RFID and the Supply Chain

For years, radio-frequency identification had a niche where its special features overcame the lower cost advantage of bar coding. But now, thanks to a shove from Wal-Mart and the DoD, RFID promises to be the integrating data-capture technology for the supply chain.

In Brief

Nudged by Wal-Mart and the DoD, Radio-frequency identification (RFID) seems destined to be the integrating data-capture technology for the supply chain. A wide range of RFID applications, related challenges and issues, deployment considerations, and the RFID application outlook are covered in this article.

The hot news this past year has been the emergence of radio-frequency identification (RFID) as a major player in the supply chain. RFID has been around for a number of years, and has performed successfully in applications where it has advantages over bar coding. Generally, these traditional applications have been of the closed-loop type, often within the four walls of the plant or warehouse. Examples include tagging of containers on a manufacturing line, or of auto bodies on an assembly line. But now RFID will be penetrating more deeply into the supply chain, given mandates to suppliers from Wal-Mart and other major retailers, as well as the U.S. Department of Defense (DoD). This new focus on RFID promises significant changes in supply chain operations, especially in the ways that manufacturers deal with suppliers and customers.

What Is It?

The basic elements of an RFID system are: 1) a tag, or transponder, that contains electronically encoded information, stored on a microchip that can be retrieved by 2) a reader (analogous to a scanner) that uses 3) an antenna or coil to transmit a radio signal that communicates with the tag. The antenna can be packaged as part of the reader. Stored data is decoded and routed to a local or host computer (Figure 1).
Raytheon’s RFID Supply Chain Strategy

In response to the U.S. Department of Defense (DoD) push for rapid implementation of RFID technology to expedite logistics operations, Waltham, MA based Raytheon Company is stepping up to the challenge, with an integrated knowledge management (KM) approach. "Communities of practice (CoP) and other knowledge management processes that we have developed around many of Raytheon’s integrated supply chain management activities have been powerful tools to speed program implementation and leverage our organizational learning," said George Ellis, the director of integrated logistics and head of the integrated logistics CoP for Raytheon. CoPs are networks of people who come together in an organization to share experiences, insights, and best practices. Some of the CoPs at Raytheon include supplier certification, integrated logistics, supplier quality, UID (Unique Identification Program), and RFID.

An industry leader in defense and government electronics, space, information technology, technical services, business aviation, and special mission aircraft, Raytheon utilizes an integrated approach of KM, CoPs, and Raytheon Six Sigma (R6s) to meet the goals of its demanding supply chain management organization. Lessons learned during Raytheon’s successful implementation of the DoD’s UID, are helping it to rapidly deploy RFID throughout its supply chain.

The requirement: According to current DoD policy, RFID tags that carry data are required to be attached to packages at multiple levels, including item packages, cases, and pallets. Unique identifiers are required to be attached or directly marked on individual items using a high-density, 2-D (data matrix) bar code to carry the UID data elements; see Figure 2. Raytheon’s approach is to first pilot their processes, then deploy them to the various business units charged with applying RFID.

Attaining compliance with the DoD’s UID requirements (including a January 1, 2004 deadline) paved the way for the company’s developing its RFID compliance program, which included a January 2005 deadline. Raytheon looked to leverage the learning generated through the UID process to leverage and speed integration of RFID compliance.

In the program concept, RFID is viewed as an enabler of the DoD’s integrated supply chain. At the manufacturer/supplier level, cases and pallets are labeled with passive RFID tags. Cases are associated with an individual pallet. At distribution centers, cases and pallets are read as they are received, and new shipments are...
labeled. Orders are verified for accuracy. Traveling on commercial and military carriers, cases and pallets are associated with active RFID to provide total asset visibility. Moving through the theater depot and battlefield levels, customers (military personnel) have visibility of requisitions and are confident in the status provided by the system. Data are timely and accurate, via a network of linked RFID readers that provide asset visibility along the entire supply chain.

Raytheon’s RFID rollout program is benefiting from its integrated learning approach. Capitalizing on its success in the UID program, Raytheon is able to replicate the learning and leverage the knowledge to meet the RFID challenge head on. “Raytheon’s intent is to not only comply with the DoD RFID requirement, but to be recognized as an industry leader in the ‘smart’ application of RFID technology,” said Timothy Wholey, Raytheon’s vice president of enterprise supply chain. “This includes the use of RFID to increase internal efficiencies in addition to applying RFID tags to shipment packaging.” Wholey feels that the best way to learn how to make optimal use of RFID technology is by setting up pilots and gaining hands-on experience. And of course, sharing that information throughout the organization is essential.

UID implementation has provided a solid start. UID is a globally unique “part identifier” containing data elements used to track DoD parts throughout their life cycle. The DoD requires the application of unique identifying markings in product categories involving: a) product cost over $5000; b) serially managed projects; c) mission-essential elements; d) controlled inventory; or e) a consumable or material for which permanent identification is essential.

Thus, UID allows the DoD greater asset management through: a) improved acquisition and tracking of equipment; b) the capture and use of accurate data; and c) improved life-cycle management of materials.

Raytheon’s management of projects such as UID involves a systematic approach that incorporates applied learning and a structured, proven implementation model. First, a cross-functional team of individuals was assembled from throughout the corporation (representatives from related functions such as engineering, finance, contracts, and supply chain management). This team then came together in a centralized location for a kickoff meeting that included company management, several leading-edge technology providers, and benchmarking partners to learn and share information within the group. During UID implementation, Raytheon used several technology providers in order to test the technologies, experience levels of support, and maximize the knowledge available throughout the technology sector.

Continual communication is key to Raytheon’s implementation model. In the UID process, conference calls are held with the UID team on a regular basis, often weekly. Technology also plays a role, as the group meets

Figure 2. RFID tags must be attached to pallets, cases, and item packages, according to current U.S. Department of Defense (DoD) policy. Items themselves have to carry a unique identifier (UID) represented by a data matrix bar code. Source: U.S. Department of Defense.
Tags can be integrated into labels ("smart labels"), laminated on plastic cards ("smart cards"), or embedded in plastic housings. They can be passive or active. Passive or "read-only" tags are more common. They are activated by power transmitted from the reader. They contain specific data that cannot be modified; it is only read out in response to a query from the reader.
as it exists. Active or "read-write" tags, on the other hand, powered by an internal battery, allow for rewriting or modifying of existing data. Thus there can be two-way communication between tag and reader. For instance, a tag affixed to a work in process (WIP) tray can communicate instructions to a machine, which in turn performs a required procedure, then transmits "work completed" information back to the tag. The new information written on the tag becomes part of the history of the items in the tray (Figure 3).

Active tags have a longer transmission range. They are usually heavier than passive tags, are more expensive, and may have a limited operating life. However, they provide a valuable, dynamic exchange of information throughout a process.

There are also combination tags that employ a fixed, unchangeable portion of data, such as a serial number, but allow for modification of other parts of the data. Obviously each type of tag performs a specific role for which it is designed and cost-justified.

Operating frequencies must be considered when selecting tags. Typically they are identified as low-frequency, high-frequency, and ultra-high-frequency (UHF). Low frequency systems operate at about 125 kHz, with a typical maximum read range of up to 20 in. High frequency systems operate at 13.56 MHz, with a typical maximum read range of up to three feet. Ultra high frequency systems operate at various frequencies, including 915 MHz and 2.45 GHz. Typical read range is three to ten feet, but some systems may reach 20 feet or more.

Readers are essentially transmitters and receivers. They can be fixed or mobile. The fixed reader is typically used at a portal through which tagged goods pass. An example of a portal may be a shipping/receiving door, through which a pallet of tagged cartons may be moved by lift truck. A mobile reader can be hand-held, or mounted on a lift-truck terminal. It functions in a manner similar to a bar-code scanner, as a "license plate" identifier.

Why Use It?

Although bar coding has provided increased efficiencies in manufacturing and distribution for years, it has limitations that can be transcended with RFID. As a result, even greater levels of efficiency can be achieved. Bar coding is an optical technology, while RFID is radio-based. A major advantage of RFID is that it does not require line-of-sight contact as does bar coding. Also, multiple tags can be read, essentially at the same time, as contrasted with bar-code scanning of one label at a time. These two factors can result in significant time and labor savings in a distribution operation.

Not requiring line-of-sight reading means that packages and other tagged items need not be positioned with the code on the outside when placed on conveyors and sortation systems. As a result, operators may not be required, and high operating speeds can be handled.

Consider the previous example of a pallet load of individually tagged cartons passing through a shipping/receiving door. Because line-of-sight reading is not a factor, time is saved: 1) when the pallet is built up at shipping, because operators need not position cartons with their labels (tags) facing the outside of the stack, and 2) similarly, no positioning of cartons is needed at receiving. Time is also saved because multiple tags can be read simultaneously, regardless of location within the pallet stack, as contrasted with performing line-of-sight scans one label at a time.

Once the pallet is unloaded, where does it go? A great deal of money is lost each year because returnable pallets and containers are not recycled back to their point of origin after customer deliveries have been made. By carrying an RF identifier tag, a pallet’s movement and location can be tracked throughout the transportation cycle. And, the pallet can be identified in shipping yards where it might be mixed in with thousands of pallets having many different owners.

Not requiring line-of-sight scanning also means that RFID tags can operate
through packaging materials such as cardboard and plastic stretch wrap. RFID tags can also operate in harsh environments including paint booths and grimy conditions, as well as severe weather conditions such as ice, snow, and fog. However, the presence of metal may distort RF signals, as can electromagnetic background noise.

In addition to improving the speed of operations, RFID can also improve accuracy. Bar-code technology itself is highly accurate. However, in many cases human intervention is required, as when an operator lines up a hand-held scanner with a label. If a scan is not performed when an inventory move is made, information flow is short-circuited at a particular stage of a process — or at a particular level in a supply chain. Because RFID does not require operator intervention, the potential for human error is circumvented.

Security is yet another RFID benefit. Personnel badges can be embedded with RF transponders that provide individual tracking and ID, and promote hands-free access to secure areas. Tags on high-value items can trigger alarms if they are moved in a theft attempt. And, by providing unique identifiers for individual items, RFID can help detect product counterfeiting.

Product visibility throughout the supply chain, not just within the four walls of a plant or distribution center, represents one of the most important benefits of RFID. Using the Electronic Product Code (EPC) Network (see accompanying box, "RFID and Standards"), a manufacturer can provide visibility for the product as it moves through the various levels of the supply chain. It can provide shipment status, track product lots, manage returns, and maintain warranty information. Obviously all trading partners in the supply chain must take the necessary steps to support RFID implementation and operation of the information network. The manufacturer can take the lead in guiding suppliers and customers through the necessary implementation process.

Where Has It Been Used?

The following are just a few examples of important RFID applications to date. In some cases they represent the closed-loop, internal operations that were the traditional RFID "turf" prior to the newer, broader supply-chain focus.

Work-in-process monitoring. An early industrial application of RFID tags was at a GM plant in 1984. Tags were affixed to carriers on which vehicle chassis were mounted. When a tag was read, components for use in assembly of the vehicle were routed to the line on a JIT basis.

Railcar monitoring. Identification of railcars with RFID has been in place for at least ten years. The objective is to make more efficient use of railcar fleets. Typically field-programmable RFID tags provide 12-character identification of each car by type, ownership, and serial number. Tags are attached to the railcar undercarriage. Antennae are placed within or beside tracks, and readers are installed within 40 ft. to 100 ft.

In-plant product tracking. A West Coast manufacturer of disc drives is using RFID tags to track carriers of substrates through several production operations. The company had been using bar coding, but the code-carrying labels degraded during grinding and polishing operations. And, manual scanning of bar codes tended to interrupt material flow. RFID met these challenges, and also made possible the networking of information throughout the plant floor, and its access from multiple locations.

How it works: In the grinding department, operator ID and lathe numbers, substrate thickness, and production machine number are input to a fixed terminal, and the data are then transmitted to a tag by a read/write head. Tag information is then used to route the carrier to an appropriate quality control station, which is equipped with a read/write head. The carrier continues on to a plating operation, and subsequently moves to a robotic sortation cell, based on information on the tag. Here carriers are sorted by substrate thickness.
Process data are encoded on the tag prior to reaching a conveyor unload station. An expansion to this basic system provides the capability of accessing and communicating work-in-process data for any carrier, at any stage in the process.2

Difficult environments. The disc-drive manufacturer mentioned above also uses a network of RFID-tagged cassette carriers at another West Coast plant, to move through various production operations. At one station, each carrier must be submerged in de-ionized water to protect against contamination. Production data can be transferred between the reader and the RF tag, while both are submerged, even for extended periods of time (the longer a disc remains submerged in de-ionized water, the smaller is the risk of contamination).3

Another difficult environment is being met by a TV picture-tube plant in Europe that collects information about each tube being made, using RFID tags. A read/write tag is placed on each tube’s hanger carrier that moves on an overhead conveyor. Part of the process involves exposing the tube to a 160,000-volt surge. The hangers are actually exposed to 50,000 volts, and the tags are insulated to protect their encoded data. Each tag contains an ID number and production data. Once it passes through the high-voltage environment, each tube is checked and new data transferred to the tag. Faulty units are pulled for rework.4

Receiving raw materials. RFID technology has helped speed processing time for loads of nuts by 60 percent at Paramount Farms, Lost Hills, CA. A major producer of almonds and pistachio nuts, the company grew nuts in its own orchards, as well as purchasing them from a network of growers with whom it partners. As its production goals increased, efficiency and productivity had to increase as well, and Paramount felt that an upgrade in its information system was essential if expansion and improvement goals were to be attained.

Accordingly, the company turned to use of RFID tags on load trailers, integrated with a system of hand-held computers, a central server, and an Internet browser. Each trailer load consists of about 50,000 pounds of green (undried) nuts. As a loaded trailer arrives at a scale house, a fixed reader interrogates the trailer’s RFID tag, and the captured data are processed through the computer system. At this point the scale-house worker knows the trailer’s net weight, license plate number, equipment number, and owner (grower) name.

Scale-house operators then use hand-held computers to gather load details such as grower name, ranch, field, product temperature, and harvest method. Some of the data are used to determine processing priority. For example, loads arriving with temperatures over 100 degrees F go immediately to the front of the line.

The grower receiving system provides the basis for fair payment to grower partners. Data accuracy associated with the system also helps the company control raw material costs, and drives its annual production planning process.5

What Are the Challenges?

Cost. Passive RFID tags costs can range from 20 cents to over ten dollars, depending on the type of tag and quantities ordered. Active tags can range from a dollar to many multiples. In contrast, bar-code labels currently cost pennies. It is expected that as RFID applications proliferate, tag costs will continue to decrease. Although the costs of RFID readers are generally higher than for laser scanners, they are for all practical purposes comparable.

However, the issue is not direct replacement of bar codes and scanners with RFID tags and readers. The potential benefits of RFID in the supply chain are much broader than might be suggested from a swap in any particular process point.

Certainly, RFID users need to develop appropriate justification for use of this technology. The benefits of RFID are so clear in certain situations that its use is readily justified. On the other hand, for suppliers serving retailers and the DoD, the primary justification may be complying with the RFID tagging mandate in order to retain the business. Such companies are advised to...
review their internal operations and look for ways to improve their efficiencies — and reduce costs — through use of RFID in their own facilities.

One of the "hidden costs" in RFID implementation may be the cost of reconfiguring processes, information flow, or even possibly facilities. In order to realize the full power of non-intrusive RFID in receiving operations, for instance, the receiving method may have to be reconfigured to resemble a flow-through operation. This scenario would contrast with the batch-style, stepwise procedure involving operator-initiated bar-code scanning.

Information management. A recent webcast survey revealed that many companies are uncertain about handling the large amounts of data that may be generated by RFID, and how such data may impact their present operations. An individual tag may respond many times to a signal from a reader. If a number of tags are within the reader’s range, a large number of responses must be properly interpreted and processed before the information can be used in an application. Special control software and middleware are typically used to monitor, process, and transmit data in RFID applications.

Standards. Survey participants also cited the global evolution of RFID standards as another area of concern. Current standards work is focused on the EPC Global standard and DoD numbering system; see the accompanying box, "RFID and Standards." However, there is ongoing concern about obsolescence of current technology as EPC and ISO standards evolve, and new products are developed.

Tag performance. Survey participants also expressed a need to learn more about tag quality — strength, readability, data capacity, size, and failure rate. RFID systems provide very high accuracy. However, certain factors do affect performance. Reading distance may determine choice of tags and readers, and may also affect process layout and design. Metals and liquids can distort or absorb RF signals. Electromagnetic background noise from equipment in a plant or warehouse may affect transmission.

Implementing an RFID system typically involves careful planning of processing and handling methods and selection of the right tag, antenna, and operating frequency for the job. Pilot runs and pre-deployment testing should be conducted to reveal any

---

**RFID and Standards**

In the past, use of RFID in supply chains was limited by an insufficient body of applicable standards. To this end, an Electronic Product Code (EPC) standard has been developed. Initial work was done at the Auto-ID Center of Massachusetts Institute of Technology. Today support and continued development of the EPC standard is being performed by EPC Global, a joint venture of the Uniform Code Council (UCC) and EAN International. (The latter organization administers the European Article Numbering [EAN] System, which is the bar-code standard used throughout Europe, Asia, and South America).

Thus, RFID-related standards, designed to address such technology aspects as radio frequency bands and communication with networked readers, are based on the EPC, which is a product numbering standard. This code uniquely identifies objects such as pallets, cases, or individual items. It also identifies manufacturers and SKUs. And, it provides the basis for an information network for exchanging product information among various levels in the supply chain. Promoting information sharing over the Internet, the EPC network makes possible the tracking of product information across the supply chain using RFID technology, and providing item-level history from manufacturer to end user.

According to the most recent policy guidelines released by the DoD, suppliers have the option of using either EPC data format or DoD format. Thus, consumer goods suppliers can use the same code for the DoD as they use for retailers.

In the past, use of RFID in supply chains was limited by an insufficient body of applicable standards. To this end, an Electronic Product Code (EPC) standard has been developed. Initial work was done at the Auto-ID Center of Massachusetts Institute of Technology. Today support and continued development of the EPC standard is being performed by EPC Global, a joint venture of the Uniform Code Council (UCC) and EAN International. (The latter organization administers the European Article Numbering [EAN] System, which is the bar-code standard used throughout Europe, Asia, and South America).

Thus, RFID-related standards, designed to address such technology aspects as radio frequency bands and communication with networked readers, are based on the EPC, which is a product numbering standard. This code uniquely identifies objects such as pallets, cases, or individual items. It also identifies manufacturers and SKUs. And, it provides the basis for an information network for exchanging product information among various levels in the supply chain. Promoting information sharing over the Internet, the EPC network makes possible the tracking of product information across the supply chain using RFID technology, and providing item-level history from manufacturer to end user.

According to the most recent policy guidelines released by the DoD, suppliers have the option of using either EPC data format or DoD format. Thus, consumer goods suppliers can use the same code for the DoD as they use for retailers.
RFID Tagging: From Toll Roads to Animals to High Fashion and Beyond

Uses of RFID technology go far beyond typical industrial applications. Most tollway users are familiar with use of ID tagging to facilitate toll collection without requiring on-site cash payments, as well as automatic payment systems at gasoline stations.

Tracking of valuable livestock was an early European application (late 70s) that was subsequently duplicated elsewhere. Essentially a small (approximately 1/8 in. x 3/4 in.) glass capsule containing RF data was injected under the skin of each animal involved. As livestock were moved through a "squeeze point" in a pen, each individual animal was accounted for by an RFID signal.

Monitoring of valuable livestock continues to be a significant use of RFID. Other examples of animal tagging include monitoring of salmon migration patterns, and tagging of laboratory animals and wildlife.

A high-fashion application described in the trade media involved the use by an upscale retailer of RFID technology for labeling shoes and garments. As a service to customers, staff can scan the tag on, say, a suit. A videotape can then demonstrate the suit worn on a fashion runway, or present photos and sketches, and provide information on color, fabrics, and related accessories. Dressing rooms also are equipped with interactive touch-screen displays. Additional potential refinements include real-time details on in-stock inventory, and integration of store and website data.

Improved port security is another recent RFID application. The Federal Communications Commission (FCC) recently amended its rules to allow more powerful RFID systems to be used for seaport and other homeland security activities. Such systems allow for the contents of sea-going containers to be identified without having to open or x-ray them. In addition to providing more efficient security checking, the new rules should also help lower shipping costs.

Examples of other possible RFID scenarios include the following:
- A shirt containing an RFID tag activates the correct setting on a washing machine.
- A food product gives operating instructions to a microwave oven.
- A milk carton signals passing of an expiration date, and adds a line for milk to an electronic shopping list.
- A medicine container provides dosage instructions and tracks patient usage.
- A grocery checkout system automatically debits groceries from a customer's account before the customer leaves the store.
- A tiny (11 mm) RFID tag may be implanted in hospital patients (for patient ID and medical history) and/or staff personnel (to permit access to secured medical records). Final FDA approval is being awaited pending review. The implant is done in the fatty tissue below the right tricep.

interference or performance issues prior to final startup.

Privacy issues. Various civil rights and privacy advocacy groups warn that RFID technology can represent a threat to the privacy of individuals by its ability to not only track the buying habits of consumers, but also their movements, whereabouts, and other details of their daily lives. As a result, some are calling for stricter controls and privacy safeguards. See the accompanying box, "Is Big Brother in Your Grocery Cart?"

What's the Outlook?

Will RFID eliminate use of bar codes? Probably not. Certainly ongoing RFID developments continue to produce greater memory capacities, wider reading ranges, and faster processing. Supply chain execution systems, such as warehouse management systems, are increasingly utilizing RFID for their data-capture technology. Nevertheless, for the foreseeable future, we can expect to see the two technologies coexist, for several reasons:
Bar coding is a well-established and well-proven technology. It operates within a huge information infrastructure that would be extremely costly to replace in a rapid fashion. Chances are that the application of RFID in the supply chain will follow an evolutionary, "wait-and-see" path that will support the coexistence of complementary technologies.

Suppliers will likely face some customers that will embrace RFID and in fact mandate its use, while at the same time they will serve other customers continuing to use bar codes as before. The duplication of systems will entail an added cost if both categories of customers are to be served, but it is probably an unavoidable cost.

In the same vein, the above suppliers will also face diversity among their own suppliers. Large companies may provide RFID-tagged raw materials, while some smaller suppliers may still employ bar-code labeling. Thus duplication will also occur in internal operations. Eventually the latter class of suppliers may have to drop bar coding (as a result of mandates or for other reasons), but it will not happen overnight.

It should be clear that broad-scale adoption of RFID technology represents a large investment with considerable risk. The situation is analogous to the adoption of bar coding years ago. The dilemma is similar: Move too soon, and you may suffer the well-known fate of many pioneers. Move too late, and you may be left behind. In any case, you need to allow for careful planning.

Users in manufacturing and distribution are advised to carefully examine the flows of material and information in their facilities. Are these flows in parallel, or do they diverge? Are there opportunities for modifications to layout, material flow, storage, and picking procedures? How about improvements to technology application and information systems? Comparing current performance against that expected from RFID deployment would produce valuable information that would help in the justification process. Placing value on such factors as customer satisfaction, improved sales, and reduced logistics costs would be an important factor in securing management approval.

---

Is Big Brother in Your Grocery Cart?

The above is the title of a web page on the site of Consumers Against Supermarket Privacy Invasion and Numbering (CASPIAN).\(^1\) The premise of this and other advocacy groups is that RFID, though its use in retail establishments, provides an ever-growing database about individuals that can be accessed by the government and others. Recently, CASPIAN organized a protest against a German grocery store that prompted the store to refrain from using RFID chips in customer loyalty cards. Likewise, a leading clothing retailer decided against embedding RFID chips into some clothing items when CASPIAN threatened a boycott.\(^2\)

While not necessarily trying to prohibit RFID in consumer settings, some advocacy groups are calling for establishment of privacy safeguards. One such safeguard would be for the tag embedded in a product or article of clothing to be automatically deactivated once the consumer leaves the store. The U.S. Congress has been petitioned to consider legislation aimed at inhibiting technologies such as RFID from potentially invading the privacy of individuals. As companies such as Wal-Mart and Target implement RFID programs in their stores, additional attention undoubtedly will be paid to their operations by privacy advocates. It may well be that providers and users of RFID technologies will have to implement certain privacy safeguards in the future.

Going beyond retail, a more direct type of human tracking was revealed recently when school authorities in Osaka, Japan decided to implement RFID tracking of schoolchildren. Chip-embedded tags will be placed into schoolbags, name tags, or clothing. Readers will be installed in school gates and other locations, and the data used to track children's movements at the school.\(^3\)
The best advice seems to be, prepare for RFID even if you are not facing a supplier mandate today. Check out what others in your industry are doing. Talk to suppliers, consultants, and integrators. Try to determine what help you may need as current standards evolve. And, as you put an RFID solution in place, provide for adequate testing and pilot runs before full deployment. There is probably no such thing as too much testing.

Ray Kulwiec is a writer specializing in material handling, manufacturing, and supply chain topics. Based in Arlington Heights, IL, he has covered these fields for many years as an editor, and has served on the board of the Materials Handling & Management Society. He can be reached at rkulwiec@aol.com

Footnotes
2. "How RFID manages 1.4 million items a week on Seagate's shop floor," Modern Materials Handling, ADC News & Solutions, September 1988, Reed Business Information, Newton, MA.
3. "RFID goes underwater for first time," Modern Materials Handling, ADC News & Solutions, April 1999, Reed Business Information, Newton, MA.
4. "Nothing too shocking for this RFID system," Modern Materials Handling, ADC News & Solutions, May 1999, Reed Business Information, Newton, MA.
11. "Is Big Brother in your grocery cart?", www.nocards.org
12. Rose, Barbara, "Price, privacy are issues, but RFID already in use," Chicago Tribune, 4/18/04.

© 2005 AME® For information on reprints, contact: Association for Manufacturing Excellence www.ame.org