THE USE AND STANDARDIZATION OF BARCODES IN RAILROAD WHEEL AND WHEELSET MANUFACTURING

Tim Epperson, President
Arkansas Industrial Computing, Inc.
6100 Getty Drive, Suite N
Sherwood, AR USA 72117
501-834-9540
time@WheelShopAutomation.com

ABSTRACT

This paper discusses the current state of barcode label usage in railroad wheel and wheelset manufacturing. It proposes some minimal standards for labeling and label content along with requirements for label placement. Also discussed is how the labels are used in the industry and ways to maximize the usage of the data contained on the labels.

INTRODUCTION

At the time this paper is being written, there is no conclusive barcode label standard for use on railroad wheels. There have been discussions by the AAR to establish a barcode label standard but no committee has yet taken this task.

Barcode labels have been applied to railroad wheels for over ten years. Even though there is no standard, the technology is being used successfully by the wheel manufacturers and the wheelset manufacturers. The problem is each manufacturer develops their own label and label format. Some of the formats are customer driven and some are manufacturer driven. All formats have some similarities but each manufacturer has their own design.

BARCODE OVERVIEW

Before addressing the use of barcodes for railroad wheels, a quick overview of barcodes will be presented.

Barcodes were first used in 1973. Since then they have become commonplace in our society. The primary barcode used in the United States is the UPC (Universal Product Code) barcode. The UPC barcode was developed for the grocery industry to allow large numbers of products to be "checked-out" accurately with little effort.

There are several benefits to using barcodes, such as:

- Speed
- Accuracy
- Uniform Data Collection
- Timely Feedback
- Improved Productivity
- Increased Profitability

Barcodes are 10 times faster to use than manual data entry. A human makes about one error in every 300 characters entered, where a barcode generates one error in every 3,000,000 characters!

UPC BARCODE

The UPC barcode looks confusing but in reality it is very simple. The primary content is a five-digit manufacturer code and a five-digit product code. The manufacturer codes are assigned and maintained by the Uniform Code Council (UCC). The product codes are assigned by the manufacturer for each product they make.

Each number in a barcode is made up of seven elements. An element is either black or white—a black element is a bar and a white element is a space. For instance the number "1" is composed of seven elements, "0011001" where 0 represents a space and 1 represents a bar. A UPC barcode contains three guard bars. The guard bars tell the scanner where the manufacturer and product codes begin and end. Finally, the barcode contains a "number system" character for identifying the product type and a "check digit" which validates that the other digits were read correctly.

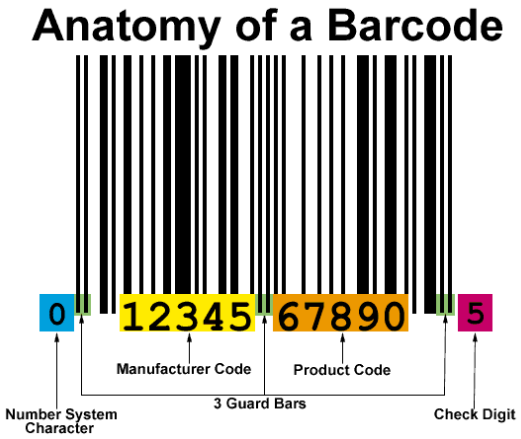


Figure 1 - UPC Barcode Format

CODE 39 – THE RAILROAD STANDARD

There are over 400 different barcode types or symbologies in use today. Of those only about five are standardized and prevalent in industry. The most common symbology used outside of retail is Code 39. Code 39 is a large barcode that is easy to read and relatively robust due to its size. It is the symbology of choice for all railroad wheel manufacturers. Code 39 is an alphanumeric code, which supports numbers, capital letters and seven special characters. The Code 39 barcode is

made up of nine elements, which makes it a larger code than the UPC code.

Figure 2 shows the format of a Code 39 barcode. The Code 39 barcode can contain as many characters as necessary as long as the scanner being used can read it. This allows for variable length data to be represented.

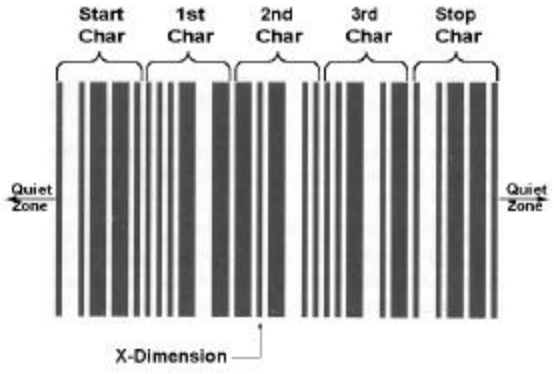


Figure 2 - Code 39 Barcode Format

One critical parameter of any barcode is the X-dimension. This is the narrowest element—space or bar—of a barcode. The X-dimension can vary from less than 0.009 inches to about 0.020 inches. The X-dimension determines how far the scanner must be from the barcode to be read. It is also a determining factor in the size of the barcode. The ideal barcode has a very large X-dimension which makes it easy to read and difficult to damage. A typical size for a Code 39 barcode is 9.4 characters per inch.

Another factor in the size of the barcode is an area called quiet zones as shown in Figure 2. Quiet zones must be 10 times the narrowest element or 0.25 inches minimum. This is required to be able to tell where the barcode starts and ends.

Popular 1D Barcode Symbologies

Symbology	**Character set and use**
Codabar	Numeric plus -,$/+:
Code-128	Full ASCII High Density
Interleaved 2 of 5	Numeric only Shipping containers
UPC	Numeric only Retail
Code 39	Alphanumeric plus space-.$/+% General Manufacturing

BARCODE SCANNERS

In the railroad manufacturing business, there are primarily two types of barcode scanners being used—fixed and hand-held. Several things determine the type of barcode scanner to be used in a particular application. If the product to be scanned will be moving down a conveyor, fixed moving beam scanners can be used without a human to start scanning. If the item to be scanned is part of an assembly, then typically a hand-held scanner must be used to access the barcode.

Fixed scanners can be separated into three types—raster, omni-directional and holographic. Raster scanners use one line of light from a laser diode to "draw" the beam across the barcode thousands of times per second. Omni-directional scanners work like raster scanners except they have multiple scan lines at various angles to prevent having to orient the barcode precisely. A relatively new type of scanner in the field is the holographic scanner. Holographic scanners add a third dimension to the scanning equation by projecting multiple scan lines at varying distances. This allows for the product being scanned to vary significantly in height size and still be scanned.

Hand-held scanners come in several varieties as well. Laser scanners use the same principal as fixed raster scanners and move the beam across the barcode. Lasers are the most commonly used hand-held scanners in the industrial environment. Hand-held laser scanners are rugged and can read barcodes from as far as six feet. However, they cannot compensate well for damaged barcodes.

CCD scanners use LEDs to illuminate the barcode area and take a picture of the code. CCDs are cheaper than lasers and are typically short-range scanners (6-10 inches). Because they take a "picture" of the barcode they can compensate for some damage and are more robust than laser scanners.

The last type of hand-held scanner is the area imager. These scanners are used to read 2 dimensional barcodes. The technology is the same as the CCD scanners except that they can read more area and cost a little more. Area imagers are also short range scanners (4-10 inches).

All scanners use either the visible red or infrared light part of the spectrum. Infrared scanners can "see through" dirt on a label but the disadvantage is that the operator cannot see the light to help align the scanner to the label. This problem is solved by adding a visible dot where the scan line is for the operator to see.

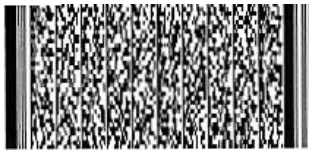
All modern scanners can read the most popular barcode symbologies without any special configuration. However if you know what symbology you will be scanning, most scanners can be configured to ignore other symbologies to eliminate scanning the wrong barcode.

TWO-DIMENSIONAL BARCODES

Separate pieces of information are either grouped together in one barcode or spread across several barcodes to provide all of the information needed for a wheel. An alternative to scanning several barcodes is to use two-dimensional (2D) barcodes. 2D barcodes have information stored in the standard horizontal direction as well as in the vertical direction. You can think of them as containing several of the standard one-dimensional barcodes stacked one on top of the other.

Two-dimensional barcodes allow the end user to collect all of the information about a product with a single scan. This requires a barcode scanner that is capable of reading 2D barcodes, which costs roughly twice the price of a 1D scanner. This price difference is narrowing as the popularity of the 2D barcodes increases.

Popular Two-Dimensional Barcodes



PDF417 – PDF stands for Portable Data File and is capable of storing over 1800 characters in a standard PDF417 code.

MaxiCode is an error correcting two-dimensional matrix symbol developed by UPS. It is designed specifically for sortation and tracking applications.

Data Matrix is an error correcting two-dimensional matrix symbol developed by International Data Matrix. Data Matrix is typically used for part marking applications.

Data Matrix can be stamped into metal parts for permanent marking.

Another key difference between traditional 1D barcodes and 2D barcodes is their redundancy. A 1D barcode can be made unreadable with a simple pen stroke. 2D symbols use error correction that allows the barcode to be damaged extensively and still be read.

PDF417 is the most flexible of the 2D barcode symbologies. PDF stands for "Portable Data File—a PDF417 barcode can contain up to 1,100 characters in the same space as a typical Code 39 barcode containing 20 characters.

The PDF417 format (Figure 3) was developed by Symbol Technologies to encode shipping manifests into barcodes. The barcode can contain numbers, letters and even binary data.

Symbol Technologies placed PDF417 into the public domain. The American National Standards Institute (ANSI) has published a new standard, ANSI MH 10.8.3M, for 2D barcodes. It recommends the use of PDF417 for all shipping, receiving and supporting electronic data interchange (EDI) documentation. Most standards associations will use this ANSI standard as the basis for their specific industry's application specification. PDF417 will transform the way EDI is carried out worldwide.

WHY BARCODE WHEELS?

The AAR requires that the wheel shop mounting the wheels onto an axle record mounting information as well as certain wheel information. The minimum amount of information that the wheel shop must retrieve from the wheel is the serial number and tape size. The serial number must be associated with every wheel mount and the tape size must match between wheels in a wheelset. To make the wheel serial number unique, the year of manufacture is added since most wheel manufacturers repeat serial numbers each year.

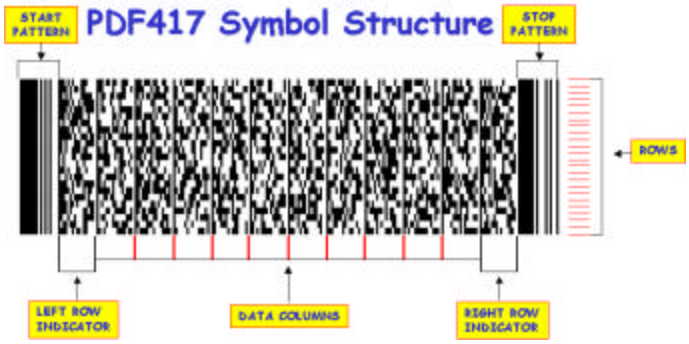


Figure 3 - PDF 417 Symbol Structure

Barcodes are an efficient and accurate method of retrieving the data required by the AAR from the wheel. It is also helpful for the wheel shop to record wheel type and manufacturer for inventory and planning purposes. Collecting this information allows tracking usage by size, wear type and manufacturer.

With barcodes the wheel press operator does not have to remove their gloves to write down the required information. Besides being more accurate, barcodes increase productivity and eliminate paperwork.

The shipping departments in wheel shops are using barcodes. They decrease the amount of time it takes to produce shipping manifests and reduce errors. More information can be tracked while simplifying the process.

New car manufacturers are using the wheel and axle barcodes to track trucks and wheelsets under cars.

CURRENT USAGE OF WHEEL BARCODES

Even without an AAR standard, the U.S. railroad wheel manufacturers that do apply barcode labels include the same information. The typical wheel barcode label looks like the one shown in Figure 4 (without the PDF417 barcode).

The first line of the label contains the AAR Approved Manufacturers' identification, the serial number and the month and year of manufacture. The order of this information is not consistent across manufacturers nor are the characters that separate the fields.

The second line contains the wheel design, the wheel class, the bore size and the AAR specified tape size. Again, the format

varies between manufacturers. Some bore diameters are in decimal and some in fractions while the tape size varies from two to three characters.

The third line is currently only used by Standard Steel and contains the wheel heat number.

When the wheel design data retrieved from the barcode is used in real-time it can prevent operator errors by detecting mismatched wheel sizes and types.

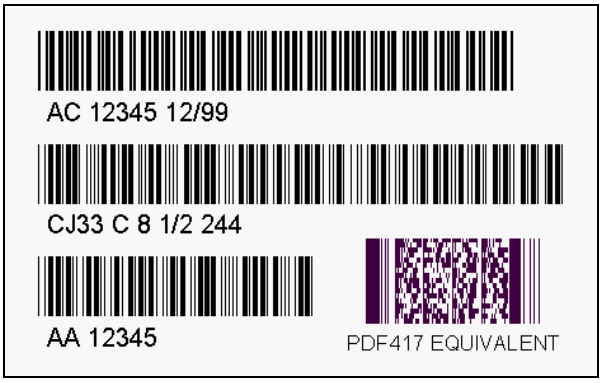


Figure 4 – Actual Wheel Barcode Label Comparing Code 39 and PDF417

LABEL PLACEMENT

Many wheel shops and car manufacturers are using automated data collection systems for recording the AAR required information. Part of the data collection process requires that data be collected after the wheel is mounted into an assembly or even after is it placed under the railcar. When the wheel is made part of an assembly, there are only a few areas that can be easily accessed. In addition to the need to view the label, there is also a need to protect the label during the manufacturing process. Labels on the tread of the wheel very seldom last after the wheel mounting process. This is undesirable because the wheel serial number needs to be accessible during bearing mounting for associating the wheels with the bearings as well as the truck and car assembly. They must also be scanned in the event of a misfit. The only location accessible during the mounting process and on the finished car is the plate of the wheel.

The wheel manufacturers will benefit from having a label on the wheel tread. Placing one label on the plate and one on the tread has solved this problem.

LABEL CONSTRUCTION

There are many base materials that barcode labels are constructed from—paper, polyester, ceramic, Teflon and aluminum, to name a few. Aluminum or ceramic labels are the most durable but they are more expensive and must be pre-printed.

Film-based materials, such as polyester, are inherently stronger than paper labels. Applications involving harsh chemicals or extreme outdoor conditions require film-based labels. Polyester labels will withstand the wide temperature range and environment that wheels are subjected to. They also and can be printed on demand.

LABEL PRINTING

The best label printing technique for polyester labels is thermal-transfer. Thermal printing uses heat from a stationary print head that contains many small resistive heating elements. These elements create dot patterns that produce the actual image on paper. Thermal-transfer printers use heat-activated ribbons that actually transfer the ink to the paper. Once an area of a ribbon has been transferred, it cannot be used again. Thermal-transfer printers also provide the high resolution required for printing high quality barcodes.

Some magnetic flux inspection stations use chemicals that cause the barcodes to smear. The thermal transfer printing process is resistant to chemicals as well.

If you plan to print 2D barcodes, be sure the printer you select can print the symbology you need.

LABEL ADHESIVES

Getting labels to adhere to a wheel's surface is not a trivial problem. The rough surface and the temperature range make it difficult to get the labels to stick. Acrylic-based adhesives are typically used for labels that are exposed to wide temperature ranges.

Label manufacturers are very secretive about their label adhesive—and rightly so. Since this is a difficult problem most manufacturers will either have the proper adhesive or spend time and money developing the proper adhesive. Either way they will not be quick to give out the properties of their adhesive. Find a label vendor with experience with barcoding rough surfaced steel and work with them until they get it right.

BARCODE VERIFICATION

Verification is often overlooked in the wheel business since there is really no specification to meet. There are barcode verifiers that scan the barcode and make sure it meets the ANSI standards. There are hand-held verifiers or you can attach a verifier to your barcode printer.

At a minimum, you should scan your own barcodes. If you cannot read them then there is a 100% chance that your customer cannot read them either. It is much cheaper to find the problem in your facility than it is to fix it at the customer's facility.

PROTECTION OF YOUR LABELS

Even if you apply the labels properly with excellent adhesive and print with chemical resistant methods, your labels will be exposed to the elements. You should take care during shipping and storage to minimize exposure to the elements. Wheels should be shipped and stored on their edge when outdoors. Wheels laying flat with the label facing up are subject to being submerged in water or covered in snow and ice.

DATA FORMATS IN BARCODES

The barcode labels consist of both human readable and non-human readable data—the two do not necessarily have to match. For instance, the text on the label could read 'H28 C 8 1/2" 39' where the barcode would read 'H28 C 8 1/2 039'. Computers do not know what an inch is so the '' symbol is not necessary. Leaving out unnecessary characters can allow the barcode to be larger and easier to scan. Computers do like structure in their programming. To have a tape size that is sometimes three characters and sometimes two is more difficult to program around. Again, consistency is important.

The format also needs to include field delimiters. A delimiter is a character—such as a space—that separates the fields in a barcode that contains more than one piece of information. One character for a delimiter is sufficient. More than one character violates the "unnecessary character" rule above.

IDENTIFYING THE INFORMATION

One of the confusing aspects of scanning barcodes into a computer is identifying the data that is being scanned—"Am I scanning the barcode with the serial number in it or am I scanning the barcode that contains the wheel design?" Or, "Am I even scanning a wheel barcode?" This is complicated by the fact that other wheelset component manufacturers are adding barcodes to their products (i.e. bearings, axles).

Can't we just have the operator scan the right thing in the right order? Not easily. There are times when one barcode will scan while another on the same label has been damaged. The operator must have the ability to scan in any order and scan any or none of the barcode.

The popularity of the Internet has created new ways of sharing data between dissimilar systems. One of these tools is a data format called Extensible Markup Language (XML) which allows us to say "Here is the wheel serial number and it is "1232435". XML is an industry standard controlled by the World Wide Web Consortium—the same group that establishes the standards for Hyper Text Markup Language (HTML), which is the format of every web page you view.

Here is the XML code for a wheel serial number:

```
<SerialNo>55102</SerialNo>
```

There is no mistaking that this is the serial number. Figure 5 shows the XML code for a wheel. Every wheel data field is easily identified even if it is not in a predefined order. Note that we added certification number. If the customer cares about this information then they will use it, otherwise the program reading the data ignores it. This was done to show that wheel vendors could add their own information to an XML barcode.

The problem becomes putting that much information on a barcode label. Here is where we make use of the 2D barcode format PDF417. Figure 6 is a PDF417 barcode containing the XML wheel data presented in Figure 5. Not only is it more complete, it is approximately one-fourth the size of the current barcodes and includes error corrections for more reliable reads.

```
<Wheel>
   <Mfg>AC</Mfg>
   <SerialNo>55102</SerialNo>
   <MfgDate>01/01</MfgDate>
   <Size>CH36</Size>
   <Class>C</Class>
   <BoreWhole>10</ BoreWhole>
   <BoreFract>15/16</ BoreFract>
   <TapeSize>244</TapeSize>
   <HeatNo>123456</HeatNo>
   <CertNo>5551212<CertNo>
</Wheel>
```

Figure 5 –Wheel Data in XML Format

If the PDF417 barcodes are used with the data in XML format then there is no longer a problem deciding what piece of data is being scanned. A bearing would identify itself, as would a brake hose. A standard should be developed that defines an entire railcar where every part can be easily scanned and identified.

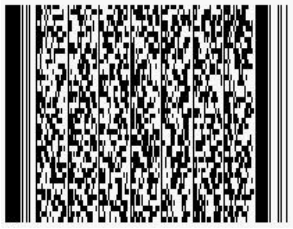


Figure 6 – PDF417 Barcode with Wheel Data in XML Format

ESTABLISHING STANDARDS

Barcode labeling of railroad wheels is currently working. However, it could become chaotic as more and more manufacturers begin to add barcode labels if a standard is not established. Some foreign manufacturers are already introducing barcode labels that do not follow the format used by U.S. manufacturers.

Below are some recommendations based on the ideas presented in this paper.

Some de Facto standards in use should remain:

- Code 39 Symbology
- First line data from existing barcodes
- Second line data from existing barcodes

New standards recommended:

- Standardize order of fields in 1D barcodes
- Standardize delimiters for fields (eliminate redundant characters)
- Define optional heat number barcode format for the third line barcode on existing barcodes
- Establish "markers" for data (what is this data)

- Standardize label placement and orientation
- Require validation on a sample basis
- Allow (but do not require) 2D barcodes
- Utilize XML to facilitate EDI in 2D barcodes

CONCLUDING REMARKS

The key for any company required to provide barcodes is not to view it as an expense of doing business. Barcodes make EDI possible, so trading partners can electronically share information. EDI lets everyone in the supply chain react quickly, allowing for reduced costs.

If you take advantage of barcoding and EDI, instead of using it to simply label product before it goes out the door to your customer, you can streamline your operation into a more efficient, profitable and competitive business.

Barcodes have been around for almost 30 years and they have stayed because they simplify business transactions. The rail industry has been slow in embracing their usage. As with any industry, there is a need for standardization before the lack of standardization becomes a problem.

WEB RESOURCES

Below are some resources on the Internet for barcode and XML-EDI information.

www.webermarking.com - Weber Marking Systems web site. Good how-to's for getting started barcoding.

www.autoid.org - Standards and technical information

www.adams1.com/pub/russadam/barcode1.html - General barcode information and links to other sites.

www.xml.org - Non-profit website dedicated to XML

www.geocities.com/WallStreet/Floor/5815/xmlediinex.htm - Links to information about XML-EDI