the human readable or other graphical elements encroach into this area. Do not violate the quiet zone (Figure 2).

Start/Stop Characters: Most common symbologies employ Start/Stop characters or patterns. The primary purpose of these characters is to indicate the direction of scan to the bar code reader. Unlike human-readable text that must be read in a specific direction to be understood, a bar code can be scanned left to right or right to left. The Start/Stop characters tell the bar code reader whether the data are to be decoded forward or backwards. This ensures that the bar code reader will output the data in the proper order. A few symbologies do not utilize Start/Stop characters and are very insecure as a result. The legacy symbology Pharma Code, for example, produces different decodes depending on the direction the bar code is presented to the scanner.

Data Characters: The data characters of a linear bar code contain the encoded information (Figure 2). For example, suppose that the user would like to encode a unique identifier into a bar code. The user defined this identifier as, e.g., ab123456. The data characters are the information sent to the bar code printer and the information decoded by the bar code scanner.

Check Character/Digit: Many symbologies employ check digits (Figure 2). They are optional in some and automatically

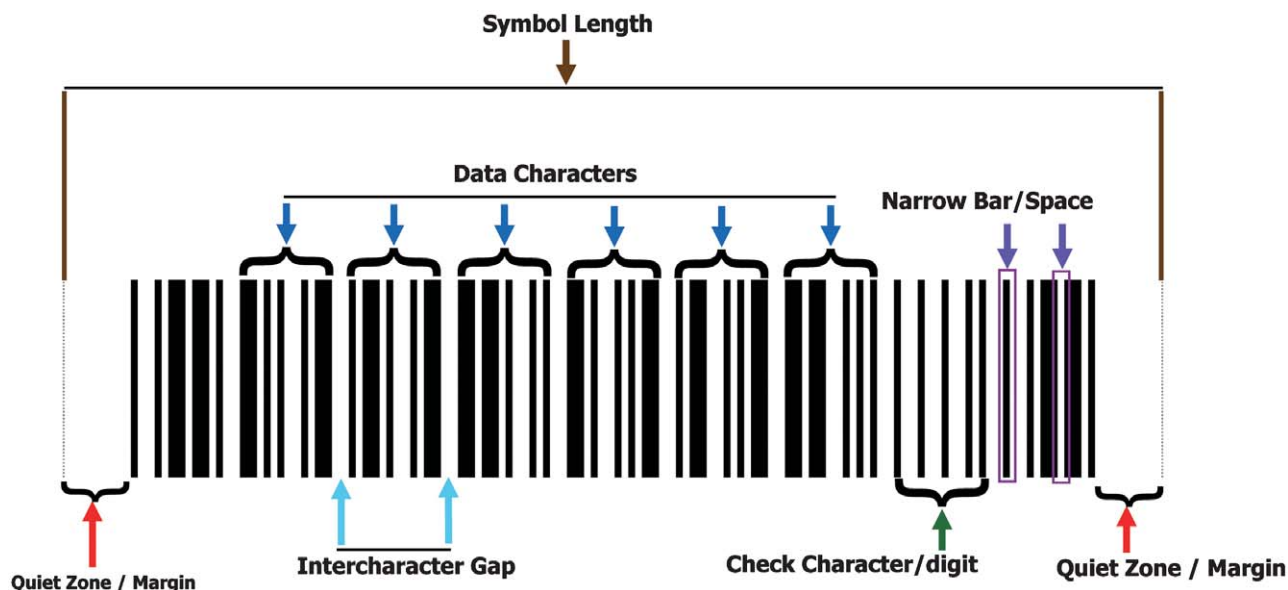


Figure 2. The general anatomy of a linear bar code.

built into others. Their function is to provide a higher level of data integrity and should *always* be enabled whenever possible, especially in applications where absolute data integrity is critical. The check character in a bar code works as follows:

1. The bar code printer calculates a check character value based on the data to be encoded.
2. This check character is included in the symbol.
3. The bar code scanner decodes the symbol and extracts the check character.
4. The bar code scanner performs the same calculation performed by the bar code printer and compares the result to the decoded value for the check character.
5. If the calculated value and the actual value for the check character are identical, the data is outputted. If not, the bar code scanner will continue to decode in pursuit of a match.

To further increase the data security of the bar code, the modulo value or check character, is used to calculate the check sums of the bar code.

Narrow Bar Width: The narrow bar width is the nominal dimension of the smallest bars and spaces in a bar code symbol and is used for determining the size scale of the bar code (Figure 2). The most common unit of measure is either the mil (0.001 inch, primarily in the U.S.) or mm (millimeter). When determining the size of the bar code for a specific application, choose the largest narrow bar size the application will allow. A larger bar code is easier to print and read accurately and provides a greater depth of field for the bar code reader.

Contrast Ratio: This is the percentage of contrast between the bars and spaces of the bar code. The better the contrast, the easier it is for the bar code scanner to differentiate between the bars and spaces of the bar code. The bar code scanner will read the code more easily, and the chance of noise interference will be reduced in the process.

Bar Height: This is the measurement along the length of the bars regardless of orientation. Microscan recommends that the bar height be as high as possible. The taller the bar code, the more area the bar code reader has to scan the symbol. If part of the bar code is damaged, the scanner has a greater chance of still decoding the symbol on a tall bar code (Figure 3).

SYMBOLGY FAMILIES

To create the best possible bar code for the application, one must first understand the advantages and disadvantages of the available symbolgies. Since several of the symbolgies



Figure 3. Bar height serves as the redundancy for a linear bar code. To maximize bar height, place human-readable text to the side of the bar code on a microplate label.

share similar characteristics, they can be grouped into families. The most common families are Ratio and Modular bar codes and Discrete and Continuous bar codes.

Character Construction: Ratio and Modular Bar Codes

Two methods are commonly used for encoding data into a bar code: ratio and modular. The ratio-based method utilizes only elements of two widths to create characters (Figure 4). The narrow element width is nominally equal to X . The wider element width is defined as a ratio of X , such as $2X$ or $3X$. Ratio-based symbolgies were the first symbolgies to be widely adopted, and several remain very popular.

Modular symbolgies divide the area for each character into a number of equally sized modules. The width of the modules is nominally equal to X . Each module is either light or dark. Identical adjacent modules make up bars and spaces wider than $1X$. The width of each bar or space is a whole multiple of the module width (Figure 5).

The bar code symbolgies developed over the last few years, such as Code 128, have been almost exclusively modular because the modular structure creates a much more compact bar code. More data can be encoded into a much smaller space. The advantage to using ratio-based symbolgies is that they are more impervious to printing inaccuracies. The bar code reader must only discriminate between two different widths, as opposed to reading a modular symbol that is constructed with four different element widths. This is usually not an issue unless the narrow bar width approaches the maximum resolution of the bar code printer.

Symbol Construction: Continuous and Discrete Bar Codes

The characters of both modular and ratio-based bar codes are formatted in one of two ways: discrete or continuous. In a discrete symbolgy, each character begins and ends with a bar. The individual characters are separated by spaces that do not contain information. The space between characters is referred to as the Intercharacter Gap, similar to the spaces in between the following letters: A B C D. Generally, the Intercharacter Gap should not be greater than four times the Narrow Bar Width ($4\times$).

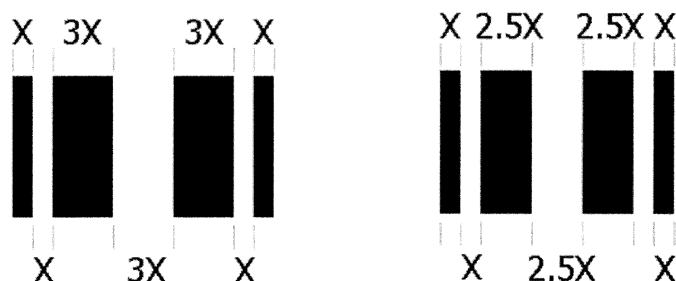


Figure 4. Ratio-based characters typically utilize only two widths of elements.

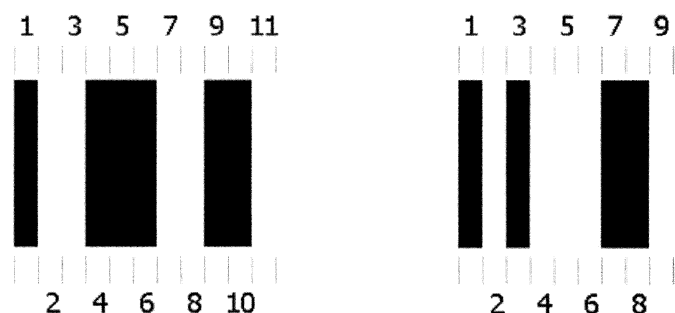


Figure 5. The area for each character in a modular symbol is divided into a number of equally sized modules. The width of the modules is nominally equal to X.

In a continuous symbology, each character begins with a bar and ends with a space. There is no space between characters. For example, the data would resemble the format of the following letters: abcde.

SYMBOLOGIES

Linear Bar Codes

Literally hundreds of linear symbologies are in use today. However, only a few are widely adopted and appropriate for use in the Life Sciences. Listed below are some of the more common symbologies employed.²

UPC/EAN was developed by the Uniform Code Council (UCC) for use in the retail grocery industry. It has several good features, including a mandatory check digit and good density. *Advantage:* The UPC code has good data security and immunity to ink spread when “similar-edge” algorithm is used. *Disadvantage:* It has a limited number of characters (numeric characters only) and is used for point-of-sale applications.

Code 39 was the first alphanumeric symbology and is still widely used today, Code 39 is also recommended by the NCCLS for specific applications.³ *Advantage:* Code 39 offers good security and an alphanumeric character set. *Disadvantage:* Since it is not as dense as Code 128, Code 39 is not recommended for applications requiring long data identifiers.

Code 128 is a very reliable symbology offering three different character sets. *Advantage:* Its large character set combined with high density and flexibility has earned it the recommendation of NCCLS⁴ and ISBT,⁵ among others. Code 128’s mandatory check character maximizes data integrity. *Disadvantage:* Since Code 128 is a modular symbology, users must be aware that problems can arise when the narrow bar width approaches the resolution of the bar code generation system.

Codabar was originally developed for the blood bank industry, but the industry has now started to use Code 128. While Codabar is still used in a number of applications, it offers no advantages and several disadvantages. The code’s most significant drawbacks are very low security and a limited character set.

Interleaved 2 of 5 is widely used in shipping applications. *Advantage:* It is the highest density linear bar code for numeric only strings of fewer than 10 characters. *Disadvan-*

tage: Interleaved 2 of 5 has very low security. The symbology uses two bar patterns for start and stop instead of full characters, which can lead to truncation errors.

Code 93 uses the same character set as Code 39. Because Code 93 is a modular symbology, it produces a much more compact bar code than ratio-based Code 39. *Advantage:* Code 93 always uses two check digits to ensure data security. It is also the densest linear symbology for random alphanumeric strings. *Disadvantage:* The symbology is not a standard symbology read by most scanners, and its varying dimensions can be difficult to print accurately.

RSS is a new family of linear symbologies recently introduced by the UCC for small, space-constrained applications. *Advantage:* The RSS family is the most compact linear bar code symbology offered today and has limited orientation requirements. *Disadvantage:* RSS uses multiple bar code widths. As with other modular symbologies, users must be aware that difficulties can arise when the narrow bar width approaches the resolution of the bar code generation system.

Stacked Symbologies

Stacked bar codes were developed in the 1980s to encode more data in a smaller footprint than allowed by the then current linear bar codes. Today, the primary advantage to using a stacked symbology is to encode more data into a symbol that can still be read by a laser bar code scanner. While matrix codes are much more space efficient and offer increased data capacity than stacked 2D codes, matrix codes must be read with an image-based reader.⁶

One significant drawback to stacked symbologies is their sensitivity to scanner tilt. To decode the symbol, the laser beam must be aligned so that the beam passes through the rows one at a time. The stacked symbology PDF417 provides the user with a little more tolerance. Since PDF417 has three different encoding schemes that read every three rows, the laser beam can pass through up to three rows at a time and still decode the symbol (Figure 6).

Code 49 was introduced in 1987 and was designed for labeling small objects. *Advantage:* It has a smaller footprint than most standard linear bar codes. *Disadvantage:* It has a maximum capacity of 49 alphanumeric characters and does not offer built-in error correction.

Code 16K was introduced a year after Code 49 and has an inverted Code 128 character set and has much more data capacity than Code 49. *Advantage:* It is much more compact than standard linear bar codes. *Disadvantage:* It is not widely used and does not offer built-in error correction.

PDF417 symbology stands for Portable Data File and unlike the other stacked symbologies offers the robust Reed-Solomon form of error correction. This enables the symbol to sustain considerable damage and still be readable. PDF417 has three different encoding schemes that repeat every three rows. So, for example, the bar pattern for the character “A” in row one is not the same pattern for “A” in row 2. However, it is the same pattern in row 4. Since the encoding scheme repeats every three rows, the symbology can sustain a certain degree of

A - 10 mil, PDF417



B - 10 mil, 2D Data Matrix Code



Figure 6. (A) An example of a 2D stacked bar code. (B) An example of a 2D matrix code.

scanner tilt and still be readable. *Advantage:* PDF417 has high data capacity and offers Reed-Solomon error correction, which makes it highly secure. It can also be read with a laser scanner in many applications. *Disadvantage:* Like other stacked symbologies, it is sensitive to scanner tilt and is not as space efficient as matrix codes.

RSS/Composite Symbology The linear symbology RSS has a two-dimensional option called a Composite component. If additional information is needed, the Composite component can be attached to the top of the RSS symbol. The composite options are based on PDF417 and Micro-PDF417. *Advantage:* The composite component increases the data capacity of the RSS symbol. *Disadvantage:* Because the composite symbol is printed so small, the symbol's sensitivity to scanner tilt becomes even more of a concern and can affect ease of use. An image-based reader is recommended for reading RSS/Composite symbols.

Matrix Codes

Matrix codes are becoming increasingly popular in the life sciences for their data capacity and exceptionally small footprints. The most popular code in use today is Data Matrix (Figure 6). Originally developed by a NASA engineer for marking and tracking space shuttle parts, the symbol was introduced into the public domain in 1995, and the AIM standard released in 1996.⁷

Data Matrix is primarily used for its small size and exceptional data capacity, capable of encoding up to 2335 alphanumeric characters. If there is 1 square inch of space on the bottom of a well or a slide, the item can be marked with a five- or six-digit Data Matrix symbol. Data Matrix has additional benefits as well. Data Matrix offers the robust Reed-Solomon method of error correction and has no orientation requirements.⁸

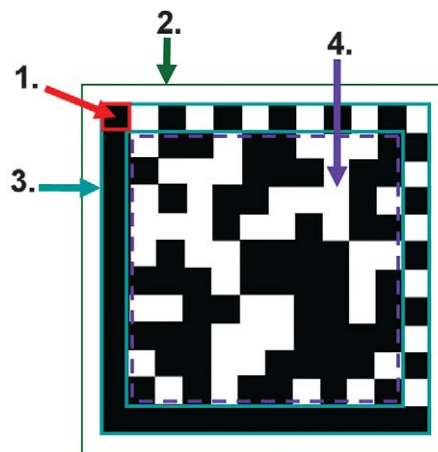


Figure 7. 1. Element (module): Square-shaped cell that encodes one bit of binary data, “0” or “1.” 2. Quiet zone: The AIM specification calls for a minimum of one element width (1X) on each side of the symbol. 3. Structure Finder Pattern: The outermost rows and columns, composed of two solid lines and two alternating dark/light lines. The finder pattern is also used to define physical size, orientation, distortion, and the number of rows and columns in the symbol. 4. Data Region: The area inside the finder pattern, which contains the data and error correction codewords.

The Data Matrix symbol consists of elements that resemble a checkerboard pattern. Since both the light and dark elements are the same size throughout the symbol, it can accommodate a variety of marking methods (Figure 7). The border of the symbol—or finder pattern—is composed of two sides forming an “L” shape and two sides alternating light and dark elements. The Quiet Zone requirement for Data Matrix is a one-element width on each side of the symbol. Data Matrix can have multiple data regions, separated by the “alignment pattern” of each symbol. Depending on the needs of the application, Data Matrix symbols can be either square or rectangular, making them exceptionally flexible for space-constrained applications.⁹

Advantages and Disadvantages: The primary drawback to using Data Matrix, like other matrix codes, is that it must be read with an image-based reader. Imagers are typically more expensive than a laser bar code scanner. However, for certain applications, Data Matrix may prove to be the only solution available. For applications such as marking each individual well on a microplate, Data Matrix provides the only viable option. A lab might also consider using Data Matrix for the high data security the symbol provides. Data Matrix can sustain a higher percentage of damage than a bar code can and still be readable.

HOW TO SELECT A BAR CODE

With so many different symbologies to choose from, it is easy to get overwhelmed trying to select the best bar code possible for an application. Before evaluating symbologies, first

determine the objectives for the application. What does the bar code system need to accomplish? What function will it provide in the automation process? For example, a lab may need to determine the exact location of a specimen at any given time. Another objective may be to encode all relevant information into a bar code on reagent packs so that calibration and expiration date checking can be accomplished automatically.

Next, research all industry standards relevant to the application. Many industry associations have already selected a specific symbology or family of symbologies for certain applications. Some specifications are very general and simply recommend a symbology for a specific application. Other specifications are very detailed, specifying the density, row height, and additional formatting guidelines.

If there is not a standard that applies to the application, then determine the requirements and limitations of the application. First evaluate the physical requirements: How much real estate is available for the bar code? For the bar code reader? Table 1 provides the physical parameters of many standard bar codes. Next, select the required information to be encoded into the bar code. Will the data be numeric only, or will alphanumeric characters be required as well?

Evaluate the materials to be used. Will the code be applied directly to the object, or will the bar code be printed on a label first? What type of environment will the media need to withstand? Last, based on the real estate available, select a bar code element size (narrow bar). This dictates the overall physical size of the bar code. While selecting a narrow bar code width, evaluate the physical parameters of each of the symbologies under consideration to determine which one will meet the needs of the application.

Before a final decision is made, think about the future. Will the symbol need to contain more data in the future? Will the selected hardware or media meet future needs? For example, will new tests be added, imposing new environment demands on the bar code labels? When possible, try to meet the needs of tomorrow's applications at the same time. For example, if a lab is implementing a linear bar code system today, but plans to transition to matrix codes in 2 to 3 years, it may be more cost-beneficial to purchase imagers instead of laser scanners. While laser scanners may be less expensive, imagers can read both linear and 2D matrix codes, saving the lab the additional time and expense of replacing the laser scanners down the road.

PRINTING CONSIDERATIONS

Media

Before selecting a printing method, it is important to note that a label is not just a label. Labels consist of specific layers. Any variation in one of the layers changes the media's application. This is particularly important in the life sciences where labels must withstand many different changes in the environment, depending on the application. For example, bar code labels on microplates are often subjected to extreme environmental conditions. Freeze/thaw cycles and exposure to chemical solvents can affect the integrity of the adhesives.¹⁰ Tables 2 and 3 provide reference information on the environmental performance properties of 1 mL polyester.

Printing

The printing options available to laboratories can be placed into two categories. The lab must first decide whether to print the labels themselves or have them pre-printed. There are two common methods of off-site printing. Pre-printed labels can be purchased from a label manufacturer and then applied on site either by hand or by an automated machine. Or the lab can choose to purchase pre-labeled plates from a plate vendor. Some vendors also offer microplates with pre-marked individual wells.¹⁰

Off-site printing is best for large volumes of labels containing fixed data that does not change. Print-on-demand, on-site printing is better suited for small to medium volumes of labels or for applications with variable data. There is less waste involved, and the time required for inventory management of label stock is minimal. There are several different print-on-demand methods of printing available to laboratories:

Dot matrix drives a small round pin into an ink ribbon that makes contact with the media. *Advantage:* It is inexpensive and readily available. *Disadvantage:* It generates poor print permanence and poor print quality. It also has high maintenance costs and typically is not compatible with chemically resistant labels.

Laser printing can be described as the surface of media exposed to an optical image, which generates an electrostatic image that is brought into contact with toner particles.

Table 1. The physical parameters of common linear and stacked bar code symbologies

7.5 mL	Code 39	Code 93	12 of 5	Codabar	Code 128	UPC	PDF 417	
Character length								
10 characters	1.5"	0.98"	0.7"	1.05"	0.7"	0.75"	0.69" (1 column)	0.95" (3 column)
20 characters	2.75"	1.7"	1.35"	1.92"	1.15"	N/A		
50 characters	6.5"	3.78"	3.25"	4.5"	2.45"	N/A	0.69" (1 column)	0.95" (3 column)
Check digit	X	X	X	X	X	X	X	X
Numeric	X	X	X	X	X	X	X	X
Alphanumeric	X	X			X		X	X

Table 2. Environmental performance properties of 1 mL polyester

Environment	Test method	Typical results
High service temperature*	30 days at elevated temperatures	Slight discoloration at 230°F (110°C), no visible effect to print. Material discolored but functional up to 266°F (130°C)
Autoclave	3 cycles of 1 hour in 250°F (121°C)/15 psi pressure cooker and 23 hours at room temperature	No visible effect after 3 cycles
Liquid nitrogen†	3 cycles at 4 hours at –320°F (–196°C) and 20 hours at room temperature	No visible effect after 3 cycles
Freezer	3 cycles of 16 hours at –94°F (–70°C) and 8 hours at room temperature	No visible effect after 3 cycles
Liquid nitrogen to boiling water†	1 hour at –320°F (–196°C) then placed in boiling water 212°F (100°C) for 10 minutes	No visible effect
Freezer to boiling water	1 hour at –94°F (–70°C) then placed in boiling water 212°F (100°C) for 10 minutes	No visible effect

Testing conducted in the Brady® Research Laboratory, Milwaukee, WI.

*Samples for this testing were placed only on glass panels and glass test tubes.

†Also tested labels on aluminum foil.

Advantage: It's the most common method for printing bar codes. The equipment is readily available and it produces an excellent quality bar code. **Disadvantage:** Laser printing has low print permanence and higher costs due to more expensive media and a higher percentage of media waste. A full sheet of label stock must be used, regardless if one label or a sheet of labels is needed.

In the **Thermal Transfer** printing process, the print head comes in contact with the ribbon that releases ink above certain threshold temperatures. The image is created by heat

generated by the printhead that is then transferred to the ribbon. **Advantage:** Thermal transfer printing produces the most stable image for a variety of environments. A wide variety of substrate and ribbon formulations meet the needs of many applications. It is also an economical print method and provides increased control of waste while delivering excellent print quality. **Disadvantage:** Since thermal transfer offers so many options, operator training is generally recommended. Routine maintenance is critical to maintain optimal print quality.

Table 3. Chemical performance properties of 1 mL polyester

Chemical reagent	Objective observation of visual change			
	Effect to label stock		Effects to printed image	
	Flat	Wrapped	Without rub	With rub wrapped
Ethanol	No visible effect	No visible effect		
Toluene	Slight adhesive ooze	Slight adhesive ooze		
Isopropanol	No visible effect	No visible effect		
Chloroform	Adhesive ooze	No visible effect		
Xylene	No visible effect	No visible effect		
Dimethylsulfoxide (DMSO)	No visible effect	Slight adhesive ooze		
Methylene chloride	Adhesive ooze	Slight adhesive ooze and label unwrap		
50% acetic acid	No visible effect	No visible effect		
10% hydrochloric acid	No visible effect	No visible effect		
10% sodium hydroxide	No visible effect	No visible effect		
10% chlorox solution	No visible effect	No visible effect		

Testing conducted in the Brady® Research Laboratory, Milwaukee, WI.

Rating Scale:

1 = no visible effect.

2 = light smear or print removal, detectable but minimal smear.

3 = moderate smear or print removal (print still legible).

4 = severe smear or print removal (print illegible or just barely legible).

5 = complete print and/or topcoat removal.

SELECTING A SCANNER

As with selecting a symbology, determining the physical requirements of the application will help determine which type of bar code scanner should be used for the most optimal results.

First, determine if the application requires a hand-held scanner or a fixed-position scanner. The easiest way to determine this is to answer the question: Does it make more sense to present the bar coded object to the scanner or the scanner to the bar coded object? Even applications that are typically thought of as hand-held applications are extremely successful applications for a fixed-position scanner. Depending on the object and the chemicals involved, it may be more convenient to place an object within the field of view of a fixed-position scanner than to pick up a hand-held scanner, maneuver it around until it reads the bar code, then set the scanner back down again.

What type of symbology will be used?

Consider what type of symbology will be used and the object it will be applied to. If the application calls for a linear black-on-white bar code printed on a thermal-transfer label, a wide selection of bar code scanners should be able to read it. If the application calls for a Data Matrix code etched onto a glass slide, an image-based reader will be required.

How far is the bar code from the scanner?

Another important consideration is the required distance between the bar code reader and the bar code being scanned. The physical distance, along with the X-dimension of the bar code, will determine the read range capabilities.

Is code placement consistent?

Are the bar code labels hand-applied or applied by a machine? Will the bar codes always be in the same location or orientation? The answers to these questions will help determine what type of scan pattern may be required.

What is the speed of the application?

The speed requirements of an application are determined by three factors: the speed the bar code is traveling past the reader, the bar code orientation (ladder or picket fence), and the row height of the bar code. Row height is especially important for bar codes in the ladder orientation. As a general rule, in order to ensure a good read on a symbol, Microscan recommends that the bar code reader obtain a minimum of five good reads on the label.

What are the environmental conditions?

Will the scanner be located inside a freezer? Will it need to read bar codes with condensation on the labels? Will it be exposed to chemicals? If the environment is particularly harsh, work-arounds can always be created to fit the needs of the application. For example, air can be blown on the bar code reader's window to control the buildup of condensation.

CONCLUSION

Bar codes are a key piece in the laboratory automation puzzle. While the number of different factors initially may appear large, the implementation of tracking with bar codes can, and has been, successfully implemented.

Key steps to success include:

1. Identifying objectives and requirements of the completed solution.
2. Assessing future needs.
3. Having good communication of requirements to all vendors to minimize unforeseen surprises once the solution is implemented.

ACKNOWLEDGMENTS

The authors would like to thank James R. Gross, Laboratory Market Manager at Brady®, Milwaukee, WI, for providing information on the various printing methods and label media available to laboratories. They would also like to thank Matt Allen, Product Marketing Manager at Microscan Systems, for his helpful discussions during the development of this tutorial and for reviewing the manuscript.

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