Fast and Accurate Sample ID in the Lab

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Laboratories—whether clinical, analytical, or pure research—can scarcely automate today without barcodes. While other technologies may someday offer more cost-effective ID techniques, barcodes are generally the best technology for positive sample identification within modern labs.

The use of barcodes in laboratory environments has proliferated because they offer exceptional speed of data collection along with unparalleled accuracy—no trade-off is required between doing it fast and getting it right (see table below). And because scanning a barcode symbol is the simplest of actions, very little training is required. So the rationale for barcode technology is compelling—it is fast, accurate, easy-to-use, and inexpensive.

Comparison of Manual Data Entry vs. Barcode Data Entry

(12-character alphanumeric message)	**MANUAL ENTRY**	**BARCODE SCANNING**
TIME REQUIRED	4 to 6 seconds	0.5 - 2 seconds
ACCURACY	1 error/300 characters	≈1 error/10 million characters

How Do Barcodes Work?

While barcodes have been a part of our lives for years, not everyone understands the technology. Barcode scanning is based on a simple principle: light is reflected in different amounts by different colored surfaces. To decode the information in a barcode symbol, most barcode scanners use a small spot of light passed over the bars and spaces. The scanner can be a hand-held wand, a fixed-beam device, or a moving-beam device.

The barcode symbol will reflect the spot of light back into the scanner in varying amounts. The dark bars of the symbol will absorb light, while the white spaces will reflect it. These differences in reflectivity are translated into electrical signals by a light detector inside the scanner. The signals are converted into binary ones and zeros, which are used in various combinations to stand for specific numbers and letters. (If you desire more "barcode basics" information, contact the author whose e-mail address appears at the end of this document.)

Which Barcode Symbology Should Be Used in the Lab?

Barcodes can generally be classified as linear, stacked, or two-dimensional. Differences among these types are of two kinds: 1) How much data can be encoded in a given amount of space; and 2) What type of scanning device is required.

Linear barcodes
The original barcode symbologies were all linear; that is, a single-line scan path was sufficient for decoding. Linear barcodes are ubiquitous, appearing on everything from all retail items to library books to identification badges.

Linear symbologies are limited in the number of characters they can encode in a lineal inch of space. While there are many variables—barcode symbol density, alpha vs. numeric characters, and scanner capabilities—a good rule of thumb is about ten characters per inch can be encoded with a linear symbology.

Using an alphanumeric barcode, the number of possible unique combinations is significant. For example, some labs use a base 31 numbering system, composed of ten digits and all non-vowel alphabetic characters, for a total of 31. (Vowels are eliminated to prevent the inadvertent use of an inappropriate expression in the sequence.) With 31 possible characters per position and, say, four positions (four characters in the barcode message), the result is 31^4 combinations, or 923,521 unique messages. Expand the message length to six characters and the unique combination total is well over 800 million. Using this approach, it's hard to imagine "running out of numbers."

Based on experience in transfusion medicine—a true life-or-death identification challenge for the lab—the linear symbology called "Code 128" (shown above) has some features that make it particularly suitable for use in this type of application:

- *Fully alphanumeric*—Code 128 has the capability of encoding ten digits, (0-9), all upper- and lower-case alphabetic characters (A-Z, a-z), and more than thirty ASCII control characters. *No matter what characters your part/serial number uses, Code 128 can encode them.*
- *Widely supported*—Created in 1981, Code 128 was quickly accepted by the Automatic Identification Manufacturers, Inc. (AIM) as a Uniform Symbology Specification. All major scanner (barcode reader) companies support Code 128 in their decoders; it is in the public domain and is probably one of the three most popular symbologies in the world today. *Regardless of scanner type you choose, it will be able to read Code 128 symbols.*

- *Continuous/High density code*—Continuous codes make use of every bar and space in the symbol. No space is wasted separating adjacent characters from one another. In addition, Code 128 has a special numeric-only subset of particular usefulness when encoding a long string of numeric data. *Code 128 labels can accommodate a lot of data in a limited space*.
- *Flexibility*—Code 128 provides unique flexibility by enabling the user to switch from one subset to another even within the same symbol. *Barcode messages can be structured to make the most efficient use of space.*
- *Data security*—This is a critical concern for labs. Data collection errors can skew test results, create false positives, and even endanger lives. In addition to three self-checks per character, every Code 128 message requires a check character, to ensure that the entire message has been scanned correctly. This weighted check digit routine is capable of detecting both errors of transcription and transposition. *You can rely on the accuracy of data collected via Code 128.*
- *Ease of printing*—Code 128 is easy to print using all common barcode printing technologies. *Code 128 should pose no printing problems for any thermal transfer printer*.

Stacked symbologies

Beginning in the early 1980s, stacked symbologies were developed to enable the encoding of more data in the same space a linear symbol would occupy. Stacked symbols, as the name implies, simply stack multiple linear symbols on top of one another. Common stacked symbologies include Code 16K, Code 49, and PDF417 (shown below).

These multi-row arrays of linear symbols have one advantage over their more-sophisticated cousins, 2-D symbols (discussed below). Stacked symbols can be read by a moving-beam laser scanner, while two-dimensional symbols require a more expensive camera-based reader Perhaps because the price difference between a 2-D scanner and a moving-beam model is only slight, none of the stacked symbologies has gained significant traction within most lab applications.

Two-dimensional symbologies

Expanding upon the concept of the stacked symbol, two-dimensional symbologies don't just stack up linear ones but are different symbol structures entirely. They employ sophisticated error corrections techniques, the symbols are omnidirectional (they can be read in any orientation), and they can provide a complete read even if a portion of the symbol is missing or destroyed.

In North America, the Data Matrix symbology (shown above) appears to be the most widely used within lab settings. Along with all 128 ASCII characters, Data Matrix will also encode all ISO and EBCDIC characters; a single Data Matrix symbol can encode up to 3116 individual characters of information.

Labeling Challenges in the Lab

After decisions about symbologies and scanning have been made, labeling challenges remain. The best barcode data collection system won't be effective if labels have fallen off their assigned items and are stuck to a bench top somewhere, are lying on the floor of the freezer, or have disappeared entirely.

Liquid Nitrogen Storage

In order to preserve biologic samples in an unaltered state, labs store the samples in extremely cold conditions, typically at least -80° Celsius and often as low as -196° C. In addition, there may be exposure to toluene, acetone, and DMSO prior to freezing. These conditions pose significant problems for the barcode labels affixed to the sample containers.

The development of a "cryo safe" barcode label represents a significant advancement in label engineering. A simple and elegant idea—the "wraparound" label—has been further enhanced with special label material, laminate, and adhesive to create a label that is truly impervious to liquid nitrogen storage.

Because most pressure-sensitive adhesives do not adhere well to wet surfaces, the tube or vial to be labeled must be clean and free from moisture. Applying the label at room temperature is always preferred to labeling a container that is already cold. When a "cryo hold" label is removed from the release liner, it should be applied to the vial immediately, as prolonged exposure to air will begin to dry out the adhesive. Some label materials can be applied to an already frozen vial, but the surface should still be wiped dry prior to application.

Stain & Chemical Resistance

Slides used in pathology labs encounter a variety of chemicals and staining processes that would destroy a normal label. Fortunately for path labs, and others that use staining techniques and other chemicals, label engineering has solved this problem. A self-laminating label is available that offers the flexibility of on-demand printing with the durability of a sealed image.

The label stock, die-cut to fit on the end of a microscope slide, goes through the thermal transfer printer looking like an open book. The image is printed on the left side of the "book." The adjacent side of the book has its release liner removed and then it is manually closed over the imaged side. The image is sealed under the clear laminate and protected from stains and chemicals.

Outsourced Labeling
Some labs have elected to entirely outsource their labeling functions. Specialist firms have developed the capability of automatically labeling a variety of labware—tubes, vials, microwell plates, and so on—to the extent that it can be done more efficiently and cost-effectively off-site and then shipped to the laboratory ready to use.

Additionally, groups of items can be kitted together by these services, matching the appropriately-numbered forms, containers, and other items together in an easy-to-use kit. Savvy lab managers are now looking outside their own facilities to accomplish tasks that are not part of their main mission, and for which outside expertise offers superior results.

Conclusions

►The more barcode scanning that happens in your lab, the more reliable your data collection will be;
►The typical trade-off between speed and accuracy isn't operative with barcodes: you can do it fast and get it right at the same time;
►You should choose barcodes that can be read by scanners you may already own—if starting new, consider Code 128 as your standard linear symbology.

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