



White
Paper

**PARTS TRACEABILITY &
PRODUCT GENEALOGY**

Anyone involved in making, storing, and distributing products understands the value of tracking them from the time they are created until the time they are sold. Tracking is the primary method of determining production output, knowing where product is located at any given time, and establishing potential income.

Bar codes have been the accepted data collection and tracking technology for nearly 30 years. They are used in a wide variety of applications, such as manufacturing, warehousing, logistics, distribution, field service, retail, medical, and hazardous waste. But some products require more than product tracking, either because of their value or for warranty, regulatory, safety, or liability issues.

Most products go through changes as they travel through the manufacturing process and even more changes as they progress through the supply chain. Recording the changes made in every component of a product throughout its life—in other words, documenting the product's genealogy—is known as parts traceability. There are a number of data capture technologies that are appropriate for traceability applications.

- Radio frequency identification (RFID) provides the means to capture and store data in real-time on a tag that accompanies the product. RFID provides a portable, dynamic database of information that travels with the product for its entire life and can be updated as events, like warranty repairs, are performed. RFID is ideally suited for a large number of traceability applications, especially on more complex products and assemblies.
- Printed serialized bar code labels can be used on products or components that will be exposed to relatively mild environments. For example, printed labels using reduced space symbology (RSS) are ideal for marking electronic components.
- Other products require marks to be etched, inked, or stamped onto the product itself so that they remain readable for the life of the part (e.g. parts on airplane engines). Direct part-marking technology uses a variety of methods to place permanent marks on all kinds of materials, including plastic, glass, rubber, metal, and ceramic.

PARTS TRACKING VS. PARTS TRACEABILITY

Understanding the differences between tracking and tracing technologies and how each can best be applied to meet specific data collection requirements helps operational managers know which is best for any given application.

Parts tracking is knowing where parts are at anytime within manufacturing and warehousing processes with the goal being to increase company efficiency. Traditional bar-code-based automated data collection (ADC) technologies are generally used to identify items at raw material through model levels. This is typically done by marking and tracking the container in which the items are conveyed or packaged, which is usually performed within shipping, receiving, and inventory functions. It most often involves the use of printed bar code labels and handheld scanners to perform the tracking functions.

For example, in the manufacturing of food items, products are typically marked with a Universal Product Code (UPC) label. The same UPC label will be used on all food items of the same brand, style, and size or weight. Retailers also track products by means of a number called a SKU, or Stock Keeping Unit. Regardless of what is being tracked—clothing, furniture, appliances, consumer electronics, or other products—a SKU is used to track all the items of that same type. The SKU group is called a lot and any single lot may contain hundreds of thousands of identical items with the same UPC code.

Parts traceability focuses on documenting the genealogy of the parts, assemblies, and sub-assemblies that comprise a finished product. The goal of parts traceability is the “cradle-to-grave” collection of product data. The driving forces behind the growth in parts traceability are new government regulations and the desire of companies to limit risks while maximizing warranty revenues.

For example, the Transportation Recall Enhancement, Accountability and Documentation (TREAD) Act, passed by the U.S. Congress in 2000, requires, among other things, that tire and automobile manufacturers be able to easily find and recall defective tires by matching the tire to the automobiles VIN number.

In response, the Automotive Industry Action Group (AIAG) developed the B-11 Parts Identification and Tracking Standard, which provides automotive OEMs and suppliers with a uniform set of guidelines for the placement of

passive read/write RFID tags on tire and wheels. RFID tags will help support the assembly process and provide item-level traceability throughout a vehicle's lifecycle. And because RFID tags can serve as a portable database residing on the tire itself, they can be used to record the automobile VIN as well as service information for the life of the tire.

So while parts tracking and traceability share some of the same ADC methodologies, they function in entirely different ways to meet very specific goals.

PARTS TRACING TECHNOLOGY

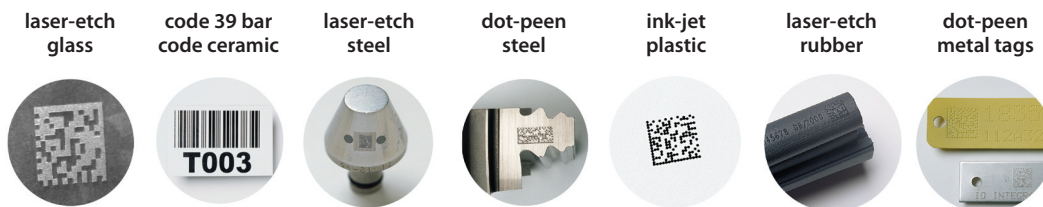
While printed bar codes can be used for some parts traceability applications, direct part marking (DPM) and RFID are quickly becoming the technologies of choice—DPM because of its permanence and RFID for its read/write capabilities as well as the advantages of carrying product genealogy data with the product instead of in a centralized database.

In general, ADC technologies fall into two categories: optical and non-optical:

Optical technologies			
Direct part marking (DPM)	Subtractive (removes material from the substrate)	Etching	Laser etching
			Chemical etching
		Dot-peening	
		Micro-drilling	
	Deposition (deposits material onto the substrate)	Ink-jet with permanent ink	
		Laser bonding	
		Permanent bar code labels	
		Nameplates	
	Bumpy barcode		
Non-optical technologies			
Radio Frequency Identification (RFID)	Active tags		
	Passive tags		

PERMANENT OPTICAL MARKING/DPM

Since most bar code labels are not “permanent” and may not stay on a part for life, manufacturers rely more on DPM, especially for parts that function in harsh environments. Direct part marking is the act of applying permanent 1-dimensional (1-D) or 2-dimensional (2-D) codes and/or human-readable information directly to an individual part using laser, chemical, ink, or physical imprint (e.g. dot-peening). DPM technology gives parts their own permanent “Social Security” number in support of safety, regulatory, and warranty efforts.



The photos above show some of the many forms that permanent identification can take.

There are trade-offs between the options available for permanent parts marking, but the decision on which to use should be based on your specific application and business objectives for marking parts.

For example, if your marking application requires the marking of products in a high-volume manufacturing line, you could immediately rule out using chemical etching and dot-peening, which might be too slow. In addition, if your parts are used in very high-abrasion environments, where the mark will be exposed, you might also rule out ink-jet as an option. And if you produce a broad range of products that require reasonably frequent set-ups for your marking process, you would most likely rule out micro-drilling and photo-etch, both of which require heavy fixturing.

So for this specific application, laser etching would most likely be your best option. Even if laser etching might be more expensive than the other options in terms of initial capital investment, it would still be your best choice based on the specific application and business processes.

Permanence

There is no single technical reference for what constitutes a “permanent” mark, so permanence is a relative term. The concept of what is “permanent” varies with the industry you are in, the application you are performing, and the technology you are using to make the mark.

In parts traceability, the term “permanent” is most often used to describe the identifying or marking of an item for the expected life of that item.

But even this definition is variable, as individual industries apply their own yardsticks for defining product life cycles. For example, people within the aerospace industry may consider the expected life of an aircraft part to be 25 years or even longer. In contrast, people in the semiconductor or telecom industries may view a given component’s life cycle as only five years. As a result, the requirements for making a “permanent” mark on a given product vary from one industry to another.

In addition, vendors of parts-marking equipment define “permanent” in terms of the typical useful lifespan within their respective technology. This can lead to differences of opinion within the vendor community itself. For instance, a vendor of ink-jet systems may consider some jet-sprayable inks to be “permanent” while a vendor of micro-drilling systems or dot-peening systems might consider any ink or paint as something less able to withstand harsh environments, harsh chemicals or extreme temperatures, and therefore not permanent.

For most manufacturing purposes, a safe yardstick for defining “permanent” marking is one that lasts throughout the item’s expected life.

Why Direct Parts Marking?

There are several reasons for using DPM; the primary ones are to:

- Provide *permanent identification* of parts and components, by use of a machine-readable part numbers. (Such ADC part numbers often will comply with, or follow the parameters of, a published industry standard. The number is required to stay on the item or part for its life, which may turn out to be as short as a few years or as long as several decades.)
- Identify items that are used or kept in *harsh environments*. (Externally applied labels would not be a consideration.)
- Identify *very small parts and components*. (This is commonly done using DPM techniques when limited available surface area prevents the use of an external label.)
- Identify *asset ownership*. (This is typically done as part of an asset-tracking application, often using a resulting mark comprised of a human-readable character string rather than a bar code.)

Labels And Nameplates

Printed bar code labels have been used for years in shipping and packing and many firms use labels for identifying their products, parts, and sub-assemblies. Whether you can do the same depends, again, on your specific application needs:

- What do you want to track?
- What is your purpose or objective for marking?
- How much information do you want to put onto your product?
- Do you want to do permanent marking?
- What is the expected life of your products?
- What environments are your products used in?
- Do you produce a large volume of product?
- Do your products physically have space available for a label?

You should remember that the method of attachment might affect the overall ruggedness of your labeling approach. Attachment methods for labels range from adhesives to mechanical devices. The more rigid the label (or nameplate), the more options you have for attachment.

A stainless steel nameplate can be considered a permanent form of identification in some applications, and can be affixed to your items using an adhesive, rivets, or other mechanical fasteners. In contrast, a paper label is typically limited to adhesive attachment only.

When traditional labels or nameplates are used for permanent marking, there are two primary concerns.

The first is harsh or challenging environments. Sea spray in naval operations can attack even some grades of stainless steel. In aerospace applications, Skydrol aviation hydraulic fluid can, over time, erode screen-printed aluminum. Extreme heat conditions can destroy polyester labels. Therefore, etching the desired mark into the surface of the item is usually a safer long-term alternative in these environments.

If you have to show a great deal of human-readable data, a warning statement, or your company's logo, you may want to consider one of the newer technologies available for labels and nameplates.

The second concern with using labels and nameplates for permanent marking has to do with available surface space on the item or part. Because labels and nameplates are often expected to carry a considerable amount of human-readable data, they may require a large surface area on the marked item.

An alternative in limited-space applications is a label with a machine-readable 2-D data matrix symbol, which can contain many more characters than the same size 1-D symbol. The symbol is also scalable from a 1-mil square to a 14-inch square, which means that a data matrix symbol has a maximum theoretical density of 500 million characters to the inch. However, the practical density is limited by the resolution of the printing and reading technology used.

NON-OPTICAL TECHNOLOGIES/RFID

RFID is a flexible technology that is convenient, easy to use, and ideally suited for parts traceability applications. It combines advantages not available with other identification technologies. RFID can be supplied as read-only or read/write, does not require contact or line-of-sight to be used, can function under a variety of environmental conditions, and provides a high level of data integrity.

RFID is similar in concept to bar coding. Bar code systems use a reader and coded labels that are attached to an item, whereas RFID uses a reader and special RFID devices (e.g. tags, inserts, etc.). Bar code uses optical signals to transfer information from the label to the reader; RFID uses RF signals to transfer information. Radio waves transfer data between an item with an RFID device attached and an RFID reader. The device may contain data about the item, such as what the item is, what time it traveled through a certain zone, and even a parameter such as temperature. RFID devices, such as a tag or label, can be attached to virtually anything—from a vehicle or piece of equipment to a pallet of merchandise, box, carton or the finished item itself.

RFID offers real-world, real-time advantages for suppliers and manufacturers alike. When its rewritable memory chip and wireless data communications capabilities are applied to every product shipped, an RFID tag allows a company to actively track changes in the status of each product at each step along its journey.

An RFID "tag" consists of an application-specific integrated circuit (ASIC) and an antenna that can be mounted on various substrates (e.g. a paper label for use as a carton tag or sealed in a plastic housing for use on a recyclable plastic container).

Active vs. Passive Tags

There are two basic types of RFID tags. Active tags carry their own power source (batteries) and can be read from a much greater distance since the tag itself is transmitting data, but they are larger, more expensive, and impractical for parts tracking and traceability.

Passive tags are the most common used for ADC applications. When a passive tag is interrogated, the energy from the reader powers the tag, allowing it to be read and written to.

The operation of passive tags has been compared to that of a mirror, which doesn't emit light, it simply reflects it back. The passive tag works the same way, reflecting back specific radio energy transmitted by the external reading device, with data applied on top of this energy.

And since radio energy is being transmitted, the waves are generally able to pass through most non-metallic materials, such as paper, wallboard, many woods, and most plastics.

READING MARKS AND BAR CODE LABELS

How you go about reading the mark or label is a central element of your overall parts traceability plan. A poor quality or hard to read bar code in a tracking application may be inconvenient, but in a parts traceability application it will bring the system to a halt.

Reading DPM can be particularly challenging, so the process controls used in creating the mark and maintaining the optimal print contrast ratio levels required for acceptable scanning performance are essential. And unlike bar codes, the low contrast in most DPM marks makes it all but impossible to use a standard laser scanner.

Choosing the right approach can be distilled down to three options:

Traditional Bar Code Scanner:

Chances are very good you can use a traditional bar code scanner (i.e. linear imager or laser scanner), if the product you are identifying:

- Will not be used in extremely harsh environments (which means you can use labels that have high contrast);
- Has sufficient available surface area (which means you can use a 1-D symbology such as Code 39 or Code 128); and
- Is subject to an industry standard that allows the use of 1-D symbols.

Industrial Imager:

If your product or part does not meet the criteria above, chances are you will need to employ DPM using a 2-D matrix symbology such as a data matrix or QR code. And you will need a special industrial reader called an imager to read the 2-D matrix codes.

Laser Scanner:

If you decide to mark your product or parts with a 2-D stacked symbology such as PDF417, you might be able to scan with a traditional laser scanner. But beware: very few industry specifications for parts traceability programs allow the use of PDF417. The structure of such stacked symbologies is generally considered less than desirable for most direct-part-marking applications.

PARTS TRACEABILITY APPLICATIONS

Several industry and government segments use parts traceability for similar reasons—usually because bar code labels are not permanent enough to meet the lifetime product genealogy requirements of certain types of parts or cannot hold enough information.

Commercial and Military Aerospace Applications

Government regulations require the tracking and recording of actions taken with every critical line-replaceable part, such as the flight computer or communication and navigation radios (about 5,000 on a typical airliner).

For years, various bar codes, metal tags, and handwritten identification tags have been applied or attached to aviation parts to fulfill that requirement. But because each manufacturer, airline, and supplier has devised its own unique tracking system, there has been a proliferation of bar codes and labels applied to those critical parts. On many aircraft parts today, it is not unusual to find as many as a half-dozen or more different bar codes and traveler tags.

The move to require that each critical part on a commercial plane be marked with its own individual identification number is supported by the world's largest airframe manufacturers and engine builders. The part marking and tracking initiative, called SPEC 2000, is designed to improve component traceability and air safety, while reducing maintenance costs.

Sponsored by the Air Transport Association, SPEC 2000 sets information standards for parts and repair services for commercial and civilian aircraft. SPEC 2000 has the support of the Federal Aviation Administration and Europe's Joint Aviation Authorities. The 2-D data matrix code was chosen to support SPEC 2000 direct part marking for part traceability.

In commercial aerospace and aviation applications, DPM is used to permanently identify high-value parts, or those that are subject to theft or counterfeit. For example, jet engine compressor blades are highly engineered and cannot be marked with a paper bar code label. Wing hydraulic parts are subject to harsh lubricants that damage many label materials, requiring that a special 2-D bar code be etched, printed, or stamped directly on the metal parts.

In 2001, to demonstrate the technology behind SPEC 2000, Boeing Commercial Aircraft used DPM to identify and track more than 5,000 of the six million parts on a 777 aircraft.

The U.S. Department of Defense has also issued a directive calling for U.S. military services to begin identifying military aircraft, naval systems, and land-based vehicles and equipment with ADC technology. The DoD has chosen to follow an international standard called American National Standards Institute (ANSI) MH10.8, a set of part marking standards similar to SPEC 2000 developed specifically for military applications. Today, the military is marking a number of parts aboard some models of helicopters to better track them.

Electronics Applications

The telecom industry uses part marking to identify and track critical electronic components and circuit boards for digital switching systems.

In Europe, the Electrical and Electronic Equipment (EEE) Directive was developed to reduce the impact on the environment associated with the production, use, and disposal of electrical and electronic equipment. Manufacturers are now required to track their products from production to disposal and document that environmentally hazardous materials (heavy metals, arsenic, etc.) are disposed of properly.

Parts traceability technologies are enabling the proper disposal of electronics by documenting any hazardous materials in the product, so when it reaches its end of life it can be disposed of properly or returned to the manufacturer for recycling and/or disposal.

Automotive Applications

Parts traceability is taking on a new significance in the automotive industry as regulations, like the TREAD Act, and warranty issues take a front seat in the minds of the industry. Automotive manufacturers are searching for ways to actively track parts through the supply chain—from supplier through assembly and delivery to the customer.

The AIAG B-11 standard, the first RFID standard in the world for item-level traceability, provides a tool that can assist car and tire manufacturers and tire retailers in documenting the genealogy of tires throughout production, assembly and distribution.

Product traceability capabilities could enable more targeted recalls, resulting in increased safety for consumers and lower costs for manufacturers. The B-11 standard also provides a useful technology tool to help automakers and retailers streamline their respective supply chains through increased real-time visibility of their parts and processes.

In the automotive industry, all three ADC technologies—bar codes, direct part marking, and RFID—are used to trace parts throughout their movement from supplier to manufacturer, to distributor, to customer.

GETTING STARTED

There are many aspects to parts traceability, but getting started does not have to be complicated. You need to first define your business objectives and identify your ADC processes. Regardless of what your items or products look like, or how big or small your system might be, a parts traceability system has five basic parts:

- Classify - marking (or tagging) of the item
- Clarify - validation (making sure the data in the mark is readable)
- Collect - reading (or scanning) the mark
- Computing - the means by which you provide user direction and feedback
- Communication - how and to where you transmit the data after the mark is read

Smoothly integrating these parts into your overall processes and systems will streamline the addition of parts traceability into your ADC capabilities.

RESOURCES

Symbology Research Center

www.rvsi.com/acuitycimatrix/rr-src1.htm

The Symbology Research Center provides objective expertise, advice, and help on just about any direct parts marking problem. The SRC has helped scores of industry groups and hundreds of individual firms in determining the best options for permanent marking. SRC's technical staff developed the techniques used for marking the tiles on the NASA space shuttles and determined the best methods for the direct marking of aircraft landing gear. SRC engineers have developed ways of permanently marking just about every known material, from titanium to glass, from rubber to feathers.

Association for Automatic Identification & Mobility (AIM)

www.aimglobal.org

AIM is a global trade association comprised of providers of components, networks, systems, and services that manage the collection and integration of data with information management systems. AIM's Web site has information on ADC technologies, standards, and applications.

Intermec Technologies Corp.

www.intermec.com

Intermec and its partners offer the only complete source of information and products that support all three ADC technologies—bar code labels, RFID, and direct part marking—as well as the infrastructure to make it all come together.

Intermec's Web site has a wealth of industry-specific information on parts tracking and traceability applications.



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